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FPL

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U. S. Nuclear Regulatory Commission
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Florida Power & Light Company
St. Lucie Units 1 and 2
Docket Nos. 50-335 and 50-389

Subject: Supplemental Response to NRC Generic Letter 2004-02, "Potential Impact of Debris Blockage on Emergency Recirculation During Design Basis Accidents at Pressurized-Water Reactors"

References:

(1) Generic Letter 2004-02, "Potential Impact of Debris Blockage on Emergency Recirculation During Design Basis Accidents at Pressurized-Water Reactors," dated September 13, 2004

(2) Letter L-2005-034 from J. A. Stall (FPL) to U. S. Nuclear Regulatory Commission, "Potential Impact of Debris Blockage on Emergency Recirculation During Design Basis Accidents at Pressurized Water Reactors," dated March 4, 2005 (ML050670429)

(3) Letter from B. T. Moroney (U. S. Nuclear Regulatory Commission) to J. A. Stall (FPL), "St. Lucie Plant, Units 1 and 2 – Request for Additional Information (RAI) Related to Generic Letter 2004-02, Potential Impact of Debris Blockage on Emergency Sump Recirculation During Design Basis Accidents at Pressurized Water Reactors," dated June 2, 2005 (ML051520202)

(4) Letter L-2005-145 from J. A. Stall (FPL) to U. S. Nuclear Regulatory Commission, "Request for Additional Information - Potential Impact of Debris Blockage on Emergency Recirculation During Design Basis Accidents at Pressurized Water Reactors," dated July 20, 2005 (ML052080038)

(5) Letter L-2005-181 from J. A. Stall (FPL) to U. S. Nuclear Regulatory Commission, "Potential Impact of Debris Blockage on Emergency Recirculation During Design Basis Accidents at Pressurized Water Reactors – Second Response," dated September 1, 2005 (ML052490339)

(6) Letter from B. T. Moroney (U. S. Nuclear Regulatory Commission) to J. A. Stall (FPL), "St. Lucie, Units 1 and 2, Request for Additional Information Re: Response to Generic Letter 2004-02, Potential Impact of Debris Blockage on Emergency Recirculation During Design-Basis Accidents at Pressurized-Water Reactors," dated February 8, 2006 (ML060370438)

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(7) Letter from C. T. Haney (U. S. Nuclear Regulatory Commission) to Holders of Operating Licensees for Pressurized Water Reactors, "Alternate Approach for Responding to the Nuclear Regulatory Commission Request for Additional Information RE: Generic Letter 2004-02," dated March 28, 2006 (ML060860257)

(8) Letter from C. T. Haney (U. S. Nuclear Regulatory Commission) to Holders of Operating Licenses for Pressurized Water Reactors, "Alternate Approach for Responding to the Nuclear Regulatory Commission Request for Additional Information Letter Regarding Generic Letter 2004-02," dated January 4, 2007 (ML063460258)

(9) Letter from W. H. Ruland (U. S. Nuclear Regulatory Commission) to A. Pietrangelo (Nuclear Energy Institute), "Content Guide for Generic Letter 2004-02 Supplemental Responses," dated August 15, 2007 (ML071060091)

(10) Letter from W. H. Ruland (U. S. Nuclear Regulatory Commission) to A. Pietrangelo (Nuclear Energy Institute), "Revised Content Guide for Generic Letter 2004-02 Supplemental Responses," dated November 21, 2007 (ML073110389)

(11) Letter from W. H. Ruland (U. S. Nuclear Regulatory Commission) to A. Pietrangelo (Nuclear Energy Institute), "Supplemental Licensee Responses to Generic Letter 2004-02, Potential Impact of Debris Blockage on Emergency Recirculation During Design Basis Accidents at Pressurized-Water Reactors," dated November 30, 2007 (ML073320176)

(12) Letter L-2007-155 from J. A. Stall (FPL) to U. S. Nuclear Regulatory Commission "Request for Extension of Completion Date of the St. Lucie Unit 1, St. Lucie Unit 2 and Turkey Point Unit 3 Generic Letter 2004-02 Actions," dated December 7, 2007 (ML073450338)

(13) Letter L-2007-194 from J. A. Stall (FPL) to U. S. Nuclear Regulatory Commission "Response to Questions Regarding Request for Extension of Completion Date of the St. Lucie Unit 1, St. Lucie Unit 2 and Turkey Point Unit 3 Generic Letter 2004-02 Actions," dated December 20, 2007 (ML080090147)

(14) Letter from T. H. Boyce (U. S. Nuclear Regulatory Commission) to J. A. Stall (FPL) "St. Lucie Nuclear Plant, Units 1 and 2, and Turkey Point Nuclear Plant, Unit 3 – Generic Letter 2004-02, Potential Impact of Debris Blockage on Emergency Recirculation During Design-Basis Accidents at Pressurized Water Reactors, Extension Request Evaluation," dated December 28, 2007 (ML073610401)

(15) Letter L-2008-030 from G. L. Johnston (FPL) to U. S. Nuclear Regulatory Commission "Supplemental Response to NRC Generic Letter 2004-02, "Potential Impact of Debris Blockage on Emergency Recirculation During

Design Basis Accidents at Pressurized-Water Reactors," dated February 27, 2008 (ML080650560)

The purpose of this submittal is to provide the Florida Power & Light Company (FPL) updated supplemental response to Generic Letter (GL) 2004-02 (Reference 1) for St. Lucie Units 1 and 2. The U. S. Nuclear Regulatory Commission (NRC) issued Reference 1 to request that addressees perform an evaluation of the emergency core cooling system (ECCS) and containment spray system (CSS) recirculation functions in light of the information provided in the GL and, if appropriate, take additional actions to ensure system functions.

Additionally, the GL requested addressees to provide the NRC with a written response in accordance with 10 CFR 50.54(f). The request was based on identified potential susceptibility of the pressurized water reactor (PWR) recirculation sump screens to debris blockage during design basis accidents requiring recirculation operation of ECCS or CSS and on the potential for additional adverse effects due to debris blockage of flowpaths necessary for ECCS and CSS recirculation and containment drainage.

Reference 2 provides the initial FPL response to the GL. Reference 3 requested additional information regarding the Reference 2 response to the GL for St. Lucie Plant, Units 1 and 2. Reference 4 provided the FPL response to Reference 3. Reference 5 provides the second of two responses requested by the GL. Reference 6 requested FPL to provide additional information to support the NRC staff's review of References 2, 4, and 5. Reference 7 provided an alternative approach and timetable that licensees may use to address outstanding requests for additional information (i.e., Reference 6).

Reference 8 supplemented Reference 7 with the NRC expectation that all GL 2004-02 responses will be provided no later than December 31, 2007. For those licensees granted extensions to allow installation of certain equipment in spring 2008, the NRC staff expects that the facility response will be appropriately updated with any substantive GL corrective action, analytical results, or technical detail changes within 90 days of the change or outage completion. As further described in Reference 8, the NRC expects that all licensees will inform the NRC, either in supplemental GL 2004-02 responses or by separate correspondence as appropriate, when all GSI-191 actions are complete.

Reference 9 describes the content to be provided in a licensee's final GL 2004-02 response that the NRC staff believes would be sufficient to support closure of the GL. Reference 10 revised the guidance provided in Reference 9 by incorporating minor changes which were viewed by the NRC as clarifications.

Reference 11 authorized all PWR licensees up to two months beyond December 31, 2007 (i.e., to February 29, 2008), to provide the supplemental responses to the NRC.

In Reference 12, FPL requested an extension for completing St. Lucie Unit 1 and Unit 2 chemical effects testing and analysis activities until June 30, 2008, and in-vessel and ex-vessel downstream effects evaluations until March 31, 2008. Reference 13 provided FPL's response to NRC questions regarding Reference 12. The request for an extension was approved in the Reference 14 evaluation.

In Reference 15, FPL provided the initial GL 2004-02 supplemental response using the content guide provided in Reference 9. This letter provides an updated supplemental response, as discussed in References 12, 13, 14, and 15, using the NRC Revised Content Guide for GL 2004-02 Supplemental Responses, dated November 21, 2007, that was provided by the NRC in Reference 10.

Attachment 1 provides a summary level description of the approach taken for St. Lucie Unit 1 to provide reasonable assurance that long-term core cooling is maintained, as requested by the revised content guide. Attachment 2 provides the updated supplemental response to GL 2004-02 for St. Lucie Unit 1. Information previously provided in Reference 15 continues to apply except where supplemented or revised. A revision bar in the right hand margin of the updated supplemental response indicates where information has been either supplemented or revised.

Attachment 3 provides a summary level description of the approach taken for St. Lucie Unit 2 to provide reasonable assurance that long-term core cooling is maintained, as requested by the revised content guide. Attachment 4 provides the updated supplemental response to GL 2004-02 for St. Lucie Unit 2. Information previously provided in Reference 15 continues to apply except where supplemented or revised. A revision bar in the right hand margin of the updated supplemental response indicates where information has been either supplemented or revised.

This letter also serves to inform the NRC that all GL 2004-02 related GSI-191 actions for St. Lucie Units 1 and 2 are complete. There are no new regulatory commitments made by FPL in this submittal.

This information is provided in accordance with 10 CFR 50.54(f).

Please contact Ken Frehafer at (772) 467-7748 if you have any questions regarding this response.

I declare under penalty of perjury that the foregoing is true and correct.

Executed on JUNE 30, 2008.

Sincerely yours,

Gordon L. Johnston
Site Vice President
St. Lucie Plant

Attachments: (4)

cc: NRC Regional Administrator, Region II
USNRC Project Manager, St. Lucie Nuclear Plant
Senior Resident Inspector, USNRC, St. Lucie Nuclear Plant

ATTACHMENT 1

St. Lucie Unit 1
GL 2004-02
Summary Description of Approach

SUMMARY DESCRIPTION OF APPROACH

The following key aspects summarize the FPL approach to GL 2004-02 at St Lucie Unit 1.

Design Modifications:

- New sump strainers ensure adequate NPSH during recirculation with margin for chemical effects.
- Cal-sil banding ensures that strainer design basis debris loads will not be exceeded.
- New high pressure safety injection (HPSI) pump seals ensure long term operation of the HPSI pumps.
- The minimum refueling water tank (RWT) water level is administratively controlled at 32.5 feet to be consistent with the proposed license amendment request to revise the plant technical specifications.

Process Changes:

- Specifications were updated to ensure that strainer design basis loads will not be exceeded.
- Walkdowns, the sump water level calculation, and procedural control of the RWT level confirms that design basis sump water supply will be available.

Supporting Analyses:

- The downstream effects evaluations confirm that no other modifications are required to ensure that long-term cooling capability is maintained.
- The coating adhesion tests confirm that current inspection methods are adequate to control the quantity of degraded qualified coatings.
- The evaluation of in-vessel chemical effects confirms that fuel temperatures will be maintained at an acceptably low value.

Conservatisms and Margin:

FPL made significant improvements in the emergency core cooling system (ECCS) to address the issues identified in Generic Letter 2004-02. FPL included a number of conservatisms in the plant modifications and analyses to ensure sufficient margin is available. These margins are summarized below:

- The surface area for the recirculation sumps was increased from approximately 24 ft^2 to 8275 ft^2. The replacement screens have been manufactured by General Electric and have a nominal hole size of 0.0625 inch compared to the previous screens' openings of ¼ inch mesh size. These screens are distributed around 260 degrees of containment which effectively lowers the approach velocities to the replacement screens.

- In the debris generation analysis, the zone of influence (ZOI) used for Nukon Insulation is 17.0D. WCAP-16710-P testing confirmed that the zone of influence could be reduced further to 5D. As such, the strainer system was qualified utilizing a quantity of fiber that is significantly greater than is expected to be generated.

- A uniform factor of 1.1 has been applied to the ZOI radius to ensure the calculation was conservative.

- 100% of the Calcium Silicate generated is assumed to transport to the strainers.

- Irrespective of the conservatively high quantity of fiber considered, debris head loss testing iterations at various bed thicknesses determined the highest head loss fiber quantity for the ultimate strainer design and hydraulic analysis.

- In the transport analysis, 100% of unqualified coatings, regardless of types and location inside containment, were assumed to fail as particulates and transport to the screen. EPRI and industry testing indicates some unqualified coatings do not fail and some coatings fail as chips and may not transport to the sump.

- The near-field effect was not credited in the debris head loss testing or for the debris transport analysis. The steps taken to minimize near-field effects in the head loss tests included placing the flow return near the bottom of the test tank to help suspend debris and using motor driven agitators to ensure that debris remained suspended. This maximized the amount of debris on the screen and provided very conservative head loss results.

- The PSL-1 strainer design does not credit debris transport holdup within containment due to residue on walls or floors, hold-up to due to curb effects or due to trapped volumes or pools. With the exception of fiber, 100% of the debris is assumed to transport to the strainers. For the case of fiber, PSL-1 head loss testing demonstrated that a reduced fiber debris load provided the highest head loss case.

- For the downstream effects wear analysis, the total debris load was determined for a bounding LBLOCA in accordance with NEI 04-07. A minimum sump water volume for recirculation was determined for a SBLOCA to maximize the debris concentration in containment. All debris was assumed to be in the sump pool and eroded (to the extent it would be after 30 days) at the start of recirculation.

- A design flow rate of 8530 gpm is conservatively assumed to apply for the entire duration of the event. However, this flow rate includes an operating LPSI pump and is based on the simultaneous hot and cold leg recirculation mode, which is not initiated until 4 to 6 hours into the event by the supply of LPSI flow. Additionally, it is expected that one train would be secured at some time in the event when decay heat and pool temperature is reduced. This reduction in flow would be expected to reduce the head loss across the strainer and, together with reduced pool temperature, vastly increase the NPSH margin.

The combination of design modifications, process changes, and supporting analyses provides reasonable assurance that long-term core cooling is maintained. This submittal demonstrates compliance with the applicable GL 2004-02 regulatory criteria, and FPL is requesting a license amendment that will raise the plant Technical Specification minimum RWT water level to 32.5 feet.

ATTACHMENT 2

St. Lucie Unit 1
Updated Supplemental Response GL 2004-02

UPDATED SUPPLEMENTAL RESPONSE TO GL 2004-02

This final supplemental response to NRC Generic Letter (GL) 2004-02 updates information previously submitted in FPL letter L-2008-030, Supplemental Response to NRC Generic Letter 2004-02, "Potential Impact of Debris Blockage on Emergency Recirculation During Design Basis Accidents at Pressurized-Water Reactors," dated February 27, 2008. Changes to the February supplemental response and new information are shown in the text with revision bars. Where the text from the February supplemental response was moved unchanged to meet the format requirements of the NRC staff's Revised Guidance document, this text is shown as boxed text.

Additional information to support the staff's evaluation of St. Lucie Unit 1 compliance with the regulatory requirements of GL 2004-02 was requested by the NRC in a Request for Additional Information (RAI) dated February 8, 2006 (NRC Letter to FPL (J. A. Stall), St. Lucie Plant, Units 1 and 2, Request for Additional Information RE: Response to Generic Letter 2004-02, "Potential Impact of Debris Blockage on Emergency Sump Recirculation at Pressurized-Water Reactors" (TAC Nos. MC4710 and MC4711), dated February 8, 2006). Each RAI question is addressed in this response. The RAI question (and specific RAI response) is identified by the RAI question number in the following format: [RAI ##], where ## is the RAI question number.

Topic 1: Overall Compliance

FPL Response

The initial St Lucie Unit 1 response to GL 2004-02, that was submitted to the NRC on September 1, 2005 (September 1 response), was based on information that was available at that time. The St. Lucie Unit 1 Supplemental Response to Generic Letter 2004-02 was submitted to the NRC on February 27, 2008. That response reported on corrective actions taken up to that date. Additional testing and analysis have since been completed. Test results and conclusions are discussed in this response under Topics 3.m, Downstream Effects – Components and Systems, 3.n, Downstream Effects – Fuel and Vessel, and 3.o, Chemical Effects.

As noted in Topic 3.g, Net Positive Suction Head Available (NPSH), sump level calculations were revised to accommodate potential areas for water holdup based on lessons learned from the NRC audit of the Waterford sump program. As further discussed in Topic 3.p, Licensing Basis, FPL recently determined that an amendment to the Technical Specifications, raising the minimum Refueling Water Tank (RWT) level, is required to correctly bound St. Lucie Unit 1 strainer test results and calculations. Hence, an amendment to the St. Lucie Unit 1 Technical Specifications requesting the necessary increase in RWT level is being submitted. Until this amendment is approved and implemented on-site, existing administrative controls for maintaining a higher water level in the RWT will remain in effect. Some calculations and results provided in Topic 3.f Head Loss and Vortexing, and in Topic 3.g Net Positive Suction Head Available (NPSH), credit this current/higher RWT level.

<u>GL 2004-02 Applicable Regulatory Requirements</u>

10 CFR 50.46 requires that the ECCS have the capability to provide long-term cooling of the reactor core following a LOCA. As described in the remainder of the supplemental responses, much has been done to ensure that the potential impact of debris blockage on emergency recirculation during design basis accidents has been adequately addressed, such that long-term core cooling is maintained.

Based on the completed corrective actions, enhanced procedural controls, and planned Technical Specification amendment, and completion of the confirmatory tests and analyses, St. Lucie Unit 1 has been demonstrated to be in compliance with the regulatory requirements listed in GL 2004-02. Table 1-1 provides a St. Lucie Unit 1 regulatory compliance matrix.

Table 1-1: GL 2004-02 Regulatory Compliance

Regulatory Statute	Applicable Requirement	Basis For Compliance with GL 2004-02
10 CFR 50.46 (b)(5)	Long-term cooling. After any calculated successful initial operation of the ECCS, the calculated core temperature shall be maintained at an acceptably low value and decay heat shall be removed for the extended period of time required by the long-lived radioactivity remaining in the core.	• New sump strainers ensure adequate NPSH during recirculation with margin for chemical effects • Cal-sil banding ensures that strainer design basis debris loads will not be exceeded • SPEC-C-034 update ensures that strainer design basis loads will not be exceeded • Walkdowns, Sump Water Level Calculation, and procedural control of the RWT level have confirmed that design basis sump water supply will be available • New HPSI pump seals ensure long term operation • Resolution of multistage pump issues ensures that ECCS pumps can provide long term cooling capability. • Downstream effects evaluations confirmed that no other modifications are required to ensure long-term cooling capability is maintained. • Coating adhesion tests confirm that current inspection methods are adequate to control quantity of degraded qualified coatings • Evaluation of in-vessel chemical effects confirms that fuel temperatures will be maintained at an acceptably low value. • Minimum RWT water level is administratively controlled at 32.5 feet consistent with proposed LAR to revise Technical Specification.
10 CFR 50, Appendix A, GDC 35	Criterion 35--Emergency core cooling. A system to provide abundant emergency core cooling shall be provided. The system safety function shall be to transfer heat from the reactor core following any loss of reactor coolant at a rate such that (1) fuel and clad damage that could interfere with continued effective core cooling is prevented and (2) clad metal-water reaction is limited to negligible amounts.	The assurance of long-term cooling capability during recirculation ensures that the design basis emergency core cooling capabilities are maintained.
10 CFR 50, Appendix A, GDC 38	Criterion 38--Containment heat removal. A system to remove heat from the reactor containment shall be provided. The system safety function shall be to reduce rapidly, consistent with the functioning of other associated systems, the containment pressure and temperature following any loss-of-coolant accident and maintain them at acceptably low levels.	The assurance of long-term cooling capability during recirculation ensures that the design basis containment heat removal capabilities are maintained.

Regulatory Statute	Applicable Requirement	Basis For Compliance with GL 2004-02
10 CFR 50, Appendix A, GDC 41	Criterion 41--Containment atmosphere cleanup. Systems to control fission products, hydrogen, oxygen, and other substances which may be released into the reactor containment shall be provided as necessary to reduce, consistent with the functioning of other associated systems, the concentration and quality of fission products released to the environment following postulated accidents, and to control the concentration of hydrogen or oxygen and other substances in the containment atmosphere following postulated accidents to assure that containment integrity is maintained.	Assurance of long-term cooling capability during recirculation ensures that containment spray capability is maintained which, in turn, ensures that containment atmosphere cleanup capability is preserved.

Topic 2: General Description of and Schedule for Corrective Actions

FPL Response

The corrective actions identified for St. Lucie Unit 1 have been completed. Florida Power & Light requested, and received, a short extension to complete selected confirmatory tests and analyses. The delayed tests and analyses are those that depend on the resolution of chemical effects issues and those that are impacted by the recent revision to WCAP-16406-P, Evaluation of Downstream Sump Debris Effects in Support of GSI-191, Revision 1, August, 2007.

A general description of the actions already taken is presented below. Additional details are contained in subsequent sections of this response.

The original sump screens have been completely replaced with a strainer system that has a strainer surface area of 8,275 ft^2. The new system consists of 21 strainer modules with interconnecting piping, and is passive (i.e., it does not have any active components or rely on backflushing). The strainer system is described in the response to NRC Topic 3.j, Screen Modification Package.

The high pressure safety injection (HPSI) pump seals and cyclone separators have been replaced with a seal system that does not use cyclone separators or rely on the HPSI pumped water for flushing and cooling the mechanical seals. The new seal system recirculates the seal cavity water through an external heat exchanger to flush and cool the seal faces. The new seal system will prevent the potential failure of shaft seals that could be caused by the carryover of debris in the pumped water when the HPSI pumps take suction of potentially debris-laden fluid from the new containment strainer system in the recirculation mode.

The calcium-silicate insulation (cal-sil) on selected piping in the containment has been reinforced with a banding system to reduce the cal-sil zone of influence (ZOI) from 5.45D to 3.0D. The banding system consists of ½-inch wide stainless steel bands spaced approximately 3 inches on center. The banding system and the test that confirms the efficacy of the system are described in the response to NRC Topic 3.b, Debris Generation/Zone of Influence (ZOI) (excluding coatings).

A walkdown to confirm the absence of potential choke points was completed. The results of this walkdown are described in the response to NRC Topic 3.l, Upstream Effects.

The downstream effects assessments of the fuel and vessel have been completed. The St Lucie Unit 1 calculation using plant-specific parameters and WCAP-16793-NP methodology to confirm that chemical plate-out on the fuel is acceptable has been completed. This assessment was completed in accordance with the schedule provided to the NRC Staff in letter L-2007-155. This is discussed further in the response to NRC Topic 3.n, Downstream Effects – Fuel and Vessel.

The downstream effects assessment of pumps has been revised to incorporate the methodology of WCAP-16406-P, Revision 1, "Evaluation of Downstream Sump Debris Effects in Support of GSI-191" (WCAP-16406-P). This assessment was completed in accordance with the schedule provided to the NRC Staff in letter L-2007-155. A summary of the assessment results is provided in the response to NRC Topic 3.m, Downstream Effects – Components and Systems.

Enhancements to programmatic controls have been put in place at St. Lucie Unit 1. Engineering procedures have been revised to provide guidance to the design engineer working on plant modifications to take into account the impact of the design on the "containment sump debris generation & transport analysis and/or recirculation functions."

As an enhancement to the existing process for controlling the quantities of piping insulation within the containment, the engineering specification that controls thermal insulation was revised to provide additional guidance for maintaining containment insulation configuration.

New controls have been instituted limiting the permissible quantity of unqualified coatings in the containment building to ensure that the ECCS strainer design requirements, as documented in the St. Lucie Unit 1 debris generation calculation, remain within permissible limits.

Based on the results of the latent debris and foreign material walkdowns that were performed, it was determined that changes in the St. Lucie Unit 1 housekeeping procedures are not required because of the limited amount of material observed.

The September 1 response stated that updates to the licensing basis would be performed in accordance with the requirements of 10 CFR 50.59. However, it has recently been determined, based on a review of the Waterford audit results, that the current administratively controlled Refueling Water Tank (RWT) water should be incorporated into the Technical Specifications.

Chemical effects testing has been performed by Alion Science and Technology. A summary is provided in the response to NRC Topic 3.o, Chemical Effects.

This submittal provides the final conclusions regarding St. Lucie Unit 1 compliance with GL 2004-02. This submittal also includes responses to the RAIs.

As discussed further in Topic 3.p *Licensing Basis*, FPL is submitting an amendment request to raise the Technical Specification minimum level for the Refueling Water Tank (RWT).

Topic 3.a: Break Selection

FPL Response

In agreement with the staff's SE of NEI 04-07, the objective of the break selection process was to identify the break size and location which results in debris generation that will maximize the head loss across the containment sump strainers. Breaks were evaluated based on the methodology in Nuclear Energy Institute (NEI) guidance document NEI 04-07 as modified by the staff's SE of NEI 04-07.

The following specific break location criteria were considered:

- Breaks in the reactor coolant system with the largest amount of potential debris within the postulated ZOI,
- Large breaks with two or more different types of debris, including breaks with the most variety of debris,
- Breaks in areas with the most direct path to the sump,
- Medium and large breaks with the largest potential particulate debris to insulation ratio by weight, and
- Breaks that generate an amount of fibrous debris that, after transport to the sump strainers, could form a uniform "thin bed."

The spatial distribution of the strainer modules around the containment perimeter minimizes any beneficial effects that debris transport mechanisms would have on reducing the quantity and mix of debris that could be transported to a strainer module (or modules). Therefore, for St. Lucie Unit 1, the break location is of secondary importance, and the primary consideration is the debris generated by the break.

[RAI 34] Reactor Coolant System (RCS) piping and attached energized piping was evaluated for potential break locations. Inside the bioshield, breaks in the hot legs (42-inch ID), cold legs (30-inch ID), crossover legs (30-inch ID) and the pressurizer surge line (12-inch nominal) were considered. Feedwater and main steam piping were not considered for potential break locations because ECCS in recirculation mode is not required for Main Steam or Feedwater line breaks. The other piping lines located in the same general area as the RCS piping were not considered for potential break locations because they have a smaller diameter (10 inches maximum), which will produce a much smaller quantity of debris.

[RAI 33] Inside the bioshield, the break selection process used the systematic approach in the staff's SE of NEI 04-07. Break locations were selected in 5-foot increments along the applicable RCS piping to determine the maximum worst case debris mix.

A hot leg or cold leg line break at the reactor pressure vessel (RPV) was also considered. The RPV is covered with Transco reflective metallic insulation (RMI) on the vessel, and Nukon insulation on the top head. This break would affect the reactor insulation and the insulation on the RCS lines adjacent to the break up to the penetrations. However, this debris would fall to the bottom of the reactor vessel cavity. In addition, the amount of debris would be bounded by a hot or cold line break elsewhere on the line. Therefore, a hot leg or cold leg break at the RPV was not analyzed.

Outside the bioshield, breaks were considered in the safety injection lines. The safety injection lines are of smaller diameter than the RCS piping, and are located in the same general area inside the bioshield. Therefore, inside the bioshield, a break in these lines would be bounded by the reactor coolant loops, and thus need not be analyzed. However, each safety injection line travels outside the bioshield before the second isolation valve. (These lines each have a check valve located inside the bioshield that will isolate the RCS from the upstream portion of the line outside the bioshield.) The safety injection lines are the only RCS-connected larger lines that travel outside the bioshield before the second isolation valve, and, therefore, were selected in order to include a break outside the bioshield.

The two steam generator (SG) loops are nearly identical, except that Loop B also includes the pressurizer and associated piping. Both SG loops were investigated, and it was found that Loop B contained the limiting breaks.

The postulated break locations were as follows:
S1 Loop B hot leg at the base of the steam generator (42-inch ID)
S2 Loop B crossover leg at the base of the steam generator (30-inch ID)
S3 Safety Injection line outside the missile barrier (12-inch nominal line)

Break S1 generated the greatest quantity of debris. Therefore, it was selected for the strainer design basis.

Topic 3.b: Debris Generation/Zone of Influence (ZOI) (excluding coatings)

FPL Response

The debris generation calculation used the methodologies of Regulatory Guide 1.82, Rev. 3, NEI 04-07 and the staff's SE of NEI 04-07. However, there have been changes in the input to the analyses since the September 1 response.

Debris specific ZOIs were used in the debris generation calculation for low density fiber glass (LDFG), reflective metal insulation (RMI) and calcium-silicate (cal-sil). The ZOIs for insulation materials, with the exception of reinforced cal-sil, were obtained from Table 3-2 and § 3.4.2.2 of the staff's SE of NEI 04-07. The ZOI for reinforced cal-sil is based on testing. The ZOI for each debris type is discussed below.

The ZOI used for LDFG (Nukon and Transco Thermal-Wrap) is 17.0D, which was obtained from Table 3-2 of the NRC staff's SE of NEI 04-07. The staff's SE of NEI 04-07 does not have specific ZOI information for Transco Thermal-Wrap, which is installed on the steam generators. This insulation is fiber blanket insulation with stainless steel jacketing, which is similar to Nukon. For this reason, the Nukon ZOI is applied to Transco Thermal-Wrap.

The ZOI used for RMI is 2.0D, which was obtained from Table 3-2 of the NRC staff's SE of NEI 04-07.

Two ZOIs were used for cal-sil; 5.45D for unmodified cal-sil and 3.0D for reinforced cal-sil. The ZOI for unmodified cal-sil was obtained from Table 3-2 of the staff's SE of NEI 04-07. The ZOI for reinforced cal-sil is based on testing as discussed below.

In order to reduce the quantity of cal-sil debris that could be generated by a LOCA, reinforcing stainless steel bands were installed on selected sections of cal-sil insulated piping during the recently completed outage, SL1-21 (spring 2007). The banding system consists of ½-inch wide stainless steel bands that are installed around the outside of the insulation jacket. The bands are spaced approximately 3 inches on center. Tests to determine the efficacy of the banding system were conducted by Westinghouse utilizing the facilities of Wyle Laboratories. A description of the tests and the test results are contained in WCAP-16851-P ("Florida Power and Light (FPL) Jet Impingement Testing of Cal-Sil Insulation," Rev. 0, October 2007). The tests confirmed that when this stainless steel banding system is in place "... the material outside a ZOI of $\geq$ 3D may be excluded as a debris source for the purposes of GSI-191 post-LOCA sump screen, downstream and chemical evaluations," (i.e., the ZOI for the reinforced cal-sil is 3.0D). The test thermal-hydraulic conditions (pressure and temperature) were selected so that conditions associated with a postulated large-break LOCA (LBLOCA) blowdown were accurately simulated, and the data from the test is directly applicable to PWRs without any scaling or other type of compensation. This included simulating an instantaneous break to create an initial shock wave followed by a 30-second blowdown (which bounds a PWR LBLOCA).

The cal-sil on small attachments to the piping, such as Tees and valves was not reinforced. This was taken into account in the debris generation calculation by adding the calculated volume of cal-sil on these attachments, 10.21 ft^3, to the calculated volume of cal-sil debris.

The updated debris generation calculations make use of two assumptions related to non-coating debris generation.

Assumption 1

Supporting members fabricated from steel shapes (angles, plates) are installed to provide additional support for the mirror insulation on equipment such as reactor coolant pumps, Steam Generators and Pressurizer. It is assumed that, as a result of the postulated pipe break, these supporting members will be dislodged from the equipment, and may be bent and deformed, but will not become part of the debris that may be transported to the sump.

Assumption 2

In the September 1 response, it was noted that an analytical process was used that conservatively overstated the quantity of debris from insulation by 5-15%. This analytical process has been completely replaced. However, a 10% margin has been added to the insulation volume results. In addition, a uniform factor of 1.1 is applied to the ZOI used for calculating piping insulation volumes to account for minor variances such as insulation around valves, irregularities in the as-installed configuration, etc.

The quantities of debris and the ZOI for each debris type are provided in Table 3.b-1 below.

Table 3.b-1: Destruction ZOI and Break Comparison

Debris Type	Destruction ZOI	Break S1 (Note 1)	Break S2 (Note 1)	Break S3 (Note 1)
RMI	2.0D	857.2 ft^2	419.4 ft^2	0.0 ft^2
Cal-Sil (total)		91.1 ft^3	56.6 ft^3	24.4 ft^3
Reinforced	3.0D			
Unreinforced	5.45D			
Nukon	17.0D	169.0 ft^3	111.0 ft^3	9.1 ft^3
Transco Thermal-Wrap	17.0D	1197.6 ft^3	866.5 ft^3	4.7 ft^3
Insulation Jacketing (total)		4988 ft^2	3396 ft^2	241 ft^2
Cal-Sil (total)				
Reinforced	3.0D			
Unreinforced	5.45D			
Nukon	17.0D			
Transco Thermal -Wrap	17.0D			
Coatings (Note 2)				
Qualified – Concrete	4.0D	3.66 ft^3	1.80 ft^3	0.50 ft^3
Qualified – Steel	4.0D	1.59 ft^3	1.25 ft^3	0.25 ft^3
Unqualified	N/A	9.96 ft^3	9.96 ft^3	9.96 ft^3
Latent Debris (15% fiber, 85% particulates)	N/A	134.7 lbm	134.7 lbm	134.7 lbm
Foreign Materials (Note 3)	N/A	88.1 ft^2	88.1 ft^2	88.1 ft^2

Notes:
1. Break locations are discussed in the response to NRC Topic 3.a, Break Selection.
2. The destruction ZOI for qualified coatings is discussed in the response to NRC Topic 3.h, Coatings Evaluation.
3. Strainer "Sacrificial" Area (see Topic 3.d, Latent Debris)

It is also noted that FPL has determined that there is approximately 128.5 ft^2 of PVC jacketing on conduits inside of containment. This conduit did not have a post-LOCA qualification record that would substantiate whether or not the PVC jacketing would remain intact. Post-LOCA qualification testing has been conducted on this material. The testing has confirmed that the jacketing remains attached and does not become a coating-like debris that can transport to the sump. A negligible amount (less than 1%) of PVC coating debris was generated during testing. Hence, analyzed debris loading assumptions are maintained.

Topic 3.c: Debris Characteristics

FPL Response

[RAI 35] As discussed in the staff's SE of NEI 04-07, the categories in any size distribution are related to the transport model. A conservative, straightforward, transport model was used for St. Lucie Unit 1 because the distribution of the strainer modules around the containment perimeter minimizes the effects that debris transport mechanisms would have on the quantity and mix of debris that reaches the module(s). As a result, instead of a CFD based transport analysis, the St. Lucie Unit 1 transport model consisted of assuming that transportable debris reaches the modules. Therefore, detailed debris size distributions or other transportability characteristics are not required or developed for transport analyses. A discussion of the debris that was assumed to be transportable is provided in the response to NRC Topic 3.e, Debris Transport. Because a detailed transport model was not developed, the debris characteristics related to downstream effects analyses are addressed in the response to NRC Topic 3.m, Downstream Effects-Components and Systems.

For the purpose of determining the strainer debris load and head loss, the only size distribution that was used was for low density fiber glass (LDFG) insulation, which consisted of a large size, 6"x3"x1", and a small size 1"x1"x1". These sizes were used in performing the generic LDFG erosion testing. The technical basis for the applicability of LDFG erosion testing is provided in the response to NRC Topic 3.e, Debris Transport.

The bulk densities that were used to ensure that the proper quantities of the surrogate materials were used in the sector head loss tests (excluding chemical effects) are provided in Table 3.c-1 below.

Table 3.c-1: Bulk Densities Used For Sector Tests

Debris Type	Bulk density
Cal-sil	14.5 lbs/ft^3
Fiber	2.4 lbs/ft^3
Zinc Filler (surrogate for zinc coatings)	457 lbs/ft^3
Silicon Carbide (surrogate for coatings)	94 lbs/ft^3

The technical basis for the surface areas of signs, placards, tags, tape, etc is provided in the response to NRC Topic 3.d, Latent Debris.

The specific surface area, S_V, is a parameter that is used in the NUREG/CR-6224 head loss correlation. The head loss across the strainers was determined by testing, not the NUREG/CR-6224 correlation. Therefore, the specific surface area was not calculated or used. The head loss determination is described in the response to NRC Topic 3.f, Head Loss and Vortexing.

Topic 3.d: Latent Debris

FPL Response

The bases and assumptions related to latent and miscellaneous debris, and the resulting quantities used for analyses and testing, have been updated since the September 1 response. In that response it was noted that the quantity of latent debris was an assumed value in lieu of applied survey results, and that the sacrificial area for miscellaneous debris was an estimated value. Subsequently, walkdowns have been completed in the St. Lucie Unit 2 containment specifically for the purpose of characterizing latent and miscellaneous debris. The results of the walkdowns are discussed below and summarized in Table 3.b-1 in the response to NRC Topic 3.b, Debris Generation/Zone of Influence (ZOI) (excluding coatings). The walkdowns utilized the guidance in NEI 02-01 and the staff's SE of NEI 04-07. The methodology, the results, and the justification for basing Unit 1 latent and miscellaneous debris on Unit 2 data are discussed below.

The methodology used to estimate the quantity and composition of latent debris in the Unit 2 containment is that of the staff's SE of NEI 04-07, Section 3.5.2. Samples were collected from eight surface types; floors, containment liner, ventilation ducts, cable trays, walls, equipment, piping and grating. For each surface type, a minimum of four (4) samples were collected, bagged, and weighed to determine the quantity of debris that was collected. A statistical approach was used to estimate an upper limit of the mean debris loading on each surface. The horizontal and vertical surface areas were conservatively estimated. The total latent debris mass for a surface type is the upper limit of the mean debris loading multiplied by the conservatively estimated area for that surface type, and the total latent debris is the sum of the latent debris for each surface type.

St. Lucie Unit 1 and Unit 2 are of a similar design. The internal containment horizontal and vertical surface areas are similar. The procedures for containment closeout are similar and the organizations who perform these procedures are the same. Therefore, the Unit 2 latent debris is representative of the Unit 1 latent debris.

Based on the walkdown data, the quantity of latent debris in the Unit 2 containment is estimated to be 67.36 pounds. However, in order to ensure that differences are bounded, the Unit 2 quantity of latent debris is doubled to 134.72 pounds (100% margin) for use in the Unit 1 analyses. The latent debris composition is assumed to be 15% fiber and 85% particulate in agreement with the staff's SE of NEI 04-07.

Two Unit 2 containment walkdowns were performed for the purpose of identifying and measuring plant labels, stickers, tape, tags, and other debris. This information was used to determine the strainer area that is assumed to be covered by miscellaneous ("foreign") debris in the strainer head loss analyses. Based on the walkdown data, the quantity of miscellaneous debris in the Unit 2 containment is estimated to be 70.482 ft^2. Unit 1 and Unit 2 are of a similar design, and the procedures for labeling and lights are similar between Unit 1 and Unit 2. Therefore, the miscellaneous debris will be similar. However, in order to allow for differences, the quantity of miscellaneous debris that was determined in the Unit 2 walkdown was increased to 88.10 ft^2 (~25% margin) for use in Unit 1 analyses and testing.

Topic 3.e: Debris Transport

FPL Response

[RAI 41] In the September 1 response it was noted that debris transport would be analyzed using the computational fluid dynamics (CFD) based methodology outlined in NEI 04-07. However, the spatial distribution of the strainer modules around the containment perimeter minimizes the effects that debris transport mechanisms would have on the quantity and mix of debris that could be transported to the strainer modules. As a result, for the purposes of determining the strainer debris load and head loss, it was conservatively assumed that debris was uniformly distributed throughout the containment prior to the start of recirculation, and that transportable debris reached the strainer modules. For example, no credit was taken for an inactive volume or for the settling of fine debris. Because transport effects were not credited, a CFD transport analysis was not performed for the installed St. Lucie Unit 1 strainers. However, the determination of the transportable fraction is discussed below because it was used in the determination of the debris that ultimately reached the strainer surfaces.

The fraction of fibrous material (Low density fiber glass, LDFG) that is transportable during recirculation is approximately 34.2%. However, the sector head loss test conservatively assumed a transportable fraction of 36% for fibrous material. Reflective metal insulation (RMI) and insulation jacketing are not transportable during recirculation (i.e., the transportable fraction is 0.0%). As discussed below, these values are based on the fraction of the sump pool that is turbulent and conservative estimates of the flow velocities in the fraction that is non-turbulent.

The fraction of the sump pool that is turbulent was calculated to be 20.6% for large pieces, and 30.6% for small pieces. The difference is due to a conservative assumption that fibrous material was assumed to erode and be transported to the strainers from two areas; (a) the turbulent zone and (b) the non-turbulent zone where the flow velocity is greater than the incipient tumbling velocity. Areas where the flow velocity exceeded the incipient tumbling velocity were included with the turbulent zone. Since small pieces have a lower incipient tumbling velocity, there is a larger area of containment where this velocity is exceeded, and this larger area increased the fraction that was defined as turbulent for small pieces. This model is conservative compared to a CFD analysis because a CFD analysis would be expected to reveal low-flow areas and dead spots in places that are sheltered from the break's turbulence, and these low flow areas and dead spots would not experience complete erosion.

The flow velocities in the non-turbulent areas inside the bioshield were based on the assumption that the entire flow moves in one direction from the break. This is conservative because the distribution of the strainers (which are the recirculation intake points) ensures that water will flow to several sectors, not in one direction. Inside the bioshield, the flow velocity was calculated to be 0.113 ft/sec. The flow velocities in the non-turbulent areas outside the bioshield were based on the assumption that; (a) flow is from containment spray and is evenly distributed throughout the containment, and (b) the flow moves towards the nearest module. Outside the bioshield, two flow velocities were calculated; 0.14 ft/sec for 26.4% of the area and 0.07 ft/sec for 73.6% of the area.

In the non-turbulent zone where the flow velocity is less than the incipient tumbling velocity a fraction of the fibrous material was assumed to erode and be transported. The erosion fraction was determined by tests conducted by Alion Science and Technology. Testing was performed in both a vertical test loop and a horizontal transport flume. Large sample pieces (6 inch x 3 inch x 1 inch) were tested at an average flow velocity of 0.37 ft/s, and small sample pieces (1 inch x 1 inch x 1 inch) were tested at an average flow velocity of 0.12 ft/s. Three methods were used to analyze the test results, and the most conservative method yielded an upper bound value of 10%. That is, the non-transportable fiber that is submerged in the containment pool of St. Lucie Unit 1 is expected to release 10% of its mass, which then travels to the sump strainer modules. The size distribution was assumed to be 60% small pieces and 40% large pieces in agreement with the staff's SE of NEI 04-07. With the assumptions and test data described above, the transportable fraction of fibrous debris was calculated to be 34.17%.

RMI and insulation jacketing are considered to be non-transportable because the maximum calculated flow velocity is 0.14 ft/sec. As discussed in NUREG/CR-6808 (NUREG/CR-6808, LA-UR-03-880, "Knowledge Base for the Effect of Debris on Pressurized Water Reactor Emergency Core Cooling Sump Performance," Los Alamos National Laboratory, 2003) the velocity required to transport intact RMI is >1 ft/sec, and from 0.2 to 0.8 ft/sec for single sheets. The velocity required to transport "crumpled" sheets is not provided, but is qualitatively stated as "lower" than the provided velocities. Given that the maximum calculated velocity, 0.14 ft/sec, is below the minimum required velocity, 0.2 ft/sec, it is judged reasonable to consider RMI and insulation jacketing non-transportable. The qualitative statement that "crumpled" sheets transport at lower velocities is countered by the margin (approximately 100%) in the velocity calculations.

The Quantity of debris that ultimately arrives at the strainer modules is provided in Table 3.e-1 below.

Table 3.e-1: Debris at Sump Strainer Modules for Limiting Case

Constituent	Quantity Generated	Transportable Fraction	Quantity at Strainer
INSULATION			
RMI	857.2 ft^2	0.0	0.0 ft^2
Calcium Silicate (Note 1)	91.1 ft^3	1.0	91. 1 ft^3
Nukon (Note 2)	169.0 ft^3	0.3417	57.75 ft^3
Transco Thermal Wrap (Note 2)	1197.6 ft^3	0.3417	409.22 ft^3
Insulation Jacketing	4988 ft^2	0.0	0.0 ft^2
QUALIFIED COATINGS			
Concrete)	3.66 ft^3	1.0	3.66 ft^3
Steel	1.59 ft^3	1.0	1.59 ft^3
UNQUALIFIED COATINGS			
Unqualified Coatings Log with Margin Added (50%)	4.17 ft^3	1.0	4.17 ft^3
RCP Motor	1.85 ft^3	1.0	1.85 ft^3
HVAC Duct Joints	2.34 ft^3	1.0	2.34 ft^3
Steel Piping (Uninsulated)	0.87 ft^3	1.0	0.87 ft^3
Steel Piping (Zones 1,2)	0.73 ft^3	1.0	0.73 ft^3
LATENT DEBRIS			
15% Fiber	20.2 lbm	1.0	20.2 lbm
85% Particulate	114.5 lbm	1.0	114.5 lbm
FOREIGN MATERIALS (Note 3) (Signs, placards, tags, tape, etc.)	88.1 ft^2	N/A	88.1 ft^2

Notes:
1. The sector test head loss test results were conservatively based on assuming 109.4 ft^3 of cal-sil. See the response to Topic 3.f, Head Loss and Vortexing.
2. The transportable fraction for insulation fiber is 34.17%. The sector head loss test results were conservatively based on assuming a transportable fraction of 36%, that is, 36% of the available fiber is transported to the strainers. However the limiting head loss occurred at 25% of this calculated fiber load. See the response to Topic 3.f, Head Loss and Vortexing, for additional discussion.
3. Foreign material is actually a "sacrificial area" and a transport fraction is not applicable.

Topic 3.f: Head Loss and Vortexing

FPL Response

A piping schematic of the ECCS and containment/reactor building spray systems is provided in Figure 3.f-1 below. A description of the strainer system, including the capability to accommodate thin bed effects, is provided in the response to NRC Topic 3.j, Screen Modification Package.

[RAI 37] [RAI 40] The entire distributed strainer system is fully submerged from the initiation of recirculation through the duration of the event. At the minimum Large Break LOCA (LBLOCA) water level, the submergence of the highest opening in the strainer system is 14 inches. At the minimum Small Break LOCA (SBLOCA) water level, the submergence of the highest opening in the strainer system is 8 inches.

The potential for vortexing was evaluated for the strainer modules and the highest opening in the strainer system and the inlet to the pump suction line. The results confirm that vortexing will not occur in the strainer system or pump suction inlet.

Of the 21 strainer modules, there are two that are most susceptible to vortex formation due to their submergence, physical proximity to the pump suction line, and placement out on the open containment floor. The possibility of vortex formation at these two modules was evaluated and found to be negative, with a large margin. The evaluation included the assumption of a flow rate 3 times higher than the average module flow value to account for the proximity of these modules to the pump suction lines. This evaluation is, therefore, considered bounding for the rest of the module locations.

The highest opening in the strainer system is the vent on top of the intake manifold that acts as a collector for the strainer module piping runs. The possibility of vortex formation was evaluated at this location and found to be negative with a large margin. This evaluation conservatively assumed a flow rate based on a pressure differential across the vent hole greater than the maximum "crush pressure" used for strainer structural analysis.

[RAI 40] Vortexing will not occur at the sump ECCS/CSS suction inlets because water from the strainers is piped directly to the suction inlets. That is, there is no location between the strainers and pump suction inlets where vortexing could occur.

[RAI 40] The possibility of buoyant debris accumulation is bounded by the case of the two modules located out on the containment floor. As noted above, the minimum submergence for the strainer system is 14 inches for the LBLOCA, and 8 inches for the SBLOCA. This is judged to provide adequate separation between floating debris and the strainer system perforated surfaces.

[RAI 39] The new strainer system has a surface area of approximately 8,275 ft^2, which can accommodate the maximum debris load from the bounding break discussed in the response to NRC Topic 3.a, Break Selection. The strainer capability to accommodate a thin bed is discussed in the response to NRC Topic 3.j, Screen Modification Package.

The head loss from this system is made up of two components; the strainer disk head loss and the module/piping head loss.

The strainer disk head loss, excluding chemical effects, is based on the sector head loss tests that were run specifically for St. Lucie Unit 1 by Continuum Dynamics, Inc (CDI).

The sector test used two discs of a modular strainer immersed in a test tank. The sector discs were aligned vertically in the same manner as the plant strainer discs are installed above their plenums. The sector tests were performed with a submergence of 11.88 +1/-0 inch. The sector tests simulated the strainer approach velocities and plant debris loads with one exception. That exception is that the quantity of cal-sil used in the test corresponded to 109.4 ft^3, which is 20% greater than the 91.1 ft^3 that was calculated for the bounding case. The sector test head loss was scaled to the full sized strainer system based on velocity, kinematic viscosity, and bed thickness differences. The scaling process assumed that flow through the strainer internals is turbulent due to the abrupt direction changes and abrupt expansions from the strainer discs to plenum.

At the conclusion of the tests it was determined that the maximum head loss was found to be a case with 25% plant transportable fiber. One possible mechanism for this effect is that as fiber content increases, the particulate to fiber ratio decreases such that the fiber bed is cleaner, and water passes more easily through the debris bed.

[RAI 36] The near-field effect was not credited in the design or tests. The steps taken to minimize near-field effects in the tests included placing the flow return near the bottom of the test tank to help suspend debris, and using five (5) motor driven agitators to ensure that debris remained suspended. The agitators were started prior to debris addition to facilitate mixing and prevent settling of debris prior to strainer test pump startup. The materials used to represent the St. Lucie Unit 1 debris in the test are listed in Table 3.f-1 below.

The module/piping head losses are the hydraulic losses associated with flow from the strainer plenums to the manifold and then through the manifold discharge piping to the ECCS suction. Assumptions, margins and conservatisms used in establishing the head losses are:

- A maximum temperature of 210°F.
- A minimum temperature of 65°F.
- A flow rate of 8530 gpm that is conservatively assumed to apply for the duration of the event. It is based on simultaneous hot and cold leg recirculation, which is not initiated until 4 to 6 hours into the event.
- A transportable fraction of 36% was assumed for low density fiberglass (LDFG) in the sector tests (i.e., 36% of the LDFG was assumed to erode and reach the strainers). The actual transport fraction was calculated to be 34.17%.
- The quantity of cal-sil in the sector test was based on 109.4 ft^3 at the strainer modules. The calculated quantity is 91.9 ft^3.
- Debris accumulation was assumed to be proportional to flow rate.
- Debris head loss is assumed to be directly proportional to the debris bed thickness and flow rate through the debris bed. Debris bed compression is not taken into account.
- Pipe connections between the 10-foot sections of pipe are modeled as orifices that restrict the flow, which is conservative.

[RAI 39] The head loss for the strainer system, not considering chemical effects, is provided in Table 3.f-2 below. The piping head loss with clean strainers is smaller than the piping head loss with debris laden strainers. This is because unbalanced flow (with the majority of the flow entering the strainers nearest the sump) can be modeled with clean strainers, and the unbalanced flow leads to lower piping head loss.

Table 3.f-1: Sector Test Debris Materials

Debris Type	Material	Density	Manufacturer
Fiber	Transco Thermal Wrap (shredded)	2.4 lb/ft^3	Transco
Cal-Sil	Thermo 12 Gold (pulverized)	14.5 lb/ft^3	Industrial Insulation Group
Inorganic Zinc	Carboline Carbo-Zinc 11 filler	457 lb/ft^3	Carboline
Particulates	Silicon Carbide (~ 10 micron dia)	94 lb/ft^3	Electro Abrasives

Table 3.f-2: Strainer System Head Loss Summary (Excluding Chemical Effects)

Condition	Flow Rate (gpm)	Strainer Head Loss (ft)	Piping Head Loss (ft)	Total Head Loss (ft)
Debris Laden (210 °F)	8,530	1.92	5.87	7.79
Debris Laden (65 °F)	8,530	5.77	5.87	11.64
Clean	8,530	0.11	1.85	1.96

The St. Lucie Unit 1 chemical effects testing report has concluded that a bump up factor of 3.3 applies to debris laden strainer screen head loss due to chemical effects. For the limiting NPSH case (210°F), the strainer head loss including chemical effects is 5.55 feet for a total head loss of 11.42 feet.

St. Lucie Unit 1 head loss testing of a debris laden strainer section was conducted by CDI for GE at final fluid temperatures between 60 degrees F and 99 degrees F. Head loss values were then scaled by viscosity ratios to strainer design conditions (210 degrees F). Part of the test plan and protocol was to observe and photograph each test case to ensure the absence of 'boreholes.' The tests confirmed that for the St. Lucie Unit 1 limiting head loss test cases, no boreholes were observed.

For the limiting design case (lowest pool level) a small amount of containment (previously existing air) pressure is credited in addition to vapor pressure for prevention of flashing at the immediate strainer/debris bed surface.

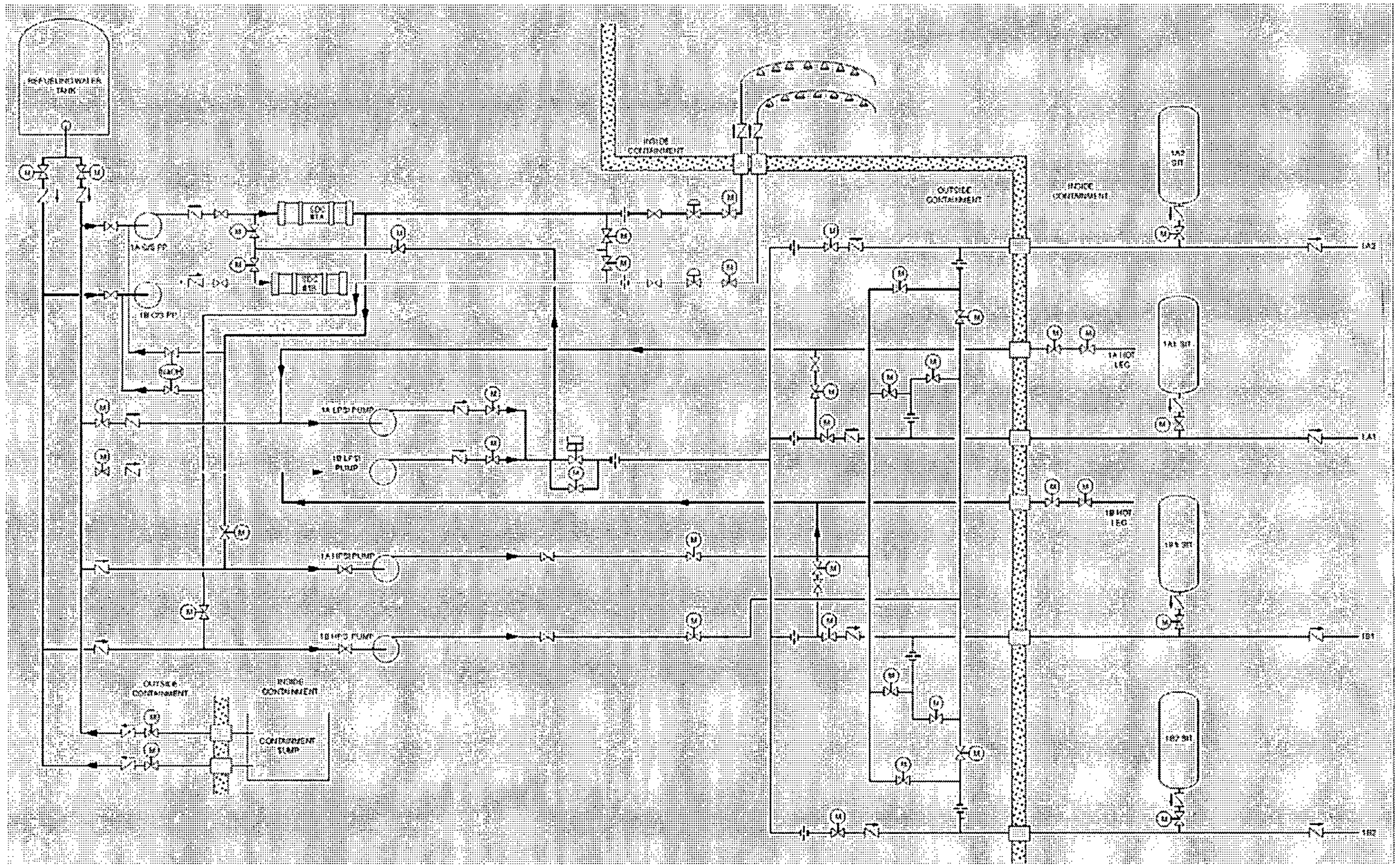


Figure 3.f-1: ECCS/CSS Piping Schematic

Topic 3.g: Net Positive Suction Head (NPSH)

FPL Response

The minimum LBLOCA post LOCA containment water level will reach an elevation of 23.86 ft (assuming an RWT level of 32.5 ft and minimum levels assumed in other injected tanks). The minimum SBLOCA post LOCA containment water level will reach an elevation of 23.36 ft (assuming an RWT level of 32.5 ft and minimum levels assumed in other injected tanks).
The LBLOCA flow rate used to calculate the NPSH margin is 8,530 gpm, which is the same as that used to determine the strainer system head loss discussed in the response to NRC Topic 3.f, Head Loss and Vortexing. This flow is conservatively assumed to apply for the duration of the event. It is based on simultaneous hot and cold leg recirculation, which is not initiated until 4 to 6 hours into the event. The maximum flow rate is made up of the following components:

- Two Containment Spray System (CSS) pumps 8,130 gpm
- One Low Pressure Safety Injection (LPSI) pump 400 gpm
- Total 8,530 gpm

The HPSI pump flow is 640 gpm per pump. However, because the HPSI pump operates in "piggy back" mode on the CSS pump during recirculation, the HPSI flow is included in the CSS pump flow above.

The temperature range used to calculate the NPSH margin is 65°F to 260 °F. The minimum NPSH margin occurs at a temperature of approximately 200 °F.

The bases for the assumptions used in the flow parameters are the maximum expected flow rates based on emergency operating procedure (EOP) equipment lineups and the worst postulated single active component failure.

For the design basis case, the minimum NPSH margin, including chemical effects, is approximately 5.1 ft for the LBLOCA, and 4.6 ft for the SBLOCA. Note that the minimum NPSH margin for the CS pump for the LPSI failure to trip (described below) is 3.6 ft for the LBLOCA and 3.1 ft for the SBLOCA. The key assumptions are listed below:

- Containment accident pressure is consistent with Regulatory Guide 1.1 guidance (i.e., for lower temperatures where the vapor pressure of water is less than the partial pressure of air, the total containment pressure is set equal to the minimum partial pressure of air and is not increased: for higher temperatures where the vapor pressure of water is greater than the minimum partial pressure of air, the total containment pressure is set equal to the vapor pressure of water).
- NPSH required ($NPSH_R$) is based on pump test curves.
- Strainer head loss, excluding chemical effects, was determined by testing.
- 1% is added to flow rates to account for uncertainties.

The maximum flow losses (including debris and chemical effects) determined for the St. Lucie Unit 1 ECCS/CS strainer, plenum and piping system by calculation and by testing are subtracted from available NPSH to determine overall pump NPSH margin over the NPSH required.

Following a large break LOCA (LBLOCA) both trains of the Low Pressure Safety Injection (LPSI) Pumps, Containment Spray (CS) pumps and High Pressure Safety Injection (HPSI) pumps are automatically started. At a minimum, recirculation is not initiated until at least 20 minutes after the LBLOCA. At the present time, the RWT level is administratively controlled to be above the Technical Specification level, which increases the water volume available for recirculation and extends the time to the Recirculation Actuation Signal (RAS) beyond 20 minutes.

Just prior to RAS, operators are procedurally directed to align the containment spray to the HPSI pump suction ("piggy-back" mode). On receipt of the RAS, the LPSI pumps are stopped automatically and the CS and HPSI pumps continue to operate taking suction from the containment sump. At 4 to 6 hours post-LOCA, one LPSI pump is started when the hot leg injection mode is manually initiated by operator action. For the purposes of establishing the demands on the sump strainers, simultaneous hot and cold leg recirculation flow, which is the highest post-RAS recirculation flow, is assumed for the entire event.

Following a small break LOCA (SBLOCA), both trains of the HPSI and LPSI pumps are started automatically on a Safety Injection Actuation Signal (SIAS). Both trains of the CS pumps may start if the containment pressure setpoint is reached. For a SBLOCA, where the RCS pressure is above the LPSI pumps shut-off head, the LPSI pumps do not deliver flow into the RCS during the injection phase of the small break LOCA. Under these conditions the time to the Recirculation Actuation Signal (RAS), which is based on refueling water tank (RWT) level, is increased beyond the LBLOCA value of 20 minutes.

On receipt of RAS, recirculation flow will begin. The range of SBLOCA breaks includes those that require recirculation from the containment sump as well as those that permit the operators to depressurize the RCS and initiate the shutdown cooling mode of decay heat removal, which does not require suction from the containment sump. Because the SBLOCA produces less debris, the debris load on the sump strainers is less than the design basis debris load. However, for the purpose of evaluating the sump strainer under SBLOCA conditions, it is conservatively assumed that the recirculation flow from the containment sump and the debris load are the same as the LBLOCA, and that the water level is that of the SBLOCA.

The single failure relevant to sump strainer performance is the failure of an operating LPSI pump to trip on receipt of the RAS. It is expected that the Operator would take action to trip this pump manually during verification of RAS actions, one of which is to "ENSURE LPSI Pumps STOPPED." Thus, this condition is expected to be temporary or short term. Nevertheless, the consequences of a LPSI pump failing to trip at RAS have been analyzed. The analysis showed that the maximum differential pressure from this condition is 5.2 psi, which is well below the design value of 20 psi. The analysis also showed there is sufficient NPSH margin for the CSS pumps to continue operating (3.6 ft for an LBLOCA and 3.1 ft for an SBLOCA). However, there is insufficient NPSH to support continued LPSI pump operation after RAS. Should this condition lead to the loss of one LPSI pump, this is an existing design basis case that is analyzed in the UFSAR and does not lead to unacceptable consequences.

Post LOCA containment water level is calculated considering the minimum volume of water released from the Reactor, RCS system, SIT tanks and RWT tank following a LOCA for the minimum containment water level. The volumes of water held up are then calculated and subtracted from the total water volume. The water level is then calculated based on free volume of station geometry below elevation 24 ft.

FPL has reviewed the results of the Waterford audit with respect to containment water level and has revised the post-LOCA containment water level calculations. The revised calculation incorporates water hold up issues and volume changes which include:

- Volume of water from the Refueling Water Tank (RWT).
- Volume of water required to fill the empty containment spray pipe headers. The volume of the spray piping was calculated using the piping isometrics.
- Volume of water in the containment spray droplets. This volume was calculating utilizing the containment spray flow, the droplet fall distance, and droplet terminal velocity.
- Volume of water held up as film on containment surfaces. Conservatively the water condensation film on the surfaces was calculated using the total heat sink area which includes horizontal and vertical surfaces from Section 6.2 of the UFSAR. Average condensate film thickness on heat sink surfaces was determined and a 10% margin added for additional conservatism.
- Volume of water held up in the refueling canal.
- Volume of water as steam in the containment atmosphere.
- Volume of water to reflood the reactor vessel following a Large Break LOCA (LBLOCA).
- Volume changes due to changes in specific volume due to volumes heating (RWT and others) and volumes cooling (RCS).

Post LOCA containment pool level is determined by calculating free containment volume based on containment building geometry below the approximate post LOCA water levels. These free volumes include containment sump, reactor cavity, electrical tunnel and access, blowout tunnel, Reactor Drain Tank pit, ECCS suction piping, trenches stairways, equipment cubicles and drains system among others. This is conservative because numerous components such as piping, conduit, stairs, and structural supports are not credited for water displacement.

The following table provides a summary of post LOCA containment pool water sources.

In the event of a:	LBLOCA	SBLOCA
Reactor Vessel:	4,652 ft^3	NA
Reactor Coolant Pumps:	449 ft^3	NA
Steam Generators:	3,396 ft^3	NA
Pressurizer:	600 ft^3	NA
R. C. Piping: (hot and cold leg)	1,064 ft^3	NA
Safety Injection Tanks:	4,360 ft^3	4,360 ft^3
Boric Acid Tank:	722 ft^3	722 ft^3
NaOH Storage Tank:	536 ft^3	536 ft^3
Total volume inside containment at LOCA @ T=0 =	15,779 ft^3	5,618 ft^3
Refueling Water Storage Tank:		
335,700 gal/7.4805 =	44,877 ft^3	44,877 ft^3
Total volume inside containment at RAS =	60,656 ft^3	50,495 ft^3

The regulatory position stated in Regulatory Guide 1.1 is that ECC and CS systems should be designed so that adequate NPSH is provided to ECC and CS system pumps assuming:

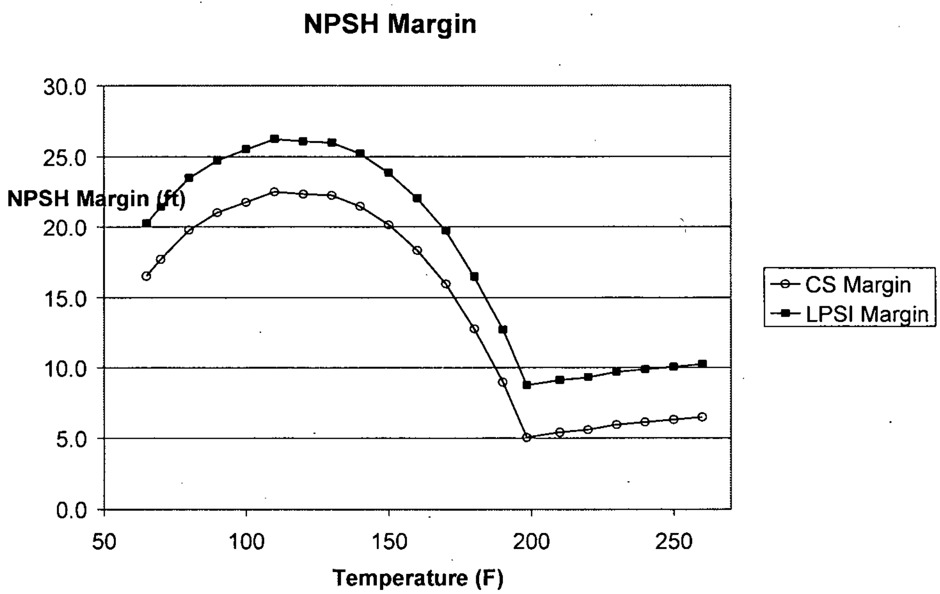
- maximum expected temperatures of pumped fluids, and
- no increase in containment pressure from that present prior to postulated loss of coolant accidents.

The NPSH calculation was performed consistent with Regulatory Guide 1.1

The containment sump strainer design temperature of 210 degrees F was chosen for NPSH considerations because it is close to the maximum pool temperature possible with containment pressure minimized, being no greater than prior to the postulated event (partial pressure of existing air ignored). At higher temperatures head losses are lower due to viscous effects.

For the purposes of calculating NPSH margin, containment accident pressure is set at the vapor pressure of water corresponding to the sump liquid temperature for pressures above that existing prior to the start of the postulated event (the partial pressure of air is ignored). Therefore, the St. Lucie Unit 1 NPSH calculation is consistent with Safety Guide 1.1 and the traditional conservative industry method of determining ECCS/CS pump NPSH during the recirculation mode of operation.

The NPSH margin was calculated and plotted for various sump fluid temperatures. Note that the full 30-day debris load (non-chemical debris and the maximum bump up factor) is applied at the initiation of recirculation. This is extremely conservative since as the chemical products are being created during the 30 days, the sump pool is cooling down providing additional margin. The plots of NPSH margin versus temperature for the containment spray and low head safety injection pumps are provided below for the design basis LBLOCA case.


NPSH Margin
NPSH Margin (ft)
30.0
25.0
20.0
15.0
10.0
5.0
0.0
50
100
150
200
250
Temperature (F)
CS Margin
LPSI Margin

Topic 3.h: Coatings Evaluation

FPL Response

Coatings are classified as qualified or unqualified. The qualified coating systems used in the St. Lucie Unit 1 containment are listed in Table 3.h-1 below.

Table 3.h-1 Qualified Coatings in the St. Lucie Unit 1Containment

Substrate	Application	Coating Product	Application Thickness (mils)
Steel	1st Coat	Carboguard 890	6
	2nd Coat	Carboguard 890	6
	1st Coat	Carbozinc 11	5
	2nd Coat	Phenoline 305	6
Concrete Floor	1st Coat	Carboguard 2011S	50
	2nd Coat	Carboguard 890	7
	3rd Coat	Carboguard 890	7
	1st Coat	Carboline 195	20
	2nd Coat	Phenoline 305	6
Concrete Wall	1st Coat	Carboguard 2011S	35
	2nd Coat	Carboguard 890	7
	3rd Coat	Carboguard 890	7
	1st Coat	Carboline 195	20
	2nd Coat	Phenoline 305	6
Concrete Sump	1st Coat	Phenoline 300	15
	2nd Coat	Phenoline 300	10
	3rd Coat	Phenoline 302	10

[RAI 30] For St. Lucie Unit 1, the analyzed LOCA cases generated sufficient fiber to form a thin fiber bed. Consistent with the staff's SE of NEI 04-07 for thin fiber bed cases, all coating debris is treated as particulate with 100% transportation of generated coatings to the sump screen. ElectroCarb black silicon carbide with 10-micron particle diameter was used as a surrogate for coatings other than inorganic zinc because 10 microns is the limiting size for head loss, and the density (94 lb/ft^3 approximates the density of coating systems. Carboline Carbo-zinc filler was used as the surrogate for inorganic zinc because it is the principal constituent.

Selected features of the treatment of qualified and unqualified coatings in the determination of coating debris that reaches the sump strainers have been updated since the September 1 response. These changes are discussed individually below.

[RAI 29] The qualified coating ZOI in the September 1 response for St. Lucie Unit 1 was 10D. The ZOI for qualified coatings has subsequently been reduced to 4D. The 4D ZOI is based on testing that was completed at the St. Lucie Plant during February of 2006.

A description of the test, the test data, and the evaluation of the test data, were previously provided to the NRC staff for information on July 13, 2006 in FPL Letter L-2006-169 (R.S. Kundalkar (FPL) to M.G. Yoder (NRC), "Reports on FPL Sponsored Coatings Performance Tests Conducted at St. Lucie Nuclear Plant," July 13, 2006). The evaluation of the test results confirms that a 4D ZOI is applicable to the in-containment qualified coating systems at St. Lucie Unit 1. As stated in the test plan, heat and radiation increase coating cross linking, which tends to enhance the coating physical properties. Therefore, since artificial aging, heat, or irradiation to the current plant conditions could enhance the physical properties and reduce the conservatism of the test, the test specimens were not aged, heated, or irradiated.

The coating thicknesses in the September 1 response were assumed to be 3 mils of inorganic zinc primer plus 6 mils of epoxy (or epoxy-phenolic) top coat for qualified coatings and 3 mils of inorganic zinc (IOZ) for unqualified coatings. Subsequently the analyses have been updated. The current debris generation model conservatively assumes the maximum thicknesses for each applicable coating system.

The coating area in the ZOI in the September 1 response was assumed to be equal to the surface area of the ZOI. Subsequently, the updated debris generation calculations calculate the quantity of qualified coatings for each break by using the concrete and steel drawings to determine the amount of coating that will be within the ZOI for each break. Coatings that are shielded from the jet by a robust barrier are not included in the total. The calculated volume of qualified steel coating is then increased by 10% to account for small areas of additional items such as piping, pipe/conduit/HVAC/cable tray supports, stiffener plates, ladders, cages, handrails, and kick plates.

The estimated quantity of unqualified/failed coatings in the September 1 response was 11 ft^3. With the changes discussed above, the estimated quantity of unqualified/failed coatings is now 9.96 ft^3.

Subsequent to the September 1 response, the process for controlling the quantity of degraded qualified coatings in containment has been enhanced to ensure that it does not exceed the sump strainer design basis.

The previous program for controlling in-containment coatings was described in the FPL response to NRC Generic Letter 98-04, "Potential for Degradation of the Emergency Core Cooling System and the Containment Spray System After a Loss-of-Coolant Accident Because of Construction and Protective Coating Deficiencies and Foreign Material in Containment" in letter L-98-277 on November 9, 1998. The letter summarized the program in place at that time for assessing and documenting the condition of qualified/acceptable coatings in primary containment at St. Lucie Unit 1.

[RAI 25] The current program for controlling the quantity of unqualified/degraded coatings includes two separate inspections by qualified personnel during each refueling outage, and notification of plant management prior to restart if the volume of unqualified/degraded coatings approaches pre-established limits.

The first inspection takes place at the beginning of every refueling outage, when areas and components from which peeling coatings have the potential for falling into the reactor cavity are inspected by the FPL Coating Supervisor. The second inspection takes place at the end of every refueling outage when the condition of containment coatings is assessed by a team (including the Nuclear Coating Specialist) using guidance from EPRI Technical Report 1003102 ("Guidelines On Nuclear Safety-Related Coatings," Revision 1, (Formerly TR-109937)). Accessible coated areas of the containment and equipment are included in the second inspection. Plant management is notified prior to restart if the volume of unqualified/degraded coatings approaches pre-established limits.

The initial coating inspection process is a visual inspection. 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. Following identification of degraded coatings, the degraded coatings are repaired per procedure if possible. For degraded coatings that are not repaired, areas of coatings determined to have inadequate adhesion are removed, and the Nuclear Coatings Specialist assesses the remaining coating to determine if it is acceptable for use. The assessment is by means of additional nondestructive and destructive examinations as appropriate.

Topic 3.i: Debris Source Term

FPL Response

Information related to programmatic controls for foreign materials was provided to the NRC in previous submittals. Such information was provided in letter L-2003-201 which responded to NRC Bulletin 2003-01, and most recently in letter L-2005-181 which responded to GL 2004-02. In general, the information related to programmatic controls that was supplied in these responses remains applicable. However, subsequent to the September 1 response, modifications, tests and walkdowns have been completed, and these have been used to inform and update the programmatic controls that support the new sump strainer system design basis.

The results of the recently completed walkdowns to assess the quantities of latent and miscellaneous debris are discussed in the response to NRC Topic 3.d, Latent Debris. These walkdowns were conducted without any preconditioning or pre-inspections. Consequently, the debris found during the walkdowns is characteristic of approximately 23 years of operation under the existing housekeeping programs. In addition, as discussed in the response to NRC Topic 3.d, *Latent Debris*, the St. Lucie Unit 2 quantity of latent debris is doubled (100% margin) for use in the St. Lucie Unit 1 analyses and testing, and the St. Lucie Unit 2 quantity of miscellaneous debris is increased by approximately 25% for use in St. Lucie Unit 1 analyses. Based on these walkdowns, it was determined that current housekeeping procedures were appropriate, hence no changes have been made to these procedures.

Currently insulation and materials inside containment are controlled by procedures that require; (a) a review of changes to insulation or any other material inside containment that could affect the containment sump debris generation and transport analysis and/or recirculation functions and (b) a review of the effect of any change package for its impact on containment sump debris generation and transport. This guidance has been enhanced by a new engineering specification that brings together, in one document, the insulation design documents that determine the design basis for the insulation debris component of the containment recirculation strainer design. This specification provides guidance for evaluating and maintaining piping and component insulation configuration within the containment building at St. Lucie Unit 1. In addition, the St. Lucie Plant procedure for controlling work orders was revised to assure that insulation work inside containment required signoff to the requirements of this specification.

One new procedure has been written for inspection of the new strainer system, and the containment close-out procedure has been updated. The new procedure requires that there are no holes, gaps or tears greater than 1/16 inch (0.0625 inch) in any component of the strainer system (e.g., including connections). The containment closeout procedure was updated to include all of the strainer system components in the final containment closeout inspection. The effect of these changes is to ensure that all components (strainer modules, piping, and pipe connections) are inspected, and that there are no holes, gaps or tears greater than 1/16 inch in any strainer system component.

It is further noted that the Plant General Manager and the Site Vice President perform a walkdown of the containment prior to entry into Mode 4 to assess restart readiness at the end of each outage.

The Maintenance Rule requires assessment of risk resulting from the performance of maintenance activities. Prior to performing maintenance activities (including but not limited to surveillance, post-maintenance testing, and corrective and preventive maintenance), the licensee assesses and manages the increase in risk that may result from the proposed maintenance activities. The scope of the assessment may be limited to those structures, systems, and components (SSCs) that a risk-informed evaluation process has shown to be significant to public health and safety. In general, the risk assessment ensures that the maintenance activity will not adversely impact a dedicated/protected train. The dedicated/protected train ensures a system is capable to perform its intended safety function. St. Lucie implements the requirement via procedures.

Temporary configuration changes are controlled by plant procedure. This process maintains configuration control for non-permanent changes to plant structures, systems, and components while ensuring the applicable technical reviews and administrative reviews and approvals are obtained. If, during power operation conditions, the temporary alteration associated with maintenance is expected to be in effect for greater than 90 days, the temporary alteration is screened, and if necessary, evaluated under 10 CFR 50.59 prior to implementation.

There have not been any recent or planned insulation change-outs in the containment which will reduce the debris burden at the sump strainers.

Actions have been taken to modify existing insulation to reduce the debris burden at the sump strainers. Stainless steel bands have been installed over the calcium silicate thermal piping insulation for selected areas of piping located within the St. Lucie Unit 1 Containment Building. The application and justification for the calcium-silicate banding is included in the information provided in the response to NRC Topic 3.b, Debris Generation/Zone of Influence (excluding coatings). The banding will enhance the overall sturdiness of the piping insulation. Portions of the piping insulation associated with the Reactor Coolant System, Safety Injection System, Component Cooling System, Chemical and Volume Control System, and Steam Generator Blowdown System have been banded.

There have not been any modifications made to equipment or systems to reduce the debris burden at the sump strainers.

Note that programmatic controls related to coatings are provided in the response to NRC Topic 3.h, Coatings Evaluation.

Topic 3.j: Screen Modification Package

FPL Response

The original sump screens have been completely replaced with a single, non-redundant, distributed sump strainer system that consists of 21 strainer modules and interconnecting piping. The strainer system uses the General Electric discreet modular stacked disc strainers. The strainer surface area is approximately 8,275 ft^2.

[RAI 32] The new strainer system is completely passive (i.e., it does not have any active components or rely on backflushing).

As in the original sump screen design, the new distributed strainer system serves both ECCS suction intakes. Because the original St. Lucie Unit 1 strainer did not utilize redundant sump strainers, this is not a departure from the existing design basis. It is consistent with the current design basis, Technical Specifications, and regulatory commitments for St. Lucie Unit 1. Because a single non-redundant strainer system is used, the system has been designed such that there is no credible passive failure mechanism that could render both ECCS trains inoperable. Active strainer failure mechanisms are not considered because the strainer system is completely passive. The strainer system structural design is discussed in the response to NRC Topic 3.k, Sump Structural Analysis.

The strainer modules use an arrangement of parallel, rectangular strainer disks that have exterior debris capturing surfaces of perforated plate covered with woven wire mesh. The wire mesh decreases the head loss across the strainer plates by breaking up debris beds. Each strainer disk, constructed of two plates, has an open interior to channel disk flow downward to the strainer plenum. The disks are mounted on the discharge plenum, which channels disk flow to the interconnecting suction piping. Type 304 or other austenitic stainless steel is used as the primary material of construction.

For St. Lucie Unit 1, the analyzed LOCA cases generated sufficient fiber to form a thin fiber bed or greater. However, the debris plate and the small pitch between disks allow the GE Modular Strainer to mitigate thin bed effects.

The strainer perforations are nominal 1/16th-inch diameter holes. This is an enhancement from FPL's statement in the September 1, 2005 submittal, where the stated expectation was only that the perforation size would be smaller than a 1/8-inch by 1/8-inch square.

The strainer modules are grouped together into 4 groups. Each group is piped separately to the strainer manifold where the total strainer flow is combined. The manifold is connected to the recirculation suction inlets by two outlet pipes, one for each ECCS inlet.

The outlet pipes from the strainer manifold terminate at the ECCS recirculation suction inlets. Debris intrusion is prevented by an interface collar and backing plate installed at the suction inlets.

The entire strainer system is designed and situated to be fully submerged at the minimum containment water level during recirculation. Perforated passive vents are provided to preclude air entrapment during containment flood-up prior to recirculation. During flood-up, water would fill the strainer system from the bottom up, forcing air out of the perforated vents, thereby venting the system. Because the vents are below the containment water level prior to the start of recirculation, air will not be sucked in through the perforated panels. Venting is passive and uses perforations at least as small as the strainer perforated plate. Fabrication and installation tolerances of equipment are such that debris larger than allowable cannot bypass the strainer system. Therefore, debris retention capacity of the entire system is at least as good as the strainer modules.

The strainer modules and suction manifold are designed in accordance with ASME Section III subsection NC (Class 2 components) or NF (supports). The capability of the strainer perforated plate disks as structural members is based on the equivalent plate approach as specified by ASME Section III Article A-8000. Modification of existing supports or design of new supports is in accordance with AISC, 9th Edition or ASME Section III, Subsection NF.

The capability of the strainer system to accommodate the maximum mechanistically determined debris volume has been confirmed by a combination of testing and analysis. The volume of debris at the screen is discussed in the response to NRC Topic 3.c, Debris Characteristics. The capability to provide the required NPSH with this debris volume is discussed in the response to NRC Topic 3.g, Net Positive Suction Head (NPSH). The capability to structurally withstand the effects of the maximum debris volume is discussed in the response to NRC Topic 3.k, Sump Structural Analysis.

One additional modification was completed that supports the new strainer installation. This modification created two 22-inch diameter core bores for the 18-inch piping that connects the suction manifold to the ECCS inlets. The core bores are a nominal 22-inch diameter to allow for a circumferential gap between the 18-inch nominal piping and the bioshield concrete. The configuration has been analyzed to be acceptable with regard to bioshield structural integrity.

Topic 3.k: Sump Structural Analysis

FPL Response

The previous sump strainer system has been completely replaced by a new distributed strainer system. The new system is passive, and does not utilize backflushing. It is described in the response to NRC Topic 3.j, Screen Modification Package. Assurance that the strainer system is inspected for adverse gaps or breaches prior to concluding an outage is discussed in the response to NRC Topic 3.i, Debris Source Term.

The new strainer system is comprised of several components. Twenty one (21) strainer modules are connected by four (4) pipe runs that terminate at a common suction manifold. The common manifold is connected to the ECCS/CSS suction inlets by piping that runs through two (2) horizontal 22-inch nominal diameter core bores in the 4 foot thick secondary shield wall. The pipe runs that connect the strainer modules and common suction manifold are 12-inch stainless steel, schedule 10S. The pipe runs that connect the common manifold to the ECCS/CSS suction inlets are 18-inch stainless steel, schedule 10S.

The strainer system is no longer protected by the secondary biological shield wall as was the original sump screen. Analyses and walkdowns have been performed which confirm that the strainer modules, interconnecting piping, manifold and appurtenances are not subject to high energy line break (HELB) jet impingement, pipe whip or missiles. The analyses assumed a HELB ZOI of 10D. The approved "leak-before-break" methodology was used to eliminate the reactor coolant system (RCS) loops from consideration. Therefore, dynamic effects due to breaks in the RCS loops were not considered in the structural analysis/design of the strainer system. Main steam and feedwater piping were eliminated from review because breaks in these lines do not require the plant to enter into recirculation mode.

The system only operates once the containment is filled with water, and the entire system is fully submerged. The system is designed to vent during containment flood up, so there is no requirement to be leak tight. However, the strainer components and piping systems are designed using ASME Section III as a guide where applicable. The component anchorages and piping supports are designed following the AISC Manual of Steel Construction.

For purposes of describing the structural analysis, it is useful to divide the strainer system into the following components:

- Strainer modules (disks and plenums)
- Common manifold
- Piping and pipe supports
- The anchorages for the strainer plenums and manifold box
- The horizontal 22" diameter core bores through the 4'-0" thick secondary shield wall

The strainer module and manifold element stresses were determined using the ANSYS computer program, and the allowable stresses were obtained from ASME Section III Appendices. Weld stresses for the strainer modules were evaluated by ANSYS, the Blodgett method, or hand calculation, and allowable stresses were obtained from ASME Section III Appendices. The manifold is a box shaped structure and meets the structural design requirements. The strainer module is a more complex structure, and the structural loads and load combinations are summarized in Tables 3.k-1 and 3.k-2 below. The strainer module structural qualification results are summarized in Table 3.k-3.

The 12-inch pipe runs that connect the strainer modules and common suction manifold have specially designed pipe clamps that allow for thermal expansion. The interface and pipe support configuration for the 18-inch pipe runs are designed such that negligible loads are imposed on the ECCS/CSS guard pipes and containment penetrations.

Piping was analyzed using hand calculations and an S&L proprietary finite element modeling computer program PIPSYSW. Pipe supports were analyzed using hand calculations. Expansion anchor base plates for pipe supports, strainer and manifold anchorages were analyzed using hand calculations and an S&L proprietary finite element modeling computer program APLAN. The core bores are qualified using hand calculations. The piping, pipe supports, anchorages and core bores were qualified using the allowable stress method. Portions of the core bore were qualified using ultimate strength design. The resulting design margins (ratio of stress allowable / calculated stress) were greater than 1.0 for all components.

With regard to trash racks, the GE design is robust and the trash rack function is incorporated into the strainer module design. Separate trash racks are not required. This is consistent with the original St. Lucie Unit 1 strainer/sump design, which did not have separate trash racks.

Table 3.k-1: Strainer Module Loads and Load Combinations

Load	Strainer Load Combination
1	$D + L + E_1$
2	$D + L' + E_2$
3	$D + L + T + E_1$
4	$D + L' + T + E_2$
5	$D + L + T + E'_1$
6	$D + L + L' + T_A + F_t$
7	$D + L' + T_A + E'_2 + P_{CR}$

Table 3.k-2: Structural Load Symbols

Symbol	Load Definition
D	Dead Load, in air
L'	Debris Weight Submerged plus Hydrodynamic Mass
L	Live Load, Outage Maintenance Personnel
F_t	Flow Initiation Transient Momentum Load
T	Normal Operating Thermal Load
T_A	Accident Thermal Load
E_1	Earthquake Load, OBE in air
E_2	Earthquake Load, OBE in water
E'_1	Earthquake Load, SSE in air
E'_2	Earthquake Load, SSE in water
P_{cr}	Differential (Crush) Pressure

Table 3.k-3: Strainer Module Stress Ratio Results

Load Combination	1	2	3	4	5	6	7
Allowable Stress	Sh	1.2 Sh	1.2 Sh	Sy	Sy	Sy	Sy
Value (ksi)	16.6	19.9	19.9	22.5	22.5	22.5	22.5
Stress Ratio (Note 1)							
Plenum Cover	24.3	12.47	28.11	16.92	27.08	20.55	4.08
Plenum Rib	12.73	8.13	15.26	9.19	14.53	11.40	1.88
Plenum Box	14.16	8.46	15.88	9.56	15.13	11.85	2.32
Plenum Joint	9.17	5.39	10.11	6.09	9.69	7.46	1.16
Wedge	5.60	8.05	1.90	3.22	4.69	4.52	1.99
Tie Rod	73.45	40.61	76.25	45.92	69.23	62.67	5.95
Ribs	11.97	7.09	13.31	8.02	12.64	10.00	2.99
Main Frame	16.42	10.30	19.34	11.65	18.31	14.61	2.84
Composite Plate	16.10	9.57	17.94	10.81	15.91	15.75	15.75
Composite Plate (Note 2)	N/A	N/A	N/A	N/A	N/A	N/A	1.0

Notes:
1. Stress Ratio = ASME Code Stress Limit at 300 °F / Calculated Stress
2. Deflection Ratio = Deflection Limit at 240 °F / Calculated Deflection

Topic 3.I: Upstream Effects

FPL Response

[RAI 42] In the September 1 St. Lucie submittal it was noted that it was planned to obtain additional confirmation that there are no choke points. This confirmation was obtained from a walkdown that was conducted in the St. Lucie Unit 1 containment specifically to evaluate ECCS recirculation flow paths. The walkdown utilized the guidance in Nuclear Energy Institute (NEI) Report 02-01, NEI Report 04-07, and the staff's SE of NEI 04-07.

[RAI 38] The information obtained during the walkdown confirms that water will not be held up by choke points or otherwise prevented from reaching the ECCS intakes via the distributed strainer system. Special attention was paid to the fuel transfer canal, which is drained by two 6-inch nominal diameter pipes. These pipes are oriented horizontally with the bottom of the pipe approximately 3 inches above the transfer canal floor. They are not screened or capped. Because of the size and orientation of these drain pipes they will not create a choke point that would retain water in the fuel transfer canal. However, because the pipes are 3 inches above the floor, it is assumed that the water below 3 inches is held up and does not reach the sump.

Other specific NEI and NRC concerns that were addressed in the walkdown are itemized below:

- There were no gates or screens in the recirculation flow paths.
- All passages have sufficient flow clearances such that choke points are not expected.
- Curbs and ledges within the flow paths were found to be unable to retain water from returning to the sump area. Curbs at upper elevations had at least one open side to allow the free flow of water to the ground floor.
- No potential choke points were observed at upper elevations, including floor grates, which would be expected to retain fluid from reaching the containment floor.
- The containment floor was surveyed for choke points formed by equipment, components and other obstructions. Where equipment congestion did occur, other flow paths were available so as to not restrict water transport.

Topic 3.m: Downstream Effects – Components and Systems

FPL Response

In the September 1 response it was noted that, at that time, the downstream evaluations identified instrumentation and eight (8) components that required further evaluation. Subsequently, the strainer opening size has been reduced from an assumed square opening of 1/8-inch by 1/8-inch (diagonal dimension of 0.177 inch) to an actual round opening of 1/16-inch diameter (0.0625 inch), the high pressure safety injection (HPSI) pump seal cyclone separators have been removed and the seals replaced, and stainless steel bands have been installed on selected cal-sil insulation.

The new strainer system is described in the response to NRC Topic 3.j, Screen Modification Package. The HPSI pump seal replacement is described in the response to NRC Topic 2, General Description of and Schedule for Corrective Actions. Cal-sil banding is discussed in the response to NRC Topic 3.b, Debris Generation Zone of Influence (ZOI) (excluding coatings).

[RAI 31] The analysis of downstream effects at St. Lucie Unit 1 primarily follows that set forth in WCAP-16406-P, Revision 1. A summary of the application of those methods is provided below with a summary and conclusions of the downstream effects calculations performed. Any exceptions or deviations from the NRC-approved methodology are noted below. The methodology, summary, and conclusions are provided as related to downstream component blockage and wearing, the subjects addressed by Topic 3.m.

Blockage/Plugging of ECCS and CSS Flowpaths and Components

GL 2004-02 Requested Information Item 2(d)(v) addresses the potential for blockage of flow restrictions in the ECCS and CSS flowpaths downstream of the sump screen, while item 2(d)(vi) refers to plugging of downstream components due to long-term post-accident recirculation. The difference in requirements is that the instantaneous blockage of a flow restrictions due to the maximum debris size that pass the recirculation sump filtration system, or the gradual build-up of any size debris resulting in plugging of downstream components long-term. The evaluations performed for downstream components at St. Lucie Unit 1 considered both blockage and plugging as required for a particular component type, although the terminology was used interchangeably in the evaluations. The following summarizes the evaluation of downstream components that was performed at St. Lucie Unit 1, using the blockage and plugging terminology consistent with the GL 2004-02 Requested Information Item.

As part of the resolution for GSI-191, the existing sump screen system was removed and replaced with General Electric (GE) stainless steel modular sump strainers. Following the installation, the nominal strainer opening size has been reduced from a 1/4" square opening (diagonal dimension of 0.354 inch) to a nominal round opening of 1/16-inch diameter (0.0625 inch). The new strainer system is described in the response to NRC Topic 3.j, Screen Modification Package.

GL 2004-02 Requested Information Item 2(d)(v) requires that the licensee state "the basis for concluding that adverse gaps or breaches are not present on the screen surface." The inspection procedure to ensure that adverse gaps or breaches are not present on the screen surface is described in NRC Topic 3.i, Debris Source Term.

WCAP-16406-P Section 5.5 provides assumed particle dimensions for recirculation debris ingestion based on sump screen hole dimensions. Rather than the WCAP-16406-P suggested asymmetrical dimensions, the St. Lucie Unit 1 downstream components were analyzed for blockage based on a maximum 0.100 inch spherical particle. The actual maximum spherical size particulate debris that can pass through the strainer system and into the ECCS and CSS recirculation flowpaths is documented as 0.066 inch.

All ECCS and CSS downstream components that see active flow during recirculation (including control valves, orifices, flow elements, containment spray nozzles, and heat exchanger tubes) were analyzed for blockage due to this maximum particulate debris size. All flowpaths that could see recirculation flow per the plant design basis were considered. In accordance with the WCAP-16406-P methodology, the minimum clearance dimension within the component was checked to ensure it is larger than 0.100 inch. The results of that analysis are summarized below. Where necessary, low-flow components and piping were analyzed for plugging due to settling, as described below. Finally, static instrument sensing lines, relief valves, and check valves required to close during recirculation were analyzed for potential debris interference as discussed below.

<u>Control Valves</u>

WCAP-16406-P Section 7.3 lists possible failure modes for valve types that can be expected in the recirculation flowpaths. The SER Section 3.2.5 notes that this list is comprehensive and acceptable for general use, but notes that it is not all-inclusive. In accordance with the SER recommendation, all valves in all possible recirculation flowpaths were considered and found to be of standard types as listed in WCAP-16406-P Section 7.3. Every recirculation control valve was compared to the general criteria in WCAP-16406-P Table 8.2-3; any valve requiring further evaluation for plugging per WCAP-16406-P Section 8.2.4 was identified, including all throttled valves (globe, needle, and butterfly) and globe and check valves less than 1.5 inch nominally. The minimum flow clearance through these valves was determined from vendor drawings, and for throttled valves based on the subcomponent dimensions and lift settings. This minimum flow clearance was compared to the cross-sectional area of a 0.100 inch sphere to ensure that blockage would not occur. The WCAP-16406-P does not require analyzing valves for debris settling. In general, control valves see higher flow velocities than the pipe leading to them, and therefore the valves were not checked for debris settling where the pipe velocity was sufficient (see below).

Root valves and other valves in static instrument sensing lines were analyzed with those instrument lines as discussed below. Relief valves were analyzed for interference as discussed below. Check valves that open but then may require closing during recirculation were also checked for possible interference issues as identified in WCAP-16406-P Table 7.3-1. This could occur where low flow causes debris settling around the valve seat while open, and then the debris prevents proper closure when the check valve should close. In accordance with WCAP-16406-P guidance, a flow velocity of 0.42 ft/s was considered sufficient to prevent debris settling and thereby preclude interference with proper valve closure. The flow velocity for settling was determined from the larger flow area of the nominal pipe size leading to the valve.

Because all flow clearances were sufficiently large to preclude blocking and flow velocities are fast enough to preclude plugging and interference, all control valves at St. Lucie Unit 1 were found to be acceptable with respect to blockage and plugging during recirculation. Again, relief valves and instrumentation root valves were addressed separately as discussed below.

Relief Valves

Relief valves on the recirculation flow paths were also considered for interference issues. Here, the maximum pressure in the primary line during recirculation operation was conservatively determined based on maximum containment pressure, pump shut-off heads, and no line losses. Where the relief valve set pressure was higher than this pressure, it was determined not to open during recirculation and therefore debris interference was not an issue. If a relief valve could potentially open, then blockage and the effects of debris interference with closure would be considered. This was not applicable to St. Lucie Unit 1 because all relief valves were found not to be subject to opening during recirculation.

Heat Exchangers

All heat exchangers that see recirculation flow were also considered for blockage and plugging. This included both the major heat exchangers as well as those in the pump seal subsystems that see debris-laden flow. In accordance with WCAP-16406-P Section 8.3.1, the inner diameter of tubes was compared to the maximum assumed particle size. In accordance with the SER Section 3.2.6, the heat exchanger tubes were also checked for plugging due to settling within the tubes, by comparing the minimum average flow velocity in the tubes to the WCAP-16406-P settling velocity (0.42 ft/s). All heat exchangers were found to be acceptable with respect to blockage and plugging.

Orifices, Flow Elements, Spray Nozzles

All orifices, flow elements, and spray nozzles in the ECCS and CSS recirculation flowpaths were checked for blockage. In accordance with WCAP-16406-P Section 8.4, the minimum flow clearance of each was compared to the maximum assumed particle size. All orifices, flow elements, and spray nozzles were found to be acceptable with respect to blockage. The WCAP-16406-P does not suggest analyzing orifices, flow elements, and spray nozzles for debris settling. In general, orifices, flow elements, and spray nozzles see higher flow velocities than the pipe leading to them, and therefore were not checked for debris settling where the pipe velocity was sufficient (see below).

Instrumentation Lines

All instrumentation branch lines on the ECCS and CSS recirculation flow paths were analyzed for blockage and plugging. WCAP-16406-P Section 8.6 generically justifies static flow (water-solid) sensing lines on the basis of minimum expected flow velocities compared to debris settling velocities. However, the St. Lucie Unit 1 review of instrument lines was plant specific. First, the actual orientation of each instrument line was determined. Water-solid sensing lines oriented horizontally or above are considered not susceptible to debris settling into the lines. For any instrument lines oriented below horizontal, the actual minimum flow velocity through the header line at the point of the branch was determined. This velocity was compared to the WCAP-16406-P bounding settling velocity of 0.42 ft/s, as opposed to the lower debris-specific settling velocities listed in WCAP-16406-P Table 8.6-1. This approach is consistent with the recommendation of the SER to WCAP-16406-P. All sensing lines were found to be acceptable with respect to plugging due to debris settling. Because the lines are water-solid, they are not susceptible to direct blockage due to large debris flowing into the lines.

Any sampling lines on the ECCS and CSS recirculation flowpaths that are required by plant procedure to be used post-accident were also considered. The sampling lines were analyzed as any other flow path when opened to take a sample: blockage and plugging of the tubing and each component was considered. The orientation of each sampling line was also checked, like an instrument line, to ensure it was not susceptible to settling of debris into the line when water-solid. All sampling lines were found to be acceptable.

Per the guidance of WCAP-16406-P Section 8.6.10, the St. Lucie Unit 1 RVLIS design was compared to the generic designs reviewed and deemed acceptable by the WCAP-16406-P. The plant design was found to be consistent, and therefore it is expected to be acceptable with regards to recirculation operation. However, the SER Section 3.2.6 notes that "evaluation of specific RVLIS design and operation is outside the scope of this SE and should be performed in the context of a licensee's reactor fuel and vessel evaluations." This is discussed in Enclosure 3, L &C 19.

Piping

The WCAP-16406-P does not require evaluation of piping for potential blockage or plugging. However, in accordance with the SER Section 3.2.6, ECCS and CSS system piping was evaluated for potential plugging due to debris settling. As stated above, control valves in the ECCS and CSS lines were checked to ensure debris settling does not interfere with valve movement. The valves were checked using the flow area of the pipe in which the valves are installed. Therefore, the evaluation for control valves was used to validate that settling will not occur in the system pipes generally. It was verified that the analysis of control valves included valves in all lines in the ECCS and CSS, so that local flow velocities of the various line sizes and flow rates in the St. Lucie Unit 1 ECCS and CSS were all considered. As with other settling reviews, the minimum expected system flow rates in each line were used to minimize the flow velocity. The average velocity was determined for each pipe size based on the specific flow rate in that line and compared to the bounding settling velocity of 0.42 ft/s. All valves, and therefore all lines, were found acceptable with respect to plugging. Piping was not considered specifically for blockage because flow restrictions in the lines are more limiting with respect to minimum flow clearance.

Pumps

The WCAP-16406-P addresses two concerns with regard to debris blockage or plugging. First, Section 7.2 states that debris in the pumped flow has the potential of blocking the seal injection flow path or limiting the performance of the seal components due to debris buildup in bellows and springs. A review of the St. Lucie Unit 1 ECCS and CSS pump seals in accordance with the WCAP-16406-P methodology determined that all of the pumps have seal piping arrangements which preclude the injection of debris laden post-LOCA fluids into the seal cavity chamber so that sump debris will not enter the seal chamber and will not impact the operation of seal internal components. The St. Lucie Unit 1 HPSI pump seals previously had a seal cooling system relying on process water with a cyclone separator. Consistent with WCAP-16406-P guidance as augmented by the SER Section 3.2.5, a plant-specific review of pump operation determined that a water seal system that utilizes recirculated seal cavity fluid was preferable to the use of injected process fluid and was subsequently installed. Further, the SER Section 3.2.6 disagreed with a WCAP-16406-P statement that seal failure due to debris ingestion is considered unlikely, because the WCAP-16406-P statement was founded upon only a single test. However, since the St. Lucie Unit 1 pump seals use only recirculated seal cavity fluid in the spring and bellow areas of the seal that were identified as a concern, the SER Section 4.0 limitation expressing concern with this WCAP-16406-P statement is not applicable. Otherwise, the SER endorses the mechanical seal analysis recommended by the WCAP-16406-P with respect debris interference.

WCAP-16406-P Section 7.2.3 further states that running clearances of 0.010 inch on the diameter could be clogged when exposed to pumpage with 920 PPM and higher debris concentration from failed containment coatings. It states that as a consequence of the clogging, a packing type wear pattern was observed on the rotating surface. This clogging of running clearances creates asymmetrical wear, but was not identified as having a negative impact on pump performance aside from increased wearing (which was considered as discussed below). Also, the WCAP-16406-P states that shaft seizure due to packing debris build-up is unlikely. The SER Section 3.2.5 also endorses this WCAP-16406-P guidance.

No other areas of concern for debris plugging or blockage within ECCS and CSS pumps were identified by either the WCAP-16406-P or the SER. Wear analysis of the pumps due to debris-laden water in close-tolerance running clearances, including packing type debris build-up, was considered as discussed below.

Conclusion (Blockage/Plugging)

As summarized above, analysis of all lines and components in the recirculation flowpaths at St. Lucie Unit 1 determined that there is no potential for either debris blockage or long-term plugging, which would threaten adequate core or containment cooling.

Wearing of ECCS and CSS Recirculation Flowpath Components

GL 2004-02 Requested Information Item 2(d)(vi) concerns excessive wear of ECCS and CSS recirculation components due to extended post-accident operation with debris-laden fluids. All ECCS and CSS downstream components that see active flow during recirculation (including pumps, control valves, orifices, flow elements, containment spray nozzles, piping, and heat exchanger tubes) were analyzed for wear due to an analytically determined bounding debris load for the full recirculation mission time. All flowpaths that could see recirculation flow per the plant design basis were considered.

The evaluation of long-term wearing of ECCS and CSS recirculation components was performed for a 30-day period following initiation of recirculation post-LOCA. The 30-day period is consistent with the SE of NEI 04-07, WCAP-16406-P, and the St. Lucie Unit 1 UFSAR. All components were analyzed for a full 30 days of operation, unless plant specific procedures and system configurations established a shorter maximum duration of operation. WCAP-16406-P Section 4.2 provides guidance for reducing mission times outside of plant licensing basis for components that are predicted to fail due to recirculation wear. However, consistent with SER Section 3.2.2, only plant-specific component mission time input in accordance with design and licensing basis was utilized for any deviation from a 30-day mission time, and only existing design basis hot-leg recirculation methods were credited. The following summarizes the evaluation of downstream components that was performed at St. Lucie Unit 1.

Debris Concentration and Size Distribution

The St. Lucie Unit 1 debris concentration and size distribution for downstream effects wear was calculated based upon the methodology provided by WCAP-16406-P, except as otherwise noted.

The total debris load was determined for a bounding LBLOCA in accordance with NEI 04-07. A minimum sump water volume for recirculation was determined for a SBLOCA to maximize the debris concentration in containment. All debris was assumed to be in the sump pool and eroded (to the extent it would be after 30 days) at the start of recirculation. Only RMI and fiberglass insulation (Nukon and Thermal Wrap) were categorized as fines versus debris too large to pass the strainer; this categorization was based on industry experimental data. All other debris was assumed to be entirely fines, capable of passing the strainer unless its final eroded size is larger than 0.100 inch based on a detailed size distribution described below (see above regarding debris size assumed to pass through the strainer). Based on these inputs, the initial debris concentration at the start of recirculation was calculated.

The debris concentration was then depleted over the recirculation mission time in accordance with the methodology presented in WCAP-16406-P Section 5. For the purposes of debris depletion, only latent particulate debris, Cal-Sil, and unqualified coatings were size distributed. The Cal-Sil and latent debris size distributions were calculated from industry data. The distributions were calculated based on empirical data and for the specific debris types at St. Lucie Unit 1, but the distribution was not based on plant-specific testing. For unqualified coatings, the size/mass distributions of the WCAP-16406-P were used. Qualified coatings were taken to fail entirely to 10 micron spherical particulate, which is consistent with the WCAP-16406-P as amended by the SER Section 3.2.15 since a fibrous thin-bed was substantiated. The particulate debris distribution (in addition to reducing the amount of debris assumed to initially pass the strainer, as discussed above) was utilized to deplete the particulate over time due to settling in the reactor vessel. Consistent with the WCAP-16406-P guidance, the particulate debris size subject to vessel depletion was calculated for each debris type based on force balance methods using a maximum core flow rate (cold leg recirculation for a hot leg break) to minimize debris settling. All particulate debris was assumed to be spherical for determination of settling size. Debris smaller than the calculated size for a given type was taken to remain in solution throughout recirculation. The depletion coefficient for depletable particulate was calculated according to WCAP-16406-P Section 5.8 based on plant specific inputs for conditions to minimize depletion.

Two deviations were taken from the WCAP-16406-P approach with respect to fibrous debris depletion. First, all fiber was assumed to be depletable and no fibrous debris is too small to remain in solution. Second, in lieu of the 95% fiber capture efficiency for the strainer suggested by WCAP-16406-P, or an empirically determined fiber capture efficiency as stated by the SER Section 3.2.17, the strainer capture efficiency was calculated based on an equation originally found in Draft Rev. 0 of the WCAP-16406-P. This resulted in a conservative strainer capture efficiency of only 49%. However, in all cases, the depletion coefficient used for the fibrous debris was the SER and WCAP-16406-P conservatively agreed value of (λ = 0.07/hr or half-life of 10 hours).

For analysis of abrasive wear (pump moving parts), the debris was further categorized based on the size distribution of particulate debris as erosive versus abrasive debris. All fibrous debris was assumed to be large enough to be abrasive. For particulate debris, a modification to the WCAP-16406-P methodology was used to refine the distribution of abrasive versus erosive debris. While the WCAP-16406-P considers 50 microns to be the constant threshold for abrasive debris (which is equal to 2.5X the wear ring gap of the hypothetical pump considered therein), St. Lucie Unit 1 used 2.5X the actual wear ring gap at any given time to define the threshold for abrasive-sized particulate. In other words, as the wear ring gap opens, the abrasive debris is reduced. However, the amount of abrasive debris that was reduced was then taken to contribute to erosive wear.

The calculation of erosive wear considered the effect of small particulates. Credit was taken for reduced erosive wear in accordance with the Hutchings Summation methodology presented in WCAP-16406-P Appendix F. The Hutchings Summation was conservatively calculated based upon the particulate distribution discussed above.

The time-dependent debris concentration calculated according to the above methodology was then utilized for the calculation of wear on all ECCS and CSS recirculation components. The calculation of wear for each type of component, including the effect of the wear on component performance, is summarized below.

Pumps

The ECCS and CSS pumps were analyzed for wear in general accordance with the methodology presented in Sections 7.2 and 8.1 of WCAP-16406-P. The depleting abrasive and erosive debris concentrations as discussed above were a primary input of the analysis.

For all pumps, the wear rings were assumed to have a starting gap equal to the midpoint of the wear ring acceptability range prescribed by the pump manufacturer. All wear rates were calculated specifically for each St. Lucie Unit 1 pump based on actual pump dimensions, materials, and operating speeds, and the debris concentration at a given time (the generic wear rates determined in the WCAP-16406-P were not applied). The wear analysis considered the combined effect of abrasive wear due to larger debris and debris packing, and erosive wear due to smaller debris (as defined above). The wear rate at each hour was numerically integrated to determine the total material wear following the recirculation mission time.

Pump wear analysis considered the combined effect of abrasive wear due to larger debris, and erosive wear due to smaller debris (as defined above). In accordance with WCAP-16406-P Appendix Q and the SER Section 3.2.23, a penalty was applied to the debris concentration wear rate because the total concentration of abrasive particulates and fibrous debris exceeds 720 PPM. A conservative deviation from the WCAP-16406-P approach was made in that all debris large enough to be abrasive was considered to wear equally, as opposed to the WCAP-16406-P approach of taking coatings as softer. In accordance with the SER Section 3.2.23, the ratio of abrasive to fibrous debris was verified as less than 5 to 1.

The single-stage LPSI and CS pumps were analyzed for symmetrical wearing of the inboard and outboard wear rings (no "suction multiplier" was applied). Packing-type wear was also not applied to the single-stage pumps, in accordance with the WCAP-16406-P. The total material wear after the recirculation mission time was then used to determine the final wear ring gaps for the suction and discharge side. The change in gap was used to evaluate the impact on pump hydraulic performance per the approach of WCAP-16406-P Section 8.1. The discharge head following 30 days of wear was determined to be acceptable for the LPSI and CS pumps. Per WCAP-16406-P Section 8.1.4, no vibration analysis was performed for single-stage pumps. The mechanical seals were evaluated for debris interference concerns as discussed above.

The multistage HPSI pumps were also analyzed for concurrent abrasive and erosive wear. Here, however, packing-type abrasive wear was found to be more limiting than free-flowing abrasive wear. Therefore, the HPSI pumps were analyzed according to the Archard wear model presented by WCAP-16406-P Appendix O. For inputs into the Archard wear equation, the pressure drop across the wear rings was calculated for the actual St. Lucie Unit 1 pumps based on actual pump head at the expected recirculation flow rate, actual pump (subcomponent) dimensions were used, the eccentricity was assumed maximum, and the wear coefficient was taken as the bounding of the range provided by the WCAP-16406-P. The packing was assumed to occur immediately upon pump recirculation initiation, and to continue until a wear ring gap of 50 mils was attained, at which point the packing at each discharge-side wear ring was assumed to expel, in accordance with the WCAP-16406-P methodology. If the expulsion of the packing occurred prior to the end of the analyzed mission time, the wear of the discharge side wear ring was analyzed for continuing abrasive and erosive wear (free-flow) until the end of the mission time. The suction-side wear rings were taken to wear asymmetrically as a result of the packing-wear on the discharge side, and were analyzed using a suction multiplier of 0.205, per PWR Owners Group document OG-07-510.

The final wear ring gap of the suction and discharge sides after the recirculation mission time was then utilized to perform hydraulic and vibration analyses of the multistage pumps. Based on the pumps' starting discharge head (per IST history) and the acceptable range, the discharge head following 30 days of wear was determined to be acceptable for the HPSI pumps. The shaft centering load (Lomakin effect) method in WCAP-16406-P Appendix O was used to evaluate the HPSI pumps for vibration failure due to wear. In order to maximize vibration, the centering load was maximized by assuming a minimum friction coefficient, maximum eccentricity, and also maximized in relation to C_d (diametric clearance) and f (friction coefficient). Again, the wear ring pressure drop was calculated based on actual pump head at the expected recirculation flow rate. The resulting shaft stiffness based on the centering load and wear ring gap was calculated using the suction and discharge side wear ring gaps following 30 days of wear. The stiffness was compared with the stiffness that would result from doubling the manufacturer's allowable wear ring gap (symmetric wear acceptability criterion from WCAP-16406-P). The shaft stiffness of the HPSI pumps under asymmetric wear was found to be greater than this acceptance criteria, and therefore the HPSI pumps were determined to be acceptable with respect to vibration. The mechanical seals were evaluated for debris interference concerns as discussed above.

Non-mechanistic failure of an ECCS or CSS pump seal is considered as a single-failure in the plant design basis and is acceptable. The WCAP-16406-P attempts to justify failure of the seals due to recirculation debris, which is a potential common-mode failure. The pump seals at St. Lucie Unit 1 have been evaluated as not susceptible to failure by debris-laden water because they recirculate only seal cavity fluids. Therefore the only potential failure that must be considered is an assumed single failure, which again is part of the existing design basis of the plant (bounded by a moderate energy line break in the pump room). The potential effect of debris causing an increased leakage flow through the disaster bushing following that single-failure has been evaluated and been determined to be acceptable.

The WCAP-16406-P criteria were based on performance of each individual component. However, the SER further identifies the need to check the entire ECCS and CSS systems in an integrated approach to ensure that the combination of pump and system component wear would not threaten adequate core cooling, considering increased system flow and decreased pump performance due to wear. This system assessment determined that these systems remain capable of fulfilling their required safety related functions in the presence of debris-laden fluid following a LBLOCA at St. Lucie Unit 1.

Heat Exchangers

In accordance with WCAP-16406-P Section 8.3, the recirculation heat exchangers (both the primary system heat exchangers, and the pump seal heat exchangers) were analyzed for erosive wear. The standard erosive wear formulas in the WCAP-16406-P, adjusted for the actual material hardness and adjusted via the Hutchings Summation described above, were used with the St. Lucie Unit 1 heat exchanger dimensions and maximum recirculation flow rates to predict the maximum erosive wear over 30 days of recirculation. All heat exchangers were found to have sufficient wall thickness margin for a maximum possible differential pressure across the heat exchanger tubes.

Valves

The WCAP-16406-P guidance is that manual throttle valves should be analyzed for the effects of erosive wear. It is assumed that a manually throttled valve as defined in WCAP-16406-P is one that requires an operator to locally throttle the valve (at the valve location) as opposed to a remote manual valve that can be adjusted from the control room. It is further assumed that a remote manual valve can be adjusted from the control room to compensate for an increase in flow area due to erosive wear. Therefore, erosion wear analyses were not performed for remote manual valves. Since there are no locally throttled ECCS or CSS valves at St. Lucie Unit 1 no wear analysis was required to assess downstream effects on valves in the recirculation paths.

Orifices, Flow Elements, Spray Nozzles

All orifices, flow elements, and the containment spray nozzles in the St. Lucie Unit 1 recirculation flowpaths were analyzed for the effects of erosive wear upon performance. The standard erosive wear formulas in the WCAP-16406-P, adjusted for the actual material hardness and adjusted via the Hutchings Summation described above, were used with the St. Lucie Unit 1 component dimensions and maximum recirculation flow rates to predict the maximum erosive wear over 30 days of recirculation. The total material wear was used with the WCAP-16406-P formulas to predict the maximum change in flow rate due to the erosive wear of an orifice, flow element or spray nozzle. A conservative deviation was made from the WCAP-16406-P guidance in that a 3% limit for change in flow was applied for all orifices, flow elements, and spray nozzles. Furthermore, all orifices were assumed to be sharp-edged, which creates a higher change in flow rate for a given amount of wear. Based on the analysis, all St. Lucie Unit 1 orifices, flow elements, and the containment spray nozzles were found to be acceptable.

Piping

The SER to WCAP-16406-P requires that licensees perform a piping wear evaluation. The SER Section 3.2.6 does not detail the scope of the assessment, but since it refers to the need for a vibration assessment if areas of high piping wear are identified, it is taken to mean that piping should be checked for wall-thinning (structural) purposes like the heat exchanger tubes. With regard to pipe wall erosion, WCAP-16406-P states "There is no expected impact on ECCS and CSS piping based on downstream sump debris...since the pipe wall thickness is sufficiently larger than expected wear." To validate this assumption, the material wear of the bounding orifice in the ECCS and CSS was compared to the pipe wall thicknesses used in the systems. This conservative material wear exceeds that applicable to piping because the flow velocities in piping are much less compared to the bounding orifice velocity (the wear rate is proportional to the flow velocity squared), while the material of construction is the same. The material wear was found to be insignificant compared to the pipe wall thick-nesses used in the ECCS and CSS. Therefore, all pipes were determined to have sufficient margin, and the erosion was considered so slight as to not require vibration analysis.

Conclusion (Wear)

No other components required erosive wear analysis. As summarized above, analysis of all lines and components in the recirculation flowpaths at St. Lucie Unit 1 determined that the components are expected to wear acceptably based on the WCAP-16406-P criteria for 30 days of recirculation.

The WCAP criteria were based on the performance of each individual component. The SER further identifies the need to check the ECCS and CSS systems in an integrated approach to ensure that the combination of pump and system component wear would not threaten adequate core cooling, considering increased system flow and decreased pump efficiency due to wear. Based on an overall system performance assessment, the ECCS and CSS remain capable of fulfilling their required safety related functions in the presence of debris-laden fluid following a LBLOCA at St. Lucie Unit 1.

Summary of Design or Operational Changes

Additionally, NRC Content Guide Topic 3.m requests that licensees "Provide a summary of design or operational changes made as a result of downstream evaluations." Three plant design changes made in response to GSI-191 contribute to the resolution of downstream effects:

- As previously discussed, in response to downstream blockage concerns the new strainer system was designed with a nominal strainer opening holes of 1/16-inch diameter (0.0625 inch), reduced from the previous 1/4" square opening (diagonal dimension of 0.354 inch). The new strainer system is described in the response to NRC Topic 3.j, Screen Modification Package. The actual maximum spherical size particulate debris that can pass through the new strainer system and into the ECCS and CSS recirculation flowpaths is documented as 0.066 inch.

- Also as previously discussed, the St. Lucie Unit 1 HPSI pump seals were redesigned. The previous seal cooling system relying on process water with a cyclone separator was replaced with a closed-cycle seal system that utilizes recirculated seal cavity fluid.
- Additionally, reinforcing steel bands have been installed on selected Cal-Sil insulated piping impacted by GSI-191 postulated LOCA breaks. This reduced the quantity of Cal-Sil insulation that can be generated during a LOCA and thus resulted in decreased wearing of downstream components. Cal-Sil banding is discussed in the response to NRC Topic 3.b, Debris Generation Zone of Influence (ZOI) (excluding coatings).

The only operational change made related to downstream effects is that inspection requirements were updated for the new strainer system. Inspection of the strainer system requires verification of maximum strainer equipment gaps to meet new specifications to maintain debris bypass size limits, and inspection now includes new strainer system piping and manifolds in addition to the strainer filtration surface. This procedure is discussed further in NRC Topic 3.i, Debris Source Term.

No other design or operational changes were required in response to ECCS and CSS downstream effects evaluations.

Enclosure 3 provides the responses to the Limitations and Conditions on WCAP-16406-P, Revision 1.

Topic 3. n: Downstream Effects – Fuel and Vessel

FPL Response

FPL is participating in the PWR Owners Group (PWROG) program to evaluate downstream effects related to in-vessel long-term cooling. The results of the PWROG program are documented in WCAP-16793-NP (WCAP-16793-NP, "Evaluation of Long-Term Cooling Considering Particulate, Fibrous and Chemical Debris in Recirculating Fluid," Rev. 0, May, 2007), which was provided to the NRC staff for review in June 2007. The program was performed such that the results apply to the entire fleet of PWRs, regardless of the design (e.g., Westinghouse, CE, or B&W).

The PWROG program demonstrated that the effects of fibrous debris, particulate debris, and chemical precipitation would not prevent adequate long-term core cooling flow from being established. In the cases that were evaluated, the fuel clad temperature remained below 800°F in the recirculation mode. This is well below the acceptance criterion of 2200°F in 10 CFR 50.46, Acceptance criteria for emergency core cooling systems for light-water nuclear power reactors. The specific conclusions reached by the PWROG are noted below.

- Adequate flow to remove decay heat will continue to reach the core even with debris from the sump reaching the RCS and core. Test data has demonstrated that any debris that bypasses the screen is not likely to build up an impenetrable blockage at the core inlet. While any debris that collects at the core inlet will provide some resistance to flow, in the extreme case that a large blockage does occur, numerical analyses have demonstrated that core decay heat removal will continue. Per WCAP 16793-NP, Revision 0, no plant specific evaluation is recommended. This conclusion thus applies to St. Lucie Unit 1.

- Decay heat will continue to be removed even with debris collection at the fuel assembly spacer grids. Test data has demonstrated that any debris that bypasses the screen is small and consequently is not likely to collect at the grid locations. Further, any blockage that may form will be limited in length and not be impenetrable to flow. In the extreme case that a large blockage does occur, numerical and first principle analyses have demonstrated that core decay heat removal will continue. Per WCAP 16793-NP, Revision 0, no plant specific evaluation is recommended. This conclusion thus applies to St. Lucie Unit 1.

- Fibrous debris, should it enter the core region, will not tightly adhere to the surface of fuel cladding. Thus, fibrous debris will not form a "blanket" on clad surfaces to restrict heat transfer and cause an increase in clad temperature. Therefore, adherence of fibrous debris to the cladding is not plausible and will not adversely affect core cooling. Per WCAP 16793-NP, Revision 0, no plant specific evaluation is recommended. This conclusion thus applies to St. Lucie Unit 1.

- Using an extension of the chemical effects method developed in WCAP-16530-NP to predict chemical deposition of fuel cladding, two sample calculations using large debris loadings of fiberglass and calcium silicate, respectively, were performed. The cases demonstrated that decay heat would be removed and acceptable fuel clad temperatures would be maintained.

WCAP-16530-NP, Revision 0 evaluated the potential for chemical precipitation to form on the cladding surface as summarized in the preceding bullet, which is demonstrated in WCAP-16793, Revision 0, to produce acceptable fuel clad temperature results for two sample cases. As recommended in the WCAP-16793-NP, Revision 0, FPL has performed a plant-specific calculation using plant-specific parameters and the recommended WCAP methodology. The results of this calculation confirm that chemical plate-out on the fuel does not result in the prediction of fuel cladding temperatures approaching the 800 °F value. The calculation concluded that the maximum fuel cladding temperature is 378.7 degrees F.

Enclosure 1 provides the responses to the Limitations and Conditions on WCAP-16530-NP, Revision 0. Enclosure 2 provides the responses to the Limitations and Conditions on WCAP-16793-NP, Revision 0.

Topic 3. o: Chemical Effects

FPL Response

The objective of the chemical effects section is to evaluate the effect that chemical precipitates have on head loss and core cooling. The November 2007 Revised Content Guide for Generic Letter 2004-02 Supplemental Responses specifies the following:

1. Provide a summary of evaluation results that show that chemical precipitates formed in the post-LOCA containment environment, either by themselves or combined with debris, do not deposit at the sump screen to the extent that an unacceptable head loss results, or deposit downstream of the sump screen to the extent that long-term core cooling is unacceptably impeded.
2. Content guidance for chemical effects is provided in Enclosure 3 to a letter from the NRC to NEI dated September 27, 2007 (ADAMS Accession No. ML0726007425) and identifies the following technical issues:

   2.1 Sufficient 'Clean' Strainer Area: 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.

   2.2 Debris Bed Formation: Licensees should discuss why the debris from the break location selected for plant-specific head loss testing with chemical precipitate yields the maximum head loss. For example, plant X has break location 1 that would produce maximum head loss without consideration of chemical effects. However, break location 2, with chemical effects considered, produces greater head loss than break location 1. Therefore, the debris for head loss testing with chemical effects was based on break location 2.

   2.3 Plant Specific Materials and Buffers: Licensees should provide their assumptions (and basis for the assumptions) used to determine chemical effects loading: pH range, temperature profile, duration of containment spray, and materials expected to contribute to chemical effects.

   2.4 Approach to Determine Chemical Source Term (Decision Point): Licensees should identify the vendor who performed plant-specific chemical effects testing.

   2.5 Separate Effects Decision (Decision Point): State which method of addressing plant-specific chemical effects is used.

   2.6 AECL Model: Since the NRC USNRC is not currently aware of the testing approach, the NRC USNRC expects licensees using it to provide a detailed discussion of the chemical effects evaluation process along with head loss test results. Licensees should provide the chemical identities and amounts of predicted plant-specific precipitates.

   2.7 WCAP Base Model: Input of plant parameters into the WCAP-16530 spreadsheet should be done in a manner that results in a conservative amount of precipitate formation. In other words, plant parameter inputs selection will not be biased to lower the predicted amount of precipitate beyond what is justified. Analysis, using timed additions of precipitates based on WCAP-16530 spreadsheet predictions should account for potential non-conservative initial aluminum release rates. Licensees should list the type (e.g., AlOOH) and amount of predicted plant-specific precipitates.

2.8 WCAP Refinements: State whether refinements to WCAP-16530-NP were utilized in the chemical effects analysis. Conservative assumptions in the WCAP-16530 base model were intended to balance uncertainties in the GSI-191 chemical effects knowledge. Therefore, overall chemical effects assessment remains conservative when implementing these model refinements.

2.9 Solubility of Phosphates, Silicates and Al Alloys: Licensees should clearly identify any refinements (plant-specific inputs) to the base WCAP-16530 model and justify why the plant-specific refinement is valid.

- For crediting inhibition of aluminum that is not submerged, licensees should provide the substantiation for the following: (1) the threshold concentration of silica or phosphate needed to passivate aluminum, (2) the time needed to reach a phosphate or silicate level in the pool that would result in aluminum passivation, and (3) the amount of containment spray time (following the achieved threshold of chemicals) before aluminum that is sprayed is assumed to be passivated.
- For any attempts to credit solubility (including performing integrated testing), licensees should provide the technical basis that supports extrapolating solubility test data to plant-specific conditions. In addition, licensees should indicate why the overall chemical effects evaluation remains conservative when crediting solubility given that small amount of chemical precipitate can produce significant increases in head loss.
- Licensees should list the type (e.g., AlOOH) and amount of predicted plant specific precipitates.

2.10 Precipitate Generation (Decision Point): State whether precipitates are formed by chemical injection into a flowing test loop or whether the precipitates are formed in a separate mixing tank.

2.11 Chemical Injection into the Loop: Licensees should provide the one-hour settled volume (e.g., 80 ml of 100 ml solution remained cloudy) for precipitate prepared with the same sequence as with the plant-specific, in-situ chemical injection.

- For plant-specific testing, the licensee should provide the amount of injected chemicals (e.g., aluminum), the percentage that precipitates, and the percentage that remains dissolved during testing.
- Licensees should indicate the amount of precipitate that was added to the test for the head loss of record (i.e., 100 percent 140 percent).

2.12 Pre-Mix in Tank: Licensees should discuss any exceptions taken to the procedure recommended for surrogate precipitate formation in WCAP-16530.

2.13 Technical Approach to Debris Transport (Decision Point): State whether near-field settlement is credited or not.

2.14 Integrated Head Loss Test with Near-Field Settlement Credit: Licensees should provide the one-hour or two-hour precipitate settlement values measured within 24 hours of head loss testing.

2.14a Integrated Head Loss Test with Near-Field Settlement Credit: Licensees should provide a best estimate of the amount of surrogate chemical debris that settles away from the strainer during the test.

2.15 Head Loss Testing Without Near Field Settlement Credit: Licensees should provide an estimate of the amount of debris and precipitate that remains on the tank/flume floor at the conclusion of the test and justify why the settlement is acceptable.

2.15a Head Loss Testing Without Near Field Settlement Credit: Licensees should provide the one-hour or two-hour precipitate settlement values measured and the timing of the measurement relative to the start of head loss testing (e.g., within 24 hours).

2.16 Test Termination Criteria: Provide the test termination criteria.

2.17 Data Analysis: Licensees should provide a copy of the pressure drop curve(s) as a function of time for the testing of record. Licensees should explain any extrapolation methods used for data analysis.

2.18 Integral Generation (Alion): Licensees should discuss why the test parameters (e.g., temperature, pH) provide for a conservative chemical effects test.

2.19 Tank Scaling / Bed Formation: Explain how scaling factors for the test facilities are representative or conservative relative to plant-specific values. Explain how bed formation is representative of that expected for the size of materials and debris that is formed in the plant specific evaluation.

2.20 Tank Transport: Explain how the transport of chemicals and debris in the testing facility is representative or conservative with regard to the expected flow and transport in the plant-specific conditions.

2.21 30-Day Integrated Head Loss Test: Licensees should provide the plant-specific test conditions and the basis for why these test conditions and test results provide for a conservative chemical effects evaluation. Licensees should provide a copy of the pressure drop curve(s) as a function of time for the testing of record.

2.22 Data Analysis Bump Up Factor: Licensees should provide the details and the technical basis that show why the bump-up factor from the particular debris bed in the test is appropriate for application to other debris beds.

<u>FPL Response to Issue 3.o.1</u>:

Chemical precipitates that form in the post-LOCA containment environment combined with debris do not result in an unacceptable head loss. The effects of the sump chemical environment were evaluated in an integrated chemical effects head loss test by Alion at the VUEZ test facility. The results of the chemical effects testing has been incorporated into the NPSH calculations as discussed in NRC Topic 3.g, Net Positive Suction Head (NPSH), above.

<u>FPL Response to Issue 3.o.2.1</u>

Although Saint Lucie Unit 1 (St. Lucie Unit 1) installed a very large strainer (>8000 ft^2), the debris load is sufficient to cover the sump screen. St. Lucie Unit 1 did not perform a "simplified" chemical effects evaluation.

FPL Response to Issue 3.o.2.2

St. Lucie Unit 1 has performed prototype sector testing of the GE Modular Stacked Disc Strainer at the CDI test facility without chemical surrogates to develop the non-chemical debris head losses. The Modular Strainer also makes use of the GE Debris Plate to mitigate thin-bed effects. Based on the plant specific head loss testing, two (2) debris load cases were selected to be evaluated for chemical effects representing the range of debris loads.

Case 1: Thin-bed load case

This load case produced a debris bed thickness of 0.19" and is composed of calcium silicate and fiberglass along with latent dirt/dust and coatings particulate. This debris load produced the highest non-chemical head loss in the non-chemical prototype testing and represents a very high particulate to fiber ratio thin-bed with minimal porosity.

Case 2: Maximum load case

Although this load case contained the maximum design basis debris load, it did not produce the highest non-chemical debris head losses in the non-chemical prototype sector test. This load case produces a debris thickness of 0.73" and is composed of calcium silicate and fiberglass along with latent dirt/dust and coatings particulate. This debris load produced a much lower head loss than the thin bed load case but was evaluated for impact of chemical effects on the maximum debris loading. Both cases 1 and 2 were evaluated in chemical effects testing.

FPL Response to Issue 3.o.2.3

The following assumptions were applied to chemical effects testing for head loss.

- The pH profile is based on an initial reactor coolant system pH value of 5.0 (2600 ppm Boron) immediately after the LOCA. The pH of the sump is raised to a maximum value of 9.9 with NaOH. Residual acids (HCl and Nitric) are produced over the 30-day mission time. Post-LOCA Containment Sump pH Values for St. Lucie Unit 1, the HCl and nitric acids are assumed to fully dissociate in the containment sump water. It is assumed that these acids neutralize the sodium hydroxide and the resulting salt does not affect the solution's pH. Additionally, the effect of hydriodic acid (HI) is considered negligible for calculating the sump pH.

- The containment and sump temperature profile ranges from 100°F to 260°F. The maximum test temperature and range is 190°F to 100°F. Material corrosion greater than 190°F was included in the test by adding more surface area for a prescribed period of time.

- Containment sprays are assumed to be in operation for the full 30-day mission time.

- The materials considered for chemical effects are: concrete, zinc, carbon steel, aluminum, and fiberglass.

FPL Response to Issue 3.o.2.4

Alion Science and Technology performed plant-specific chemical effects testing. The testing protocol is the VUEZ 30-day integrated chemical effects testing.

FPL Response to Issue 3.o.2.5

St. Lucie Unit 1 does not use the WCAP or AECL based models for testing. Additionally, near field settling was not credited and the test was run for 30 days. Therefore, responses to items 3.o.2.6 through 3.o.2.17 are not applicable.

FPL Response to Issue 3.o.2.18

Alion's VUEZ CE Test Program is designed to replicate the potential corrosive interactions of the spray and pool fluid chemistry with those materials and debris sources in containment and resident on the sump screen. These potential interactions may cause additional precipitates and/or impacts on debris head loss over the 30-day mission time. To provide a representative test, certain scaled parameters are selected to ensure that the reactions take place in the correct quantity and environment and that the resulting debris head losses satisfactorily reflect any chemical effects. Critical plant parameters include sump screen area, recirculation fluid volume, recirculation flow rate, containment debris, and recirculation pool chemistry (temperature and pH).

The test tank and setup represents these containment parameters to replicate the corrosion potential of the structural materials inside containment. The test preserves the material surface area to pool volume similar to the integrated chemical effects testing (ICET) tests; past experience with these types of corrosion tests have shown that the release rate is based on surface area of the material and not necessarily the mass.

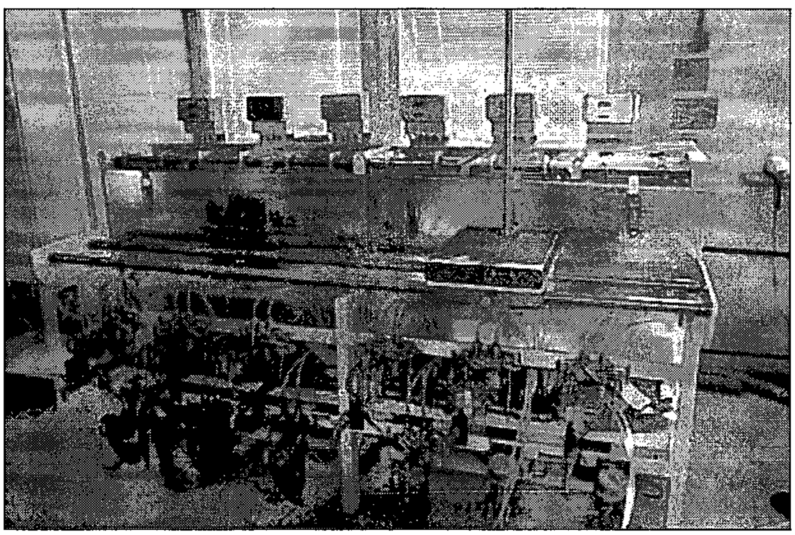


Figure 3.o.2.18-1: VUEZ Test Tanks (row of six)

Submerged materials are insulation, debris or other material that is below the sump water level and not transported to the sump. This material does not directly contribute to sump screen head loss but can affect pool pH and chemical properties. Unsubmerged materials are materials within containment that undergo coolant spray but are above the pool volume. These materials do not contribute to head loss or pool chemistry directly but can affect the pool pH and chemistry due to coolant spray corrosion and run off that enters the containment pool. Materials that reach the sump screen are insulation and debris that are created by the line break and transport to the sump screen via the containment pool recirculation. These materials contribute to the sump screen head loss via bed thickness and porosity.

The containment materials included are divided into the three categories that correspond to exactly where the materials will lie within the test tank: submerged, unsubmerged, and on the sump screen. Each category is scaled according to either pool volume ratio or screen area ratio of the plant versus the test apparatus based on the transport characteristics or residence of the debris within the containment.

Chemical loads that are present in the containment pool were conserved by using the same concentration (ppm by weight value) in testing as is present in containment.

The chemical effects testing parameters are derived from the containment parameters and are conservative for the following reasons:

1. The quantities of materials that contribute to chemical effects are provided by the plant personnel based on the design documents, walkdowns or conservative estimates. The materials included in the tests are concrete, aluminum, zinc, carbon steel, dirt/dust and LOCA generated debris. Metallic coatings are represented by sheet materials.

2. The scale between the containment material to pool volume and test material to pool volume is preserved to the extent possible.

3. Although the test was limited to a maximum temperature of 190°F, the release of materials expected in containment at temperatures greater than 190°F was accounted for through an increase materials (additional coupons).

4. The test fluid pH profile throughout the test is based on design basis containment sump pH profile.

The following sections discuss the selection of the test parameters.

<u>Temperature Adjustment/Temporary Material</u>

The test program was designed to replicate the potential corrosive interactions of the spray and pool fluid chemistry with those materials and debris sources in containment and resident on the sump screen. To provide a representative test, it was necessary to ensure that the quantity of corrosion products released in the plant containment environment were reproduced in the test environment such that the resulting debris head losses satisfactorily reflected the plant's chemical effects. Since the test has limit of 190°F, and adjustment is required to ensure the quantity of material released at 190°F in the test equaled the quantity of materials released at temperatures above 190°F.

The elemental release rates were determined based on the method and equations in WCAP-16530-NP and are based on the Arrhenius principle. The release rates from the plant and test profiles were correlated to determine material adjustments or dwell adjustments for the chemical effects testing to conservatively generate the chemical effects products that would not otherwise be generated since the post LOCA containment and sump temperatures are higher than the maximum operating temperature that can be attained in the test apparatus.

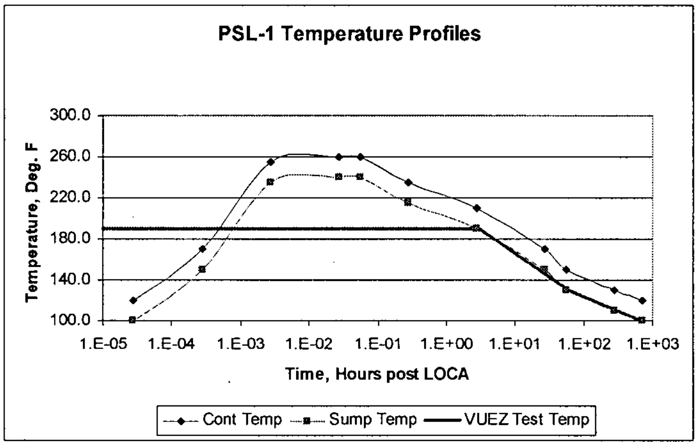


Figure 3.o.2.18-2: St. Lucie Unit 1 Temperature Profile

The test method focuses on the pre-recirculation time period and on the post recirculation time period up to the time the sump temperature drops to 190°F. In these time periods the plant's temperature profile is higher than the test apparatus temperature profile and therefore the higher the plant's temperature, the higher chemical release rates and consequently the higher the total releases. To match the plant's total releases during this period above 190°F, the quantity of material in the test apparatus was increased until such time the temperature fell below 190°F. The method used to determine the additional quantity of materials was based on the method and equations in WCAP-16530-NP.

The WCAP-16530-NP method first evaluates the elemental release rates of Al, Si and Ca as function of time, for the time period that the plant sump temperature is higher than 190°F, for the respective plant and test temperature and pH profiles. The elemental release rates of Al, Si and Ca as a function of time for these time periods are then calculated and the ratio of the elemental releases (sump/VUEZ test) as a function of time determined. These elemental ratios of the release rates are integrated as a function of time. The integrated ratios of the release rates in effect show the relationship between the plant and test time that would result in the generation of equal releases of Al, Si and Ca within a time interval of interest. The results of this evaluation are used to increase the test material to generate the same integrated releases within any time period that the plant temperature exceeds the test temperature.

Acids and Bases (pH)

Post-LOCA containment recirculation spray and sump bounding pH values were evaluated based on the borated water concentrations for the RWT, SITs, as well as the NaOH concentration in the sodium hydroxide tank. In addition, the pH values consider the generation of hydrochloric acid (HCl) and nitric acid (HNO_3) per the methodology reported in NUREG/CR-5950. The results of this calculation demonstrate that the recirculation and sump pH values are between 6.98 and 9.88.

The test begins with the addition of the requisite amount of boron (2600 ppm) through the addition of boric acid. The pH during this phase is approximately 5.0. Reviewing the industry testing, ALION benchtop tests and VUEZ results have revealed that the primary release during this phase is calcium and it is not overly sensitive to small changes in pH units. It has been noted that debris in demineralized water will raise the pH of the water due to the alkalinity of the fiberglass and calcium silicate. When adding the requisite amount of boron to the system, the pH was approximately 6.0. The final tests performed for St. Lucie Unit 1 achieved the target pH of 5.0 during the boron acid addition.

It is noted that the HCl and HNO3 acids are not generated immediately and occur over the entire 30-day mission time. However as identified in 3.o.2.3 above, these acids are assumed to fully dissociate in the containment sump water. It is assumed that these acids neutralize the sodium hydroxide and the resulting salt does not affect the solution's pH. Additionally, the effect of hydriodic acid (HI) is considered negligible for calculating the sump pH.

Conservative Effect on Test

St. Lucie Unit 1 is represented and categorized as an ICET#4 environment as shown in Table 3.o.2.18-1 since St. Lucie Unit 1 contains both calcium silicate and fiberglass insulation.

Table 3.o.2.18-1: St. Lucie Unit 1 Containment Material Surface Area to Pool Volume Ratios

Containment Materials	St. Lucie Unit 1 Specific		ICET Test #4		WCAP-16530	
Zinc Coatings	9.6	ft^2/ft^3	4.6	ft^2/ft^3	28.0	ft^2/ft^3
Aluminum	0.11	ft^2/ft^3	3.5	ft^2/ft^3	5.42	ft^2/ft^3
Copper	0.0	ft^2/ft^3	6.0	ft^2/ft^3	11.11	ft^2/ft^3
Carbon Steel	0.004	ft^2/ft^3	0.15	ft^2/ft^3	10.78	ft^2/ft^3
Concrete Surface	0.02	ft^2/ft^3	0.045	ft^2/ft^3	4.79	ft^2/ft^3
Fiber	0.02	ft^3/ft^3	0.137[1]	ft^3/ft^3	0.23	ft^3/ft^3
Calcium Silicate	0.0017	ft^3/ft^3		ft^3/ft^3	0.18	ft^3/ft^3

The amount of zinc coatings included in the St. Lucie Unit 1 test is larger than ICET#4 due to the derivation of the surface area by Alion. Alion considered the failed coatings as 10 micron spheres per NEI-04-07 and then calculated the surface area of the 10 micron sphere. This conservatively increased the surface area of zinc considerably over that of the IOZ intact coated surface. The difference between the ICET test and St. Lucie Unit 1 is not significant.

The results of ICET#4 indicated negligible chemical effects during the test and upon cooling. As documented in NUREG-6914, §2.1, Test 4 did not produce any precipitates upon cooling to room temperature. Deposits were noted in the fiberglass debris. The low levels of dissolved aluminum in solution provided strong evidence of aluminum passivation due to large amounts of dissolved silica from the calcium silicate. It should be noted that based on Test#1 and other industry testing, large amounts of aluminum in solution can inhibit the dissolution of fiberglass as well. Therefore the chemical effects in ICET#4 were relatively insignificant compared to those in ICET#1 (100% fiberglass). Due to the considerable calcium silicate loading at St. Lucie Unit 1, the non-chemical debris loading is expected to be of more significance than the chemical effects.

In light of the ICET#4, the VUEZ test was designed to promote corrosion and precipitate formation within an integrated environment representative of the post-LOCA containment sump. The pH of the test was designed to reach the maximum lower and upper bound pH values to promote dissolution and corrosion of aluminum. The temperature range was based on the plant specific profile and maximized during the beginning of the test. The lower bound temperature of 100°F is a reasonable long term pool temperature.

FPL is aware the aluminum solubility is a function of both pH and temperature and by selecting the maximum pH and maximum temperature, the test was designed to provide a conservative corrosion/dissolution of aluminum. Longer term however, keeping the pH and temperature high

[1] For ICET#4 the insulation makeup was 80% calcium silicate and 20% fiber

may have an unconservative effect of promoting the precipitation of aluminum and impacting head loss. The reality of the chemistry is that only small changes in pH could occur from the HCl and nitric acids and are considered negligible in the NAI sump pH calculation for purposes of affecting the pH. Although it is conservative to perform a test with a maximum pH for corrosion and then a minimum pH for precipitation, these bounding reverse pH swings cannot occur in containment.

In summary, the chemical effects test is designed to exercise the limits of pH based on the conservative plant design basis to promote corrosion products and precipitation.

FPL Response to Issue 3.o.2.19

1. Scaling Factors

The testing was conducted with scaled, representative material surface areas, sump volumes and chemical constituents to provide conditions closely simulating the post-LOCA sump environment. In order to promote the reactions that would be expected in this environment, the test vessel contained the proportions of non-metallic, metallic, and construction materials similar to those present in the St. Lucie Unit 1 containment environments.

Structural and debris materials were obtained from plant surveys or documents and scaled for input into the 30 day chemical test. In several cases, debris materials were determined to be inert and suitable surrogates were selected for development of a representative debris bed porosity. The materials considered in the test were:

- NUKON
- Aluminum
- Carbon Steel
- Zinc
- Concrete
- Calcium Silicate

The scale testing was configured to achieve the following conditions:

1. The test apparatus screen average fluid approach velocity should be greater than or equal to the containment sump screen representative average approach velocity within the limits of the test equipment.
2. The temperature and pH conditions of the tests should be as representative as possible of the actual containment conditions.
3. The ratio of the test material surface area to tank volume should be equal to that of the containment materials surface area to containment pool volume.
4. The fibrous debris bed thickness on the screen of the test apparatus should be equal to the containment sump screen equivalent debris bed thickness.

The control of the parameters defined above ensured that the corrosion/leaching conditions and debris head loss characteristics that occur during the test were representative of the containment conditions during the postulated LOCA.

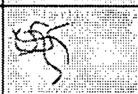
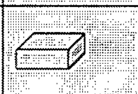
2. Bed Formation

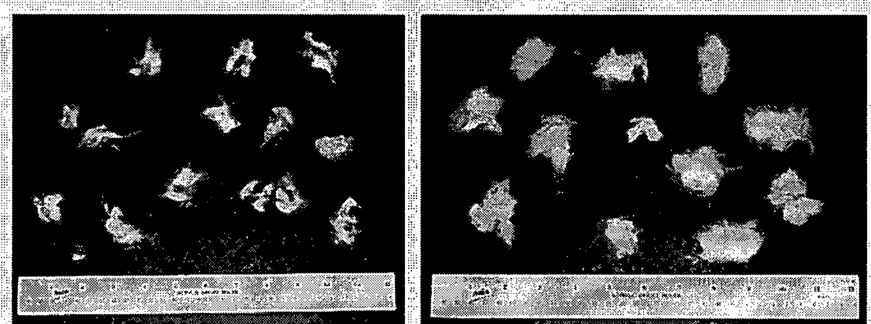
The VUEZ 30 day debris head loss testing represents a combination of ICET and vertical loop debris head loss testing. The screen installed in the test is a horizontally oriented flat plate on which the plant specific debris bed was developed and head loss measured. The screen is slightly spherical on the bottom to inhibit the formation of voids that may build up underneath the debris bed. The sump solution is circulated in the areas outside the suction plenum and drawn down through the debris bed and recirculated.

The debris beds developed in the VUEZ test loop provide a representative, average debris bed (bed thickness and composition) on which the impact of chemical effects was measured over the 30-day mission time.

The debris bed composition and thickness selected for the VUEZ chemical effects tests is based on the range of plant specific debris loads and size characteristics determined in the plant-specific debris generation, transport, head loss analysis and prototype testing. The VUEZ test size distribution is primarily represented by Classes 1 through 5 in Table 3-2 and Figure 3-3 (NUREG/CR-6808). This ensures that the characteristic size of the debris is small compared to the characteristic size of the VUEZ screen. Further, this leads on average to a higher debris density, which is expected to maximize the impact of any chemical precipitates that might form.

Table 3-2 Size Classification Scheme for Fibrous Debris[3-2]

No.		Description
1		Very small pieces of fiberglass material; "microscopic" fines that appear to be cylinders of varying L/D.
2		Single, flexible strands of fiberglass; essentially acts as a suspending strand.
3		Multiple attached or interwoven strands that exhibit considerable flexibility and that, because of random orientations induced by turbulent drag, can exhibit low settling velocities.
4		Fiber clusters that have more rigidity than Class 3 debris and that react to drag forces as a semi-rigid body.
5		Clumps of fibrous debris that have been noted to sink when saturated with water. Generated by different methods by various researchers but easily created by manual shredding of fiber matting.
6		Larger clumps of fibers lying between Classes 5 and 7.
7		Fragments of fiber that retain some aspects of the original rectangular construction of the fiber matting. Typically precut pieces of a large blanket to simulate moderate-size segments of original blanket.



Fiberglass shreds in size Class 3

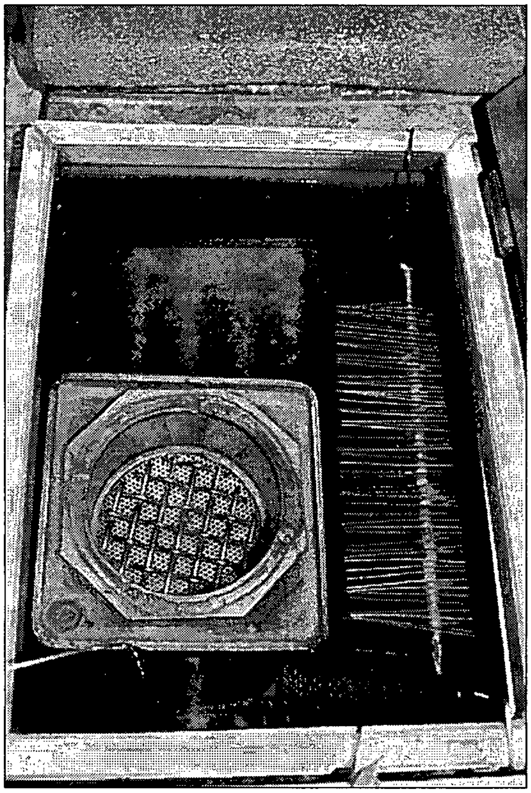
Fiberglass shreds in size Class 5

Figure 3-3. Fiberglass Insulation Debris of Two Example Size Classes

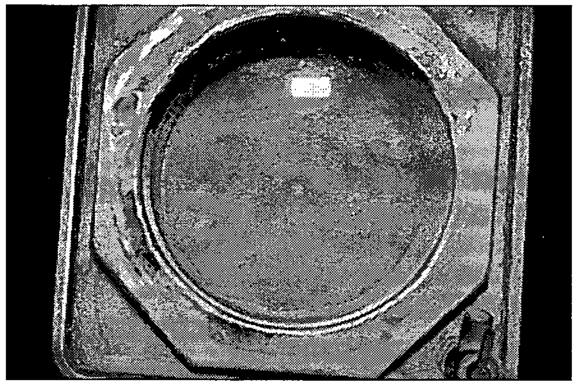
The fibrous materials are boiled to remove the trace amounts of oils or gasses trapped within the fibers. This process helps to ensure that the materials do not agglomerate, float and simulate aging (lose resiliency). The material is then shredded consistent with standard head loss testing practices (leaf shredder, cuisenart, etc.) to resemble the size distribution presented in Table 3-2 and Figure 3-3. The debris bed particulate surrogates are procured with an average size distribution near 10 micron.

The fiber and particulate mixture is thoroughly mixed in a beaker containing the test solution (Figure 3.o.2.19-1). The mixture is slowly added through a funnel to ensure an even distribution across the test screen area while the pump is circulating (Figure 5). The bed is constructed to be uniform (minimal clumps, unevenness, etc.) to the extent possible by the technicians.

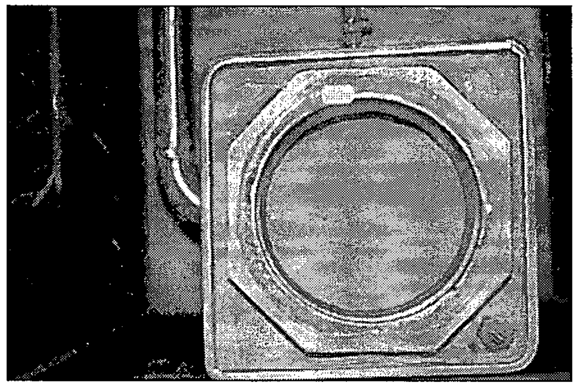
Figure 3.o.2.19-1: VUEZ Debris Bed Formation



Tank Screen and Metal Coupons



Thin-Bed Debris Bed



Thick-Bed Debris Bed

Figure 3.o.2.19-2: VUEZ Tanks Screen and St. Lucie Unit 1 Debris Beds

The debris beds formed on the VUEZ screen are similar in that all the debris is accumulated on the screen similar to the prototype testing. Historically, it has been shown that uniform debris beds produce higher head losses than non-uniform debris beds. The competition between the gravitational and hydraulic shear forces can lead to non-uniform velocity profiles on vertical screens. Low velocity, combined with a high specific gravity of debris fragments, can cause debris to preferentially accumulate near the base of a vertical screen, leaving the upper portions of the screen relatively clean. It is for this reason that up to a debris loading, uniform beds on a flat horizontal plate yield higher measured head losses than the same quantity of debris (amount per unit surface area) collected on an "advanced geometry" strainer array. The reason for this is the tendency for real strainer hardware to collect debris in a non-uniform manner. Care must, however be taken to ensure that the debris distribution on a flat plate is indeed as uniform as possible. Pictures of the sector prototype test of the thin and thick beds are provided in Figures 3.o.2.19-3 and 3.o.2.19-4. The beds are sufficiently similar in that debris is homogenously mixed into the tank and accumulates on the screen surface dependent upon localized flow velocities. The VUEZ debris bed is homogenously mixed and manually formed to be as uniform as possible to represent the overall debris bed on the sector.

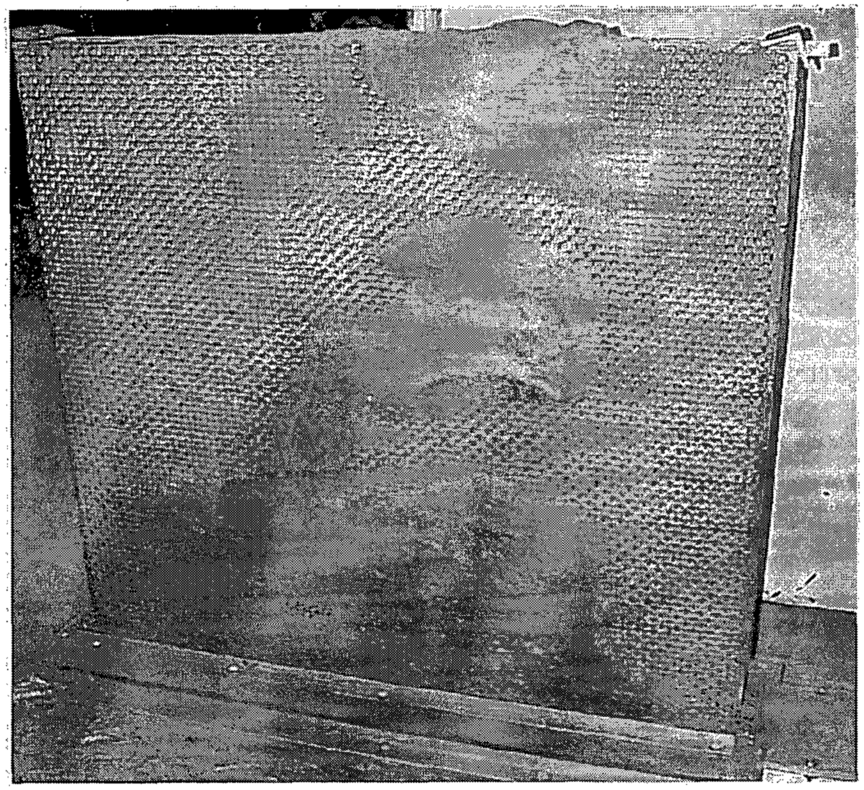


Figure 3.o.2.19-3(a): Thin-Bed Debris Bed on Test Article (Sector Test)

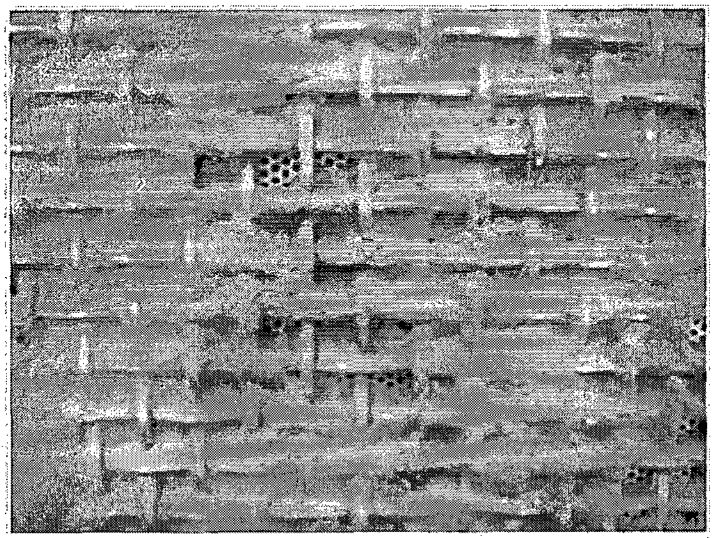


Figure 3.o.2.19-3(b): Close up of Thin-Bed Debris Bed on Test Article (Sector Test)

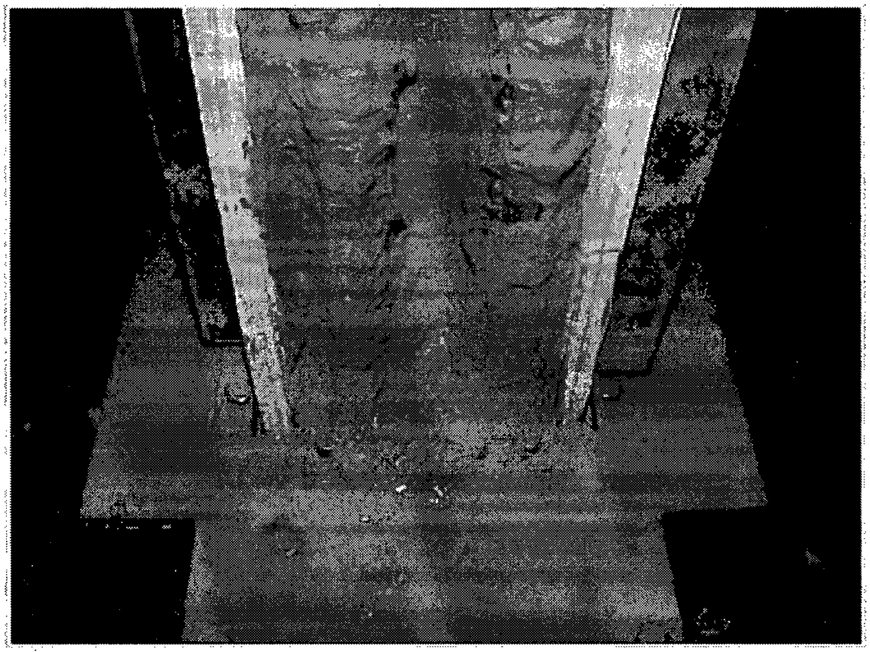


Figure 3.o.2.19-4(a): Thick Bed Debris Bed on Test Article (Sector Test)

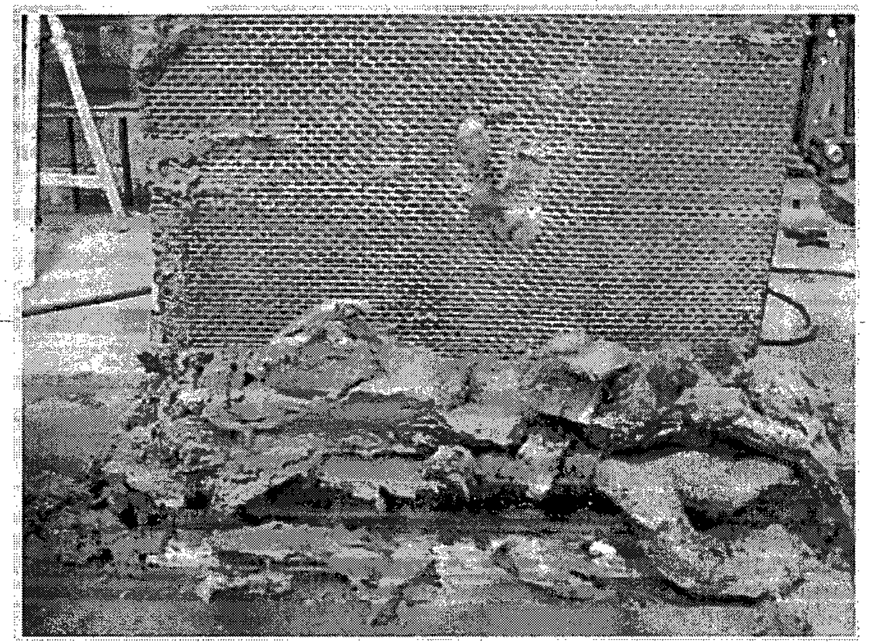


Figure 3.o.2.19-4(b): Thick Bed Debris Bed on Test Article (Sector Test)

FPL Response to Issue 3.o.2.20

The circulation of fluid is essential to the development of a homogenous chemical solution by which corrosion and subsequent precipitation can occur. The test is not a transport test therefore comparing plant floor velocities to test tank velocities is not a requirement. The test tank has sufficient turbulence to ensure the solution is passed by all metallic, concrete and fibrous surfaces and carries those dissolved species and any subsequent hydrated precipitates through the debris bed.

The circulation in the test tank is approximately 0.7 l/min. The loop is approximately 59 liter and therefore the fluid is turned over approximately once every 84 minutes. The St. Lucie Unit 1 maximum and minimum sump volume is 83,712 ft^3 and 62,922 ft^3, respectively. This would produce a pool turnover between 55 to 73 minutes at the design flow rate of 8530 gpm. Although the test tank turnover time is slightly longer, the effect is negligible since this tank has mixing and the solution is homogenous.

FPL Response to Issue 3.o.2.21

As stated in Section 3.o.2.18, the temperature and pH of the test was selected to provide reasonable and conservative conditions to promote corrosion and precipitation within the plant specific condition evaluated. St. Lucie Unit 1 has many sources of silicate (concrete, calcium-silicate and fiberglass) and these silicates will inhibit the corrosion of aluminum. The test program performed over seven (7) tests at VUEZ with two different bed thicknesses and found relatively similar results – silica can inhibit aluminum and aluminum can inhibit silica. These conditions are exclusive in that low silica tends to have high aluminum and vice versa. The potential chemical precipitates are a sodium/calcium based aluminum silicate or aluminum oxyhydroxide. The ICP data would suggest that even with silica inhibition, a small amount of sodium/calcium aluminum silicate is formed and then the solution maintains a high concentration of aluminum. In summary, two conditions are likely,

1) The amount of silica dissolution is high and aluminum is low, limiting the amount of sodium/calcium aluminum silicate, or
2) The amount of silica dissolution is low and aluminum is high, limiting the amount of sodium/calcium aluminum silicate.

In both cases, the impact of sodium/calcium aluminum silicate is nominally low due to the limiting species (either aluminum or silica). The tests have estimated this increase over the non-chemical debris head loss of approximately 3.3 times. For those circumstances that would lead to low silica dissolution, the aluminum concentration can be near 60 to 100 ppm; however the solubility of aluminum at this pH of 9.9 and temperature is greater than this. It is for this reason that the tests did not produce significant long term chemical effects. Aluminum effects typically show large increases in head loss based on past industry testing (ANL, ALION/VUEZ).

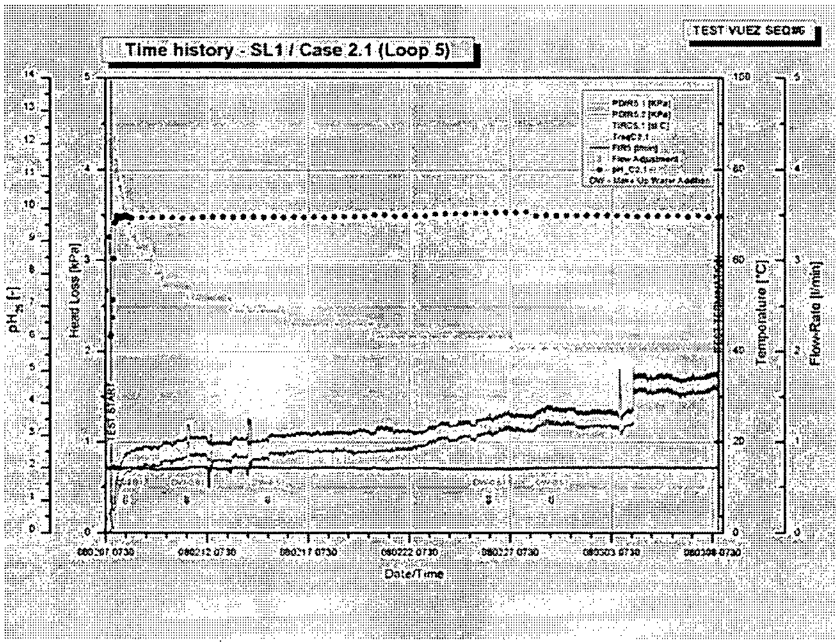


Figure 3.o.2.21-1: Min Debris Load Pressure Drop 30D Time History (Case 2.1 End)

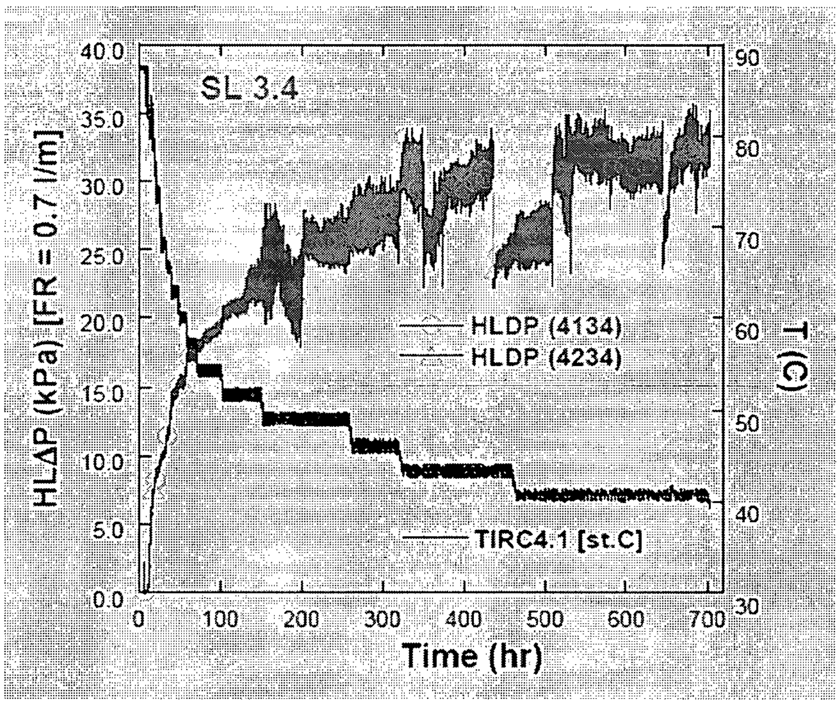


Figure 3.o.2.21-1: Max Debris Load Pressure Drop 30D Time History (Case 3.4 End)

FPL Response to Issue 3.o.2.22

St. Lucie Unit 1 evaluated the impact of chemical effects on two limiting debris beds: 1) maximum thin-bed head loss and 2) maximum debris head loss. The non-chemical head loss testing at CDI confirmed that the thin-bed head loss provided higher head losses over the maximum debris load. However, the chemical effects testing performed by Alion evaluated both the thin and thick debris bed to ensure the maximum impact of chemical effects was realized, i.e., chemical effects with a thick bed were not greater than chemical effects with a thin-bed.

The results of the chemical effects evaluation concluded that the thin-bed bump-up factor was 3.0. The thick bed bump up factor developed from the test results was 3.3. St. Lucie Unit 1 conservatively applied the envelope of the two bump-up factors for application to the limiting non-chemical debris head losses to determine the maximum chemical effects head loss for plant conditions.

The responses to the RAIs regarding Chemical Effects follows.

[RAI 2] The response to RAI 2 for St. Lucie Unit 1 is summarized in the following table:

Parameter Requested	Description of Parameter Requirements	Supplied Value
Aluminum total surface area	*Submerged and Unsubmerged (ft^2)*	Submerged 291.1 Unsubmerged 5530.9 Total 5822
Zinc total surface area	*Submerged and Unsubmerged (ft^2)*	Since completion of ICET, W WCAP 16530 has concluded that: "The zinc releases were relatively small and can be ignored in chemical effects precipitation modeling."
Carbon Steel total surface area	*Submerged and Unsubmerged (ft^2)*	200
Concrete exposed and submerged after a LOCA	*Concrete (ft^2)*	Submerged 442 Unsubmerged 858 Total 1300
Copper total surface area	*Submerged and Unsubmerged (ft^2)*	61407.6

For the purposes of chemical effects testing, it was conservatively assumed that the percentage of material submerged was no less than that used for ICET tests.

[RAI-3] For St. Lucie Unit 1 (St. Lucie Unit 1), the small amount of carbon steel knuckles and aluminum ladders stored in the containment are included in the debris quantities used for design inputs used to perform the chemical effects testing. The carbon steel DBA qualified coated scaffold poles and uncoated carbon steel knuckles are not considered as a contributor for chemical testing.

St. Lucie Unit 1 currently has approval for scaffolding storage in containment at the 23 ft - 0 in elevation. The amount is controlled by engineering specifications and only allows for scaffolding that has a DBA qualified coating applied on scaffolding in accordance with Coatings Specification. The connecting knuckles are not coated, any galvanizing or coatings were removed and bare carbon steel knuckles are stored in steel boxes on the 23 ft elevation. The maximum amount of uncoated steel knuckles approved for storage in containment is approximately 125 square-feet, and these are contained in closed steel boxes. The amount of scaffolding approved for storage in containment is 1500 square-feet. Some of the scaffolding and the connecting knuckles would be submerged in the event of a LOCA. The scaffolding is stored on the 23 ft – 0 in elevation and the calculated post-LOCA containment water level is approximately 23.86 ft. . The scaffold poles are stored in a horizontal position (2000 linear-feet) and the vertical position (1000 linear-feet). There is no adverse affect due to coatings to the Containment Spray (CS) and Emergency Core Cooling System (ECCS) since the carbon steel scaffolding connectors are uncoated, and the scaffolding is coated with DBA qualified coatings per specification.

Storage structures are made for storage of 10 aluminum ladders to be stored on the 23 feet elevation of the containment building. The total square footage of the Aluminum ladders surface area is 550 square feet. The ladders are evaluated for storage in the vertical position with the legs on the 23 feet elevation. The maximum submerged area would be approximately 7 square feet with all 10 ladders stored on the 23 feet elevation based on the 23.86 feet flood level.

Storage for 1 Stainless Steel Access ladder to be stored on the 62 feet elevation of the containment building is approved. The total square footage of the ladder surface area is 50 square feet. The ladder is stored in the horizontal position.

[RAI-4] The insulation jacketing used in St. Lucie Unit 1 is stainless steel. Therefore the condition and limitation of the request is not applicable. The original construction specification for insulation specifically banned aluminum material in insulation.

The St. Lucie Unit 1 unqualified coatings log currently lists a small amount of unqualified zinc metallic coating (8 ft^2, 4 mils) in the containment building, which is only subjected to containment spray at elevations of 40 ft and 70 ft. The calculated post-LOCA containment floodwater level is approximately 23.86 ft. There is no adverse effect due to metallic coatings to the Containment Spray (CS) and Emergency Core Cooling System (ECCS) since the amount of any metallic paint is small and is accounted for in the debris generation calculations.

The type and amount of unqualified coatings in containment during power operation is limited and tracked by specification. This information regarding metallic paints is primarily referenced in the unqualified coating log and UFSAR.

[RAI-5] A calculation was performed to determine the bounding containment recirculation spray and sump pH values for the current operating conditions based on the boron concentrations for the refueling water tank (RWT) and safety injection tanks (SITs) and the sodium hydroxide concentration and volume in the sodium hydroxide tank. The minimum 30 day post-LOCA sump pH is 8.18, the maximum 30 day post-LOCA sump pH is 9.88. and the minimum recirculation sump pH is 6.98 at the initiation of RAS. Assumptions for the values are as follows:

Containment Sump Minimum pH

- Maximum possible RWT, SIT, and RCS masses and minimum possible NaOH solution mass.
- Maximum sump boron concentration and minimum sump sodium hydroxide concentration. For this case, the maximum RCS boron concentration is assumed to be 2700 ppm.

Containment Sump Maximum pH

- Minimum possible RWT, SIT, and RCS masses and maximum possible NaOH solution mass.
- Minimum sump boron concentration and maximum sump sodium hydroxide concentration. For this case, the minimum RCS boron concentration is assumed to be 0 ppm.

[RAI 6] The ICET environment most similar to St. Lucie Unit 1 is ICET#4. St. Lucie Unit 1 contains both calcium silicate and fibrous insulation with a sodium hydroxide (NaOH) buffered environment. The environmental conditions are very similar between St. Lucie Unit 1 and ICET#4 as shown below.

Chemical Parameters	*St. Lucie Unit 1*	*ICET#4*
Boron Concentration	2600 ppm	2800 ppm
Buffer	NaOH	NaOH
Buffer Concentration	As required to reach pH 9.9 in the simulated sump fluid	As required to reach pH 10 in the simulated sump fluid
pH	9.9	9.7 to 9.9

The table below presents a comparison of the material inside St. Lucie Unit 1 and ICET#4. The different zinc coating loadings is discussed in section. 3.o.2.18.

Containment Materials	St. Lucie Unit 1		ICET#4	
Zinc Coatings	9.6	ft^2/ft^3	4.6	ft^2/ft^3
Aluminum	0.11	ft^2/ft^3	3.5	ft^2/ft^3
Copper	1.5	ft^2/ft^3	6.0	ft^2/ft^3
Carbon Steel	0.004	ft^2/ft^3	0.15	ft^2/ft^3
Concrete Surface	0.02	ft^2/ft^3	0.045	ft^2/ft^3
Fiber	0.02	ft^3/ft^3	0.137[2]	ft^3/ft^3
Calcium Silicate	0.0017	ft^3/ft^3		ft^3/ft^3

[RAI 7] The time until ECCS external recirculation initiation is approximately 20 minutes, see NRC Topic 3.g, Net Positive Suction Head (NPSH). The associated pool temperature is shown in Figure 3.o.2.18-2. The pool volume is provided in the table in NRC Topic 3.g, Net Positive Suction Head (NPSH).

[RAI-8] This RAI requested information on the FPL chemical effects testing program. This information is provided in NRC Topics 3.g, Net Positive Suction Head (NPSH), and 3.o, Chemical Effects.

[RAI-9] There are no plans to remove additional material from containment, and no plans to make a change from the existing chemicals that buffer containment pool pH following a LOCA.

[RAI 10] FPL has completed chemical effects bench testing to provide insight into the dissolution and corrosion of these materials in a combined, integrated post-LOCA environment. The benchtop tests performed and provided by Alion Science & Technology and were generic in development similar to ICET and WCAP tests.

The benchtop tests were performed prior to the St. Lucie Unit 1 plant specific 30 day integrated head loss testing and were intended to provide an expectation of what might form in the plant specific 30 day tests as compared to the ICET#4 test.

The St. Lucie Unit 1 benchtop tests were inspected and analyzed for dissolved species and precipitation. The tests investigated the dissolution and corrosion of Aluminum, Zinc, Temp-Mat, Cal-Sil, Nukon, and concrete in NaOH containing solutions at pH 8.8 to 9.1 as well as the potential formation of chemical precipitates from these reactions at elevated temperature and chemical conditions that simulate post-LOCA conditions for a typical nuclear power plant. The test materials and solutions were visually examined and analyzed by SEM, EDS, and ICP-AES, respectively.

For the NaOH environment, the bench tests were performed in 350 mL solutions with sump chemistries initially representing 2800 ppm total Boron from Boric Acid (H_3BO_3) and 0.7 ppm of Lithium from Lithium Hydroxide (LiOH) with sufficient sodium hydroxide to establish a target pH in the range of 8.8 to 9.1. The solution temperature was initially set at 200°F $\pm$ 9°F for the first

[2] For ICET#4 the insulation makeup was 80% calcium silicate and 20% fiber

several hours followed by a decrease in temperature to 140°F ± 5°F which was maintained for the remainder of the 30 day test. The pH of St. Lucie Unit 1 is 9.9 and considerably higher than that tested in the benchtop tests, but the benchtop test did provide insight into the corrosion at slightly lower pHs.

Test 1: Aluminum, Zinc, Concrete, Temp-Mat, Cal-Sil, Alkyd Paint, Dirt/Dust Corrosion and Dissolution in NaOH with pH range of 8.8-9.1 (Test 214-1).
Test 3: Aluminum, Zinc, Concrete, Temp-Mat, Alkyd Paint, Dirt/Dust Corrosion and Dissolution in NaOH with pH range of 8.8-9.1 (Test 214-3).

The ratios of benchtop test materials to fluid volumes are provided in Table 3-1 with the difference between Test 1 and 3 the removal of calcium silicate in Test 3. These are for the most part lower than the plant specific values (with the exception of concrete and calcium silicate), but still provide information relative to corrosion products in a typical chemical environment.

Table 3-1: Benchtop Material to Pool Volume Ratios

Containment Materials	Material to Volume Ratio	St. Lucie Unit 1	Units
Zinc	0.9	6.5	ft^2/ft^3
Aluminum	0.3	1.6	ft^2/ft^3
Concrete Surface	3.47	0.04	ft^2/ft^3
Temp-Mat	0.002	1.5E-4	ft^3/ft^3
Cal-Sil	0.002	0.0017	ft^3/ft^3

This benchtop program has evaluated Aluminum, Zinc, Concrete, Temp-Mat, Cal-Sil, Alkyd Paint, and Dirt/Dust corrosion and dissolution in the NaOH environment with a pH of 8.8-9.1, respectively. These tests were also performed without Cal-Sil. The following conclusions were made with respect to these tests:

1) No visible precipitation was noted during the test.
2) Chemical precipitation occurs only upon cool down to room temperature over a period of days.
3) The available Ca ions under a higher pH than 9.1 could potentially lead to the generation of calcium carbonate, $CaCO_3$.
4) Al ICP levels which decrease over time may also indicate that the Al is being used to form precipitate on the fibers.

The results of the benchtop tests were similar in observations of ICET#4 relative to the lack of visible precipitates and the potential interactions associated with calcium, silicate and aluminum. The aluminum levels did not achieve the high levels expected from the WCAP based on the pH most likely due to silica inhibition on the aluminum surface. The maximum silica levels in the benchtop tests only achieved ~13 ppm and may indicate that some level of aluminum inhibition occurs even at these levels of silica.

The benchtop program was not designed to address uncertainties in chemical effects head loss but to provide insight into the chemical reactions that would take place prior to performing an integrated 30 day chemical effects head loss test. Ultimately, St. Lucie Unit 1 performed an integrated chemical effects head loss test with plant specific values that maximized the potential for corrosion products (pH, temperature). Benchtop results as well as other industry testing have confirmed that lower pH values provide lower corrosion. Although it is acknowledged that lower pH can provide lower solubility, the two cannot occur at the same time. Given the environment contains both aluminum and silica, the formation of sodium aluminum silicate is very probable but limited by either of the two species. The more relevant of the two is most likely the excess aluminum whose solubility is sensitive to pH and temperature; however the values seen in the ICET#4, benchtop testing program and the St. Lucie Unit 1 30 day head loss test program have yielded values relatively low as compared to the solubility limit. The values utilized in the integrated 30 day test were consistent with the plant scaling parameters. No chemical surrogates were used in the St. Lucie Unit 1 chemical effects head loss testing.

The results of the St. Lucie Unit 1 chemical effects testing have provided a chemical effects increase of 3.3x over that of the non-chemical effects head loss for the limiting plant specific beds evaluated. Most of this increase occurred relatively early from the testing results associated with bed dissolution and compaction in the thin bed case and sodium aluminum silicate in the thick bed case. The long term chemical effects increases were not significant indicating that the St. Lucie Unit 1 combined calcium silicate/fiberglass plus NaOH environment was not producing much in the way of chemical effects as ICET#4 indicated.

[RAI 11] ALION Science & Technology performed 30 day integrated chemical effects head loss testing at the VUEZ Test Facility in VUEZ, Slovakia.

As stated, St. Lucie Unit 1 is represented well by ICET Test #4. WCAP-16530-NP and WCAP-16785-NP computer analyses postulated that the precipitate material is expected to be Sodium Aluminum Silicate ($NaAlSi_3O_8$) and Aluminum Oxyhydroxide ($AlOOH$) because of the excess dissolved aluminum. As noted, however, the WCAP model may over predict the precipitate quantity because of the codes inability to model the inhibiting affect of aluminum on silica. The St. Lucie Unit 1 integrated test suggest chemical effects formation of sodium aluminum silicate. The St. Lucie Unit 1 tests either produced appreciable amounts of aluminum or silica, but in no case did they occur simultaneously. Under both scenarios, minimal sodium aluminum silicate is produced since in a high aluminum dissolution case, the silica was low/inhibited and therefore the NAS was limited by the available silica in solution; on the other hand if the silica dissolution was significant, the aluminum corrosion was negligible and produced limited NAS based on the available aluminum. The scenarios where excess aluminum was available, the aluminum remained in solution due to the pH being greater than 9.

To determine the impact of sump chemistry and this precipitate on debris head loss, an integrated chemical effects head loss test was designed based on the ICET configuration. This test would allow for the direct measurement of the debris head loss during the 30-day mission time through the sump environmental history – essentially, ICET plus head loss testing.

The purpose of the St. Lucie Unit 1 30 Day Chemical Effects (CE) debris head loss test program is similar to the ICET program but has also evaluated (measured) the impacts of chemical corrosion products and chemistry on the debris head loss over the 30 day sump history. The major differences between the programs is that the ICET program had no provisions for measuring head loss across the debris bed and held the temperature profile constant at 140°F, whereas the St. Lucie Unit 1 test included head loss measurements and included a specific temperature profile ranging from 190°F down to approximately 125°F.

Integrated CE Head Loss Test Configuration and Set-up

The test was conducted in a vessel (Figure 4-1) with representative structural materials, insulation and debris samples included in the simulated containment environment, their quantities scaled to preserve the St. Lucie Unit 1 specific conditions. Representative debris samples were placed in the vessel in a chemically non-reactive container that allows recirculation fluid to flow in the region of the samples while confining the material. Test conditions, i.e., material quantities and containment environment were St. Lucie Unit 1 specific and chosen to maximize the amount of chemical effects within realistic plant limits (temperature, pH, etc.). The technical basis for scaling plant specific debris quantities to the test quantities is developed and documented under separate calculations.

The test tank has appropriate temperature control such that temperatures of the simulated sump fluid follows the time-temperature profile that matches the plant estimated temperature profile to within ±5°F. The maximum temperature of the test tank is 190°F. The test temperature profile and amount of added materials were modified to account for a potentially higher release rate (due to chemical reaction kinetics) of materials associated with the early portion of the accident where the plant sump temperature is in excess of 190°F.

The initial make-up of the solution within the tank replicates that which is assumed to occur at the start of a post-LOCA event. Buffer was added to the test tank at an appropriate conservative rate as it is expected to be introduced into the containment environment over approximately 60 to 80 minutes. Once sufficient buffer was added, no further pH adjustment was made, i.e., system pH was not artificially maintained at a certain level, but instead allowed to seek its own equilibrium level due to corrosion, etc., Based on bench-top tests and ICET results, pH does not change appreciably throughout the 30 day test once initial equilibrium is reached.

Within the test tank is a screen that was loaded with appropriately scaled quantities of the plant specific debris mixture. The screen used in the 30 day test is representative of the same design and materials as used for the actual plant strainers. The coolant was circulated through the debris bed at the same approach velocity as the new strainer approach velocity. Head loss measurements across the debris bed were recorded continuously for the duration of the test.

The test was designed to replicate the amount and rate of release of those elemental materials within containment that are potentially responsible for the formation of precipitates. Small samples of fluid were taken at regular intervals and analyzed for various metals (Al, Ca, Cu, Fe, Ni, Na, Si, and Zn) by AES ICP spectroscopy. Upon conclusion of the test, the mass of the metal coupons, and their general condition were recorded and compared to their initial state. In addition, debris bed samples were analyzed using SEM/EDS techniques.

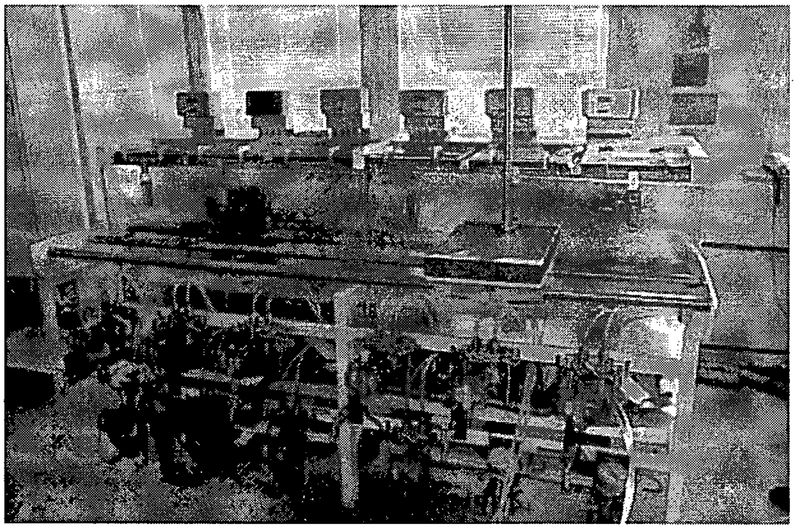


Figure 4-1: Test Reactor (Quantity 6 in a row)

The chemical fluid environment of the test was similar to that of St. Lucie Unit 1 plant in that it included boron, hydrochloric and nitric acid, lithium hydroxide and sodium hydroxide to match the plant specific conditions. The only limitation on the test was the maximum test temperature (190 deg F). Corrosion for temperatures greater than 190 deg F was accommodated by adding additional metal and concrete coupons and fiberglass materials to ensure the total release of materials at the lower temperature was equivalent to that of the higher plant specific profile (only for temperatures greater than 190 deg F). These temporary materials were removed at predetermined times. No chemical surrogates were utilized in this test and the corrosion products generated within the integrated test are expected to be similar to those generated under plant post-LOCA conditions. The test is similar to ICET but more representative of specific plant conditions along with capability of real time head loss measurements over the 30-day mission time.

[RAI 12] This RAI requested FPL provide the maximum projected head loss resulting from chemical effects (a) within the first day following a LOCA, and (b) during the entire ECCS recirculation mission time. The overall chemical effects testing program is discussed in NRC Topic 3.o, *Chemical Effects*, and the resulting NPSH is discussed in NRC Topic 3.g, *Net Positive Suction Head (NPSH)*. Note that the full 30 day debris load (non chemical debris and the maximum bump up factor) is applied at the initiation of recirculation. This is extremely conservative because, as the chemical products are being created during the 30 days, the sump pool is cooling down providing additional NPSH margin.

[RAI 13] The light precipitates were visible after the ICET test solution sat at room temperature for several days. The aluminum concentration for ICET#1 was approximately 350 ppm at a pH of 9.9. An estimate of the solubility of aluminum at 20°C is approximately 100 ppm (NUREG/CR-6913) which would support the formation of this aluminum precipitate. The aluminum concentration for St. Lucie Unit 1 is below 100 ppm at a pH of 9.9 with minimal silica inhibition and below 10 ppm with silica inhibition. St. Lucie Unit 1 is represented well by ICET#4 as all break controlling break locations contained calcium silicate insulation and ensure some silica in solution. St. Lucie Unit 1 has evaluated the impact of chemical effects for 30 days down to the minimum plant temperature of 100 deg F.

[RAI 17] St. Lucie Unit 1 is not relying on the ICET#4 results solely to address plant specific conditions or chemical effects. The ICET#4 results are in agreement with the results of the St. Lucie Unit 1 plant specific testing performed by VUEZ and informative benchtop tests. The WCAP-16785 investigations into silicate inhibition are also collaborated by the results of the ICET#4 results. The St. Lucie Unit 1 testing utilized plant specific values for calcium silicate which were less than ICET#4.

Topic 3.p: Licensing Basis

FPL Response

As discussed in other sections of this response, physical plant changes and procedural changes have been made to St. Lucie Unit 1 to resolve GL 2004-02 and GSI-191 concerns.

The St. Lucie Unit 1 UFSAR has been updated to incorporate the effects of plant modifications and evaluations performed in accordance with the requirements of 10 CFR 50.59.

Following the issuance of Bulletin 2003-01, St. Lucie Unit 1 put in-place administrative controls to maintain a higher water level in the RWT than the required Technical Specification minimum, with the intent that this higher level would remain until such time as sump issues were completely resolved. Calculations and results provided in Topic 3.f, Head Loss and Vortexing, and in Topic 3.g, Net Positive Suction Head Available (NPSH), credit this current/higher RWT level. FPL has determined that an amendment to the Technical Specifications to raise the minimum allowable RWT level to the current/higher administrative level is required in order to assure that sufficient post-LOCA containment level bounds the submerged testing and calculations for the strainer system. The amendment request for this increase in minimum Technical Specification RWT level is being submitted. The current/higher RWT level will remain in effect until the amendment request is reviewed by NRC, approved, and implemented on-site.

Enclosure 1

(St. Lucie Unit 1 Supplemental Response)

NRC Safety Evaluation Report

Limitations and Conditions for

WCAP 16530-NP Revision 0

L&C No.	NRC Limitations & Conditions (WCAP 16530-NP Revision 0)	FPL (St. Lucie Unit 1) Response
1.	A peer review of NRC-sponsored chemical effects testing was performed and a number of technical issues related to GSI-191 chemical effects were raised by the independent peer review panel members (NUREG-1861). The peer review panel and the NRC staff developed a PIRT of technical issues identified by the peer review panel. The NRC staff is working to resolve the technical issues identified in the PIRT. Part of the resolution process includes NRC-sponsored analyses being performed by PNNL. Although the NRC staff has not developed any information related to the PIRT issues resolution that would alter the conclusions of this evaluation, some issues raised by the peer review panel were not completely resolved at the time this evaluation was written. An example of such an issue is the potential influences of organic materials on chemical effects. Therefore, it is possible that additional analysis or other results obtained during the resolution of the remaining peer review panel issues could affect the conclusions in this evaluation. In that event, the NRC staff may modify the SE or take other actions as necessary.	This is not a limitation or condition. If the NRC staff modifies the SE or takes other actions, FPL will respond to any future limitations and conditions as requested.
2.	This evaluation does not address TR WCAP-16785-NP, "Evaluation of Additional Inputs to the WCAP-16530-NP Chemical Model." The NRC staff will provide comments on WCAP-16785-NP separate from this evaluation. In addition, a separate SE will address a related TR, WCAP-16793-NP, "Evaluation of Long-Term Cooling Considering Particulate, Fibrous, and Chemical Debris in the Recirculating Fluid." Chemical effects in the reactor vessel are not addressed in WCAP-16530-NP or in this SE. Therefore, the approval of this TR does not extend to chemical effects in the reactor vessels.	This is not a limitation or condition. If the NRC staff modifies the SE or takes other actions, FPL will respond to any future limitations and conditions as requested. FPL used the Pressurized Water Reactor Owners Group (PWROG) methodology, which is in accordance with WCAP-16793-NP, Revision 0, to evaluate chemical effects in the reactor vessel.
3.	If a licensee performs strainer head loss tests with surrogate precipitate and applies a time-based pump NPSH margin acceptance criteria (i.e., timed precipitate additions based on topical report model predictions), they must use an aluminum release rate that does not under-predict the initial 15 day aluminum concentrations in ICET 1, although aluminum passivation can be considered during the latter parts of the ECCS mission time in this case.	St. Lucie Unit 1 did not perform strainer head loss tests with surrogate precipitate or timed precipitate additions. The Alion VUEZ chemical effects test program was used to replicate head loss due to chemical effects. The program replicates the potential interactions of the spray and pool fluid chemistry with those materials and debris sources in containment and resident on the sump screen.
4.	For head loss tests in which the objective is to keep chemical precipitate suspended (e.g., by tank agitation): Sodium aluminum silicate and aluminum oxyhydroxide precipitate settling shall be measured within 24 hours of the time the surrogate will be used and the 1-hour settled volume shall be 6 ml or greater and within 1.5 ml of the freshly prepared surrogate. Calcium phosphate precipitate settling shall be measured within 24 hours of the time the surrogate will be used and the 1 hour settled volume shall be 5 ml or greater and within 1.5 ml of the freshly prepared surrogate. Testing shall be conducted such that the surrogate precipitate is introduced in a way to ensure transportation of all material to the test screen.	St. Lucie Unit 1 did not perform strainer head loss tests in which the objective is to keep chemical precipitate suspended.
5.	For head loss testing in which the objective is to settle chemical precipitate and other debris: Aluminum containing surrogate precipitate that settles equal to or less than the 2.2 g/l concentration line shown in Figure 7.6-1 of WCAP-16530-NP (i.e., 1-or 2- hour settlement data on or above the line) is acceptable. The settling rate shall be measured within 24 hours of the time the surrogate precipitate will be used.	St. Lucie Unit 1 did not perform strainer head loss tests in which the objective is to settle chemical precipitate and other debris.
6.	For strainer head loss testing that uses TR WCAP-16530-NP sodium aluminum silicate and is performed in a de-ionized water environment, the total amount of sodium aluminum silicate added to the test shall account for the solubility of sodium aluminum silicate in this environment.	St. Lucie Unit 1 did not utilize the testing methodology of WCAP-16530-NP.

Enclosure 2

(St. Lucie Unit 1 Supplemental Response)

NRC Draft Safety Evaluation Report

Limitations and Conditions for

WCAP 16793-NP Revision 0

L&C No.	NRC Limitations & Conditions (WCAP 16793-NP Revision 0)	FPL (St. Lucie Unit 1) Response
1.	WCAP-16793-NP states that licensees shall either demonstrate that previously performed bypass testing is applicable to their plant-specific conditions, or perform their own plant-specific testing. The staff agrees with this stated position.	The St. Lucie Unit 1 plant-specific fiber bypass testing was performed by the strainer vendor.
2.	There are very large margins between the amount of core blockage that could occur based on the fuel designs and the debris source term discussed in WCAP-16793-NP and the blockage that would be required to degrade the coolant flow to the point that the decay heat could not be adequately removed. Plant-specific evaluations referencing WCAP-16793-NP should verify the applicability of the WCAP-16793-NP blockage conclusions to licensees' plants and fuel designs.	A plant specific analysis using the Westinghouse LOCA deposition Model in reference to WCAP 16793-NP was performed for St. Lucie Unit 1. The results of the calculation yielded a maximum fuel cladding temperature and thickest calculated scale well below the threshold criteria.
3.	Should a licensee choose to take credit for alternate flow paths such as core baffle plate holes, it shall demonstrate that the flow paths would be effective and that the flow holes will not be become blocked with debris during a loss-of-coolant accident (LOCA) and that the credited flowpath would be effective.	No alternative flow paths were used for St. Lucie Unit 1. The flow paths are as described in WCAP 16793-NP, Section 5.4.2, Transport of Coolant, Dissolved Species and Suspended Solids within the ECCS, Page 5-4 and Section 5.4.3, Modeling of the Core, Page 5-5. No alternative flow paths were utilized in the LOCA Deposition Model.
4.	Existing plant analyses showing adequate dilution of boric acid during the long-term cooling period have not considered core inlet blockage. Licensees shall show that possible core blockage from debris will not invalidate the existing post-LOCA boric acid dilution analysis for the plant.	The PWR Owners Group has a project to develop the approach for boric acid precipitation analyses and evaluations, Project Number ACS-0264R1, Post LOCA Boric Acid Precipitation Analysis Methodology Program. FPL will continue to follow the project developments.
5.	The staff expects the Pressurized Water Reactor Owners Group (PWROG) to revise WCAP-16793-NP to address the staff's requests for additional information and the applicant's responses. A discussion of the potential for fuel rod swelling and burst to lead to core flow blockage shall be included in this revision.	This L&C refers to information to be included in a revision to WCAP 16793-NP. FPL will continue to follow developments out of the PWROG and evaluate new information as it becomes available.
6.	WCAP-16793 shall be revised to indicate that the licensing basis for Westinghouse two-loop PWRs is for the recirculation flow to be provided through the upper plenum injection (UPI) ports with the cold-leg flow secured.	St. Lucie Unit 1 is a Combustion Engineering plant and is not an upper plenum injection plant.
7	Individual UPI plants will need to analyze boric acid dilution/concentration in the presence of injected debris for a cold-leg break LOCA.	St. Lucie Unit 1 is a Combustion Engineering plant and is not an upper plenum injection plant.
8	WCAP-16793 states that the assumed cladding oxide thickness for input to LOCADM will be the peak local oxidation allowed by 10 CFR 50.46, or 17 percent of the cladding wall thickness. The WCAP states that a lower oxidation thickness can be used on a plant-specific basis if that value is justified. The staff does not agree with the flexibility in this approach. Licensees shall assume 17 percent oxidation in the LOCADM analysis.	The St. Lucie Unit 1 LOCADM calculation used the 17% cladding oxide thickness.
9	The staff accepts a cladding temperature limit of 800°F as the long-term cooling acceptance basis for GSI-191 considerations. Should a licensee calculate a temperature that exceeds this value, cladding strength data must be provided for oxidized or pre-hydrided cladding material that exceeds this temperature.	The St. Lucie Unit 1 LOCADM calculation used 800°F as the cladding temperature limit.
10	In the response to NRC staff requests for additional information, the PWR Owners Group indicated that if plant-specific refinements are made to the WCAP-16530-NP base model to reduce conservatisms, the LOCADM user shall demonstrate that the results still adequately bound chemical product generation. If a licensee uses plant-specific refinements to the WCAP-16530-NP base model that reduce the chemical source term considered in the downstream analysis, the licensee shall	The St. Lucie Unit 1 LOCADM calculation did not use plant-specific refinements for chemical product generation, therefore, no reduction in the chemical source term is present.

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	provide a technical justification that demonstrates that the refined chemical source term adequately bounds chemical product generation. This will provide the basis that the reactor vessel deposition calculations are also bounding.	
11	WCAP-16793-NP states that the most insulating material that could deposit from post-LOCA coolant impurities would be sodium aluminum silicate. WCAP-16793 recommends that a thermal conductivity of 0.11 BTU/hr-ft-°F be used for the sodium aluminum silicate scale and for bounding calculations when there is uncertainty in the type of scale that may form. If plant-specific calculations use a less conservative thermal conductivity value for scale (i.e., greater than 0.11 BTU/hr-ft-°F), the licensee shall provide a technical justification for the plant-specific thermal conductivity. This justification shall demonstrate why it is not possible to form sodium aluminum silicate or other scales with conductivities below the selected value.	The St. Lucie Unit 1 LOCADM calculation used the deposit thermal conductivity value of 0.11 BTU/hr-ft-°F. The Westinghouse LOCADM model listed a default value of 0.2 W/m-K, which is the metric equivalent of 0.11 BTU/hr-ft-°F.
12	WCAP-16793-NP indicates that initial oxide thickness and initial crud thickness could either be plant-specific estimates based on fuel examinations that are performed or default values in the LOCADM model. Consistent with Conditions and Limitations item number 8, the default value for oxide used for input to LOCADM will be the peak local oxidation allowed by 10 CFR 50.46, or 17 percent of the cladding wall thickness. The default value for crud thickness used for input to LOCADM is 127 microns, the thickest crud that has been measured at a modern PWR. Licensees using plant-specific values instead of the WCAP-16793-NP default values for oxide thickness and crud thickness shall justify the plant-specific values.	The St. Lucie Unit 1 LOCADM calculation used 17 percent of the cladding wall thickness for peak local oxidation allowed by 10 CFR 50.46, refer to Conditions and Limitations item number 8. The default value for the crud thickness used for input to the LOCADM calculation was 140 microns, which is a more conservative value than 127 microns.
13	As described in the Conditions and Limitations for WCAP-16530-NP (ADAMS ML073520891), the aluminum release rate equation used in WCAP-16530-NP provides a reasonable fit to the total aluminum release for the 30-day ICET tests but under-predicts the aluminum concentrations during the initial active corrosion portion of the test. To provide more appropriate levels of aluminum for the LOCADM analysis in the initial days following a LOCA, licensees shall apply a factor of two to the aluminum release as determined by the WCAP-16530-NP spreadsheet, although the total aluminum considered does not need to exceed the total predicted by the WCAP-16530-NP spreadsheet for 30 days. Alternately, licensees may choose to use a different method for determining the aluminum release, but in all cases licensees shall not use a method that under-predicts the aluminum concentrations measured during the initial 15 days of ICET 1.	The St. Lucie Unit 1 LOCADM calculation applied a factor of two to the aluminum release rate while maintaining the total aluminum release to that of the 30 day mission time,

Enclosure 3

(St. Lucie Unit 1 Supplemental Response)

NRC Safety Evaluation Report

Limitations and Conditions for

WCAP 16406-P Revision 1

L&C No.	NRC Limitations & Conditions (WCAP 16406-P Revision 1)	FPL (St. Lucie Unit 1) Response
1.	Where a TR WCAP-16406-P, Revision 1, section or appendix refers to examples, tests, or general technical data, a licensee should compare and verify that the information is applicable to its analysis.	General WCAP-16406-P examples and technical data were not used for site specific input. The wear equations developed in the WCAP-16406-P based on tests and general technical data were developed and benchmarked on equipment and with debris similar to that found at St. Lucie Unit 1. The wear equations were adjusted for the specific materials and debris concentration at St. Lucie Unit 1.
2.	A discussion of EOPs, AOPs, NOPs or other plant-reviewed alternate system line-ups should be included in the overall system and component evaluations as noted in the NRC staff's SE of NEI 04-07, Section 7.3 (Reference 13).	The downstream effects analysis for St. Lucie Unit 1 considered all procedural recirculation system line-ups that are used by the plant, including any alternate line-ups. Analysis of components in the alternate flowpaths was performed for the full recirculation mission time, like the primary flowpath components. The system evaluation discusses the procedures and alternate system line-ups.
3.	A licensee using TR WCAP-16406-P, Revision 1, will need to determine its own specific sump debris mixture and sump screen size in order to initiate the evaluation.	The downstream effects analysis uses a bounding site-specific sump debris mixture and the actual sump strainer hole size. Since site specific debris bypass test data were not available, the WCAP-16406-P methodology of strainer efficiency and retention size were utilized. The assumed maximum particulate size capable of passing the strainer was altered from the suggested WCAP-16406-P approach. Debris size distribution was determined based on experimental data (not site specific) and the St. Lucie Unit 1 specific debris types were used.
4.	TR WCAP-16406-P, Revision 1, Section 4.2, provides a general discussion of system and component mission times. It does not define specific times, but indicates that the defined term of operation is plant-specific. As stated in the NRC staff's SE of NEI 04-07, Section 7.3 (Reference 13), each licensee should define and provide adequate basis for the mission time(s) used in its downstream evaluation	Recirculation operation is analyzed for 30 days post-LOCA. The mission time of all components is 30 days unless the plant's recirculation procedures limit the time that specific components are used. The 30 day recirculation duration is based on the SE of NEI 04-07, and was reviewed and found to be consistent with the St. Lucie Unit 1 design and licensing basis.
5.	TR WCAP-16406-P, Revision 1, Section 5.8, assumes that the coolant which is not spilled flows into the reactor system and reaches the reactor vessel downcomer. This would be true for most PWR designs except for plants with UPI. Therefore, the methodology of Section 5.8 may not be applicable to plants with UPI and its use should be justified on a plant-specific basis.	St. Lucie Unit 1 utilizes lower plenum injection.
6.	TR WCAP-16406-P, Revision 1, Section 5.8, provides equations which a licensee might use to determine particulate concentration in the coolant as a function of time. Assumptions as to the initial particulate debris concentration are plant-specific and should be determined by the licensee. In addition, model assumptions for ECCS flow rate, the fraction of coolant spilled from the break and the partition of large heavy particles which will settle in the lower plenum and smaller lighter particles which will not settle should be determined and justified by the licensee.	The initial particulate debris concentration was determined for St. Lucie Unit 1 based on a plant-specific limiting debris loads and sump water volumes. Debris depletion in the calculations is based on plant specific flows, debris types and debris concentrations. The size of debris subject to settling in the lower plenum was determined on a plant-specific basis; the ECCS flows and spillage assumed are the most conservative for this purpose.
7.	TR WCAP-16406-P, Revision 1, Sections 5.8 and 5.9, assumes that debris settling is governed by force balance methods of TR Section 9.2.2 or Stokes Law. The effect of debris and dissolved materials on long-term cooling is being evaluated under TR WCAP-16793-NP	The site specific debris settling size is determined in downstream calculations which utilized force balance methods. The methodology uses empirical friction factors

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	(Reference 12). If the results of TR WCAP-16793-NP show that debris settling is not governed by force balance methods of TR Section 9.2.2 or Stokes Law, then the core settling term determined from TR WCAP-16793-NP should be used.	based on the debris shape. This methodology is benchmarked against the NRC-sponsored testing of paint chip settling reported in NUREG/CR-6916. The reactor vessel is evaluated in NRC Topic 3.n, Downstream Effects – Fuel and Vessel.
8.	TR WCAP-16406-P, Revision 1, Section 7.2, assumes a mission time of 720 hours for pump operation. Licensees should confirm that 720 hours bounds their mission time or provide a basis for the use of a shorter period of required operation.	Analysis was performed for a mission time of thirty days following initiation of LBLOCA event. No reduction in mission time is credited in this analysis. The use of a full thirty day mission time is consistent with NEI 04-07 and its NRC SER, and the UFSAR. Additionally, use of a 30 day mission time is consistent with the time periods anticipated in NUREG 0800, Section 9.2.5, Ultimate Heat Sink. Reasonable and prudent management and operator action is credited for any actions required beyond thirty days to ensure continued safe operation of needed ECCS and CSS pumps. The mission time of individual components was a full 30 days except where the plant's recirculation procedures limit the time that specific components are used.
9.	TR WCAP-16406-P, Revision 1, Section 7.2, addresses wear rate evaluation methods for pumps. Two types of wear are discussed: 1) free-flowing abrasive wear and 2) packing-type abrasive wear. Wear within close-tolerance, high-speed components is a complex analysis. The actual abrasive wear phenomena will likely not be either a classic free-flowing or packing wear case, but a combination of the two. Licensees should consider both in their evaluation of their components.	The downstream effects calculation considers the maximum of either free-flow or packing type abrasive wear until a wear ring clearance of 50 mils diametral is reached. Beyond that time, the packing is assumed expelled and free-flow wear (abrasive and erosive) is modeled.
10.	TR WCAP-16406-P, Revision 1, Section 7.2.1.1, addresses debris depletion coefficients. Depletion coefficients are plant-specific values determined from plant-specific calculations, analysis, or bypass testing. Licensees should consider both hot-leg and cold-leg break scenarios to determine the worst case conditions for use in their plant specific determination of debris depletion coefficient.	Debris depletion coefficients in the calculations are based on plant specific flows, debris types and debris concentrations and the strainer design. The ECCS flows and spillage assumed are the most conservative for this purpose of either cold or hot-leg break scenarios. The calculated plant-specific depletion coefficient is only utilized where it is lower than (i.e., more conservative) the WCAP-16406-P lower-limit values.
11.	TR WCAP-16406-P, Revision 1, Section 7.3.2.3, recognizes that material hardness has an effect on erosive wear. TR WCAP-16406-P, Revision 1, suggests that "For elastomers, the wear rate is at least one order of magnitude less than steel. Therefore, for soft-seated valves, divide the estimated wear rate of steel from above equations by 10 per Appendix F." The NRC staff agrees that the wear rates of elastomers are significantly less than for steels. However, the wear coefficient should be determined by use of a suitable reference, not by dividing the steel rate by a factor of 10.	Wear of elastomeric materials, reduced by a factor of 10, is not applicable to any of the downstream effects wear calculations.
12.	TR WCAP-16406-P, Revision 1, Section 8.1.1.2, "Evaluation of ECCS Pumps for Operation with Debris-Laden Water from the Containment Sump," states that "Sufficient time is available to isolate the leakage from the failed pump seal and start operation of an alternate ECCS or CSS train." Also, Section 8.1.3, "Mechanical Shaft Seal Assembly," states: " Should the cooling water to the seal cooler be lost, the additional risk for seal failure is small for the required mission time for these pumps." These statements refer only to assessing seal leakage in the context of pump operability and 10 CFR Part 100 concerns. A licensee should evaluate leakage in the context of room habitability and room equipment operation and environmental qualification, if the calculated leakage	Non-mechanistic failure of an ECCS or CSS pump seal is considered as a single-failure in the plant design basis and is acceptable. The WCAP-16406-P attempts to justify failure of the seals due to recirculation debris, which is a potential common-mode failure. The pump seals at St. Lucie Unit 1 have been evaluated as not susceptible to failure by debris-laden water because they recirculate seal cavity fluid. Therefore the only potential failure that must be considered is an assumed single failure, which again is part of the existing design basis of the

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	is outside that which has been previously assumed.	plant (bounded by a moderate energy line break in the pump room). This is evaluated in NRC Topic 3.m, Downstream effects – Components and Systems.
13.	TR WCAP-16406-P, Revision 1, Section 8.1.3, discusses cyclone separator operation. TR WCAP-16406-P, Revision 1, generically concludes that cyclone separators are not desirable during post-LOCA operation of HHSI pumps. The NRC staff does not agree with this generic statement. If a licensee pump contains a cyclone separator, it should be evaluated within the context of both normal and accident operation. The evaluation of cyclone separators is plant-specific and depends on cyclone separator design and the piping arrangement for a pump's seal injection system.	The HPSI pump seal configuration at St. Lucie Unit 1 was modified to utilize recirculated seal cavity fluid in the seal, which included removal of the cyclone separators. The resulting seal configuration is consistent with that already utilized on the LPSI and CSS pumps.
14.	TR WCAP-16406-P, Revision 1, Section 8.1.4, refers to pump vibration evaluations. The effect of stop/start pump operation is addressed only in the context of clean water operation, as noted in Section 8.1.4.5 of TR WCAP-16406-P, Revision 1. If an ECCS or CSS pump is operated for a period of time and builds up a debris "packing" in the tight clearances, stops and starts again, the wear rates of those areas may be different due to additional packing or imbedding of material on those wear surfaces. Licensees who use stop/start operation as part of their overall ECCS or CSS operational plan should address this situation in their evaluation.	The pump wear analysis assumes 30 days of continuous wear. St. Lucie Unit 1 procedure does not direct to stop then start the ECCS/CSS pumps during recirculation. In the event the pumps must be stopped and restarted, the Archard wear model assumed the highest friction factors and eccentricity postulated by the WCAP-16406-P. Therefore, any "additional packing" that could be caused by stopping and starting the pumps is bounded by the Archard model used.
15.	TR WCAP-16406-P, Revision 1, Section 8.1.4, states: "should the multistage ECCS pumps be operated at flow rates below 40% of BEP during the containment recirculation, one or more of the pumps should be secured to bring the flow rate of the remaining pump(s) above this flow rate." The NRC staff does not agree with this statement. System line-ups and pump operation and operating point assessment are the responsibility of the licensee. Licensees must ensure that their ECCS pumps are capable of performing their intended function and the NRC has no requirements as to their operating point during the recirculation phase of a LOCA.	The plant's procedures were not changed to reflect the WCAP-16406-P concerns. The St. Lucie Unit 1 multistage pumps performed adequately with respect to pump design and plant design basis before GSI-191 concerns. The pump assessment concludes that the HPSI pumps continue to be capable of performing their intended design basis functions based on the pump's hydraulic characteristics after 30 days of wearing.
16.	TR WCAP-16406-P, Revision 1, Section 8.1.5, makes a generic statement that all SI pumps have wear rings that are good "as new" based solely upon "very little service beyond inservice testing." A stronger basis is needed to validate this assumption, if used (e.g., maintenance, test and operational history and/or other supporting data).	The pump wear analysis assumed a starting wear ring clearance as the average of the vendor recommended gap range. The combination of low run time and very clean fluids would justify an assumption that the wear rings are "as good as new" and thus closer to the low end of the recommended ring clearance, but the wear calculation conservatively assumes that the wear rings are mid-way between the lower and the upper ring clearance recommended by the pump manufacturers.
17.	TR WCAP-16406-P, Revision 1, Section 8.3, identifies criteria for consideration of tube plugging. Licensees should confirm that the fluid velocity going through the heat exchanger is greater than the particle settling velocity and evaluate heat exchanger plugging if the fluid velocity is less than the settling velocity.	The minimum heat exchanger tube velocity was calculated and compared to the bounding particle settling velocity. No heat exchangers were found to be susceptible to debris settling within the tubes.
18.	TR WCAP-16406-P, Revision 1, Section 8.6, refers to evaluation of instrumentation tubing and system piping. Plugging evaluations of instrument lines may be based on system flow and material settling velocities, but they must consider local velocities and low-flow areas due to specific plant configuration.	The evaluation of instrumentation tubing was based primarily on the instrument line's specific configuration, and then upon the local flow velocity for instrument lines oriented below the horizontal datum. Plant-specific layout and actual local flow velocities were used in all cases.
19.	TR WCAP-16406-P, Revision 1, Sections 8.6.7, 8.6.8, 8.6.9, and	The St. Lucie Unit 1 RVLIS design was

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	8.6.10 describe, in general terms, the Westinghouse, CE, and B&W RVLIS. TR WCAP-16406-P, Revision 1, recommends that licensees evaluate their specific configuration to confirm that a debris loading due to settlement in the reactor vessel does not effect the operation of its RVLIS. The evaluation of specific RVLIS design and operation is outside the scope of this SE and should be performed in the context of a licensees reactor fuel and vessel evaluations.	compared to the generic designs reviewed and deemed acceptable by the WCAP-16406-P. St. Lucie Unit 1 utilizes a Heated Junction Thermocouple System consisting of eight pairs of heated/unheated thermocouples All eight pairs of thermocouples are located above the top of the fuel alignment plate. Since the probes are not in the lower plenum where debris could potentially settle, debris settling will not affect the operation of RVLIS.
20.	TR WCAP-16406-P, Revision 1, Section 8.7, refers to evaluation of system piping. Plugging evaluations of system piping should be based on system flow and material settling velocities. Licensees should consider the effects of local velocities and low-flow areas due to specific plant configuration. A piping wear evaluation using the free-flowing wear model outlined in Section 7 should be performed for piping systems. The evaluation should consider localized high-velocity and high-turbulence areas. A piping vibration assessment should be performed if areas of plugging or high localized wear are identified.	ECCS and CSS system piping was checked for potential plugging due to debris settling. At each control valve in the systems, the minimum expected system flow rates in each line were used to minimize the flow velocity and compared to the bounding settling velocity. The evaluation at control valve locations considered the local flow velocities of all the various line sizes and flow rates in the St. Lucie Unit 1 ECCS and CSS. All lines were found acceptable with respect to plugging. Regarding wear, the material wear of the bounding ECCS/CSS orifice, which sees much higher wear than system piping, was compared to the pipe wall thicknesses in the ECCS and CSS. The material wear was found to be insignificant compared to the pipe wall thickness. Therefore, all pipes were determined to have sufficient wear margin, and the erosion was considered so slight as to not require vibration analysis.
21.	TR WCAP-16406-P, Revision 1, Section 9, addresses reactor internal and fuel blockage evaluations. This SE summarizes seven issues regarding the evaluation of reactor internal and fuel. The PWROG indicated that the methodology presented in TR WCAP-16793-NP (Reference 15) will address the seven issues. Licensees should refer to TR WCAP-16793-NP and the NRC staff's SE of the TR WCAP-16793-NP, in performing their reactor internal and fuel blockage evaluations. The NRC staff has reached no conclusions regarding the information presented in TR WCAP-16406-P, Section 9.	Reactor internal and fuel blockage was evaluated utilizing WCAP-16793-NP and is discussed in NRC Topic 3.n, Downstream Effects – Fuel and Vessel.
22.	TR WCAP-16406-P, Revision 1, Table 4.2-1, defines a plant Category based on its Low-Head / Pressure Safety Injection to RCS Hot-Leg Capability. Figure 10.4-2 implies that Category 2 and 4 plants can justify LHSI for hot-leg recirculation. However, these categories of plants only have one hot-leg injection pathway. Category 2 and Category 4 plant licensees should confirm that taking credit for the single hot-leg injection pathway for their plant is consistent with their current hot-leg recirculation licensing basis.	This WCAP-16406-P guidance was not utilized. St. Lucie Unit 1 has single-failure tolerant hot-leg recirculation capability as part of the existing design and licensing basis. No credit was taken for a single hot-leg injection pathway as suggested by the WCAP-16406-P.
23.	TR WCAP-16406-P, Revision 1, Appendix F, discusses component wear models. Prior to using the free-flowing abrasive model for pump wear, the licensee should show that the benchmarked data is similar to or bounds its plant conditions.	The debris and wear models were conservatively applied to ensure that they conservatively predict expected wear. Actual pump dimensions, characteristics, and materials, and the actual plant debris concentration was utilized in predicting pump wear.
24.	TR WCAP-16406-P, Revision 1, Appendix H, references American Petroleum Institute (API) Standard 610, Annex 1 eighth edition. This standard is for newly manufactured pumps. Licensees should verify that their pumps are "as good as new" prior to using the analysis methods of API-610. This validation may be in the form of maintenance records, maintenance history, or testing that	The pump calculations all assume that the starting point for the wear rings is the midpoint of the manufacturers recommended ring clearance (see #16, above). Since the pump rings are in new condition, the analysis methods of API-610 are applicable.

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	documents that the as-found condition of their pumps.	
25.	TR WCAP-16406-P, Revision 1, Appendix I, provides guidelines for the treatment, categorization and amount of DBA Qualified, DBA Acceptable, Indeterminate, DBA Unqualified, and DBA Unacceptable coatings to be used in a licensee's downstream sump debris evaluation. A technical review of coatings generated during a DBA is not within the scope of this SE. For guidance regarding this subject see the NRC staff's SE of NEI-04-07 (Reference 13) Section 3.4 "Debris Generation."	This SER limitation is simply a statement of the limit of the NRC's review; no action is required. For reference, however, the amount of specific types of coatings used in the downstream effects analysis was determined on a plant-specific basis considering the types of coatings actually in use in the St. Lucie Unit 1 containment.
26.	TR WCAP-16406-P, Revision 1, Appendix J, derives an approach to determining a generic characteristic size of deformable material that will pass through a strainer hole. This approach is only applicable to screens and is not applicable to determining material that will pass through other close tolerance equipment.	This approach that is "only applicable to screens" was only applied to the sump screens (strainers in the case of St. Lucie Unit 1). The characteristic size of debris that can pass through the sump strainer was calculated and then compared to the smallest passages of downstream components. The component was deemed acceptable where the smallest passage is larger than this characteristic size, in other words the deformation of the debris was not credited to allow it to pass the downstream close tolerances.
27.	TR WCAP-16406-P, Revision 1, Appendix O, Section 2.2, states that the wear coefficient, K, in the Archard Model is determined from testing. The wear coefficient (K) is more uncertain than the load centering approach and K may vary widely. Therefore, licensees should provide a clear basis, in their evaluation, for their selection of a wear coefficient.	The Archard model wear coefficient utilized in the St. Lucie Unit 1 HPSI pump wear analysis is the "conservative upper bound" suggested by the WCAP-16406-P and 5 times larger than the value actually used in the WCAP-16406-P example. Its use resulted in calculated wear greater than the amount seen in the Davis-Besse testing. The materials, debris types and concentrations are comparable. Therefore, the K-value used appears to be the best conservative information available on ECCS pump wear when exposed to insulation and coating debris.
28.	TR WCAP-16406-P, Revision 1, Appendix P, provides a method to estimate a packing load for use in Archard's wear model. The method presented was benchmarked for a single situation. Licensees are expected to provide a discussion as to the similarity and applicability to their conditions. The licensee should incorporate its own specific design parameters when using this method.	The methodology of Appendix P was not used in the determination of packing loads. The St. Lucie Unit 1 calculation utilized the methodology discussed in Appendix O of WCAP-16406-P (centering load) for defining loads to be used in the packing wear model, and specific design parameters were applied to that methodology.
29.	TR WCAP-16406-P, Revision 1, Appendix Q, discusses bounding debris concentrations. Debris concentrations are plant-specific. If 9.02E-5 (mils/hr)/10 PPM is to be used as the free flowing abrasive wear constant, the licensee should show how it is bounding or representative of its plant.	9.02E-5 (mils/hr)/10 PPM was not used as the free flowing abrasive wear constant at the plant. The wear rate was calculated for each pump's actual material hardness and actual debris concentrations, including application of the bounding debris penalty as required.
30.	TR WCAP-16406-P, Revision 1, Appendix R, evaluates a Pacific 11-Stage 2.5" RLIJ pump. The analysis was performed by the PWROG using specific inputs. ECCS pumps with running clearance designs and dimensions significantly different than those covered by the analysis should be subjected to pump-specific analysis to determine the support stiffness based on asymmetric wear. If licensees use the aforementioned example, a similarity evaluation should be performed showing how the example is similar to or bounds their situations.	Acceptance criteria and stiffness values from Appendix R were not used. All pump calculations utilize plant specific information and data to perform wear calculation and shaft stiffness evaluations. Example data from the WCAP-16406-P is not used in any calculation. The designs and dimensions of the St. Lucie Unit 1 HPSI pumps were reviewed and found to not be significantly different than those covered by the WCAP-16406-P analysis. Multi-stage pumps were evaluated by finding the shaft stiffness at a symmetric increase in wear ring clearance equal to 2X as the as-new

L&C No.	NRC Limitations & Conditions (WCAP 16406-P Revision 1)	FPL (St. Lucie Unit 1) Response
		clearance. The stiffness of the pumps after debris induced wear was then calculated. The stiffness of the pumps after recirculation asymmetric wear was compared to the allowed stiffness equivalent to a uniform 2X initial clearance to judge the acceptability of the pump.
31.	Licensees should compare the design and operating characteristics of the Pacific 2.5" RLIJ 11 to their specific pumps prior to using the results of Appendix S in their component analyses.	The criteria and analysis specific for Pacific 2.5" RLIJ 11 as shown in Appendix S were not used. As stated in response 30 above, all pump calculations utilize plant specific information and data to perform wear calculation and shaft stiffness evaluations. Example data from the WCAP-16406-P is not used in any calculation. Multi-stage pumps were evaluated by finding the shaft stiffness at a symmetric increase in wear ring clearance equal to 2X as the as-new clearance. The stiffness of the pumps after debris induced wear was then calculated. The stiffness of the pumps after recirculation asymmetric wear was compared to the allowed stiffness equivalent to a uniform 2X initial clearance to judge the acceptability of the pump

ATTACHMENT 3

St. Lucie Unit 2
GL 2004-02
Summary Level Description of Approach

SUMMARY DESCRIPTION OF APPROACH

The following key aspects summarize the FPL approach to GL 2004-02 at St Lucie Unit 2.

Design Modifications:

- The new sump strainers ensure adequate NPSH during recirculation with new margins based on revised debris transport calculations and integrated chemical effects testing in a large flume.
- The removal of cyclone separators and installation of new high pressure safety injection (HPSI) pump seals ensure long term operation of the HPSI pumps.
- The removal of cyclone separators and installation of new containment spray (CS) pump seals ensure long term operation of the CS pumps.
- The minimum refueling water tank (RWT) water level is administratively controlled at 32.5 feet to be consistent with the proposed license amendment request to revise the plant technical specifications.

Process Changes:

- The in-containment paint specifications contained in the SPEC-C-034 update help ensure that strainer design basis paint loads will not be exceeded.
- The in-containment insulation specifications contained in SPEC-C-130 help ensure that strainer design basis insulation loads will not be exceeded.

Supporting Analyses:

- The down stream components and systems evaluations demonstrate long term post-LOCA operation of equipment, including demonstration that emergency core cooling system (ECCS)/CS recirculation pumps can operate for long term post-LOCA.
- The down stream fuel and in-vessel evaluations demonstrate that long term post-LOCA core cooling will be maintained with acceptably low fuel temperatures.
- The coating adhesion tests confirm that the current inspection methods are adequate to control quantity of degraded qualified coatings to bound assumptions in debris calculations.
- A NPSH versus temperature analysis demonstrates that adequate pump NPSH and core cooling is provided throughout the post-LOCA accident duration.

Conservatisms and Margin:

FPL made significant improvements in the ECCS system to address the issues identified in Generic Letter 2004-02. FPL included a number of conservatisms in the plant modifications and analyses to ensure sufficient margin is available. These margins are summarized below:

- The surface area for the recirculation sumps was increased from approximately 571 ft^2 to over 5600 ft^2. The replacement screens were manufactured by Performance Contracting, Inc. and have a nominal hole size of 0.0625 inch compared to the previous screens' openings of 0.090 inch mesh size. Debris interceptors are in place at the entrance to the sump trench which will further reduce the amount of debris that reaches the sump. These debris interceptors (trash racks) are distributed around 270 degrees of containment and are placed at each of 23 entrances to the containment trench system. This effectively prevents large debris from entering the sump trench from inside the bio-wall or approaching the strainers.

- Latent or miscellaneous debris was specifically accounted for in the design and testing of the strainer. Additionally, 100 square feet of sacrificial area was allotted for additional conservatism.

- In the debris generation analysis, the zone of influence (ZOI) used for Nukon Insulation is 17.0D. WCAP-16710-P testing confirmed that the zone of influence could be reduced further to 5D. As such, the strainer system was qualified utilizing a quantity of fiber that is significantly greater than is expected to be generated.

- A uniform factor of 1.1 has been applied to the ZOI radius to ensure the calculation was conservative.

- In the transport analysis, 100% of the unqualified coatings in the active pool were assumed to fail as particulates and transport to the screen. EPRI and industry testing indicates that some unqualified coatings do not fail and some coatings fail as chips and may not transport to the sump.

- In determining the velocity profile for testing, the CFD analysis calculated the average velocities by "double weighting" the fastest velocity at the increment under consideration. Weighting the average by twice the fastest velocity incorporates conservatism into the calculation.

- The amount of chemicals calculated to form in 30 days were added to the test flume, and as such a 30 day chemical effect was applied in the early stages of the event. This is extremely conservative as corrosion and formation of chemical precipitants is a time base phenomena and significant additional NPSH margin is available as the containment pool temperature decreases over time.

The combination of design modifications, process changes, and supporting analyses provides reasonable assurance that long-term core cooling is maintained. This submittal demonstrates compliance with the applicable GL 2004-02 regulatory criteria, and FPL is requesting a license amendment that will raise the plant Technical Specification minimum RWT water level to 32.5 feet.

ATTACHMENT 4

St. Lucie Unit 2
Updated Supplemental Response GL 2004-02

UPDATED SUPPLEMENTAL RESPONSE TO GL 2004-02

This final supplemental response to NRC Generic Letter (GL) 2004-02 updates information previously submitted in FPL letter L-2008-030, Supplemental Response to NRC Generic Letter 2004-02, "Potential Impact of Debris Blockage on Emergency Recirculation During Design Basis Accidents at Pressurized-Water Reactors," dated February 27, 2008. Changes to the February supplemental response and new information are indicated by revision bars. Where the text from the February supplemental response was relocated to meet the format requirements of the NRC staff's Revised Guidance document, but unchanged, the text is shown as boxed text.

Additional information to support the staff's evaluation of St. Lucie Unit 2 compliance with the regulatory requirements of GL 2004-02 was requested by the NRC in a Request for Additional Information (RAI) dated February 8, 2006 (NRC Letter to FPL (J. A. Stall), St. Lucie Plant, Units 1 and 2, Request for Additional Information RE: Response to Generic Letter 2004-02, "Potential Impact of Debris Blockage on Emergency Sump Recirculation at Pressurized-Water Reactors" (TAC Nos. MC4710 and MC4711), dated February 8, 2006). Each RAI question is addressed in this response. The RAI question (and specific RAI response) is identified by the RAI question number in the following format: [RAI ##], where ## is the RAI question number.

Topic 1: Overall Compliance

FPL Response

The initial St. Lucie Unit 2 response to GL 2004-02, that was submitted to the NRC on September 1, 2005 (September 1 response), was based on information that was available at that time. The St. Lucie Unit 2 Supplemental Response to Generic Letter 2004-02 was submitted to the NRC on February 27, 2008. That response reported on corrective actions taken up until that date. Additional testing and analysis have since been completed. Test results and conclusions are discussed in this response under Topics 3.m, Downstream Effects – Components and Systems, 3.n, Downstream Effects – Fuel and Vessel, and 3.o, Chemical Effects.

As noted in Topic 3.g Net Positive Suction Head Available (NPSH), sump level calculations were revised to accommodate potential areas for water holdup based on lessons learned from the NRC audit of the Waterford sump program. Based on these results, FPL determined that an amendment to the Technical Specifications (TS), raising the minimum Refueling Water Tank (RWT) level, is warranted to provide additional post accident sump level margin for St. Lucie Unit 2. Hence, an amendment to the St. Lucie Unit 2 Technical Specifications requesting the necessary increase in minimum RWT level is being submitted under separate cover. Until this amendment is approved and implemented on-site, existing administrative controls for maintaining a higher water level in the RWT will remain in effect. This is further discussed in Topic 3.p Licensing Basis.

This final report on St. Lucie Unit 2 demonstrates compliance with regulatory requirements of GL 2004-02, pending the approval of the above mentioned Technical Specification proposed amendment to increase the minimum water level of the RWT. Table 1-1 provides a St. Lucie Unit 2 regulatory compliance matrix.

Table 1-1: GL 2004-02 Regulatory Compliance

Regulatory Statute	Applicable Requirement	Basis For Compliance with GL 2004-02
10 CFR 50.46 (b)(5)	Long-term cooling. After any calculated successful initial operation of the ECCS, the calculated core temperature shall be maintained at an acceptably low value and decay heat shall be removed for the extended period of time required by the long-lived radioactivity remaining in the core.	• New sump strainers ensure adequate NPSH during recirculation with new margins based on revised debris transport calculations, and integrated chemical effects testing in a large flume • Removal of cyclone separators and installation of new HPSI pump seals ensure long term operation • Removal of cyclone separators and installation of new CSS pump seals ensure long term operation • Down stream components and systems evaluations demonstrate long term post-LOCA operation of equipment, including demonstration that ECCS/CSS recirculation pumps can operate for long term post-LOCA • Down stream fuel and in-vessel evaluations demonstrate that long term post-LOCA core cooling will be maintained with acceptably low fuel temperatures. • In-containment paint specifications contained in SPEC-C-034 update help ensure that strainer design basis paint loads will not be exceeded • In-containment insulation specifications contained in SPEC-C-130 help ensure that strainer design basis insulation loads will not be exceeded • Plant walkdowns, revised and new programmatic plant procedures and controls, and revised calculations provide additional assurance of required post-LOCA sump water levels for recirculation. • Coating adhesion tests confirm that current inspection methods are adequate to control quantity of degraded qualified coatings to bound assumptions in debris calculations • A NPSH versus temperature analysis is provided throughout the post-LOCA accident duration that demonstrates adequate pump NPSH and core cooling • Minimum RWT water level is administratively controlled at 32.5 feet consistent with proposed LAR to revise Technical Specification.

Regulatory Statute	Applicable Requirement	Basis For Compliance with GL 2004-02
10 CFR 50, Appendix A, GDC 35	Criterion 35--Emergency core cooling. A system to provide abundant emergency core cooling shall be provided. The system safety function shall be to transfer heat from the reactor core following any loss of reactor coolant at a rate such that (1) fuel and clad damage that could interfere with continued effective core cooling is prevented and (2) clad metal-water reaction is limited to negligible amounts.	The assurance of long-term cooling capability during recirculation, with acceptable downstream in-vessel or fuel impacts, ensures that the design basis emergency core cooling capabilities are maintained.
10 CFR 50, Appendix A, GDC 38	Criterion 38--Containment heat removal. A system to remove heat from the reactor containment shall be provided. The system safety function shall be to reduce rapidly, consistent with the functioning of other associated systems, the containment pressure and temperature following any loss-of-coolant accident and maintain them at acceptably low levels.	The assurance of adequate long-term cooling capability during recirculation for the CSS pumps ensures that the design basis containment heat removal capabilities are maintained.
10 CFR 50, Appendix A, GDC 41	Criterion 41--Containment atmosphere cleanup. Systems to control fission products, hydrogen, oxygen, and other substances which may be released into the reactor containment shall be provided as necessary to reduce, consistent with the functioning of other associated systems, the concentration and quality of fission products released to the environment following postulated accidents, and to control the concentration of hydrogen or oxygen and other substances in the containment atmosphere following postulated accidents to assure that containment integrity is maintained.	Assurance of long-term cooling capability during recirculation ensures that containment spray capability is maintained which, in turn, ensures that containment atmosphere cleanup capability is preserved.

Topic 2: General Description of and Schedule for Corrective Actions

FPL Response

The corrective actions identified for St. Lucie Unit 2 have been completed. These are summarized below, along with other work related to evaluations and the establishment of programmatic controls.

[RAI 39] As discussed in Topic 3.j, Screen Modification Package, the original containment recirculation strainer system has been removed, and the new strainer system, with approximately 5600 ft^2 of strainer area, was installed in the containment recirculation sump at St. Lucie Unit 2 during the fall 2007 outage. As discussed in Topic 3.f, Head Loss and Vortexing, head loss results are based on hydraulic calculation and temperature compensation utilizing the results of the St. Lucie Unit 2 integrated chemical effects tests in a large flume. This test methodology results in a chemical and debris laden head loss of approximately 1.946 ft. calculated at 210°F for the strainer system. As noted in Topic 1 and further discussed in Topic 3.p, Licensing Basis, St. Lucie Unit 2 has filed an accompanying amendment request for a higher minimum level in the Refueling Water Tank (RWT). This additional water inventory increases the margin of ECCS/CSS pumps by 0.83 ft, and has been included in calculations in this submittal. Topic 3.j, Screen Modification Package, provides greater detail on the sump screen modification, and Topic 3.k, Sump Structural Analysis, provides the structural evaluation.

As discussed in Topic 3.m, Downstream Effects – Components and Systems, the HPSI pumps have been modified by removing the cyclone separator and associated piping, and replacing the mechanical seals with a new seal design that uses recirculated seal cavity fluid for flushing and cooling of the seal faces. Hence, HPSI pump seal injection no longer relies on process fluid via a cyclone separator, thus the potential for debris clogging of the cyclone separator and related equipment has been eliminated as a GSI-191 downstream effects concern for the HPSI pumps. Further, the original mechanical seals on the CSS pumps also relied on cyclone separators for removal of fluid particulate in seal injection water. The CSS pumps have been modified by removing the cyclone separator and associated piping, and replacing the mechanical seals with a new seal design that uses recirculated seal cavity fluid. Hence, CSS pump seal injection no longer relies on process fluid via a cyclone separator, and the potential for debris clogging of the cyclone separator and related equipment has been eliminated as a GSI-191 downstream effects concern for the CSS pumps.

The downstream effects assessments of the fuel and vessel have been completed. The St. Lucie Unit 1 calculation using plant-specific parameters and WCAP-16793-NP methodology to confirm that chemical plate-out on the fuel is acceptable has been completed. This assessment was completed in accordance with the schedule provided to the NRC Staff in letter L-2007-155. This is discussed further in the response to NRC Topic 3.n, Downstream Effects – Fuel and Vessel.

The downstream effects assessment has been completed, including a revision of pump analysis to incorporate the methodology of WCAP-16406-P, Revision 1, "Evaluation of Downstream Sump Debris Effects in Support of GSI-191" (WCAP-16406-P). This assessment was completed in accordance with the schedule provided to the NRC Staff in letter L-2007-155. A summary of the assessment results is provided in the response to NRC Topic 3.m, Downstream Effects – Components and Systems.

As described in Topic 3.I, Upstream Effects, plant walkdowns have been completed to evaluate the potential for chokepoints in the flow path from potential break locations to the containment recirculation sump, and it was concluded that there were no chokepoints that would inhibit flow.

Topic 3.d, Latent Debris, describes plant walkdowns that have been completed to determine the amount of latent debris and miscellaneous debris present in containment under the current house keeping procedures. These walkdowns determined the amount of latent and miscellaneous debris that was present under current house keeping procedures. Also, as discussed in Topic 3.c, Foreign Materials Control Program, additional controls are in-place to further assure proper containment walkdown prior to restart, and revised programmatic controls have been put in place including specifications for insulation and coatings inside of containment.

Calculations that have been revised for post-LOCA sump levels based on observations from the Waterford audit and revised NPSH calculations were also performed with the new sump levels using the increased minimum RWT water level, and sump screen strainer pressure loss calculations that include the results of integrated chemical effects tests in a large flume. These calculations also include a hypothetical case where it is assumed that a LPSI pump fails to trip at Recirculation Actuation Signal (RAS).

This final submittal fulfills final testing commitments, incorporates test results in the strainer head loss calculations and worst case post-LOCA NPSH calculations for the ECCS/CSS pumps, and completes all downstream ex-vessel and in-vessel evaluations. This submittal demonstrates compliance with GL 2004-02 for Saint Lucie Unit 2.

Topic 3.a: Break Selection

FPL Response

In agreement with the staff's SE of NEI 04-07, the objective of the break selection process was to identify the break size and location which results in debris generation that will maximize the debris transport to the containment sump during recirculation. Breaks were evaluated based on the methodology in Nuclear Energy Institute (NEI) guidance document NEI 04-07 as modified by the staff's SE of NEI 04-07.

[RAI 33] The following specific break location criteria were considered:

- Breaks in the reactor coolant system with the largest amount of potential debris within the postulated ZOI,
- Large breaks with two or more different types of debris,
- Breaks in areas with the most direct path to the sump,
- Medium and large breaks with the largest potential particulate debris to insulation ratio by weight and,
- Breaks that generate an amount of fibrous debris that could form a uniform "thin bed."

[RAI 33] Reactor Coolant System (RCS) piping and attached energized piping was evaluated. Smaller piping has a much smaller ZOI than the RCS piping and will affect a much smaller quantity of insulation. The discrete approach described in Section 3.3.5.2 of the SER (Reference 7.1.3) was applied for these smaller lines, and the smaller lines were clearly bounded by the RCS line breaks inside the bioshield.

The staff's SE of NEI 04-07 notes that the concept of equal increments is only a reminder to be systematic and thorough. As stated in the staff's SE of NEI 04-07, the key difference between many breaks (especially large breaks) will not be the exact location along the pipe, but rather the envelope of containment material targets that is affected. Insulated piping spreadsheets, piping isometric drawings, and general arrangement drawings were used to systematically determine worse case pipe break locations using node points on the piping. Break locations were selected in 5-foot increments along the applicable RCS piping to determine the maximum worst case debris mix. This systematic technique was the basis for determining the worst case debris loads for postulated break locations based on pipe size and target debris zones of influence in the selected piping locations.

[RAI 34] Feedwater and main steam piping were not considered for potential break locations because ECCS in recirculation mode is not required for Main Steam or Feedwater line breaks. Small-bore piping breaks (less than 2-inch diameter) were not evaluated because they are not bounding.

The largest energized lines in containment that require evaluation are; the hot leg (42-inch ID), crossover leg (30-inch ID), cold leg (30-inch ID), pressurizer surge line (12-inch nominal), shutdown cooling line (12-inch nominal) and safety injection line (12-inch nominal). The other piping lines have a smaller diameter (10-inch maximum), which will produce a much smaller quantity of debris and are therefore not considered. Inside the bioshield, breaks in the hot legs, the cold legs, crossover legs and pressurizer surge line were considered.

Outside the bioshield, breaks were considered in the safety injection lines. The safety injection lines are of smaller diameter than the RCS piping, and are located in the same general area inside the bioshield. Therefore, inside the bioshield, a break in these lines would be bounded by the reactor coolant loops, and thus need not be analyzed. However, each safety injection line travels outside the bioshield before the second isolation valve. (These lines each have a check valve located inside the bioshield that will isolate the RCS from the upstream portion of the line outside the bioshield.) The safety injection lines are the only RCS-connected larger lines that travel outside the bioshield before the second isolation valve, and, therefore, were selected in order to include a break outside the bioshield.

The two steam generator (SG) loops are nearly identical, except that loop "B" also includes the pressurizer and associated piping. For this reason, only loop "B" was modeled for insulation debris purposes. Any break in loop "B" will have an equal or greater quantity of insulation due to the addition of the pressurizer and associated piping.

A hot leg or cold leg line break at the reactor pressure vessel (RPV) was also considered. The RPV is covered with Transco reflective metallic insulation (RMI) on the vessel, and Nukon insulation on the top head. This break would affect the reactor insulation and the insulation on the RCS lines adjacent to the break up to the penetrations. However, this debris would fall to the bottom of the reactor vessel cavity, and would have an indirect path to the strainer modules. In addition, the amount of debris would be bounded by a hot or cold line break elsewhere on the line. Therefore, a hot leg or cold leg break at the RPV was not analyzed.

The postulated break locations were as follows:

S1 Loop "B" hot leg at the base of the steam generator (42-inch ID)
S2 Loop "B" crossover leg 2B1 at the connection to the RCP (30-inch ID)
S3 Safety Injection line SI-150 outside the missile barrier (12-inch nominal line)

After performing several iterations, the S1 break was found to generate the greatest quantity of debris and, therefore, was selected for the strainer design basis.

Topic 3.b: Debris Generation/Zone of Influence (ZOI) (excluding coatings)

FPL Response
The debris generation calculations used the methodologies of Regulatory Guide 1.82, Rev. 3, NEI 04-07 and the staff's SE of NEI 04-07. ZOIs for insulation systems used at St. Lucie Unit 2 were obtained from Table 3-2 of the staff's SE of NEI 04-07.
The debris generation calculations have been updated and make use of three assumptions related to non-coating debris generation.

Assumption 1
Supporting members fabricated from steel shapes (angles, plates) are installed to provide additional support for the mirror insulation on equipment such as reactor coolant pumps, Steam Generators and Pressurizer. It is assumed that, as a result of the postulated pipe break, these supporting members will be dislodged from the equipment, and may be bent and deformed, but will not become part of the debris that may be transported to the sump.

Assumption 2
In the September 1 response, it was noted that an analytical process was used that conservatively overstated the quantity of debris from insulation by 5-15%. This process is no longer used. Instead, a uniform ZOI factor of 1.1 for insulation debris has been used to account

for minor variances in the insulation analysis coordinates used for the systematic break selection process, small insulated drain lines, etc. This revision to the methodology is appropriate for accommodating minor deviations and is considered to be conservative.

Assumption 3

Small drain and tap lines located throughout containment are not modeled in the debris calculation. These small lines are typically no more than two or three feet in length. In order to account for this small volume of fiber insulation, 5 ft^3 has been added to the fiber totals for the S1 and S2 breaks. No adjustment was made for the S3 break debris generation for small lines.

The insulation ZOIs and the quantities of debris are provided in Table 3.b-1 below.

Table 3.b-1: Destruction ZOI and Limiting Break Comparison

Debris Type	Destruction ZOI	Break S1(1)	Break S2(1)	Break S3(1)
Transco RMI	2.0 D	2475.72 ft^2	0.0 ft^2	0.0 ft^2
Mirror RMI	28.6 D	3591 ft^2	3591 ft^2	0.0 ft^2
SS Insulation Jacketing	17.0 D	8487 ft^2	6691 ft^2	1008 ft^2
Cal-sil(2)	5.45 D	13.76 ft^3	13.76 ft^3	13.76 ft^3
Fiberglass (Nukon/Knaupf)	17.0 D	1435.31 ft^3	1180.78 ft^3	74.61 ft^3
Foamglass	17.0 D	18.05 ft^3	11.31 ft^3	17.10 ft^3
Coatings				
Qualified - Concrete	4.0 D	6.06 ft^3	3.14 ft^3	0.32 ft^3
Qualified - Steel	4.0 D	1.65 ft^3	1.20 ft^3	0.47 ft^3
Unqualified	N/A	10.32 ft^3	10.32 ft^3	10.32 ft^3
Latent Debris (15% Fiber, 85% Particulate)	N/A	67.36 lbm	67.36 lbm	67.36 lbm
Foreign Materials				
Labels, Stickers, Tags, etc.	N/A	24.4 ft^2	24.4 ft^2	24.4 ft^2
Glass (Containment Lighting)	N/A	46.082 ft^2	46.082 ft^2	46.082 ft^2
Adhesive	N/A	0.018 ft^3	0.018 ft^3	0.018 ft^3

Notes:

1. Break locations are discussed in the response to NRC Topic 3.a, *Break Selection.*
2. 25.0 ft^3 assumed for S1 break

Topic 3.c: Debris Characteristics

FPL Response

[RAI 35] The size distribution of generated debris is a function of the insulating material and whether it lies within the ZOI. This analysis is based on two debris sizes; Smalls and Larges, and assumes a ratio of smalls to larges based on debris material type. The tables below summarize the size distribution percentages for debris sources inside and outside the ZOI

Debris Source Material (Type)	Debris Size Distribution – Inside the ZOI	
	Small Fines	**Large Pieces**
NUKON Insulation (Fiber Blankets) (Fibrous)	60%	40%
Mirror RMI Insulation (RMI)	75%	25%
CalSil Insulation (Particulates)	100%	--
Foam Glass	100%	--
Coatings (Particulates) 100	100%	--

Debris Source Material (Type)	Debris Size Distribution – Outside the ZOI	
	Small Fines	**Large Pieces**
Misc. Debris (Fibrous and Particulates)	100%	--
Latent Debris (Fibrous and Particulate)	100%	--
Unqualified Coatings (Particulates)	100%	--

The debris values for amounts, bulk densities, material densities and characteristic diameters for fibrous debris and particulates debris used in the strainer performance testing for St. Lucie Unit 2 are consistent with NEI 04-07 (GR) and recognized in the staff's SE.

The specific surface areas for fibrous and particulate debris are generally used in the prediction of head loss with the NUREG/CR-6224 correlation. St. Lucie Unit 2 does not use the NUREG/CR-6224 correlation to determine the debris bed head loss and therefore the specific surface area is not applicable.

No debris characterization assumptions that deviate from USNRC-approved guidance were utilized.

Topic 3.d: Latent Debris

FPL Response

The bases and assumptions related to latent and miscellaneous debris, and the resulting quantities used for analyses and testing, have been updated since the September 1 response. In that response it was noted that the quantity of latent debris was an assumed value in lieu of applied survey results, and that the sacrificial area for miscellaneous debris was an estimated value. Subsequently, walkdowns have been completed for St. Lucie Unit 2 specifically for the purpose of characterizing latent and miscellaneous debris. These walkdowns utilized the guidance in NEI 02-01 and the staff's SE of NEI 04-07.

The NRC's SE for NEI 04-07 recommended that a walkdown guideline be developed to assess debris sources inside containment. A walkdown plan and procedure were developed and implemented to determine the amount of foreign debris in the Unit 2 containment. Samples were collected from eight surface types; floors, containment liner, ventilation, cable trays, walls, equipment, piping and grating. For each surface type, a minimum of (4) samples were collected, bagged, and weighed to determine the quantity of debris that was collected. A statistical approach was used to estimate an upper limit of the mean debris loading on each surface. The horizontal and vertical surface areas were conservatively estimated. The total latent debris mass for a surface type is the upper limit of the mean debris loading multiplied by the conservatively estimated area for that surface type, and the total latent debris is the sum of the latent debris for each surface type.

Based on the walkdown data, the quantity of latent debris in the Unit 2 containment is estimated to be 67.36 pounds, and is included in Table 3.b-1. The latent debris composition is assumed to be 15% fiber and 85% particulate in agreement with the staff's SE of NEI 04-07.

Two Unit 2 containment walkdowns were also performed for the purpose of identifying and measuring plant labels, stickers, tape, tags, and other debris. Based on the walkdown data, the quantity of miscellaneous debris in the Unit 2 containment is estimated to be 70.482 ft^2, and is included in Table 3.b-1.

Latent or miscellaneous debris was specifically accounted for in the design of the St. Lucie Unit 2 strainers as described in section 3b above. These debris types were included in the testing program for St. Lucie Unit 2. However, as an additional conservatism, 100 square feet of margin was allotted for any additional debris that may be identified in the future.

Topic 3.i, Debris Source Term Refinements, provides information on programmatic controls regarding coatings and insulation programs. Regarding latent and miscellaneous debris, current procedures adequately address keeping loose debris and loose fibrous material at a minimum. It is further noted that detailed containment sump inspections are performed at the end of each outage and the Plant General Manager and the Site Vice President perform a walkdown of the containment prior to entry into Mode 4 to assess restart readiness at the end of each outage.

Topic 3.e: Debris Transport

FPL Response

In order to determine the distribution of this debris due to LOCA blowdown, containment spray washdown, and pool fill effects, debris distribution logic trees were utilized consistent with NEI 04-07. These trees are based on the physical configuration of the containment building. The results are subsequently used as design input to a separate analysis to determine the extent of debris transport to the ECCS sump by recirculation flow.

[RAI 41] The following outline presents the general methodology for performing the debris transport calculations to determine the amount of debris, classified by type and size, which may be transported to the containment sump during the recirculation phase of a loss-of-cooling-accident (LOCA). Further description of the model and boundary assumptions are provided below

- Perform steady state Computational Fluid Dynamics (CFD) simulation for a given break scenario.
- Post-process the CFD results by plotting 3D surfaces of constant velocity. These velocities will correspond to the incipient transport velocities tabulated in NEI 04-07 for the debris generated in the LOCA scenario.
- Project the extents of these 3D surfaces of velocity onto a horizontal plane to form a flat contour. Automatically digitize a closed curve around the projected velocity contour and calculate the area within the curve.
- Compare the area calculated above to the total floor area of the zone containing the particular debris type/size under consideration. This comparison gives the fraction of the floor area susceptible to transport.
- Tabulate the results of each calculation to determine the total fraction of debris transported to the sump for each LOCA break scenario and each debris type.

The model assumes that the same equal amount of flow is drawn through all modules in the strainer. Settling velocities and incipient tumbling velocities for the small debris insulation types found in the containment are given in NUREG/CR-6772 and are summarized in NEI 04-07 Table 4-2. All coatings, latent debris, signs, stickers, tags, tape, and other miscellaneous debris in the active pool are conservatively assumed to transport 100% to the strainer modules. Consistent with NEI 04-07 recommendations 100% of the small debris transported to the upper containment elevation will be returned to the lower containment

The erosion fraction of the fibrous material was determined by tests conducted by Alion Science and Technology. Testing was performed in both a vertical test loop and a horizontal transport flume. Large sample pieces (6 inch x 3 inch x 1 inch) were tested at an average flow velocity of 0.37 ft/s, and small sample pieces (1 inch x 1 inch x 1 inch) were tested at an average flow velocity of 0.12 ft/s. Three methods were used to analyze the test results, and the most conservative method yielded an upper bound value of 10%. That is, the non-transportable fiber that is submerged in the containment pool is expected to release 10% of its mass, which then travels to the sump strainer modules.

GAMBIT Version 2.1.6 was used to generate three dimensional solid models of the containment building from the floor elevation to the selected water surface elevation. GAMBIT was also used to generate the computational mesh and to define boundary surfaces required to perform the CFD analysis. Fluent version 6.1.22 was used to perform the CFD simulations. Fluent is a CFD software package for modeling problems involving fluid flow and heat transfer

The computational mesh generated in the model was about 2 million cells. The mesh was imported into the FLUENT (CFD) software program. The values for each boundary condition and the properties of the working fluid (water) are set in FLUENT. The two-equation standard k-ε model was used to simulate the effects of turbulence on the flow field. The results of the steady state, isothermal flow simulations included component velocities (x, y, and z directions), turbulent kinetic energy and the dissipation rate of turbulent kinetic energy for each cell in the computational mesh.

The following is a description of the boundary conditions used by Alden in modeling the St. Lucie Unit 2 containment sump flow patterns and velocity distributions.

Solid Surfaces - All of the solid surfaces in the containment building below the modeled water surface, including the walls, floors and structural supports, were treated as non-slip wall boundaries. At these surfaces the normal and tangential velocity components were set to zero.

Water Surface - The upper boundary of the CFD model representing the water free surface was set at an elevation of 23.58 ft. This water surface elevation corresponds to the minimum water level at the start of recirculation. This surface was modeled as a frictionless wall.

Sump Strainer Modules - It was assumed that an equal amount of flow was drawn through each of the modules. The strainer modules were modeled as velocity inlets, with uniform negative velocities applied to each module face. The net flow through these faces was equal to the sum of the spray and break flows.

LOCA Break and Spray Flows - It was assumed that the break flow falls to the pool water surface without contacting any equipment or structures. The break flow jet accelerates under the influence of gravity as it falls towards the water surface. This is a conservative method to model the break flow as it produces the greatest lateral outflow velocities along the floor. A single break corresponding to break S1 on the hot leg at the B Steam Generator was modeled in this simulation. Spray flow was introduced into the containment building from spray headers located in the upper containment. The spray flow was assumed to be uniformly distributed on the surface of the water.

The trash racks are discussed in section 3j. There are 20 trash racks located at the biological shield wall on the 18 foot elevation. ECCS flow from an RCS break would travel through these racks and dump into the recirculation trench that has a bottom elevation of approximately 12 feet. The trash racks prevent large debris from entering the recirculation trench and transporting to the recirculation sump screens. The newly installed strainer system is open to the trench on both ends of the containment recirculation sump. The openings in the trash racks between the steel bars are approximately ¾ of an inch. Similar structures are also utilized at the stairwell openings in the shield wall. For conservatism, and consistency with NEI 04-07, all of the small debris is assumed to be able to pass through the trash racks. The installed trash racks would effectively remove all large debris, however 10% is assumed to pass through the trash racks for added conservatism. As such, 90% of the debris that is transported to the portals is trapped by the installed trash racks. Additionally, 10% of the large debris that becomes trapped on the trash racks will erode into fines, pass through the trash rack, and be available for further transport via the CFD analysis.

The transport calculation assumed that fines will move to the sump at any flow velocity and are, therefore, assumed to be on the sump screen for determination of head loss. Additionally, all other coatings, latent debris, signs, stickers, tags, tape, and other miscellaneous debris are conservatively assumed to transport 100% to the strainer modules.

Using the results of this CFD simulation, velocity isosurfaces and streamline plots were generated for use in predicting debris transport. Plots were generated corresponding to areas where velocities are equal to or greater than the velocities associated with incipient tumbling of the debris found in each zone. The velocity plots were obtained by projecting down onto the reactor floor the maximum lateral extent of a three-dimensional volume in which the velocities were equal to or greater than the selected incipient tumbling velocity. This method accounts for velocities at all elevations in the pool. Overlays of the velocity surface with the zone definition plots were used to determine the floor area which would be susceptible to transport for each break location. Streamline plots were used to identify isolated eddies that had velocities higher than the incipient tumbling velocity but did not contribute to debris transport from the zone; these areas were not credited to the recirculation transport fraction. The fraction of the zone floor area that is susceptible to transport constitutes the recirculation transport fraction for each debris type. The total fraction of small debris transported to the strainer from each zone is determined by the following equation:

Fraction of Debris Transported to Strainer Per Zone = Erodible Fraction + (1 – Erodible Fraction)(Transport Fraction)

The following table summarizes the results of the transport analysis:

Debris at Sump Strainer Modules for Limiting Case Break S1

Debris Type (From Table 3.b-1)	**Quantity Generated** (From Table 3.b-1)	**Quantity at Strainer**
Mirror RMI	3591 ft^2	1214.80 ft^2
Cal-sil	13.76 ft^3	10.59 ft^3
Fiberglass (Nukon/Knaupf)	1435.31 ft^3	556.26 ft^3
Foamglass	18.05 ft^3	15.67 ft^3
Coatings	18.03 ft^3	15.65ft^3

Note: 100% of coatings in the active pool are assumed to be transported

Topic 3.f: Head Loss and Vortexing

FPL Response

A basic schematic of the ECCS and CSS for St. Lucie Unit 2 is provided in Figure 3.f-1 below. A description of the strainer system is provided in the response to NRC Topic 3.j, Screen Modification Package.

[RAI 40] For Large Breaks and Small Breaks, where the break flow rate provides adequate means of heat removal from the RCS in the long term, recirculation flow and subsequent simultaneous hot and cold leg injection from the HPSI pump makes up the inventory loss through the break. For these scenarios, the newly installed strainer system would be fully submerged from the initiation of recirculation through the duration of the event. As shown in the figures in Topic 3.j, Screen Modification Package, the top of each plate in seven of the eight stacks of strainers is at the same elevation. At the minimum LBLOCA containment water level (using the current administrative minimum Refueling Water Tank (RWT) level), the submergence of the highest strainer disks is approximately 22 inches. As noted in Topic 3.p, Licensing Basis, the current administrative level of the Refueling Water Tank (RWT) will be made permanent with an amendment to the TS to this higher level. An amendment request to the St. Lucie Unit 2 TS requesting the necessary increase in minimum RWT level is being submitted under separate cover.

For Small Breaks, with the RCS reflooded, the minimum water level (using current minimum RWT TS level) would be approximately 0.2 inches above the highest strainer plate. With the currently implemented administrative RWT level which is being proposed to the NRC as a permanent Technical Specifications amendment, the water level would be over 15 inches above the highest strainer plate. Under these conditions there would be virtually no debris load from the small break and HPSI flows would likely be throttled to maintain the RCS solid. It is further noted, that if reflood of the RCS is achieved after a small break LOCA, long-term core cooling would be provided by the secondary system via the steam generators or by the shutdown cooling system.

The very low strainer plate entrance velocity of approximately 0.0034 ft/sec, coupled with the approximately 12 inches of minimum water coverage at the top plates of the strainer system for the LBLOCA at RAS, will not allow floating debris to accumulate on the strainer system.

As discussed and shown in the figures in the response to NRC Topic 3.j, Screen Modification Package., the newly installed strainer system contains two closely spaced sets of 4 strainer stacks connected to the top of the lower plenum. The lower plenum has an accordion perforated divider plate in the middle, and the ECCS/CSS recirculation suction flow comes off the ends of each plenum. The entire strainer system is located in the containment recirculation sump. The containment recirculation sump is open on both ends to a large trench, approximately 5 by 12 feet, that goes around the perimeter of containment and carries most of the recirculation flow to the sump. With screen perforation sizes of only 0.0625 inches and low constant approach velocities of only approximately 0.0034 ft/sec, formation of a vortex that can transport air into the system is fundamentally precluded by design and configuration.

Table A-2 of NRC Regulatory Guide 1.82, Revision 3 states that a 1 ½ inch or deeper floor grating, or equivalent, that is at least 6 inches under water has the ability to suppress the formation of a vortex. The St. Lucie Unit 2 LBLOCA containment level meets these criteria.

Further, vortex testing of the prototype strainer demonstrated that vortex characteristics were not present and no formation occurred even when the strainer was partially uncovered.

In accordance with Regulatory Guide 1.82, Rev 3, the St. Lucie Unit 2 strainer system limits air ingestion to less than 2% by limiting Froude Number to a maximum of 0.25. The collection and flow of post LOCA water in containment is analogous to that of open channel flow. Using the Froude Number equation for channel flow, along with conservative values for the strainer design, results in a Froude Number of approximately 0.12. Hence the strainer design will limit air ingestion below 2% in accordance with the Regulatory Guide.

The potential for void formation below/downstream of the St. Lucie Unit 2 strainer system was evaluated using conventional hydraulic methods. The following assumptions/inputs were utilized:

- Containment post-LOCA water temperature of 210 °F
- Total Debris Laden Head Loss of 2.1 feet of water
- Containment water level elevation of 23.58 feet
- Sump Outlet Pipe Centerline Elevation at 9 feet

Since the containment water head is a minimum of 12 feet greater than saturation, it can be concluded that there will be 0.00% void fraction associated with the strainer discharge flow before it leaves the St. Lucie Unit 2 containment sump.

[RAI 39] Details of the final new strainer size are provided in Topic 3j, Screen Modification Package. Details of the new strainer head loss are provided below in this section. Details of the final new strainer NPSH margin are provided in Topic 3g, Net Positive Suction Head (NPSH).

The integrated head loss testing was performed by Performance Contracting, Inc., along with AREVA NP, Inc. and Alden Research. The test plan protocol implemented was developed with the NRC staff beginning in April 2007, and the NRC staff has reviewed the protocol in detail prior to its actual implementation. This protocol was further refined following comments from NRC staff members who witnessed tests in January and February 2008.

Prior to testing, CFD analyses were implemented to define a "bounding" flow stream in one foot increments to the screen. The objective of this test protocol was to allow debris settling as is reasonable to assume can occur in the actual post-LOCA environment. This data provided was utilized to create a representative and bounding flow stream in the test flume.

Non-chemical debris was procured and produced in accord with PCI standards; also in accordance with discussions held with the NRC staff over the same review period. The debris loads and flow rates were scaled to simulate the St. Lucie Unit 2 strainer assemblies operating in containment. Non-chemical debris was introduced in accordance with NRC preferences; namely, particulates first; then fine fibers; then smalls, etc.

Chemical debris was produced and accepted for use in accordance with the WCAP 16530-NP in a chemical tank prior to its introduction into the flume. Introduction of acceptable precipitates always occurred within 24 hours of its manufacture. The full transportable debris load was added to the flume, and a thin bed was not observed to form.

Based on the test results, the Design Basis Tests head loss was extrapolated over 30 days and resulted in a final head loss across the screen and debris bed of 2.21 feet of water at an average temperature of 97.6°F.

The basis for the strainer design head loss is to maintain NPSH margin for ECCS and CS pumps. NPSH margin is more restrictive than crush pressure or submergence in the design.

The clean head loss calculations for the strainer stack internal components, lower plenum, and containment recirculation pipe inlet are summarized in Table 3.f-1 for a scaled temperature of 210° F. These design features are shown in Figures 3.j – 2 through 5. As concluded from these calculations, at 210° F the strainer system with runout flow of a CSS and HPSI pump on the "A" and "B" train side, clean strainer head losses would be 1.21 feet of water on the "B" train side and 0.98 feet on the "A" train side.

Table 3.f-1 *Calculated Clean Strainer Head Losses @ 210°F

Two CSS Pumps and Two HPSI Pumps at Runout Flow from the Sump	**1 CSP & 1 HPSI Pump - "B" Train Strainer Stacks 1, 2, 3 & 4**	**1 CSP & 1 HPSI Pump - "A" Train Strainer Stacks 5, 6, 7 & 8**
Parameter	@ 210°F	@ 210°F
Uncorrected CSHL for Stack 1 or 8 (includes 6% uncertainty)	0.205	0.205
Flow, Perforated Plate Head Loss Corrections	0	0
Strainer Length Head Loss Corrections	0.015	0.015
Disk Internal Flow Restriction Head Loss	0	0
Core Tube Exit Head Loss to Plenum (includes 10% uncertainty)	0.227	0.227
Plenum Chamber Head Loss (includes 10% uncertainty)	0.021	0.017
Square Orifice Restriction to Flow in Plenum (includes 10% uncertainty)	0.485	0.319
Plenum Chamber Discharge – Sump Head Loss (includes 10% uncertainty)	0.125	0.058
*Suction Pipe Entrance Head Loss (includes 10% uncertainty)	0.134	0.134
Total Corrected Clean Strainer Head Loss (TCCSHL) with Attached Piping – Ft of Water	1.21	0.975

* Note, does not include piping and other head losses from the entrance of the suction piping to the suction of the ECCS/CSS pumps.

The total head loss across the strainer system is the combined total of the clean head loss associated with the strainer and plenum and the debris head loss. The clean strainer head loss calculation is summarized above. The debris head loss is determined based on actual test results for a scale model strainer that has been specifically corrected for the subject plant's post-LOCA water temperature. The following assumptions were utilized for debris head loss testing:

- A Design Basis temperature 210 degrees F (temperature nearest the point of least NPSH margin) will be used.
- A prototype scale strainer, which is designed to maintain the same approach velocity as the full scale production strainer, can accurately simulate the performance of the full scale production strainer utilizing the appropriate scaling factors.
- The head loss resulting from flow through a fiber - particulate debris bed at the approach velocity for the St. Lucie Unit 2 strainers (0.0034 fts) is 100% viscous flow. As viscous flow, head loss is linearly dependent on the product of viscosity and velocity. Therefore, to adjust the measured head loss across a debris bed with colder water, a ratio of water viscosities, between the warmer specified post-LOCA water temperature and the colder test temperature, can be multiplied by the measured head loss to obtain a prediction of the head loss with water at the specified post-LOCA temperature. USNRC NUREG/CR-6224 and NUREG/CR-6808 provide the basis for the assumption. Additionally, as part of the testing, the strainer assembly was inspected. Part of the test plan and protocol was to observe and photograph each test case to ensure the absence of 'boreholes'. The test report confirms that for the St. Lucie Unit 2 limiting head loss test cases, no boreholes were observed during testing.
- The total strainer head loss can be calculated by adding the Total Corrected Clean Strainer Head Loss and the St. Lucie Unit 2 Debris Head Loss (ARL Test Results), and temperature correcting the sum of the two head losses
- The replacement strainer for St. Lucie Unit 2 consists of two trains (A and B) of strainer assemblies each comprised of four strainer module stacks mounted on a common plenum. It has been determined that the 'B' train configuration results in a higher clean strainer head loss than the 'A' train. Accordingly, the St. Lucie Unit 2 'B' train strainer will be conservatively utilized as the basis for St. Lucie Unit 2 to bound all strainer module stacks.
- The calculation conservatively assumed to add 6% for uncertainty and 10% for strainer discharge and collection head loss associated with the calculations to address any non-conservatisms inherent in the use of standard head loss correlations.

The debris laden head loss results are calculated for the "A" side of the strainer system for the case where one CSS and two HPSI pumps are at runout flow from the sump. The clean strainer head loss with temperature compensation at 210°f is 1.054 feet. The debris laden strainer head loss with temperature compensation at 210°f is 1.946 feet.

Under the conditions where the operator trips a CSS pump during the injection phase, calculations have determined that the train "A" side of the strainer system has the highest head loss. Similarly, for a single failure scenario for the highest flow offset from the sump, the "A" train side has higher head losses than the "B" train. The single failure assumes that the "A" train LPSI pump did not automatically trip when the RAS signal is generated on low RWT level. After RAS, the Operator will verify that RAS actions have occurred, and take the necessary action to trip the LPSI pump. The calculation results, provided in Table 3.f 2, show that this temporary head loss condition would result in a worst case clean head loss of 3.603 feet at 210° F. However, for additional conservatism, the NPSH analysis for the ECCS and CS pumps considered an additional head loss corresponding to the high flow/all debris condition without chemical precipitate as presented in table 3.f-2.

Table 3.f-2 Worst Case Single Failure - Calculated Momentary Debris Laden Strainer Head Losses

Worst Case Single Failure of a LPSI Pump to Trip on RAS	***1 CSP & 1 HPSI & 1 LPSI Pump - "A" Train Strainer Stacks for 5, 6, 7, & 8 - Head Loss at Calculated Temperature, Ft.**
Item Description	210°F
St. Lucie Unit 2 Calculated Clean Strainer System Head Loss With Temperature Compensation, Ft. of Water (Including 10% Uncertainty Margin)	3.603
St. Lucie Unit 2 Debris laden Strainer System Head Loss With Temperature Compensation, Ft. of Water	4.019**

*Represents the highest head loss side of the strainer system under this offset flow condition. These head loss conditions would exist until the operator verified RAS actions and tripped the operating LPSI pump.
** 3.603 ft clean loss plus 0.416 ft debris

[RAI 37] The sump is fully submerged for any accident scenario that requires recirculation flow. The most severe single failure considered for the strainer design is the failure of a LPSI pump to trip upon receipt of a recirculation actuation signal (RAS) as discussed above.

[RAI 36] Near field settling was credited for the head loss testing. An analysis was performed to set the configuration of the test flume for strainer qualification test program. The calculation utilizes the results of the CFD debris transport study to define the average approach velocities to the strainer. The following methodology was utilized:

- Use the CFD post-processing software, back-calculate the trajectory of the particles to define streamline traces to each module. This identifies the path the water follows to each strainer module face.
- With the water path to each module identified, use the CFD post-processing software to define vertical planes at 1 ft increments back from the module train.
- At each 1 ft increment back from the module train, record the cross section average of the velocity magnitude across that plane. If the paths diverge around objects in the flow, follow each path individually. Record these averages over a total of 30 ft back from the module train.
- Using a spreadsheet, calculate the weighted average of the four flow streams at each 1 ft increment. The average at each increment is weighted by twice the fastest velocity at the increment under consideration. Weighting the average by twice the fastest velocity incorporates conservatism into the calculation.
- Create a plot of the calculated weighted average velocity vs. incremental distance back from the module train.

- Create up to 9 linear line segments which conservatively represent the velocity trends over the 30 ft distance.
- Calculate the width of the test flume at each line segment break.
- Create a table of flume width vs. line segment length to be used in defining the shape of the flume. The transition of the flume near the test strainer module is defined by the trajectory of the water as it approaches the modules in the prototype installation. These flow patterns are calculated in the CFD debris transport analysis and interpreted to define the shape of the flume at the test module.

St. Lucie Unit 2 head loss testing of a debris laden strainer section was conducted at Alden Labs. Head loss values were then scaled by viscosity ratios to strainer design conditions (210°F). Part of the test plan and protocol was to observe and photograph each test case to ensure the absence of 'boreholes'. The test report confirms that for the St. Lucie Unit 2 head loss test, no boreholes were observed during testing.

The PCI calculation Vortex, Ingestion and Void Fraction has summarized strainer design head losses and analyzed the specific losses attributed to the debris bed when compared to the amount of strainer submergence existing in the strainer design basis case. For the limiting design case (lowest pool level) a small amount of containment (previously existing air) pressure is credited in addition to vapor pressure for prevention of flashing at the immediate strainer/debris bed surface. However, for the overall NPSH analysis no credit is taken for containment pressure over and above that existing prior to the postulated design basis accident.

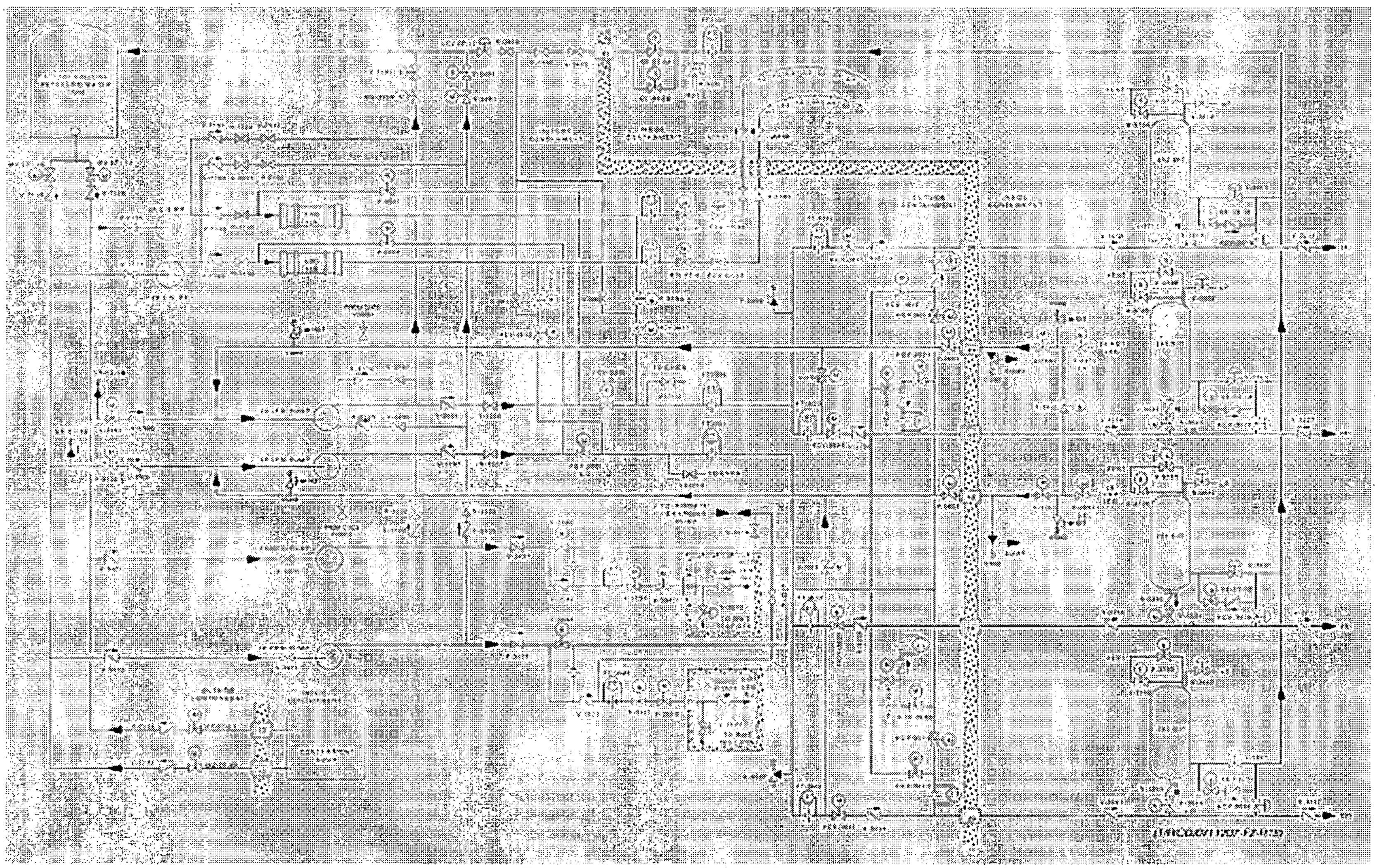


Figure 3.f-1: ECCS/CSS Piping Schematic

Topic 3.g: Net Positive Suction Head Available (NPSH)

FPL Response

The minimum LBLOCA water level will reach an elevation of 23.58 ft (assuming an RWT level of 32.5' and minimum levels assumed in other injected tanks). The minimum SBLOCA water level will reach an elevation of 23.06 ft (assuming an RWT level of 32.5' and minimum levels assumed in other injected tanks). For the purposes of NPSH calculation, the sump strainer design temperature is taken to be 210 degrees F which is close to the point of minimum NPSH margin. The pump flow rates and recirculation flow rates for the design basis case and the LPSI failure to stop (worst single failure criteria for sump flow) are provided in Table 3g-1.

Table 3g-1 Pump and System Recirculation Flow Rates

	Train	Total Sump Flow (gpm)	LSPI Flow (gpm)	CS Flow (gpm)	HPSI Flow (gpm)	Comments
Design Basis Case	A	4285		3600	685	One of two operating CS pump stopped prior to RAS. Maximum HPSI flow and Debris laden strainer.
	B	685			685	
LPSI Failure to stop	A	7785	3500	3600	685	LPSI failure to stop on RAS adds 3500 gpm to clean strainer head loss and initial test debris losses. One of two CS pumps tripped prior to RAS. Tripped CS pump not in operating LPSI train. Maximum HPSI flow
	B	685			685	

The bases for the assumptions used in the flow parameters used are listed in the comments column of the associated table and are the maximum expected flow rates based on emergency operating procedure (EOP) equipment lineups and the worst postulated single active component failure.

The basis for the required NPSH values used in St. Lucie Unit 2 calculations is the information provided from the original manufacturer's certified pump test curves at the maximum expected pump flow rates plus flow/NPSHr margin.

The maximum flow losses (including debris and chemical effects) determined for the St. Lucie Unit 2 ECCS/CS strainer, plenum and piping system by calculation and by testing are subtracted from available NPSH (static pool elevation above the pump) to determine overall pump NPSH margin over the NPSH required.

Following a large break LOCA (LBLOCA) both trains of the Low Pressure Safety Injection (LPSI) pumps, Containment Spray (CS) pumps and High Pressure Safety Injection (HPSI) pumps are automatically started taking suction from the Refueling Water Tank (RWT). Prior to the end of the RWT injection phase, the Operator will shut down one of the operating CSS pumps. This operation is conducted per procedural verification of proper containment pressure, containment fan cooler operation, and safety injection flow. Following trip of the CSS pump, the nominal flow rate from the RWT would be 4970 gpm. When the RWT reaches low level, an automatic Recirculation Actuation Signal (RAS) is generated.

RAS shuts down the operating LPSI pumps and realigns the HPSI pump and operating CSS pump to take suction from the containment sump. At this point, the sump ECCS/CSS flow rate with one CSS pump and two HPSI pumps operating could be as high as 4970 gpm.

Based on an NRC audit finding at Waterford, an additional calculation for a LBLOCA was completed. This calculation assumed a single failure of a LPSI pump to trip at the initiation of RAS. The Operator would take action to trip this pump manually during procedural verification of RAS actions. However, although this flow condition would be temporary, it would be the highest possible flow condition, 8470 gpm from the containment sump. It is noted that the calculation assumes, under these temporary conditions immediately following RAS, that the strainers would remain clean with little or no debris head loss. However, for conservatism, full debris head loss without chemical precipitate based on flume test measured head loss values approximately two hours into testing were considered.

ECCS/CSS pump NPSH calculations have been conducted for numerous pump and single failure scenarios for the LOCA where the break flow rate provides adequate means of heat removal from the RCS during long term cooling. Calculations use head losses for the sump strainers and friction/losses for the piping from the sump to the ECCS/CSS pumps. ECCS/CSS pumps were calculated to be at or near run-out flows, even though containment and or RCS back pressure would be present. Further, the calculations were conducted in accordance with the conservative assumptions of Regulatory Guide 1.1, which does not allow credit for containment air heating and the accompanying additional partial pressure of air.

The minimum required NPSH for a HPSI pump with flow at 685 gpm is 23.5 feet of water, and the minimum for a CSS pump with flow at 3600 gpm is 18.0 feet. Note that the calculations assume an additional 1% flow tolerance to bound the available pumps. As shown in Table 3.g-2, sufficient NPSH is available for the HPSI and CSS pumps for the 4970 gpm sump flow scenario.

For the case where it is assumed that a single failure does not allow a LPSI pump to trip on RAS and the operating CSS pump is on the same train as the LPSI pump, this CSS pump would have sufficient available NPSH. However, during this temporary flow upset, the opposite train HPSI pump would be relied upon as sufficient NPSH is available for this pump.

As noted in Topic 3.p, Licensing Basis, the current administrative level of the Refueling Water Tank (RWT) will be made permanent with an amendment to the Technical Specifications to this higher level. At this higher level, the Minimum Available NPSH values are shown in Table 3.g-2.

Table 3.g-2 Minimum Available NPSH Calculations @ 210°F with current Administrative RWT (Technical Specification Amended) Minimum Level

(1)Pump Scenario at RAS Initiation	(2)Sump Flow Case	HPSI NPSH		CSP NPSH	
		Minimum Available	Required	Minimum Available	Required
LBLOCA one CSS and two HPSI Pumps – Debris Laden Strainers	4,970 gpm	(3)24.713 ft	24 ft	(3)24.852 ft	18.3 ft
LBLOCA with LPSI Failure to Trip on RAS	8,470 gpm	(5)26.81 ft	24 ft	(4)19.147 ft	18.3 ft

(1) These calculations are based on the conservative assumptions of Regulatory Guide 1.1.
(2) These flows represent nominal runout values for the pumps. The NPSH calculations increased flow by 1% to account for pump flow variability tolerance.
(3) HPSI pump is on the same train as the CSS pump.
(4) This is for the worst case with a LPSI, CS, and HPSI on the same train
(5) The available NPSH for the opposite train HPSI pump which is available and sufficient for long term cooling.

Post LOCA containment water level is calculated considering the minimum volume of water released from the Reactor, RCS system, SIT tanks and RWT tank following a LOCA for the minimum containment water level. The volumes of water held up are then calculated and subtracted from the total water volume. The water level is then calculated based on free volume of station geometry below elevation 24'.

FPL has reviewed the results of the Waterford audit with respect to containment water level and has revised the post-LOCA containment water level calculations. The revised calculation incorporates water hold up issues and volume changes which include:

- Volume of water from the Refueling Water Tank (RWT) using the worst-case allowable instrument drift value.
- Volume of water required to fill the empty containment spray pipe headers. The volume of the spray piping was calculated using the piping isometrics.
- Volume of water in the containment spray droplets. This volume was calculating utilizing the containment spray flow, the droplet fall distance, and droplet terminal velocity.
- Volume of water held up as film on containment surfaces. Conservatively the water condensation film on horizontal surfaces was calculated using the total heat sink area which includes vertical surfaces from Section 6.2 of the UFSAR. Average condensate film thickness on heat sink surfaces was determined and a 10% margin added for additional conservatism.
- Volume of water held up in the refueling canal.
- Volume of water as steam in the containment atmosphere.
- Volume of water to reflood the reactor vessel following a Large Break LOCA (LBLOCA).
- Volume changes due to changes in specific volume due to volumes heating (RWT and

others) and volumes cooling (RCS).

Post LOCA containment pool level is determined by calculating free containment volume based on containment building geometry below the approximate post LOCA water levels. These free volumes include containment sump, reactor cavity, electrical tunnel and access, blowout tunnel, Reactor Drain Tank pit, ECCS suction piping, trenches stairways, equipment cubicles and drains system among others. This is conservative because numerous components such as piping, conduit, stairs, and structural supports are not credited for water displacement.

Table 3g-3 provides a summary of post LOCA containment pool water sources.

Table 3g-3 Post LOCA containment water source summary

In the event of a:	LBLOCA	SBLOCA
Reactor Vessel:	4,615 ft^3	NA
Reactor Coolant Pumps:	448 ft^3	NA
Steam Generators:	3,841 ft^3	NA
Pressurizer: (water only)	800 ft^3	NA
R. C. Piping:		
(Hot Legs)	280 ft^3	NA
(Suctions)	448 ft^3	NA
(Discharges)	324 ft^3	NA
(Surge)	29 ft^3	NA
Safety Injection Tanks:	5,680 ft^3	5,680 ft^3
Boric Acid Tank:	715 ft^3	715 ft^3
NaH_4 Storage Tank:	90 ft^3	90 ft^3
Total volume inside containment at LOCA @ T=0 =	17,270 ft^3	6,485 ft^3
Refueling Water Storage Tank:	43,629 ft^3	43,629 ft^3
Total volume inside containment at RAS =	60,899 ft^3	50,115 ft^3

No credit is taken for containment accident pressure in determining available NPSH.

The containment sump strainer design temperature of 210 °F was chosen for NPSH considerations because it is close to the maximum pool temperature possible with containment pressure minimized, being no greater than prior to the postulated event (partial pressure of existing air ignored). At higher temperatures head losses are lower due to viscous effects.

For the purposes of calculating NPSH margin, containment accident pressure is set at the vapor pressure of water corresponding to the sump liquid temperature for pressures above that existing prior to the start of the postulated event (the partial pressure of air is ignored). Therefore, the St. Lucie Unit 2 NPSH calculation is consistent with Safety Guide 1.1 and the traditional conservative industry method of determining ECCS/CS pump NPSH during the recirculation mode of operation.

The NPSH margin was calculated and plotted for various sump fluid temperatures. Note that the full 30 day debris load (both chemical and non chemical) is applied at the initiation of recirculation. This is extremely conservative since as the chemical products are being created during the 30 days, the sump pool is cooling down providing additional margin. The plots of NPSH margin versus temperature for the containment spray and high head safety injection pumps for the design basis case are provided below:

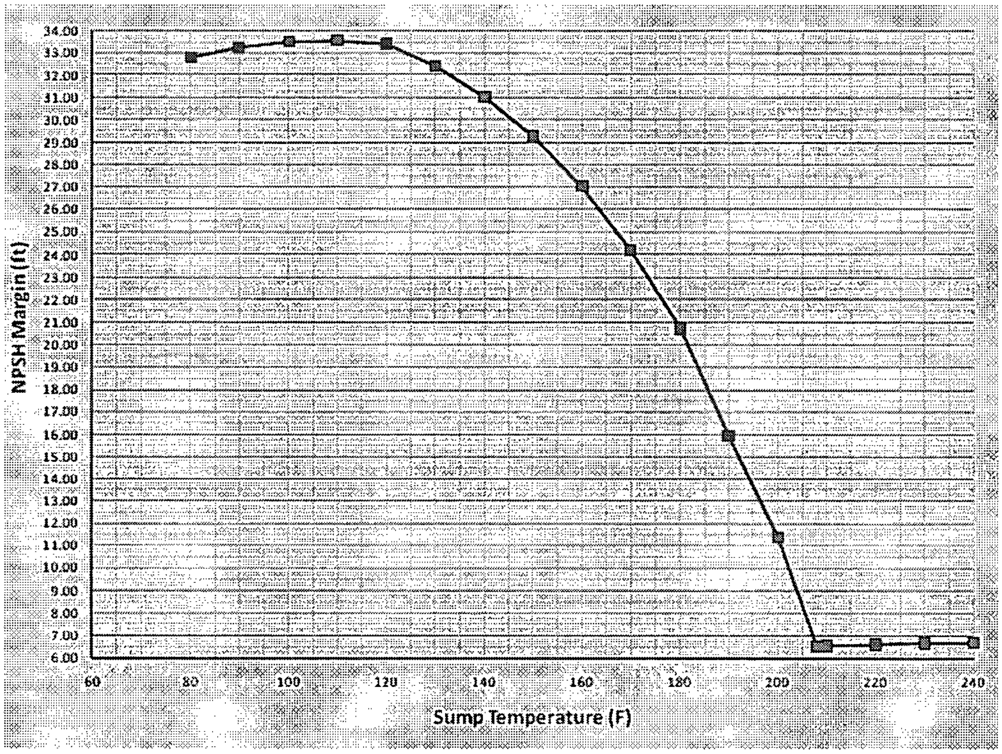


Figure 3g-1 Containment Spray Pump NPSH Margin Vs Temperature.

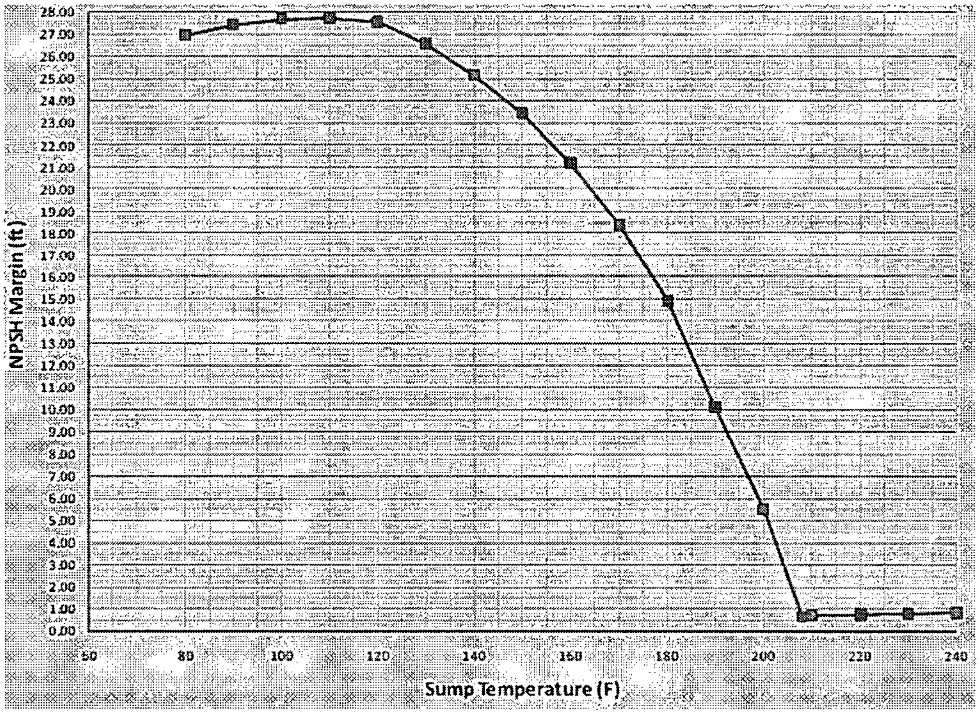


Figure 3g-2High Head Safety Injection Pump NPSH Margin Vs Temperature

Topic 3.h: Coatings Evaluation

FPL Response

Coatings inside containment are classified as Service Level 1 qualified, or unqualified. Qualified coatings are defined as coatings that will remain in place under Design Basis Accident (DBA) conditions (temperature, radiation, humidity, and pressure). The qualified coating systems used in the St. Lucie Unit 2 containment are listed in Table 3.h-1 below.

Table 3.h-1 Qualified Coatings in the St. Lucie Unit 2 Containment

Substrate	Application	Coating Product	Application Thickness (mils)
Steel	1st Coat	Carboguard 890	6
	2nd Coat	Carboguard 890	6
Steel	1st Coat	Carbozinc 11	5
	2nd Coat	Amercoat 90	8
Concrete Floor	1st Coat	Carboguard 2011S	50
	2nd Coat	Carboguard 890	7
	3rd Coat	Carboguard 890	7
Concrete Floor	1st Coat	Nu-Klad 110AA	125
	2nd Coat	Amercoat 90	8
Concrete Walls	1st Coat	Carboguard 2011S	35
	2nd Coat	Carboguard 890	7
	3rd Coat	Carboguard 890	7
Concrete Walls and Ceilings	1st Coat	Nu-Klad 114	7
	2nd Coat	Nu-Klad 114	7
	3rd Coat	Amercoat 90	8

[RAI 30] Based on the transport calculation, the analyzed LOCA cases generated sufficient fiber to form a thin fiber bed. As discussed in previous sections, FPL conducted integrated chemical effects testing in a large flume on the St. Lucie Unit 2 strainer design. This test addressed the maximum debris generation and a minimal debris generation case that can produce the "thin bed effect." Consistent with the staff's SE of NEI 04-07 for thin fiber bed cases, all coating debris is treated as particulate with 100% transportation of active pool coatings to the sump screen. Treating all coatings as particulates conservatively maximizes transport to the screen.

Assumptions made and/or data used to justify use of surrogates are as follows:

- Particles of "like" size, shape, and density will perform in the same way as other particles of "like" size, shape, and density.
- Particles of similar size that are less dense will suspend more easily, and when added to

the debris mix at the postulated mass of the actual coating material is bounding and conservative for these tests.

- Particles of smaller sizes will bound particles of larger sizes. This is because smaller particles can fill more of the interstitial spaces between fibers than will larger particles; which will increase head loss on a relative scale.
- Zinc has a specific density of 457 lb/ft3 and tin has a specific density of 455.1 lb/ft3.
- Walnut shells have a density range of 74.9 to 93.6 lb/ft3.

Walnut shell flour (based on density, size, shape, texture, etc.) was determined to be a bounding and conservative surrogate material for coatings with densities above 75 lbs/ft3, and was utilized for coatings such as epoxy, enamel, acrylic, and alkyd coatings. For inorganic zinc coatings (including primers), the use of tin powder was utilized as an acceptable surrogate.

The ZOI for qualified coatings is 4D. The 4D ZOI is based on coatings performance testing that was completed during February of 2006. It is noted that the Amercoat 90 coating showed minor amounts of erosion in the testing, hence from a 4D to 10D ZOI, it has been assumed that 1 mil of debris from Amercoat 90 is included in the debris generation.

[RAI 29] A description of the test, test data, and evaluation of the test data were previously provided to the NRC Staff for information on July 13, 2006 in FPL Letter L-2006-169 (R.S. Kundalkar (FPL) to M.G. Yoder (NRC), "Reports on FPL Sponsored Coatings Performance Tests Conducted at St. Lucie Nuclear Plant," July 13, 2006). The evaluation of the test results confirms that a 4D ZOI is applicable to the in-containment qualified coating systems at St. Lucie Unit 2, except as noted above for Amercoat 90. As stated in the test plan, heat and radiation increase coating cross linking, which tends to enhance the coating physical properties. Therefore, since artificial aging, heat, or irradiation to the current plant conditions could enhance the physical properties and reduce the conservatism of the test, the test specimens were not aged, heated, or irradiated.

The current debris generation model conservatively assumes the maximum thicknesses for each applicable coating system.

The debris generation calculations provide the quantity of qualified coatings for each break by using the concrete and steel drawings to determine the amount of coating that will be within the ZOI for each break. Coatings that are shielded from the jet by a robust barrier are not included in the total. The calculated volume of qualified steel coating is then increased by 10% to account for small areas of additional items such as piping, pipe/conduit/HVAC/cable tray supports, stiffener plates, ladders, cages, handrails, and kick plates.

The estimated quantity of qualified and unqualified failed coatings for the S1 break in the September 1 response was 10 ft^3. With the changes discussed above, the estimated quantity of qualified and unqualified failed coatings for the S1 break is now 10.32 ft^3.

The previous program for controlling in-containment coatings was described in the FPL response to NRC Generic Letter 98-04, "Potential for Degradation of the Emergency Core Cooling System and the Containment Spray System After a Loss-of-Coolant Accident Because of Construction and Protective Coating Deficiencies and Foreign Material in Containment" in letter L-98-277 on November 9, 1998. The letter summarized the program in place at that time for assessing and documenting the condition of qualified/acceptable coatings in primary containment at St. Lucie Unit 2.

[RAI 25] The current program for controlling the quantity of unqualified/degraded coatings includes two separate inspections by qualified personnel during each refueling outage, and notification of plant management prior to restart if the volume of unqualified/degraded coatings approaches pre-established limits.

The first inspection takes place at the beginning of every refueling outage, when all areas and components from which peeling coatings have the potential for falling into the reactor cavity are inspected by the FPL Coating Supervisor. The second inspection takes place at the end of every refueling outage when the condition of containment coatings is assessed by a team (including the Nuclear Coating Specialist) using guidance from EPRI Technical Report 1003102 ("Guidelines On Nuclear Safety-Related Coatings," Revision 1, (Formerly TR-109937)). All accessible coated areas of the containment and equipment are included in the second inspection. Plant management is notified prior to restart if the volume of unqualified/degraded coatings approaches pre-established limits.

The initial coating inspection process is a visual inspection. 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. Following identification of degraded coatings, the degraded coatings are repaired per specification if possible. For degraded coatings that are not repaired, areas of coatings determined to have inadequate adhesion are removed, and the Nuclear Coatings Specialist assesses the remaining coating to determine if it is acceptable for use. The assessment is by means of additional nondestructive and destructive examinations as appropriate.

The Coatings Specification has been enhanced and is used to control the quantity of degraded qualified coatings in containment.

Topic 3.i: Debris Source Term Refinements

FPL Response

Information related to programmatic controls for foreign materials was provided to the NRC in previous submittals. Information was provided in FPL letter L-2003-201 which responded to NRC Bulletin 2003-01, and most recently in FPL letter L-2005-181, September 1, 2005 which responded to GL 2004-02. In general, the information related to programmatic controls that was supplied in these responses remains applicable.

The results of the walkdowns completed in 2006 to assess the quantities of latent and miscellaneous debris are discussed in the response to NRC Topic 3.d, *Latent Debris*. These walkdowns were conducted and consequently, the debris found during the walkdowns is considered representative of normal plant operation under the existing housekeeping programs. Based on these walkdowns, it was determined that current housekeeping procedures were appropriate; hence no changes have been made to these procedures.

Procedural controls at St. Lucie Unit 2 ensure: i) that a Mode 1 through 4 containment restart cleanliness inspection is completed that verifies that no loose debris is present and, ii) restart readiness that further assures containment cleanliness. These plant procedural requirements are further reinforced by written nuclear division policy regarding required plant readiness for operation.

Subsequent to the September 1 response, additional programmatic controls have been put in place or modified in support of the installation of the new strainer system.

Currently insulation and materials inside containment are controlled by procedures that require; (a) a review of changes to insulation or any other material inside containment that could affect the containment sump debris generation and transport analysis and/or recirculation functions and (b) a review of the effect of any change package for its impact on containment sump debris generation and transport. This guidance has been enhanced by a new engineering specification that brings together, in one document, the insulation design documents that determine the design basis for the insulation debris component of the containment recirculation strainer design. This specification provides guidance for evaluating and maintaining piping and component insulation configuration within the containment building at St. Lucie Unit 2. In addition, the St. Lucie Plant procedure for controlling work orders was revised to assure that insulation work inside containment required signoff to the requirements of this specification.

The St. Lucie coatings specification assures that coatings and coating repairs inside containment are within the bounds of assumptions used in the applicable containment sump analysis. Note that programmatic controls related to coatings are provided in Topic 3.h, *Coatings Evaluation*.

A new inspection procedure was implemented for new strainers. The new procedure assures that the strainers are properly inspected and have no visible damage. The procedure also calls for the installation of protective covers to assure that outage related activities will not damage the strainers, and also calls for the removal of the covers prior to restart.

The steam generators were replaced in the fall 2007 outage. Prior to the replacement, the steam generators were insulated with Nukon blankets. The new steam generators are insulated with Transco RMI, which significantly reduces the amount of fiber in the containment.

In accordance with 10 CFR 50.65 (Maintenance Rule), St. Lucie Unit 2 maintenance activities (including associated temporary changes or temporary system alterations) are controlled by plant procedure. This process maintains configuration control for non-permanent changes to plant structures, systems, and components while ensuring the applicable technical reviews and administrative reviews and approvals are obtained. If, during power operation conditions, the temporary alteration associated with maintenance is expected to be in effect for greater than 90 days, the temporary alteration is subject to the requirements of 10 CFR 50.59 prior to implementation.

Topic 3.j: Screen Modification Package

FPL Response
The St. Lucie Unit 2 containment recirculation sump is open on both ends to a large recirculation trench that goes around the perimeter of the reactor containment and would carry most of the post-LOCA recirculation flow. Figure 3.j-1 provides a general overview of containment layout at the 18 ft elevation showing the trash racks which lead to the perimeter trench, and the general location of the containment recirculation sump. As shown in Figure 3.j-2, the bottom of the trench, approximately 12 ft elevation, is open to the containment recirculation sump which has a floor elevation of approximately 7 ft 7 inches.

The containment recirculation sump contains the Reactor Drain Tank, including related mechanical equipment, instrumentation and piping. This was also the location for the original containment recirculation sump screens and is the location of the new ECCS sump strainer system.

The recently installed St. Lucie Unit 2 strainer system has eight separate vertically installed strainer stacks with a lower plenum box. This is mounted on the lower containment recirculation suction piping housing. Two separate recirculation intake pipes are located inside of the lower housing on the East and West ends of the recirculation sump. An instructional plan view, side view and isometric view of the strainer system are provided in Figures 3.j-2, 3, and 4, respectively. Strainer stacks 5, 6, 7, and 8 service the East end of the containment recirculation sump, for the train "A" recirculation pipe intake, and stacks 1, 2, 3, and 4 service the West end for train "B". An accordion divider plate with 1/16 inch holes is installed in the plenum which prevents any transport of large particles between the East and West strainer system. This helps to provide physical protection in the lower sump while still maintaining a degree of hydraulic coupling to balance head loss differences.

A strainer stack is an assembly of strainer modules generally with 11 or 15 disks, in each module. The modules have stiffener plates and are connected with tension rods into a strainer stack. Each of the disks is ½ inch thick with an internal separation gap between disks of 1 inch. The disks are hollow and have perforations of 1/16 inch diameter on the tops, bottoms and sides. A flow control tube with flow slots for each disk runs from the top disk to the bottom, and is of varying diameters for each of the modules as it progresses from the top to the bottom of the strainer stack. A typical end strainer stack is shown in Figure 3.j-5.

As shown in Figure 3.j-4, the strainer stacks are of three basic designs. This was necessary to assure proper fit-up in the sump due to space interference limitations in the sump area. The hydraulic strainer designs of stacks 1 through 4 and 5 through 8 are all based on achieving a low approach velocity to the strainer perforations of approximately 0.0034 ft/sec, and closely balancing each ECCS/CSS train to a flow of approximately 4,250 gpm. Hence, the strainer area on each train is approximately equal to half of the total 5,607 square feet of strainer surface area.

[RAI 32] The original sump screens have been replaced with the strainer system discussed earlier. The newly installed system is passive and does not rely on active features such as back flushing or other mechanical devices.

The installation of the St. Lucie Unit 2 sump strainer system required the removal of the original sump screen system, relocation of Trisodium Phosphate Dodecahydrate (TSP) baskets, and the removal or modification of other in-sump piping and supports. These included:

- Removal of the original sump screens and most of the original framing.
- Six of the TSP containers that were originally installed in the sump were removed and relocated to the recirculation trenches.
- Three sections of Safety Injection System Piping were rerouted and re-supported.
- The Reactor Drain Tank level instrumentation tubing, nitrogen and primary makeup water supply lines, and drain and vent lines were modified including supports as necessary.
- Modification of the gallery steel and supports at the 23 foot elevation and the removal of an unneeded pipe whip restraint.

FIGURE 3.j-1
UNIT 2 CONTAINMENT TRASH RACKS AND SUMP LOCATION

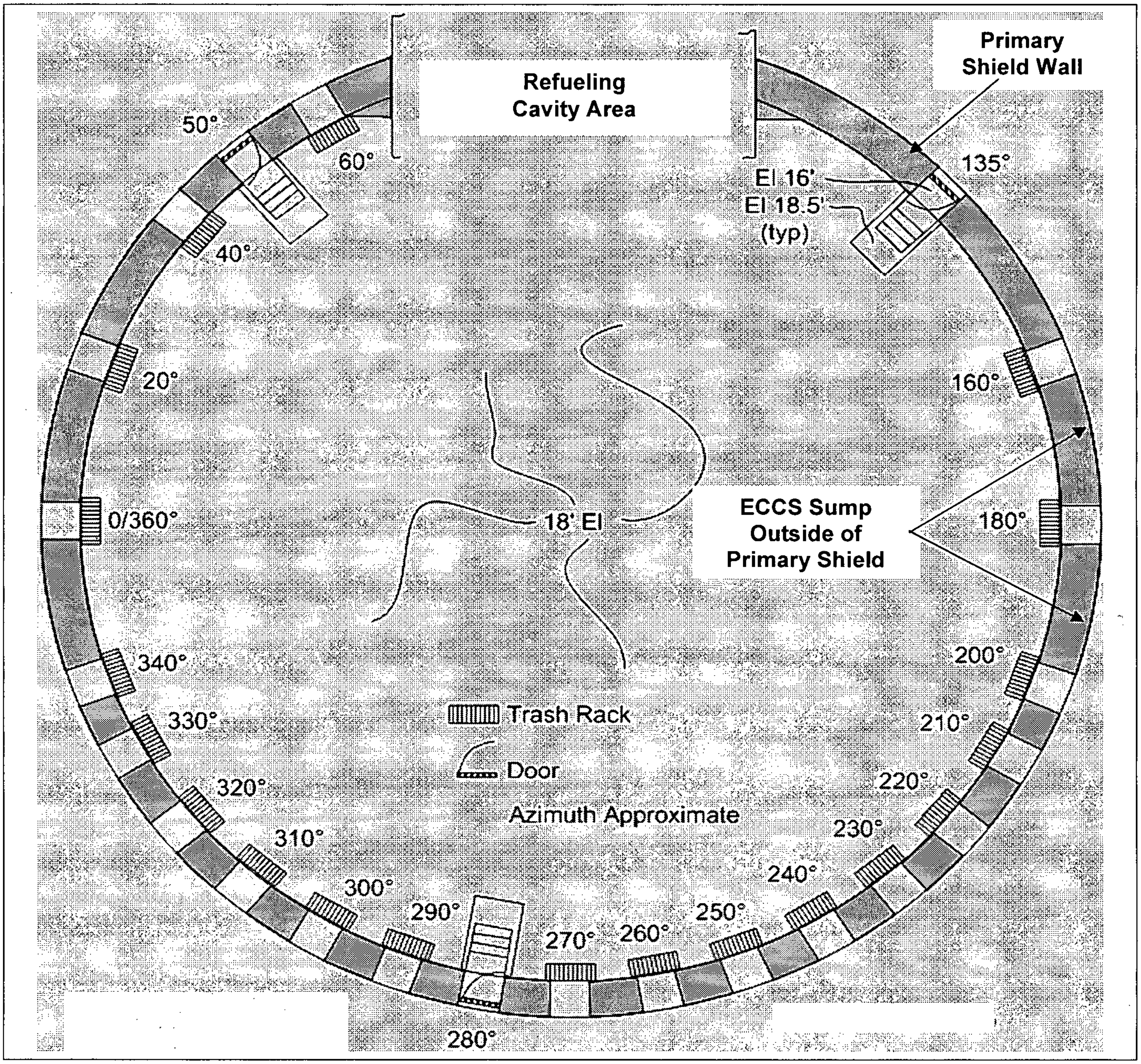


FIGURE 3.j-2
UNIT 2 CONTAINMENT RECIRC SUMP STRAINERS – TOP VIEW

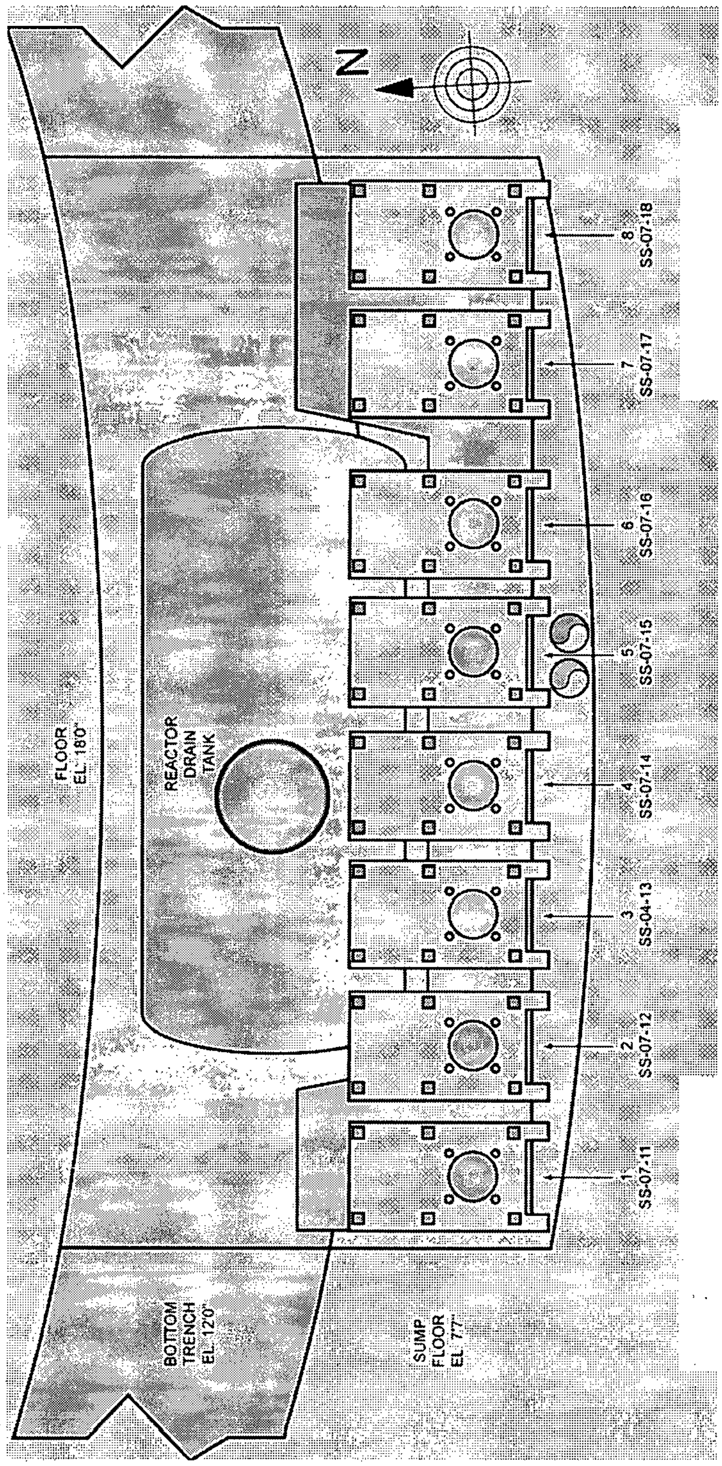


FIGURE 3.j-3
UNIT 2 CONTAINMENT SUMP STRAINER SYSTEM – SIDE VIEW

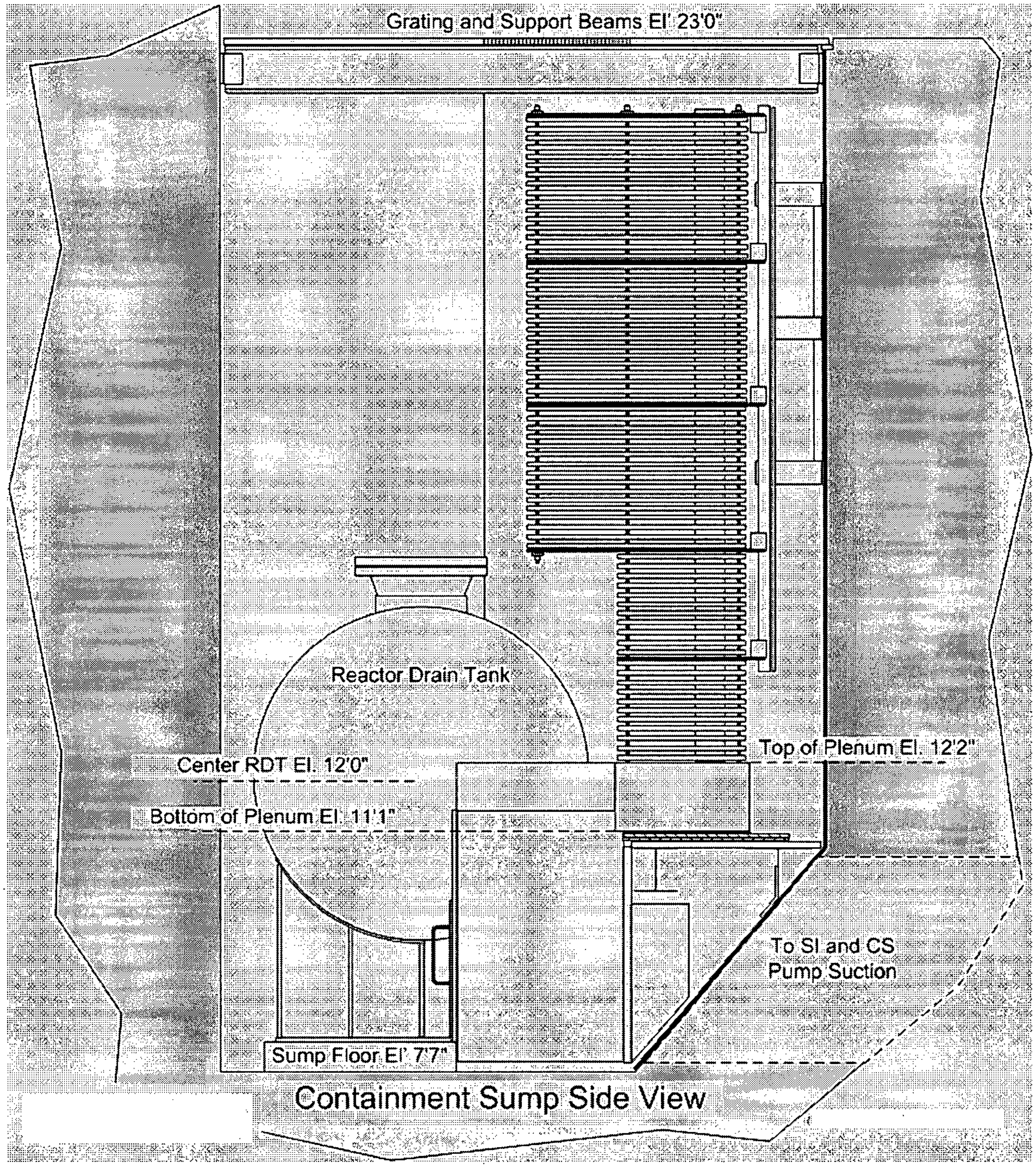


FIGURE 3.j.-4
UNIT 2 CONTAINMENT SUMP

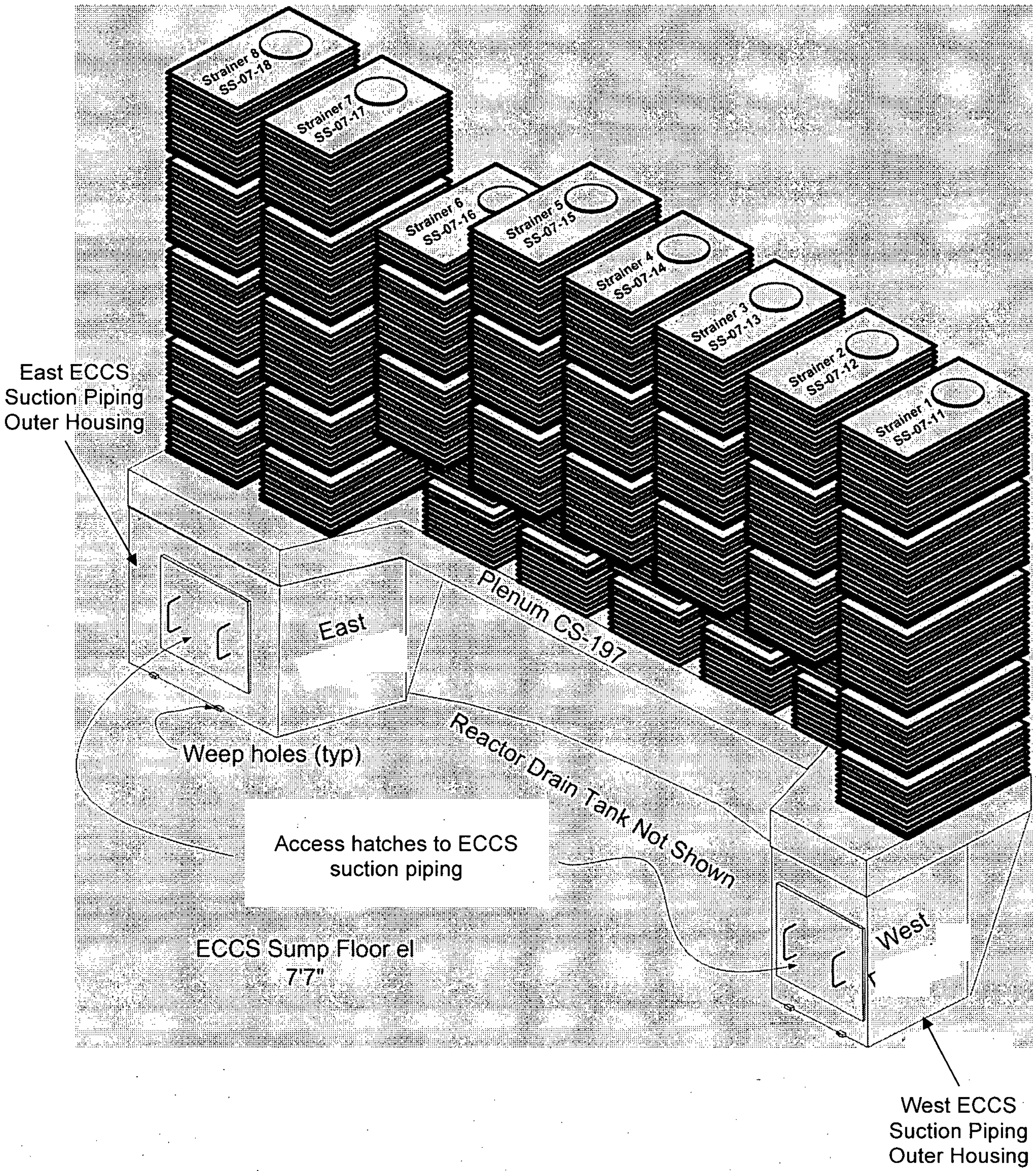
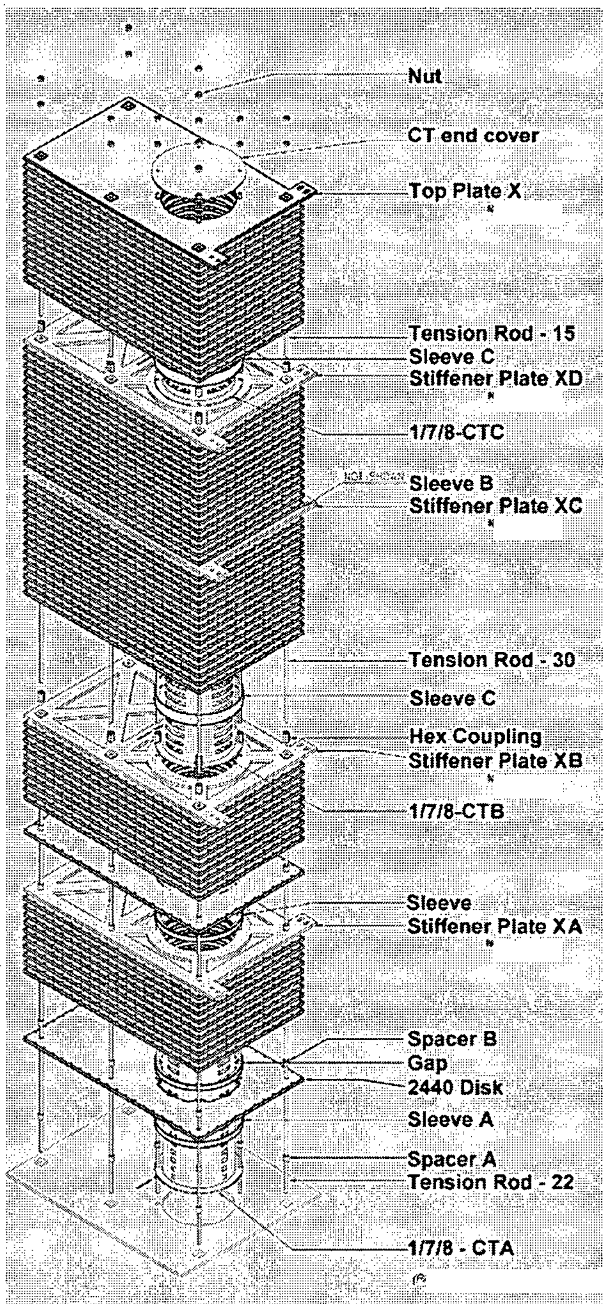


FIGURE 3.j-5
TYPICAL END STRAINER STACK



Topic 3.k: Sump Structural Analysis

FPL Response

A general description of the strainers is provided in Topic 3.j, *Screen Modification Package*. Figures 3.j-3 and 4 show the strainer stacks, lower plenum box and the east and west containment recirculation piping housings. The recirculation piping housings, some of the original supporting members, and new support bracing were used in the installation of the strainer system. The new plenum box and strainer stacks are supported by this original and reinforced portion of the structural steel. As discussed below in greater detail, for structural analysis, two separate problems were evaluated using the GTSTRUDL Code: 1) the strainer stacks and their attachment to side walls and top of the plenum, and 2) the plenum box and lower piping housings were analyzed together as one integrated plenum assembly, and this is referred to as such in the balance of this discussion.

Strainer Stack Analysis:

Each stack is essentially supported independently by the tube steel/angle iron supports and can be analyzed as an individual unit. Strainer Stacks #2 through #5 and #6 are all nearly identical overhanging strainer stacks, except that Stack #6 has five fewer disks. Hence, analysis of one of the other taller overhanging stacks bounds this stack. Stack #s 1, 7, and 8 are full stacks and are identical except for minor variances in the wall attachment assembly. As discussed below, two analyses were conducted, one for an overhanging stack and the second for a full stack.

The Strainer Assemblies are located outside of the concrete biological shield and are therefore not subject to pipe reaction forces or high energy line break jet loads from Reactor Coolant System or other ASME Code Class 1 piping. An evaluation of the ASME Code Class 2 and 3 piping in the general area of the strainers determined that there were no high energy line breaks that would result in a LOCA and require reliance on the strainer system. A two inch charging pump line that was located along the wall, did qualify as a high energy line. However, break cone analysis of the line shows no direct impact on the strainer assemblies. Hence, it was determined that the structural load analysis of the Strainer Assemblies did not require consideration for pipe reaction loads or high energy line jets. Since the strainer system is outside the biological shield wall and down in the containment sump, there is no potential missile hazard from pipe breaks.

It is further noted that the strainer assemblies are passive and do not employ mechanical or hydraulic cleaning or flushing following a LOCA, hence, there are none of these forces on the strainers.

The remaining potential loads for the Operating Basis Earthquake and Safe Shutdown Earthquake load combinations for the strainer system are provided in Table 3.k-1:

Table 3.k-1 Potential OBE and SSE Load Combinations

Load Combination	Loads	Allowable	Applicable Environmental Condition
LC1	D + L	1.0 S	Sump is dry or flooded
LC2	D + L + E	1.0 S	Sump is dry or flooded
LC3	D + L + T_o	1.5 S	Sump is dry or flooded
LC4	D + L + T_o + E	1.5 S	Sump is dry or flooded
LC5	D + L + T_o + E'	1.6 S	Sump is dry or flooded
LC6	D + L + T_a	1.6 S	Sump is dry or flooded
LC7	D + L + T_a + E	1.6 S	Sump is dry or flooded
LC8	D + L + T_a + E'	1.6 S	Sump is dry or flooded

D = Dead Weight Load component
L = Live Loads
T_o = Thermal loads at maximum normal operating temperature
T_a = Thermal loads at maximum accident design temperature
E = Operating Basis Earthquake loads
E' = Safe Shutdown Earthquake loads
S = The required section strength based on elastic design methods and the allowable stresses

Two load combination cases were analyzed in the GTSTRUDL strainer models to envelope the load combinations; an operating basis earthquake case and a safe shutdown earthquake case. Load Combination 4, LC4, bounds cases 1 and 3. In order to represent LC2 and LC4 in the calculations, the ratio of the yield stresses and water densities (at 80°F and 240°F) are used to calculate an allowable of 1.19 S. The use of this conservative Allowable and the LC4 load case in the strainer model runs conservatively bounds the service load conditions.

Load Combination 8, LC8, bounds the factored load conditions, cases 5 through 7, since it assumes higher temperature stresses and the earthquake stresses are higher than the operating basis earthquake. The resulting load combinations used in the analysis are provided in Table 3.k-2:

Table 3.k-2 OBE and SSE Load Combinations for GTSTRUDL Models

Load Combination	Loads	Allowable	Applicable Environmental Condition
LC4	$D + L_{deb} + L_{dp} + T_o + E_w$	1.19 S	Sump is submerged @ 120°F
LC8	$D + L_{deb} + L_{dp} + T_a + E'_w$	1.6 S	Sump is submerged @ 240°F

D = Dead Weight Load of strainer components
L_{deb} = Debris Weight Live Load
L_{dp} = Differential Pressure Live Load (across a debris covered strainer)
T_o = Thermal loads at 120°F
T_a = Thermal loads at 240°F
E = Operating Basis Earthquake loads
E' = Safe Shutdown Earthquake loads
S = The required section strength based on elastic design methods and the allowable stresses

The strainer components are designed to meet code acceptance requirements of the AISC Manual of Steel Construction, 9th Edition, or the ASME Boiler & Pressure Vessel Code, Section III, 1971 Edition including 1973 Addenda for stainless steel. Other design and code usage for strainer components includes:

Material Strengths at Elevated Temperatures: The material properties for stainless steel materials are used at elevated temperatures associated with the load combination and are taken from ASME B&PV Code, Section II, Part D, Material Properties, 1998 Edition.
Plenum Plates and Side Channels: Plate membrane stress and bending stress are evaluated following the more limiting allowable stress in AISC or NC-3821.5-1.
Stainless Steel Members in Compression: Allowable stresses for stainless steel members in compression are from ANSI/AISC-N690, and members in tension, shear, bending, or bearing are from AISC.
Strainer Perforated Plates: Equations from Appendix A, Article A-8000 of the ASME B&PV Code, Section III, 1971 Edition through Winter 1973 addenda (Ref. [3]) are used to calculate perforated plate stresses.
Disk Rims: The disk rim and the attached perforated plate work as a combined section to resist bending loads and are based on the design guidelines of SEI/ASCE 8-02 Standard for Cold-Formed Stainless Steel Structural Members.
Welds: Welds for non-pressure strainer support components are qualified per the AISC 9th Edition.
Rivets: Rivet capacities are based on testing, with a factor of safety calculated according to Standard SEI/ASCE 8-02 as supplemented by AISI Specification for the Design of Cold-Formed Steel Structural Members, 1996 Edition.
Mounting Hardware: The analysis and design of expansion anchors is in accordance with Florida Power & Light Specification C2.24, "Drill-in Expansion Anchors in Concrete St. Lucie Units 1 & 2 and Turkey Point Units 3 & 4," Revision 13 and FPL Standard STD-C-010, Appendix A, "Piping Seismic Analysis Methods", Revision 0.

A figure representing the models for a tall overhanging stack and a full stack are shown in Figure 3.k-1. Each stack is essentially supported independently by the tube steel/angle iron supports and can be analyzed as individual units. The disk faces, gap disks, gap rings, grill wire stiffeners, and end cover, are not included in the models (except for their mass).

The strainers were designed to a maximum crush pressure of 14 psid. The interaction ratios for the components in the models are provided in Table 3.k-3. The results of this calculation indicate the interaction ratios for the strainer assembly components are below 1.0, and that the strainers meet the acceptance criteria for all applicable loadings.

Table 3.k-3 Interaction Ratios for Strainer Assembly Components

Strainer Component	LC4-OBE	LC8-SSE
Intermediate Radial Stiffeners	0.57	0.72
Tension Rods	0.48	0.71
Spacers	0.97	0.97
Edge Channels	0.32	0.35
Core Tube (Biggest Holes)	0.07	0.09
Core Tube Mating Flange	0.09	0.13
Hex Couplings	0.07	0.07
Clip Angles	0.35	0.44
Vertical Angle Iron (support)	0.59	0.74
Tube Steel (support)	0.08	0.09
Disk Faces	0.60	0.52
Disk Rims	0.32	0.35
Wire Stiffener	0.46	0.50
Gap Disk (enveloping sleeve B)	0.12	0.11
Gap Disk stiffening ring	0.15	0.17
Sleeve C (enveloping sleeve A)	0.09	0.09
End Cover	0.12	0.13
Weld of Core Tube to Mating Flange	0.08	0.10
Weld of Tube Steel to Vertical Angle Iron	0.84	0.88
Weld of Tube Steel to Sump Wall Steel Plate	0.36	0.36
Clip Angle Bolts	0.07	0.13
Disk Face Rivets	0.17	0.18
Gap Disk Rivets	0.08	0.07
Sump Wall Steel Embedment Plate	0.47	0.75

Integrated Plenum Analysis:

A figure representing the model for the integrated plenum assembly is shown in Figure 3.k-2. The interaction ratios for the components in this model are provided in Table 3.k-4. The results of this calculation indicate the interaction ratios for the plenum components are below one, and that the strainers meet the acceptance criteria for all applicable loadings.

Table 3.k-4 Interaction Ratios for Plenum Assembly Components

Plenum Component	LC4-OBE	LC8-SSE
Channel Box Channels	0.62	0.66
Spacer Rods inside Plenum	0.19	0.20
Angle Framing	0.93	0.95
Support Plate Beams	0.16	0.33
W8x31, C.S.	0.07	0.18
Tube Steel Posts	0.04	0.09
Internal Pipe Posts	0.42	0.44
Stiffener Plates	0.90	0.94
Lower Internal C-shape Braces	0.31	0.32
Top Cover, Bottom Cover, Side Plates	0.83	0.92
Plenum Channel Web	0.53	0.59
Angle Local Flange	0.10	0.11
Plenum Channel Local Flange	0.31	0.31
Channel Splice Bolt	0.34	0.55
Channel Splice Weld & Plate	0.44	0.69
Channel Corner Welds	0.55	0.54
Cover Plate Bolts	0.95	0.93
Cover Plate Hole Patches	0.63	0.91
Support Plate Bolts	0.41	0.78
Stiffener Angle End Bolting	0.99	0.96
Tube Steel End Welds	0.12	0.18
Support Plate-to-Plate Welds	0.28	0.35
Angle-to-Channel Welds	0.36	0.34
Channel Brace-to-Angle Welds	0.45	0.44
Corner Angle to Lower Angle Weld	0.34	0.35
Horizontal Angle to Angle Weld	0.78	0.76
Vertical Angle at Ledge to Lower Angle Weld	0.15	0.14
Stiffener Angle to Plate Weld	0.43	0.39
Stiffener Plate to Plate Weld	0.38	0.35
Plenum Flow Deflector	0.40	<0.4*
Concrete Expansion Anchors 1a	0.19	0.73
Concrete Expansion Anchors 2	0.20	0.49
Embedment Plate W2 on Ledge	0.23	<0.23*
Corner Angle / Bolt at Ledge	0.53	0.64
Embedment Plate South Wall	0.13	0.42
WT6x13.5, C.S., Existing	0.23	0.36

*Note: Interaction Ratio due to load case LC8-SSE is less than that due to LC4-OBE for these components

A special outage maintenance procedure is in place at St. Lucie Unit 2 to assure that the strainer system and trash racks are inspected. The procedure addresses carefully accessing the sump area, installing railings on the upper deck of the Reactor Coolant Drain Tank, conducting initial and final inspections of the strainer system hardware and the trash racks. The procedure also calls for the installation of a temporary protective cover over the strainers at the beginning of the outage and the removal of the cover prior to startup. A final inspection of the strainer system components and the trash racks is conducted prior to startup. As discussed in the procedure, any damage observed on the strainer system components or the trash racks is reported for evaluation and repair via Condition Reports.

FIGURE 3.k.-1
Strainer Stacks #4 and #7 GTSTRUDL Models

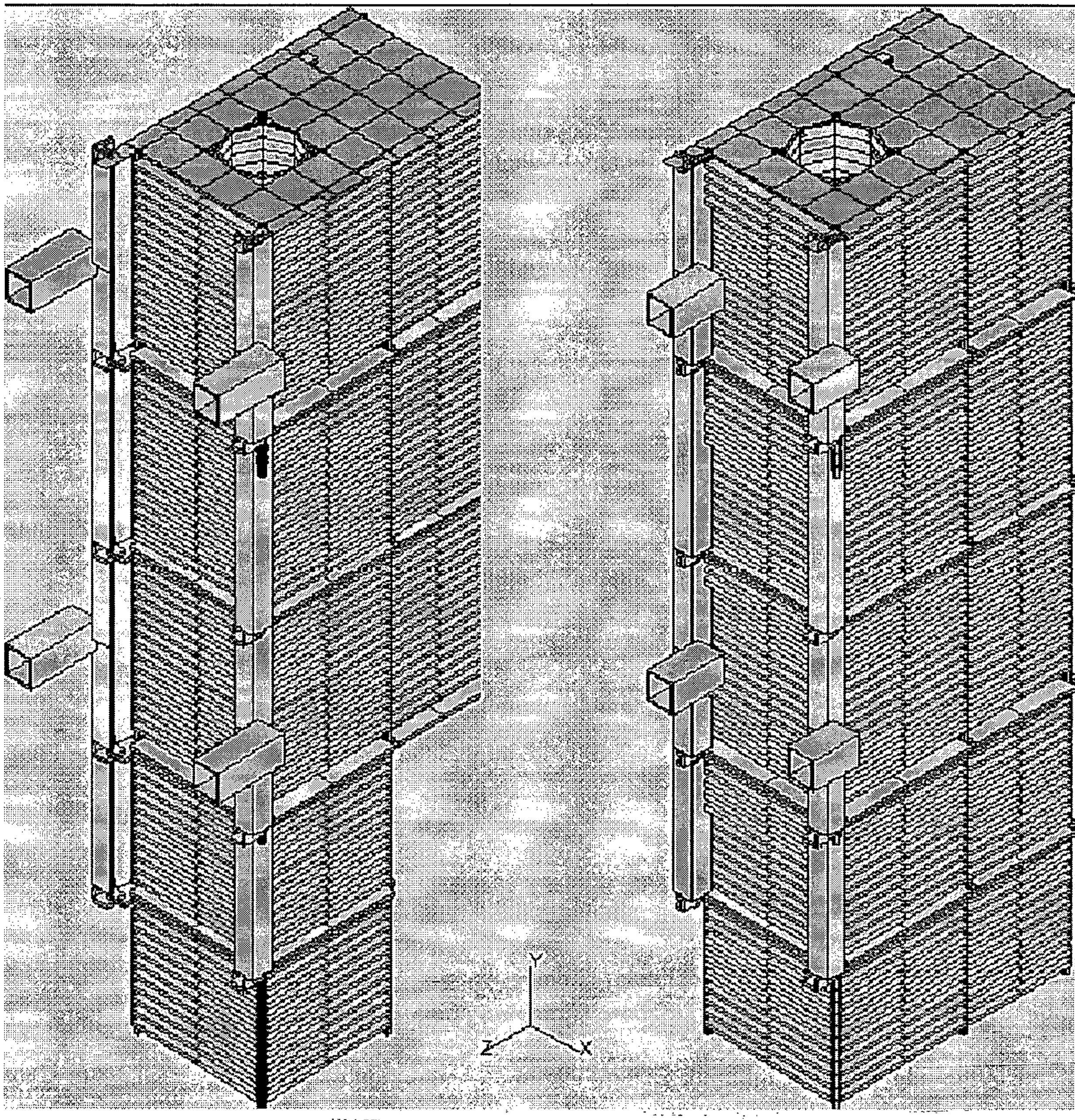
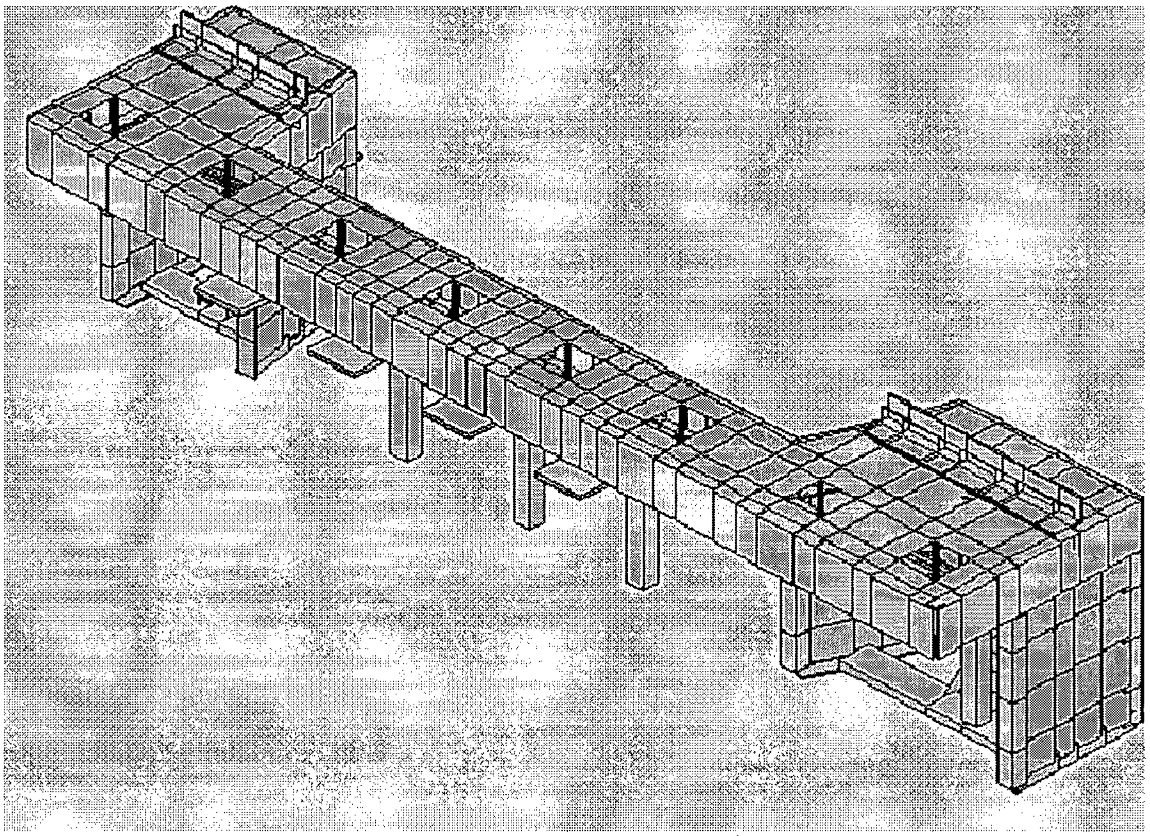


FIGURE 3.k.-2
Integrated Lower Plenum GTSTRUDL Model



Topic 3.l: Upstream Effects

FPL Response

[RAI 42] In the September 1 St. Lucie submittal it was noted that it was planned to obtain additional confirmation that there are no chokepoints. This confirmation was obtained from a walkdown that was conducted in the St. Lucie Unit 2 containment specifically to evaluate recirculation flow paths. The walkdown utilized the guidance in Nuclear Energy Institute (NEI) Report 02-01, NEI Report 04-07, and the Staff's SE of NEI 04-07.

As shown in Figure 3.j-1, there are 20 trash racks located at the biological shield wall on the 18 feet elevation. ECCS flow from an RCS break would travel through these racks and dump into the recirculation trench that has a bottom elevation of approximately 12 feet. The trash racks prevent large debris from entering the recirculation trench and transporting to the recirculation sump screens. The newly installed strainer system is open to the trench on both ends of the containment recirculation sump. The openings in the trash racks between the steel bars are approximately ¾ of an inch. A photo of typical trash racks at St. Lucie Unit 2 is shown in Figure 3.l -1. Similar structures are also utilized at the stairwell openings in the shield wall. A calculation was performed which estimated the flow rate, from the 18 foot elevation through the trash racks, at approximately 0.04 ft/sec. At this low flow rate it would be difficult for large debris to even reach the trash racks. Because of the large size of the racks, the low approach velocity, the quantity of them, and the relatively large size of the openings between slats, debris could not fully block all of the trash racks and prevent the flow of water past the shield wall into the trench.

Further, in the long term recirculation mode, only one CSS pump would be operating and much of this spray flow would enter the trench and sump from the 23' floor elevation outside of the bioshield wall, bypassing the trash racks. Hence, for long term cooling out of the break location, flows across the18 feet floor elevation would be limited to the HPSI pumps and a portion of one CSS pump. With a sump level for the large break LOCA at the 23.58 feet elevation, flow into the recirculation trench is not expected to be impeded at the trash racks. Large debris would likely gather at the bottom of the trash racks, allowing continued flow through the higher part of the racks.

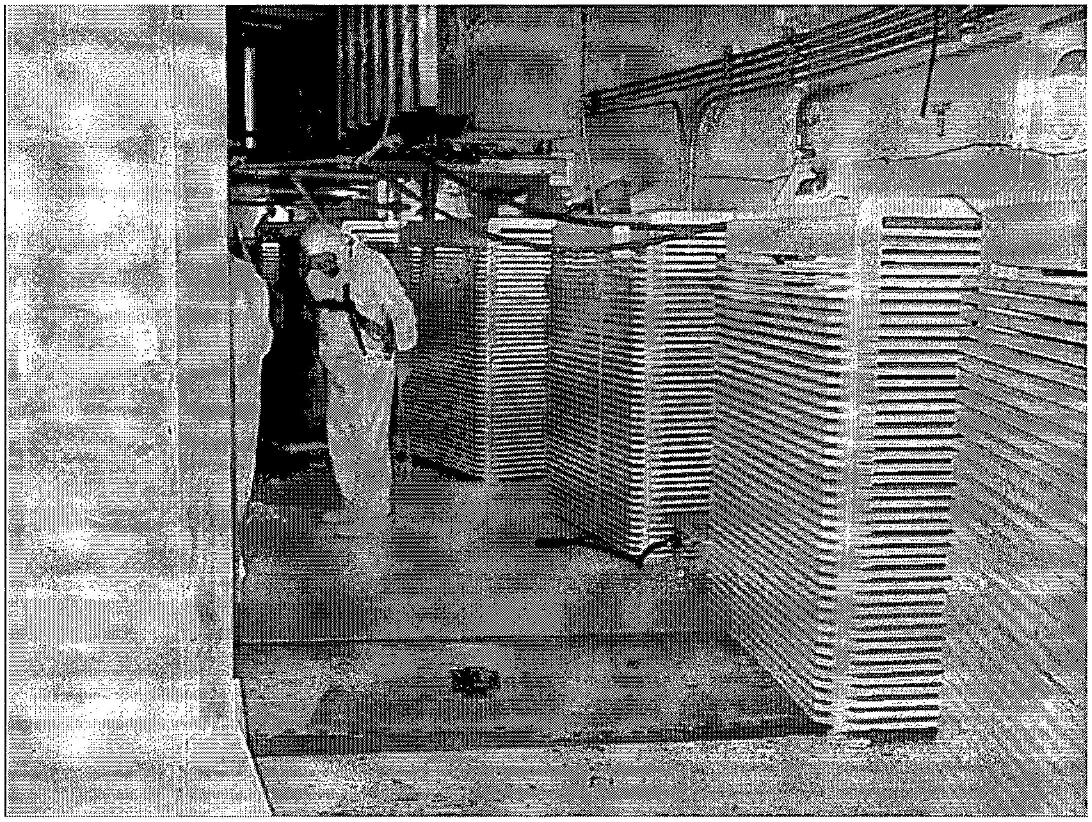
The walkdown also noted a second potential chokepoint in the recirculation trench near azimuth 225, which has a significant amount of piping, valves and pipe support. This region would be susceptible to clogging from large debris pieces. Since the trash racks inside the bioshield wall will remain unaltered, the recirculation trench is protected from large debris intrusion and is not a chokepoint.

[RAI 38] The information obtained during the walkdown confirms that water will not be held up by chokepoints or otherwise prevented from reaching the containment recirculation intakes via the strainer system. Special attention was paid to the fuel transfer canal, which is drained by two 6-inch nominal diameter pipes. These pipes are oriented horizontally with the bottom of the pipe approximately 3 inches above the transfer canal floor. They are not screened or capped. Because of the size and orientation of these drain pipes they will not create a chokepoint that would retain water in the fuel transfer canal. However, because the pipes are 3 inches above the floor, it is assumed that the water below 3 inches is held up and does not reach the sump.

Other specific NEI and NRC recommendations that were addressed in the walkdown are itemized below:

- All passages have sufficient flow clearances such that chokepoints are not expected.
- Curbs and ledges within the flow paths were found to be unable to retain water from returning to the sump area. Curbs at upper elevations had at least one open side to allow the free flow of water to the ground floor.
- No potential chokepoints were observed at upper elevations, including floor grates, which would be expected to retain fluid from reaching the containment floor.
- The containment floor was surveyed for chokepoints formed by equipment, components and other obstructions. Where equipment congestion did occur, other flow paths were available so as to not restrict water transport.
- New scaffold and lead blanket storage boxes installed on the 23' elevation are expected to have no significant impact on flow modeling and do not create any new chokepoints due to their location and construction.
- The ECCS trench contains a significant amount of piping and pipe supports in some areas. Since the trench is protected from the intrusion of large debris by the trash racks on the 18' elevation, the trench will not be a choke point. There is also a direct flow path from the inner annulus via a portal directly into the sump and grated areas above the sump from the 23' elevation.

FIGURE 3.I-1
Photo of Typical Trash Racks at the 18 foot elevation



Topic 3.m: Downstream Effects – Components and Systems

FPL Response

In the September 1 response it was noted that, at that time, the downstream evaluations identified instrumentation and six (6) components that required further evaluation. Subsequently, as described in Topic 3.j., the strainer opening size has been reduced from an assumed square opening of 1/8th-inch by 1/8th-inch (diagonal dimension of 0.177-inch) to an actual round opening of 1/16th-inch diameter (0.0625-inch). In addition, the HPSI pump seal water cyclone separators have been removed and the seals replaced, and the CSS pump seal water cyclone separators have been removed and the seals replaced.

[RAI 31] The analysis of downstream effects at St. Lucie Unit 2 has been completed and primarily follows that set forth in WCAP-16406-P, Revision 1. A summary of the application of those methods is provided below with a summary and conclusions of the downstream effects calculations performed. Any exceptions or deviations from the NRC-approved methodology are noted below. The methodology, summary, and conclusions are provided as related to downstream component blockage and wearing, the subjects addressed by Topic 3.m.

Blockage/Plugging of ECCS and CSS Flowpaths and Components

GL 2004-02 Requested Information Item 2(d)(v) addresses the potential for blockage of flow restrictions in the ECCS and CSS flowpaths downstream of the sump screen, while item 2(d)(vi) refers to plugging of downstream components due to long-term post-accident recirculation. The difference in requirements is that the instantaneous blockage of a flow restrictions due to the maximum debris size that pass the recirculation sump filtration system, or the gradual build-up of any size debris resulting in plugging of downstream components long-term. The evaluations performed for downstream components at St. Lucie Unit 2 considered both blockage and plugging as required for a particular component type, although the terminology was used interchangeably in the evaluations. The following summarizes the evaluation of downstream components that was performed at St. Lucie Unit 2, using the blockage and plugging terminology consistent with the GL 2004-02 Requested Information Item.

As part of the resolution for GSI-191, the existing sump screen system was removed and replaced with PCI strainer structure composed of vertical strainer stacks resting on a plenum assembly. Following the installation, the nominal strainer opening size has been reduced from a 0.09" nominal square opening to a nominal round opening of 1/16-inch diameter (0.0625 inch). The new strainer system is described in the response to NRC Topic 3.j, *Screen Modification Package*.

GL 2004-02 Requested Information Item 2(d)(v) requires that the licensee state "the basis for concluding that adverse gaps or breaches are not present on the screen surface." The inspection procedure to ensure that adverse gaps or breaches are not present on the screen surface is described in NRC Topic 3.i, *Debris Source Term.*

WCAP-16406-P Section 5.5 provides assumed particle dimensions for recirculation debris ingestion based on sump screen hole dimensions. Rather than the WCAP-16406-P suggested asymmetrical dimensions, the St. Lucie Unit 2 downstream components were analyzed for blockage based on a maximum 0.100 inch spherical particle. The actual maximum spherical size particulate debris that can pass through the strainer system and into the ECCS and CSS recirculation flowpaths is documented as 0.06875 in.

All ECCS and CSS downstream components that see active flow during recirculation (including control valves, orifices, flow elements, containment spray nozzles, and heat exchanger tubes) were analyzed for blockage due to this maximum particulate debris size. All flowpaths that could see recirculation flow per the plant design basis were considered. In accordance with the WCAP-16406-P methodology, the minimum clearance dimension within the component was checked to ensure it is larger than 0.100 inch. The results of that analysis are summarized below. Where necessary, low-flow components and piping were analyzed for plugging due to settling, as described below. Finally, static instrument sensing lines, relief valves, and check valves required to close during recirculation were analyzed for potential debris interference as discussed below.

Control Valves

WCAP-16406-P Section 7.3 lists possible failure modes for valve types that can be expected in the recirculation flowpaths. The SER Section 3.2.5 notes that this list is comprehensive and acceptable for general use, but notes that it is not all-inclusive. In accordance with the SER recommendation, all valves in all possible recirculation flowpaths were considered and found to be of standard types as listed in WCAP-16406-P Section 7.3. Every recirculation control valve was compared to the general criteria in WCAP-16406-P Table 8.2-3; any valve requiring further evaluation for plugging per WCAP-16406-P Section 8.2.4 was identified, including all throttled valves (globe, needle, and butterfly) and globe and check valves less than 1.5 inch nominally. The minimum flow clearance through these valves was determined from vendor drawings, and for any throttled valves based on the subcomponent dimensions and lift settings. This minimum flow clearance was compared to the cross-sectional area of a 0.100 inch sphere to ensure that blockage would not occur. The WCAP-16406-P does not require analyzing valves for debris settling. In general, control valves see higher flow velocities then the pipe leading to them, and therefore the valves were not checked for debris settling where the pipe velocity was sufficient (see below).

Root valves and other valves in static instrument sensing lines were analyzed with those instrument lines as discussed below. Relief valves were analyzed for interference as discussed below. Check valves that open but then may require closing during recirculation were also checked for possible interference issues as identified in WCAP-16406-P Table 7.3-1. This could occur where low flow causes debris settling around the valve seat while open, and then the debris prevents proper closure when the check valve should close. In accordance with WCAP-16406-P guidance, a flow velocity of 0.42 ft/s was considered sufficient to prevent debris settling and thereby preclude interference with proper valve closure. The flow velocity for settling was determined from the larger flow area of the nominal pipe size leading to the valve.

Because all flow clearances were sufficiently large to preclude blocking and flow velocities are fast enough to preclude plugging and interference, all control valves at St. Lucie Unit 2 were found to be acceptable with respect to blockage and plugging during recirculation. Again, relief valves and instrumentation root valves were addressed separately as discussed below.

Relief Valves

Relief valves on the recirculation flow paths were also considered for interference issues. Here, the maximum pressure in the primary line during recirculation operation was conservatively determined based on maximum containment pressure, pump shut-off heads, and no line losses. Where the relief valve set pressure was higher than this pressure, it was determined not to open during recirculation and therefore debris interference was not an issue. If a relief valve could potentially open, then blockage and the effects of debris interference with closure would be considered. This was not applicable to St. Lucie Unit 2 because all relief valves were found not to be subject to opening during recirculation.

Heat Exchangers

All heat exchangers that see recirculation flow were also considered for blockage and plugging. This included both the major heat exchangers as well as those in the pump seal subsystems that see debris-laden flow. In accordance with WCAP-16406-P Section 8.3.1, the inner diameter of tubes was compared to the maximum assumed particle size. In accordance with the SER Section 3.2.6, the heat exchanger tubes were also checked for plugging due to settling within the tubes, by comparing the minimum average flow velocity in the tubes to the WCAP-16406-P settling velocity (0.42 ft/s). All heat exchangers were found to be acceptable with respect to blockage and plugging.

Orifices, Flow Elements, Spray Nozzles

All orifices, flow elements, and spray nozzles in the ECCS and CSS recirculation flowpaths were checked for blockage. In accordance with WCAP-16406-P Section 8.4, the minimum flow clearance of each was compared to the maximum assumed particle size. All orifices, flow elements, and spray nozzles were found to be acceptable with respect to blockage. The WCAP-16406-P does not suggest analyzing orifices, flow elements, and spray nozzles for debris settling. In general, orifices, flow elements, and spray nozzles see higher flow velocities then the pipe leading to them, and therefore were not checked for debris settling where the pipe velocity was sufficient (see below).

Instrumentation Lines

All instrumentation branch lines on the ECCS and CSS recirculation flow paths were analyzed for blockage and plugging. WCAP-16406-P Section 8.6 generically justifies static flow (water-solid) sensing lines on the basis of minimum expected flow velocities compared to debris settling velocities. However, the St. Lucie Unit 2 review of instrument lines was plant specific. First, the actual orientation of each instrument line was determined. Water-solid sensing lines oriented horizontally or above are considered not susceptible to debris settling into the lines. For any instrument lines oriented below horizontal, the actual minimum flow velocity through the header line at the point of the branch was determined. This velocity was compared to the WCAP-16406-P bounding settling velocity of 0.42 ft/s, as opposed to the lower debris-specific settling velocities listed in WCAP-16406-P Table 8.6-1. This approach is consistent with the recommendation of the SER to WCAP-16406-P. All sensing lines were found to be acceptable with respect to plugging due to debris settling. Because the lines are water-solid, they are not susceptible to direct blockage due to large debris flowing into the lines.

Any sampling lines on the ECCS and CSS recirculation flowpaths that are required by plant procedure to be used post-accident were also considered. The sampling lines were analyzed as any other flow path when opened to take a sample; blockage and plugging of the tubing and each component was considered. The orientation of each sampling line was also checked, like an instrument line, to ensure it was not susceptible to settling of debris into the line when water-solid. All sampling lines were found to be acceptable.

Per the guidance of WCAP-16406-P Section 8.6.10, the St. Lucie Unit 2 RVLIS design was compared to the generic designs reviewed and deemed acceptable by the WCAP-16406-P. The plant design was found to be consistent, and therefore it is expected to be acceptable with regards to recirculation operation. However, the SER Section 3.2.6 notes that "evaluation of specific RVLIS design and operation is outside the scope of this SE and should be performed in the context of a licensee's reactor fuel and vessel evaluations." This is discussed in Enclosure 3, L &C 19.

Piping

The WCAP-16406-P does not require evaluation of piping for potential blockage or plugging. However, in accordance with the SER Section 3.2.6, ECCS and CSS system piping was evaluated for potential plugging due to debris settling. As stated above, control valves in the ECCS and CSS lines were checked to ensure debris settling does not interfere with valve movement. The valves were checked using the flow area of the pipe in which the valves are installed. Therefore, the evaluation, for control valves was used to validate that settling will not occur in the system pipes generally. It was verified that the analysis of control valves included valves in all lines in the ECCS and CSS used for recirculation, so that local flow velocities of the various line sizes and flow rates in the St. Lucie Unit 2 ECCS and CSS were all considered. As with other settling reviews, the minimum expected system flow rates in each line were used to minimize the flow velocity. The average velocity was determined for each pipe size based on the specific flow rate in that line and compared to the bounding settling velocity of 0.42 ft/s. All valve locations, and therefore all lines, were found acceptable with respect to plugging. Piping was not considered specifically for blockage because flow restrictions in the lines are more limiting with respect to minimum flow clearance.

Pumps

The WCAP-16406-P addresses two concerns with regard to debris blockage or plugging. First, Section 7.2 states that debris in the pumped flow has the potential of blocking the seal injection flow path or limiting the performance of the seal components due to debris buildup in bellows and springs. A review of the St. Lucie Unit 2 ECCS and CSS pump seals in accordance with the WCAP-16406-P methodology determined that all of the pumps have seal piping arrangements which preclude the injection of debris laden post-LOCA fluids into the seal cavity chamber so that sump debris will not enter the seal chamber and will not impact the operation of seal internal components. The St. Lucie Unit 2 HPSI and CSS pump seals previously had a seal cooling system relying on process water with a cyclone separator. Consistent with WCAP-16406-P guidance as augmented by the SER Section 3.2.5, a plant-specific review of pump operation determined that a water seal system that utilizes recirculated seal cavity fluid was preferable to the use of injected process fluid and was subsequently installed. Further, the SER Section 3.2.6 disagreed with a WCAP-16406-P statement that seal failure due to debris ingestion is considered unlikely, because the WCAP-16406-P statement was founded upon only a single test. However, since the St. Lucie Unit 2 pump seals use only recirculated seal cavity fluid in the spring and bellow areas of the seal that were identified as a concern, the SER

Section 4.0 limitation expressing concern with this WCAP-16406-P statement is not applicable. Otherwise, the SER endorses the mechanical seal analysis recommended by the WCAP-16406-P with respect debris interference. The LPSI pumps were not analyzed for blockage or plugging because they are not utilized during the recirculation phase of ECCS operation at St. Lucie Unit 2.

WCAP-16406-P Section 7.2.3 further states that running clearances of 0.010 inch on the diameter could be clogged when exposed to pumpage with 920 PPM and higher debris concentration from failed containment coatings. It states that as a consequence of the clogging, a packing type wear pattern was observed on the rotating surface. This clogging of running clearances creates asymmetrical wear, but was not identified as having a negative impact on pump performance aside from increased wearing (which was considered as discussed below). Also, the WCAP-16406-P states that shaft seizure due to packing debris build-up is unlikely. The SER Section 3.2.5 also endorses this WCAP-16406-P guidance.

No other areas of concern for debris plugging or blockage within ECCS and CSS pumps were identified by either the WCAP-16406-P or the SER. Wear analysis of the pumps due to debris-laden water in close-tolerance running clearances, including packing type debris build-up, was considered as discussed below.

Conclusion (Blockage/Plugging)

As summarized above, analysis of all lines and components in the recirculation flowpaths at St. Lucie Unit 2 determined that there is no potential for either debris blockage or long-term plugging, which would threaten adequate core or containment cooling.

Wearing of ECCS and CSS Recirculation Flowpath Components

GL 2004-02 Requested Information Item 2(d)(vi) concerns excessive wear of ECCS and CSS recirculation components due to extended post-accident operation with debris-laden fluids. All ECCS and CSS downstream components that see active flow during recirculation (including pumps, control valves, orifices, flow elements, containment spray nozzles, piping, and heat exchanger tubes) were analyzed for wear due to an analytically determined bounding debris load for the full recirculation mission time. All flowpaths that could see recirculation flow per the plant design basis were considered.

The evaluation of long-term wearing of ECCS and CSS recirculation components was performed for a 30-day period following initiation of recirculation post-LOCA. The 30-day period is consistent with the SE of NEI 04-07, WCAP-16406-P, and the St. Lucie Unit 2 UFSAR. All components were analyzed for a full 30 days of operation, unless plant specific procedures and system configurations established a shorter maximum duration of operation. WCAP-16406-P Section 4.2 provides guidance for reducing mission times outside of plant licensing basis for components that are predicted to fail due to recirculation wear. However, consistent with SER Section 3.2.2, only plant-specific component mission time input in accordance with design and licensing basis was utilized for any deviation from a 30-day mission time, and only existing design basis hot-leg recirculation methods were credited. The following summarizes the evaluation of downstream components that was performed at St. Lucie Unit 2.

Debris Concentration and Size Distribution

The St. Lucie Unit 2 debris concentration and size distribution for downstream effects wear was calculated based upon the methodology provided by WCAP-16406-P, except as otherwise noted.

The total debris load was determined for a bounding LBLOCA in accordance with NEI 04-07. A minimum sump water volume for recirculation was determined for a SBLOCA to maximize the debris concentration in containment. All debris was assumed to be in the sump pool and eroded (to the extent it would be after 30 days) at the start of recirculation. Only RMI and fiberglass insulation (Nukon) were categorized as fines versus debris too large to pass the strainer; this categorization was based on industry experimental data. All other debris was assumed to be entirely fines, capable of passing the strainer unless its final eroded size is larger than 0.100 inch based on a detailed size distribution described below (see above regarding debris size assumed to pass through the strainer). Based on these inputs, the initial debris concentration at the start of recirculation was calculated.

The debris concentration was then depleted over the recirculation mission time in accordance with the methodology presented in WCAP-16406-P Section 5. For the purposes of debris depletion, only latent particulate debris, Foamglass, Cal-Sil, and unqualified coatings were size distributed. The Cal-Sil and latent debris size distributions were calculated from industry data, and Foamglass was assumed to have a similar distribution to Cal-Sil. The distributions were calculated based on empirical data and for the specific debris types at St. Lucie Unit 2, but the distribution was not based on plant-specific testing. For unqualified coatings, the size/mass distributions of the WCAP-16406-P were used. Qualified coatings were taken to fail entirely to 10 micron spherical particulate, which is consistent with the WCAP-16406-P as amended by the SER Section 3.2.15 since a fibrous thin-bed was substantiated. The particulate debris distribution (in addition to reducing the amount of debris assumed to initially pass the strainer, as discussed above) was utilized to deplete the particulate over time due to settling in the reactor vessel. Consistent with the WCAP-16406-P guidance, the particulate debris size subject to vessel depletion was calculated for each debris type based on force balance methods using a maximum core flow rate (cold leg recirculation for a hot leg break) to minimize debris settling. All particulate debris was assumed to be spherical for determination of settling size, debris smaller than the calculated size for a given type was taken to remain in solution throughout recirculation. The depletion coefficient for depletable particulate was calculated according to WCAP-16406-P Section 5.8 based on plant specific inputs for conditions to minimize depletion.

Two deviations were taken from the WCAP-16406-P approach with respect to fibrous debris depletion. First, all fiber was assumed to be depletable and no fibrous debris is too small as to remain in solution. Second, in lieu of the 95% fiber capture efficiency for the strainer suggested by WCAP-16406-P or an empirically determined fiber capture efficiency as stated by the SER Section 3.2.17, the strainer capture efficiency was calculated based on an equation originally found in Draft Rev. 0 of the WCAP-16406-P. This resulted in a conservative strainer capture efficiency of only 59.75%. However, in all cases, the depletion coefficient used for the fibrous debris was the SER and WCAP-16406-P agreed conservative value of (λ = 0.07/hr or half-life of 10 hours).

For analysis of abrasive wear (pump moving parts), the debris was further categorized based on the size distribution of particulate debris as erosive versus abrasive debris. All fibrous debris was assumed to be large enough to be abrasive. For particulate debris, a modification to the WCAP-16406-P methodology was used to refine the distribution of abrasive versus erosive debris. While the WCAP-16406-P considers 50 microns to be the constant threshold for abrasive debris (which is equal to 2.5X the wear ring gap of the hypothetical pump considered therein), St. Lucie Unit 2 used 2.5X the actual wear ring gap at any given time to define the threshold for abrasive-sized particulate. In other words, as the wear ring gap opens, the abrasive debris is reduced. However, the amount of abrasive debris that was reduced was then taken to contribute to erosive wear.

The calculation of erosive wear considered the effect of small particulates. Credit was taken for reduced erosive wear in accordance with the Hutchings Summation methodology presented in WCAP-16406-P Appendix F. The Hutchings Summation was conservatively calculated based upon the particulate distribution discussed above.

The time-dependent debris concentration calculated according to the above methodology was then utilized for the calculation of wear on all ECCS and CSS recirculation components. The calculation of wear for each type of component, including the effect of the wear on component performance, is summarized below.

Pumps

The ECCS and CSS pumps were analyzed for wear in general accordance with the methodology presented in Sections 7.2 and 8.1 of WCAP-16406-P. The depleting abrasive and erosive debris concentrations as discussed above were a primary input of the analysis.

For all pumps, the wear rings were assumed to have a starting gap equal to the midpoint of the wear ring acceptability range prescribed by the pump manufacturer. All wear rates were calculated specifically for each St. Lucie Unit 2 pump based on actual pump dimensions, materials, and operating speeds, and the debris concentration at a given time (the generic wear rates determined in the WCAP-16406-P were not applied). The wear analysis considered the combined effect of abrasive wear due to larger debris and debris packing, and erosive wear due to smaller debris (as defined above). The wear rate at each hour was numerically integrated to determine the total material wear following the recirculation mission time.

Pump wear analysis considered the combined effect of abrasive wear due to larger debris, and erosive wear due to smaller debris (as defined above). In accordance with WCAP-16406-P Appendix Q and the SER Section 3.2.23, a penalty was applied to the debris concentration wear rate because the total concentration of abrasive particulates and fibrous debris exceeds 720 PPM. A conservative deviation from the WCAP-16406-P approach was made in that all debris large enough to be abrasive was considered to wear equally, as opposed to the WCAP-16406-P approach of taking coatings as softer. In accordance with the SER Section 3.2.23, the ratio of abrasive to fibrous debris was verified as less than 5 to 1.

The single-stage CS pumps were analyzed for symmetrical wearing of the inboard and outboard wear rings (no "suction multiplier" was applied). The single-stage LPSI pumps were not analyzed for wear because they are not utilized during the recirculation phase of ECCS operation at St. Lucie Unit 2. Packing-type wear was not applied to the single-stage pumps, in accordance with the WCAP-16406-P. The total material wear after the recirculation mission time was then used to determine the final wear rings gaps for the suction and discharge side.

The change in gap was used to evaluate the impact on pump hydraulic performance per the approach of WCAP-16406-P Section 8.1. The discharge head following 30 days of wear was determined to be acceptable for the CS pumps. Per WCAP-16406-P Section 8.1.4, no vibration analysis was performed for single-stage pumps. The mechanical seals were evaluated for debris interference concerns as discussed above.

The multistage HPSI pumps were also analyzed for concurrent abrasive and erosive wear. Here, however, packing-type abrasive wear was found to be more limiting than free-flowing abrasive wear. Therefore, the HPSI pumps were analyzed according to the Archard wear model presented by WCAP-16406-P Appendix O. For inputs into the Archard wear equation, the pressure drop across the wear rings was calculated for the actual St. Lucie Unit 2 pumps based on actual pump head at the expected recirculation flow rate, actual pump (subcomponent) dimensions were used, the eccentricity was assumed maximum, and the wear coefficient was taken as the bounding of the range provided by the WCAP-16406-P. The packing was assumed to occur immediately upon pump recirculation initiation, and to continue until a wear ring gap of 50 mils was attained, at which point the packing at each discharge-side wear ring was assumed to expel, in accordance with the WCAP-16406-P methodology. If the expulsion of the packing occurred prior to the end of the analyzed mission time, the wear of the discharge side wear ring was analyzed for continuing abrasive and erosive wear (free-flow) until the end of the mission time. The suction-side wear rings were taken to wear asymmetrically as a result of the packing-wear on the discharge side, and were analyzed using a suction multiplier of 0.205, per PWR Owners Group document OG-07-510.

The final wear ring gap of the suction and discharge sides after the recirculation mission time was then utilized to perform hydraulic and vibration analyses of the multistage pumps. Based on the pumps' starting discharge head (per IST history) and the acceptable range, the discharge head following 30 days of wear was determined to be acceptable for the HPSI pumps. The shaft centering load (Lomakin effect) method in WCAP-16406-P Appendix O was used to evaluate the HPSI pumps for vibration failure due to wear. In order to maximize vibration, the centering load was maximized by assuming a minimum friction coefficient, maximum eccentricity, and also maximized in relation to C_d (diametric clearance) and f (friction coefficient). Again, the wear ring pressure drop was calculated based on actual pump head at the expected recirculation flow rate. The resulting shaft stiffness based on the centering load and wear ring gap was calculated using the suction and discharge side wear ring gaps following 30 days of wear. The stiffness was compared with the stiffness that would result from doubling the manufacturer's allowable wear ring gap (symmetric wear acceptability criterion from WCAP-16406-P). The shaft stiffness of the HPSI pumps under asymmetric wear was found to be greater than this acceptance criteria, and therefore the HPSI pumps were determined to be acceptable with respect to vibration. The mechanical seals were evaluated for debris interference concerns as discussed above.

Non-mechanistic failure of an ECCS or CSS pump seal is considered as a single-failure in the plant design basis and is acceptable. The WCAP-16406-P attempts to justify failure of the seals due to recirculation debris, which is a potential common-mode failure. The pump seals at St. Lucie Unit 2 have been evaluated as not susceptible to failure by debris-laden water because they recirculate only seal cavity fluids. Therefore, the only potential failure that must be considered is an assumed single failure, which again is part of the existing design basis of the plant (bounded by a moderate energy line break in the pump room). The potential effect of debris causing an increased leakage flow through the disaster bushing following that single-failure has been evaluated and been determined to be acceptable.

The WCAP-16406-P criteria were based on performance of each individual component. However, the SER further identifies the need to check the entire ECCS and CSS systems in an integrated approach to ensure that the combination of pump and system component wear would not threaten adequate core cooling, considering increased system flow and decreased pump performance due to wear. An overall system performance assessment determined that these systems remain capable of fulfilling their required safety related functions in the presence of debris-laden fluid following a LBLOCA at St. Lucie Unit 2.

Heat Exchangers

In accordance with WCAP-16406-P Section 8.3, the recirculation heat exchangers (both the primary system heat exchangers, and the pump seal heat exchangers) were analyzed for erosive wear. The standard erosive wear formulas in the WCAP-16406-P, adjusted for the actual material hardness and adjusted via the Hutchings Summation described above, were used with the St. Lucie Unit 2 heat exchanger dimensions and maximum recirculation flow rates to predict the maximum erosive wear over 30 days of recirculation. All heat exchangers were found to have sufficient wall thickness margin for a maximum possible differential pressure across the heat exchanger tubes.

Valves

The WCAP-16406-P guidance is that manual throttle valves should be analyzed for the effects of erosive wear. It is assumed that a manually throttled valve as defined in WCAP-16406-P is one that requires an operator to locally throttle the valve (at the valve location) as opposed to a remote manual valve that can be adjusted from the control room. It is further assumed that a remote manual valve can be adjusted from the control room to compensate for an increase in flow area due to erosive wear. Therefore, erosion wear analyses were not performed for remote manual valves. Since there are no locally throttled ECCS or CSS valves at St. Lucie Unit 2, no wear analysis was required to assess downstream effects on valves in the recirculation paths.

Orifices, Flow Elements, Spray Nozzles

All orifices, flow elements, and the containment spray nozzles in the St. Lucie Unit 2 recirculation flowpaths were analyzed for the effects of erosive wear upon performance. The standard erosive wear formulas in the WCAP-16406-P, adjusted for the actual material hardness and adjusted via the Hutchings Summation described above, were used with the St. Lucie Unit 2 component dimensions and maximum recirculation flow rates to predict the maximum erosive wear over 30 days of recirculation. The total material wear was used with the WCAP-16406-P formulas to predict the maximum change in flow rate due to the erosive wear of an orifice, flow element or spray nozzle. A conservative deviation was made from the WCAP-16406-P guidance in that a 3% limit for change in flow was applied for all orifices, flow elements, and spray nozzles. Furthermore, all orifices were assumed to be sharp-edged, which creates a higher change in flow rate for a given amount of wear. Based on the analysis, all St. Lucie Unit 2 orifices, flow elements, and the containment spray nozzles were found to be acceptable.

Piping

The SER to WCAP-16406-P requires that licensees perform a piping wear evaluation. The SER Section 3.2.6 does not detail the scope of the assessment, but since it refers to the need for a vibration assessment if areas of high piping wear are identified, it is taken to mean that piping should be checked for wall-thinning (structural) purposes like the heat exchanger tubes. With regard to pipe wall erosion, WCAP-16406-P states "There is no expected impact on ECCS and CSS piping based on downstream sump debris...since the pipe wall thickness is sufficiently larger than expected wear." To validate this assumption, the material wear of the bounding orifice in the ECCS and CSS was compared to the pipe wall thicknesses used in the systems. This conservative material wear exceeds that applicable to piping because the flow velocities in piping are much less compared to the bounding orifice velocity (the wear rate is proportional to the flow velocity squared), while the material of construction is the same. The material wear was found to be insignificant compared to the pipe wall thick-nesses used in the ECCS and CSS. Therefore, all recirculation pipes were determined to have sufficient margin, and the erosion was considered so slight as to not require vibration analysis.

Conclusion (Wear)

No other components required erosive wear analysis. As summarized above, analysis of all lines and components in the recirculation flowpaths at St. Lucie Unit 2 determined that the components are expected to wear acceptably based on the WCAP-16406-P criteria for 30 days of recirculation.

The WCAP criteria were based on the performance of each individual component. The SER further identifies the need to check the ECCS and CSS systems in an integrated approach to ensure that the combination of pump and system component wear would not threaten adequate core cooling, considering increased system flow and decreased pump efficiency due to wear. Based on an overall system performance assessment, the ECCS and CSS remain capable of fulfilling their required safety related functions in the presence of debris-laden fluid following a LBLOCA at St. Lucie Unit 2.

Summary of Design or Operational Changes

Additionally, NRC Content Guide Topic 3.m requests that licensees "Provide a summary of design or operational changes made as a result of downstream evaluations." Three plant design changes made in response to GSI-191 contribute to the resolution of downstream effects:

- As previously discussed, in response to downstream blockage concerns the new strainer system was designed with a nominal strainer opening holes of 1/16-inch diameter (0.0625 inch), reduced from the previous 0.09" nominal square opening. The new strainer system is described in the response to NRC Topic 3.j, *Screen Modification Package*. The actual maximum spherical size particulate debris that can pass through the new strainer system and into the ECCS and CSS recirculation flowpaths is documented as 0.06875 in.
- Also as previously discussed, the St. Lucie Unit 2 HPSI and CSS pump seals were redesigned. The previous seal cooling systems relying on process water with a cyclone separator were replaced with a closed-cycle seal system that utilizes recirculated seal cavity fluid.

The only operational change made related to downstream effects is that inspection requirements were updated for the new strainer system. Inspection of the strainer system requires verification of maximum strainer equipment gaps to meet new specifications to maintain debris bypass size limits. This procedure is discussed further in NRC Topic 3.i, *Debris Source Term*.

No other design or operational changes were required in response to ECCS and CSS downstream effects evaluations.

Enclosure C provides the responses to the Limitations and Conditions on WCAP-16406-P, Revision 1.

Topic 3.n: Downstream Effects – Fuel and Vessel

<u>FPL Response</u>

FPL is participating in the PWR Owners Group (PWROG) program to evaluate downstream effects related to in-vessel long-term cooling. The results of the PWROG program are documented in WCAP-16793-NP (WCAP-16793-NP, "Evaluation of Long-Term Cooling Considering Particulate, Fibrous and Chemical Debris in Recirculating Fluid" Rev. 0, May, 2007). The program was performed such that the results apply to the entire fleet of PWRs, regardless of the design (e.g., Westinghouse, CE, or B&W).

The PWROG program demonstrated that the effects of fibrous debris, particulate debris, and chemical precipitation would not prevent adequate long-term core cooling flow from being established. In the cases that were evaluated, the fuel clad temperature remained below 800°F in the recirculation mode. This is well below the acceptance criterion of 2,200°F in 10 CFR 50.46, *Acceptance criteria for emergency core cooling systems for light-water nuclear power reactors.* The specific conclusions regarding fiber debris reached by the PWROG include:

- Adequate flow to remove decay heat will continue to reach the core even with debris from the sump reaching the RCS and core. Test data has demonstrated that any debris that bypasses the screen is not likely to build up an impenetrable blockage at the core inlet. While any debris that collects at the core inlet will provide some resistance to flow, in the extreme case that a large blockage does occur, numerical analyses have demonstrated that core decay heat removal will continue.

- Decay heat will continue to be removed even with debris collection at the fuel assembly spacer grids. Test data has demonstrated that any debris that bypasses the screen is small and consequently is not likely to collect at the grid locations. Further, any blockage that may form will be limited in length and not be impenetrable to flow. In the extreme case that a large blockage does occur, numerical and first principle analyses have demonstrated that core decay heat removal will continue.

- Fibrous debris, should it enter the core region, will not tightly adhere to the surface of fuel cladding. Thus, fibrous debris will not form a "blanket" on clad surfaces to restrict heat transfer and cause an increase in clad temperature. Therefore, adherence of fibrous debris to the cladding is not plausible and will not adversely affect core cooling.

WCAP 16793-NP Rev 0 concluded that the calculations, summarized above, for fiber debris are applicable to all PWRs, hence they are applicable to St. Lucie Unit 2.

Using an extension of the chemical effects methods developed in WCAP-16530-NP to predict chemical deposition on fuel cladding, two sample calculations using large debris loadings of fiberglass and calcium silicate were performed and are discussed in WCAP 16793-NP Rev 0. The cases demonstrate that decay heat would be removed and acceptable fuel clad temperatures would be maintained. As recommended in the WCAP-16793-NP, Revision 0, FPL performed a plant-specific calculation using St. Lucie Unit 2 parameters and the recommended WCAP methodology to confirm that chemical plate-out on the fuel does not result in the prediction of fuel cladding temperatures approaching the 800°F value This calculation concluded that the maximum fuel cladding temperature is 361.54 degrees.

Enclosure 1 provides the responses to the Limitations and Conditions on WCAP-16530-NP, Revision 0. Enclosure 2 provides the responses to the Limitations and Conditions on WCAP-16793-NP, Revision 0.

Topic 3.o: Chemical Effects

FPL Response

The objective of the chemical effects section is to evaluate the effect that chemical precipitates have on head loss and core cooling.

1. Provide a summary of evaluation results that show that chemical precipitates formed in the post-LOCA containment environment, either by themselves or combined with debris, do not deposit at the sump screen to the extent that an unacceptable head loss results, or deposit downstream of the sump screen to the extent that long-term core cooling is unacceptably impeded.
2. Content guidance for chemical effects is provided in Enclosure 3 to a letter from the NRC to NEI dated September 27, 2007 (ADAMS Accession No. ML0726007425).

   2.1 *Debris Bed Formation: Licensees should discuss why the debris from the break location selected for plant-specific head loss testing with chemical precipitate yields the maximum head loss. For example, plant X has break location 1 that would produce maximum head loss without consideration of chemical effects. However, break location 2, with chemical effects considered, produces greater head loss than break location 1. Therefore, the debris for head loss testing with chemical effects was based on break location 2.*

   2.2 *Plant Specific Materials and Buffers: Licensees should provide their assumptions (and basis for the assumptions) used to determine chemical effects loading: pH range, temperature profile, duration of containment spray, and materials expected to contribute to chemical effects.*

   2.3 *Approach to Determine Chemical Source Term (Decision Point): Licensees should identify the vendor who performed plant-specific chemical effects testing.*

   2.4 *Separate Effects Decision (Decision Point): State which method of addressing plant-specific chemical effects is used.*

   2.5 *AECL Model: Since the NRC USNRC is not currently aware of the testing approach, the NRC USNRC expects licensees using it to provide a detailed discussion of the chemical effects evaluation process along with head loss test results. Licensees should provide the chemical identities and amounts of predicted plant-specific precipitates.*

   2.6 *WCAP Base Model: Input of plant parameters into the WCAP-16530 spreadsheet should be done in a manner that results in a conservative amount of precipitate formation. In other words, plant parameter inputs selection will not be biased to lower the predicted amount of precipitate beyond what is justified. Analysis, using timed additions of precipitates based on WCAP-16530 spreadsheet predictions should account for potential non-conservative initial aluminum release rates. Licensees should list the type (e.g., AlOOH) and amount of predicted plant-specific precipitates.*

   2.7 *WCAP Refinements: State whether refinements to WCAP-16530-NP were utilized in the chemical effects analysis. Conservative assumptions in the WCAP-16530 base model were intended to balance uncertainties in the GSI-191 chemical effects knowledge. Therefore, overall chemical effects*

assessment remains conservative when implementing these model refinements.

2.8 *Solubility of Phosphates, Silicates and Al Alloys: Licensees should clearly identify any refinements (plant-specific inputs) to the base WCAP-16530 model and justify why the plant-specific refinement is valid.*

2.9 *Precipitate Generation (Decision Point): State whether precipitates are formed by chemical injection into a flowing test loop or whether the precipitates are formed in a separate mixing tank.*

2.10 *Chemical Injection into the Loop: Licensees should provide the one-hour settled volume (e.g., 80 ml of 100 ml solution remained cloudy) for precipitate prepared with the same sequence as with the plant-specific, in-situ chemical injection.*

2.11 *Pre-Mix in Tank: Licensees should discuss any exceptions taken to the procedure recommended for surrogate precipitate formation in WCAP-16530.*

2.12 *Technical Approach to Debris Transport (Decision Point): State whether near-field settlement is credited or not.*

2.13 *Integrated Head Loss Test with Near-Field Settlement Credit: Licensees should provide the one-hour or two-hour precipitate settlement values measured within 24 hours of head loss testing.*

2.14a *Integrated Head Loss Test with Near-Field Settlement Credit: Licensees should provide a best estimate of the amount of surrogate chemical debris that settles away from the strainer during the test.*

2.14 *Head Loss Testing Without Near Field Settlement Credit: Licensees should provide an estimate of the amount of debris and precipitate that remains on the tank/flume floor at the conclusion of the test and justify why the settlement is acceptable.*

2.15a *Head Loss Testing Without Near Field Settlement Credit: Licensees should provide the one-hour or two-hour precipitate settlement values measured and the timing of the measurement relative to the start of head loss testing (e.g., within 24 hours).*

2.15 *Test Termination Criteria: Provide the test termination criteria.*

2.16 *Data Analysis: Licensees should provide a copy of the pressure drop curve(s) as a function of time for the testing of record. Licensees should explain any extrapolation methods used for data analysis.*

2.17 *Integral Generation (Alion): Licensees should discuss why the test parameters (e.g., temperature, pH) provide for a conservative chemical effects test.*

2.18 *Tank Scaling / Bed Formation: Explain how scaling factors for the test facilities are representative or conservative relative to plant-specific values. Explain how bed formation is representative of that expected for the size of materials and debris that is formed in the plant specific evaluation.*

2.19 *Tank Transport: Explain how the transport of chemicals and debris in the testing facility is representative or conservative with regard to the expected flow and transport in the plant-specific conditions.*

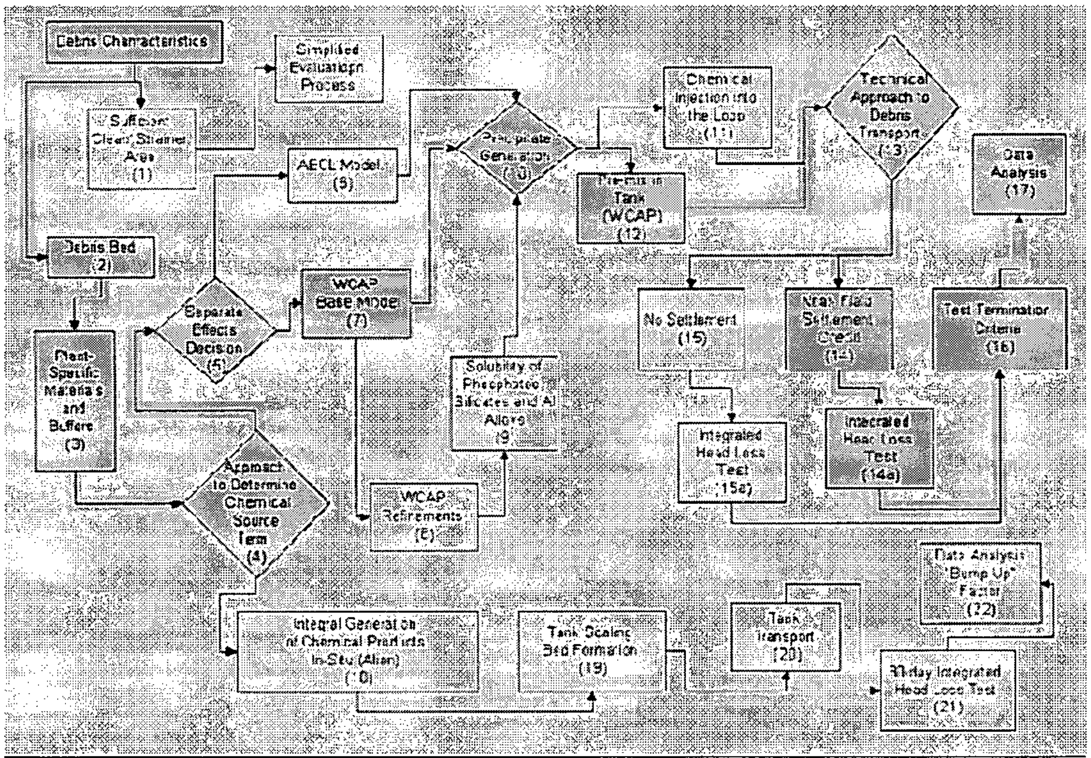
2.20 *30-Day Integrated Head Loss Test: Licensees should provide the plant-specific test conditions and the basis for why these test conditions and test results provide for a conservative chemical effects evaluation. Licensees should provide a copy of the pressure drop curve(s) as a function of time for the testing of record.*

2.21 *Data Analysis Bump Up Factor: Licensees should provide the details and the technical basis that show why the bump-up factor from the particular debris bed in the test is appropriate for application to other debris beds.*

<u>FPL Response to Issue 3o.1</u>:
Chemical precipitates that form in the post-LOCA containment environment combined with debris do not result in an unacceptable head loss. The effects of the sump chemical environment were evaluated in an integrated chemical effects head loss test by PCI with support from Areva at the Alden Research Lab. The testing program implemented assumed chemical precipitates do form in accord with the WCAP 16530-NP methodology. The affect of the chemical debris on the head loss across the screen has been measured in a test using the protocol reviewed by the NRC with PCI and the strainer users group. The results of the chemical effects testing have been incorporated into the NPSH calculations as discussed in section 3.g above.

<u>FPL Response to Issue 3o.2.</u>
Content Guide for Chemical Effects Evaluation. The chemical effects evaluation process flow chart provided in the NRC guidance document has been modified, as shown in Figure 3o-1, to highlight the process approach taken for testing and evaluation.

Chemical Effects Evaluation Process Flow Chart



FPL Response to Issue 3o.2.1
St. Lucie Unit 2 did not perform a "simplified" chemical effects evaluation.

FPL Response to Issue 3o.2.2
As discussed in section 3.a, a break at the B hot leg generates the greatest quantity of particulate and fibrous debris and therefore, was selected for the strainer design basis. During the integrated test, inspections were performed that confirmed that a fibrous thin bed was not formed upon completion of debris loaded testing. Therefore, the break at the B hot leg which generated the greatest quantity of particulate and fibrous debris yields the maximum head loss

FPL Response to Issue 3o.2.3
The following assumptions were used to determine the chemical effects loading.

- It is assumed that containment spray and sump pH will be identical and exist at the maximum pH value (7.5) throughout the 30-day mission time. This higher pH resulted in bounding final precipitate quantities.
- The temperature profile used to calculate the possible chemical effects is based on the FSAR temperature curves for accident analysis. The temperature profiles presented in the FSAR are conservative since the safety analyses assume single failures of portions of ECCS/CS supply to yield higher containment pressures and temperatures. Additionally, when calculating the sump temperature post-LOCA, the final temperature at

12 days was extended to the 30 days evaluated. This maximizes the duration at elevated temperature, which maximizes the potential for corrosion of materials within the containment.

- Containment spray is assumed to be operating for 30 days.
- Plant specific values of the quantities of materials that contribute to chemical effects were utilized. Aluminum, concrete, nukon insulation, calsil, and TSP were utilized as input the analysis.

FPL Response to Issue 3o.2.4.

The effects of the sump chemical environment were evaluated in an integrated chemical effects head loss test by PCI with support from Areva at the Alden Research Lab.

FPL Response to Issue 3o.2.5

The effects of the sump chemical environment were evaluated in an integrated chemical effects head loss test by PCI with support from Areva at the Alden Research Lab. The testing program implemented assumed chemical precipitates do form in accord with the WCAP 16530-NP methodology.

FPL Response to Issue 3o.2.6

St. Lucie Unit 2 does not use the AECL based models for testing.

FPL Response to Issue 3o.2.7

Bounding maximum debris volumes, material surface areas, and temperature and pH transient profiles were used as inputs for this analysis. Plant-specific design information was utilized as inputs.

The total mass of chemical precipitate expected to form post-LOCA was calculated as 537.96 kg. The types and quantities of chemical precipitates expected to form in the St. Lucie Unit 2 containment sump and reactor coolant system following a Design Basis LOCA are as follows; 294.84 kg of sodium aluminum silicate ($NaAlSi_3O_8$), 57.70 kg of aluminum oxyhydroxide ($AlOOH$), and 185.43 kg of calcium phosphate ($Ca_3(PO_4)_2$). This analysis was comprised of the bounding set of inputs.

FPL Response to Issue 3o.2.8

The chemical precipitates were calculated utilizing the methodology in WCAP-16530-NP. No refinements to WCAP-16530-NP were utilized in the chemical effects analysis.

FPL Response to Issue 3o.2.9

The chemical precipitates were calculated utilizing the methodology in WCAP-16530-NP. No refinements to WCAP-16530-NP were utilized in the chemical effects analysis.

FPL Response to Issue 3o.2.10

Precipitates used in testing are formed in a separate mixing tank and subsequently introduced into the test loop.

FPL Response to Issue 3o.2.11

Chemical injection into the test loop was not used for St. Lucie Unit 2 testing.

FPL Response to Issue 3o.2.12
The chemical precipitates were generated utilizing the methodology in WCAP-16530- and final SER, and PWROG letter OG-07-270. The chemical materials were generated in mixing tanks and introduced into the test flume within the parameters provided in the PWROG letter OG-07-270. Aluminum Oxyhydroxide (AlOOH) and Calcium Phosphate were injected based on the predicted chemical formation. AlOOH is more transportable than Calcium Phosphate, therefore AlOOH was introduced first for each chemical batch added to the test flume.

Section 7.3.2 of WCAP-16530-NP, Rev. 0, states that the characteristics of sodium aluminum silicate are sufficiently similar to aluminum oxyhydroxide (AlOOH), thus AlOOH was used in lieu of sodium aluminum silicate. Based on Section 7.3.2 of WCAP-16530-NP Rev. 0, the production of sodium aluminum silicate is considered hazardous. Therefore, AlOOH was generated in accordance with the directions in Section 7.3.2 of WCAP-16530-NP for strainer testing when either AlOOH or sodium aluminum silicate is required.

FPL Response to Issue 3o.2.13
Prior to testing, CFD analyses were implemented to define a "bounding" flow stream to the screen as described in section 3.e,Debris Transport. The objective of this test protocol was to allow debris settling as it can occur in the actual post-LOCA environment.

FPL Response to Issue 3o.2.14
Testing was performed within 24 hours of precipitate mixing with preparation in accordance with WCAP-16530. Settling rates were verified to be acceptable in accordance with the WCAP criteria.

FPL Response to Issue 3o.2.15
St. Lucie Unit 2 utilized near field settling. Therefore, this section is not applicable.

FPL Response to Issue 3o.2.16
The acceptance criterion or the termination criterion for this test is if the change in head loss is less than 1% in the last 30 minute time interval and a minimum of 15 flume turnovers after all the debris has been inserted into the test flume.

FPL Response to Issue 3o.2.17
Based on the test results, the Design Basis Tests head loss was extrapolated over 30 days and resulted in a final head loss of 2.21 feet of water. Pressure drop was recorded in data tables and documented in the test report.

The data was analyzed and an exponential curve fit was utilized to extrapolate the head loss to 30 days.

FPL Response to Issue 3o.2.18 through 3o.2.22
St. Lucie Unit 2 does not use the Integral Generation of Chemical Products In-Situ (Alion) model for testing. Therefore, sections 3.o.2.18 through 3.o.2.22 are not applicable

[RAI 2] The response to RAI 2 for St. Lucie Unit 2 is summarized in the following table:

Class	Material / Input	Plant Inputs
Metallic Aluminum	Aluminum Submerged (ft^2)	681.7
	Aluminum Submerged (lbm)	321.1
	Aluminum Not-Submerged (ft^2)	12952.3
	Aluminum Not-Submerged (lbm)	6100.9
Concrete	Concrete (ft^2)	15,394
Zinc	Zinc (ft^2), non topcoated	260625
Copper	Copper (ft^2)	64960
	Carbon Steel total surface area	Carbon Steel, (ft^2)

For the purposes of chemical effects testing, it was conservatively assumed that the percentage of material submerged was no less than that used for ICET tests.

[RAI 3] For St. Lucie Unit 2, the small amount of carbon steel knuckles and aluminum ladders stored in the containment are included in the debris quantities used for design inputs used to perform the chemical effects testing. The carbon steel DBA qualified coated scaffold poles and uncoated carbon steel knuckles are not considered as a contributor for chemical testing.

St. Lucie Unit 2 currently has approval for scaffolding storage in containment at the 23'-0" elevation. The amount is controlled by specification and only allows for scaffolding that has a DBA qualified coating applied on scaffolding in accordance with Coatings Specification. The connecting knuckles are not coated, any galvanizing or coatings were removed and bare carbon steel knuckles are stored in steel boxes on the 23' elevation. The maximum amount of uncoated steel knuckles approved for storage in containment is approximately 125 square-feet, and these are contained in closed steel boxes. The amount of scaffolding approved for storage in containment is 1500 square-feet. Some of the scaffolding and the connecting knuckles would be submerged in the event of a LOCA. The scaffolding is stored on the 23'-0" elevation and the calculated post-LOCA containment water level is approximately 23.58'. The scaffold poles are stored in a horizontal position, (2000 linear-feet) and the vertical position, (1000 linear-feet). There is no adverse affect due to coatings to the Containment Spray (CS) and Emergency Core Cooling System (ECCS) since the carbon steel scaffolding connectors are uncoated, and the scaffolding is coated with DBA qualified coatings.

Storage structures are made for storage of 10 aluminum ladders to be stored on the 23 foot elevation of the containment building. The total square footage of the Aluminum ladders surface area is 550 square feet. The ladders are evaluated for storage in the vertical position with the legs on the 23 foot elevation. The maximum submerged area would be approximately 7 square feet with all 10 ladders stored on 23 foot elevation based on the 23.58 foot flood level.

[RAI 4] The insulation jacketing used in St. Lucie Unit 2 is stainless steel. Therefore the condition and limitation of the request is not applicable. The original construction specification for insulation specifically required stainless steel inside the containment building.

No unqualified metallic coating is in the St. Lucie Unit 2 containment building.

The type and amount of unqualified coatings in containment during power operation is limited and tracked by specification.

[RAI 5] The pH of liquid solutions that are recirculated within the containment following a design basis accident is stabilized between 7.0 and 7.5. The pH is maintained with the use of trisodium phosphate dodecahydrate (TSP) which is stored in sixteen open baskets located in the vicinity of the containment sump. Mixing is achieved as the solution is continuously recirculated. The spray water dissolves the TSP within three hours following CSAS. Approximately one-third of the TSP dissolves during the injection mode.

[RAI 6] The chemical effects evaluation for St. Lucie Unit 2 was completed using the methodology published in WCAP-16530. The chemical effects evaluation did not deviate from, or take credit for, any independent chemical effects based benchmark testing results. Therefore, this question is not applicable to the St. Lucie Unit 2 chemical effects evaluation or related strainer performance testing activities.

[RAI 8] This RAI requested information on the FPL chemical effects testing program. This information is provided in NRC Topics 3.g, Net Positive Suction Head (NPSH), and 3.o, Chemical Effects.

[RAI 9] There are no plans to remove additional material from containment, and no plans to make a change from the existing chemicals that buffer containment pool pH following a LOCA.

[RAI 10] Bench top testing was not utilized for St. Lucie 2

[RAI 11] Performance Contracting, Inc., along with team members AREVA NP, Inc. and Alden Research Laboratories are the vendors who defined the test plan for the specified design basis. The test plan protocol implemented was developed with the NRC staff beginning in April 2007, and the NRC staff has reviewed the protocol in detail prior to its actual implementation. This protocol was further refined following comments from NRC staff members who witnessed tests in January and February 2008.

Testing used Holden, MA city tap water pre-heated and maintained to a nominal 120 °F temperature. Prior to testing, CFD analyses were implemented to define a "bounding" flow stream in one foot increments to the screen. The objective of this test protocol was to allow debris settling that can occur in the actual post-LOCA environment.

Non-chemical debris was procured and produced in accord with PCI standards; also in accordance with discussions held with the NRC staff over the same review period. Non-chemical debris was introduced in accord with NRC preferences; namely, particulates first; then fine fibers; then smalls, etc.
Chemical debris was produced and accepted for use in accordance with the WCAP 16530-NP

in a chemical tank prior to its introduction into the flume. Introduction of acceptable precipitates always occurred within 24 hours of its manufacture.

Since PCI implemented the WCAP 16530-NP to define the quantities and types of chemical precipitates to be formed in the post-LOCA; and generated/qualified these precipitates in accord with the WCAP 16530-NP and NRC preferences; the effect of the post-LOCA environment is bounded in the implemented test protocol.

[RAI 12] This RAI requested FPL provide the maximum projected head loss resulting from chemical effects (a) within the first day following a LOCA, and (b) during the entire ECCS recirculation mission time. The overall chemical effects testing program is discussed in section 3.o and the resulting NPSH is discussed in section 3.g. Note that the full 30-day debris load (both chemical and non chemical) is applied at the initiation of recirculation. This is extremely conservative since as the chemical products are being created during the 30 days, the sump pool is cooling down providing additional NPSH margin.

[RAI 14] The analytical methodology published within WCAP-16530 was used to determine the types and quantities of chemicals present post-LOCA in the St. Lucie Unit 2 sump. As the Chemical Model published with WCAP-16530-NP was accepted to determine the types and quantities of chemical precipitates expected to form post-LOCA, the effect of any dissolved metal / non-metal ions in solution (calcium or otherwise) is assumed as captured within the approved methodology. The chemical effects evaluation did not deviate from, or take credit for, any independent chemical effects based benchmark testing results.

The results of the Chemical Model yielded a total of 71.87 kg (158.44 lbm) of released calcium and 185.43 kg (408.80 lbm) of calcium phosphate.

Enclosure 1 provides the responses to the Limitations and Conditions on WCAP-16530-NP, Revision 0.

Topic 3.p: Licensing Basis

FPL Response

As discussed in other sections of this response, physical plant changes and procedural changes have been made to St. Lucie Unit 2 to resolve GL 2004-02 and GSI-191 concerns. These are summarized under NRC Topic 2.

The St. Lucie Unit 2 UFSAR has been updated to incorporate the effects of plant modifications and evaluations performed in accordance with the requirements of 10 CFR 50.59.

Following the issuance of Bulletin 2003-01, St. Lucie Unit 2 put in place administrative controls to maintain a higher water level in the RWT than the required Technical Specification minimum, with the intent that this higher level would remain until such time as sump issues were completely resolved. FPL has determined that an amendment to the Technical Specifications to raise the minimum allowable RWT level to the current/higher administrative level is warranted in order to regain margin for post-LOCA recirculation pumps. The amendment request for this increase in minimum Technical Specification RWT level is being submitted. The administrative controls for the higher RWT level will remain in effect until the amendment request is reviewed by NRC, approved, and implemented on-site.

Enclosure 1

(St. Lucie Unit 2 Updated Supplemental Response)

NRC Safety Evaluation Report

Limitations and Conditions for

WCAP 16530-NP Revision 0

L&C No.	NRC Limitations & Conditions (WCAP 16530-NP Rev. 0)	FPL (St. Lucie Unit 2) Response
1.	A peer review of NRC-sponsored chemical effects testing was performed and a number of technical issues related to GSI-191 chemical effects were raised by the independent peer review panel members (NUREG-1861). The peer review panel and the NRC staff developed a PIRT of technical issues identified by the peer review panel. The NRC staff is working to resolve the technical issues identified in the PIRT. Part of the resolution process includes NRC-sponsored analyses being performed by PNNL. Although the NRC staff has not developed any information related to the PIRT issues resolution that would alter the conclusions of this evaluation, some issues raised by the peer review panel were not completely resolved at the time this evaluation was written. An example of such an issue is the potential influences of organic materials on chemical effects. Therefore, it is possible that additional analysis or other results obtained during the resolution of the remaining peer review panel issues could affect the conclusions in this evaluation. In that event, the NRC staff may modify the SE or take other actions as necessary.	This is not a limitation or condition. If the NRC staff modifies the SE or takes other actions, FPL will respond to any future limitations and conditions as requested.
2.	This evaluation does not address TR WCAP-16785-NP, "Evaluation of Additional Inputs to the WCAP-16530-NP Chemical Model." The NRC staff will provide comments on WCAP-16785-NP separate from this evaluation. In addition, a separate SE will address a related TR, WCAP-16793-NP, "Evaluation of Long-Term Cooling Considering Particulate, Fibrous, and Chemical Debris in the Recirculating Fluid." Chemical effects in the reactor vessel are not addressed in WCAP-16530-NP or in this SE. Therefore, the approval of this TR does not extend to chemical effects in the reactor vessels	This is not a limitation or condition. If the NRC staff modifies the SE or takes other actions, FPL will respond to any future limitations and conditions as requested. FPL used the Pressurized Water Reactor Owners Group (PWROG) methodology, which is in accordance with WCAP-16793-NP, Revision 0, to evaluate chemical effects in the reactor vessel.
3.	If a licensee performs strainer head loss tests with surrogate precipitate and applies a time-based pump NPSH margin acceptance criteria (i.e., timed precipitate additions based on topical report model predictions), they must use an aluminum release rate that does not under-predict the initial 15 day aluminum concentrations in ICET 1, although aluminum passivation can be considered during the latter parts of the ECCS mission time in this case.	The St. Lucie Unit 2 chemical effects testing program was performed by PCI which implemented WCAP 16530-NP to define the quantities and types of chemical precipitates to be formed post-LOCA. St. Lucie 2 did not apply a time based chemical margin criteria, that is the total quantity of generated precipitants (30 day chemical loading) is tested in a 1-2 day test period; the time is conservatively compressed to measure the full affect of chemicals across the screens.
4.	For head loss tests in which the objective is to keep chemical precipitate suspended (e.g., by tank agitation): Sodium aluminum silicate and aluminum oxyhydroxide precipitate settling shall be measured within 24 hours of the time the surrogate will be used and the 1-hour settled volume shall be 6 ml or greater and within 1.5 ml of the freshly prepared surrogate. Calcium phosphate precipitate settling shall be measured within 24 hours of the time the surrogate will be used and the 1 hour settled volume shall be 5 ml or greater and within 1.5 ml of the freshly prepared surrogate. Testing shall be conducted such that the surrogate precipitate is introduced in a way to ensure transportation of all material to the test screen.	The St. Lucie Unit 2 chemical effects testing program was performed by PCI which did not test with the objective to suspend the chemical precipitates because the test flume was designed to bound the approach velocities to the screen. As such, this question is not applicable to the testing performed by PCI for FPL. All chemical debris generated complied with the settling rates requested in accordance with WCAP-16530-NP and was introduced into the flume within 24 hours of its generation
5.	For head loss testing in which the objective is to settle chemical precipitate and other debris: Aluminum containing surrogate precipitate that settles equal to or less than the 2.2 g/l concentration line shown in Figure 7.6-1 of WCAP-16530-NP (i.e., 1-or 2- hour settlement data on or above the line) is acceptable. The settling rate shall be measured	The St. Lucie Unit 2 chemical effects testing program was performed by PCI which did test with the objective to allow settlement of the chemical precipitates. All chemical debris generated for testing complied with the settling rates in accordance with WCAP-16530-NP and was introduced into the flume

L&C No.	NRC Limitations & Conditions (WCAP 16530-NP Rev. 0)	FPL (St. Lucie Unit 2) Response
	within 24 hours of the time the surrogate precipitate will be used.	within 24 hours of its generation
6.	For strainer head loss testing that uses TR WCAP-16530-NP sodium aluminum silicate and is performed in a de-ionized water environment, the total amount of sodium aluminum silicate added to the test shall account for the solubility of sodium aluminum silicate in this environment.	The St. Lucie Unit 2 chemical effects testing program was performed by PCI which does not use sodium aluminum silicate precipitates for testing

Enclosure 2

(St. Lucie Unit 2 Updated Supplemental Response)

NRC Safety Evaluation Report

Limitations and Conditions for

WCAP 16793-NP Revision 0

L&C No.	NRC Limitations & Conditions (WCAP-16793-NP Rev. 0)	FPL (St. Lucie Unit 2) Response
1.	WCAP-16793-NP states that licensees shall either demonstrate that previously performed bypass testing is applicable to their plant-specific conditions, or perform their own plant-specific testing. The staff agrees with this stated position.	For St. Lucie Unit 2, the bypass testing represented in WCAP-16793-NP, Section 2.1, Blockage at the Core Inlet, is applicable. The WCAP LOCA Deposition Model used a bump up factor to represent the bypass debris and allowed this bypassed material to be deposited in the core in the same manner as a chemical reaction product,. In accordance with the referenced methodology, all the St. Lucie Unit 2 plant-specific debris inputs were more than doubled (increased by 120%) in the corresponding LOCADM calculation which provided a bump up factor that conservatively bounds any credible bypass fraction for the strainer.
2.	There are very large margins between the amount of core blockage that could occur based on the fuel designs and the debris source term discussed in WCAP-16793-NP and the blockage that would be required to degrade the coolant flow to the point that the decay heat could not be adequately removed. Plant-specific evaluations referencing WCAP-16793-NP should verify the applicability of the WCAP-16793-NP blockage conclusions to licensees' plants and fuel designs.	A plant specific analysis using the Westinghouse LOCA deposition Model in reference to WCAP 16793 was performed for St. Lucie Unit 2. The results of the calculation yielded a maximum fuel cladding temperature and thickest calculated scale well below the threshold criteria.
3.	Should a licensee choose to take credit for alternate flow paths such as core baffle plate holes, it shall demonstrate that the flow paths would be effective and that the flow holes will not be become blocked with debris during a loss-of-coolant accident (LOCA) and that the credited flow path would be effective.	No alternative flow paths were used for St. Lucie Unit 2. The flow paths are as described in WCAP 16793, Section 5.4.2, Transport of Coolant, Dissolved Species and Suspended Solids within the ECCS, Page 5-4 and Section 5.4.3, Modeling of the Core, Page 5-5. No alternative flow paths were utilized in the LOCA Deposition Model.
4.	Existing plant analyses showing adequate dilution of boric acid during the long-term cooling period have not considered core inlet blockage. Licensees shall show that possible core blockage from debris will not invalidate the existing post-LOCA boric acid dilution analysis for the plant.	The PWR Owners Group has a project to develop the approach for boric acid precipitation analyses and evaluations, Project Number ACS-0264R1, Post LOCA Boric Acid Precipitation Analysis Methodology Program.
5.	The staff expects the Pressurized Water Reactor Owners Group (PWROG) to revise WCAP-16793-NP to address the staff's requests for additional information and the applicant's responses. A discussion of the potential for fuel rod swelling and burst to lead to core flow blockage shall be included in this revision.	This L&C refers to information to be included in a revision to WCAP 16793-NP. FPL will continue to follow developments out of the PWROG and evaluate new information as it becomes available.
6.	WCAP-16793 shall be revised to indicate that the licensing basis for Westinghouse two-loop PWRs is for the recirculation flow to be provided through the upper plenum injection (UPI) ports with the cold-leg flow secured.	St. Lucie Unit 2 is a Combustion Engineering plant and is not an upper plenum injection plant.
7.	Individual UPI plants will need to analyze boric acid dilution/concentration in the presence of injected debris for a cold-leg break LOCA.	St. Lucie Unit 2 is a Combustion Engineering plant and is not an upper plenum injection plant.
8.	WCAP-16793 states that the assumed cladding oxide thickness for input to LOCADM will be the peak local oxidation allowed by 10 CFR 50.46, or 17 percent of the cladding wall thickness. The WCAP states that a lower oxidation thickness can be used on a plant-specific basis if that value is justified. The staff does not agree with the flexibility in this approach. Licensees shall assume 17 percent oxidation in the LOCADM analysis.	The St. Lucie Unit 2 LOCADM calculation used the 17% cladding oxide thickness.
9.	The staff accepts a cladding temperature limit of 800°F as the long-term cooling acceptance basis for GSI-191 considerations.	The St. Lucie Unit 2 LOCADM calculation used 800°F as the cladding temperature limit.

L&C No.	NRC Limitations & Conditions (WCAP-16793-NP Rev. 0)	FPL (St. Lucie Unit 2) Response
	Should a licensee calculate a temperature that exceeds this value, cladding strength data must be provided for oxidized or pre-hydrided cladding material that exceeds this temperature.	
10.	In the response to NRC staff requests for additional information, the PWR Owners Group indicated that if plant-specific refinements are made to the WCAP-16530-NP base model to reduce conservatisms, the LOCADM user shall demonstrate that the results still adequately bound chemical product generation. If a licensee uses plant-specific refinements to the WCAP-16530-NP base model that reduce the chemical source term considered in the downstream analysis, the licensee shall provide a technical justification that demonstrates that the refined chemical source term adequately bounds chemical product generation. This will provide the basis that the reactor vessel deposition calculations are also bounding.	The St. Lucie Unit 2 base model did not use plant-specific refinements to reduce conservatisms. The St. Lucie Unit 2 LOCADM calculation did not use plant-specific refinements for chemical product generation, therefore, no reduction in the chemical source term is present.
11.	WCAP-16793-NP states that the most insulating material that could deposit from post-LOCA coolant impurities would be sodium aluminum silicate. WCAP-16793 recommends that a thermal conductivity of 0.11 BTU/hr-ft-°F be used for the sodium aluminum silicate scale and for bounding calculations when there is uncertainty in the type of scale that may form. If plant-specific calculations use a less conservative thermal conductivity value for scale (i.e., greater than 0.11 BTU/hr-ft-°F), the licensee shall provide a technical justification for the plant-specific thermal conductivity. This justification shall demonstrate why it is not possible to form sodium aluminum silicate or other scales with conductivities below the selected value.	The St. Lucie Unit 2 LOCADM calculation used the deposit thermal conductivity value of 0.11 BTU/hr-ft-°F. The Westinghouse LOCADM model listed a default value of 0.2 W/m-K, which is the metric equivalent of 0.11 BTU/hr-ft-°F.
12.	WCAP-16793-NP indicates that initial oxide thickness and initial crud thickness could either be plant-specific estimates based on fuel examinations that are performed or default values in the LOCADM model. Consistent with Conditions and Limitations item number 8, the default value for oxide used for input to LOCADM will be the peak local oxidation allowed by 10 CFR 50.46, or 17 percent of the cladding wall thickness. The default value for crud thickness used for input to LOCADM is 127 microns, the thickest crud that has been measured at a modern PWR. Licensees using plant-specific values instead of the WCAP-16793-NP default values for oxide thickness and crud thickness shall justify the plant-specific.	The St. Lucie Unit 2 LOCADM calculation used 17 percent of the cladding wall thickness for peak local oxidation allowed by 10 CFR 50.46, refer to Conditions and Limitations item number 8. The default value for the crud thickness used for input to the LOCADM calculation was 140 microns, which is a more conservative value than 127 microns.
13.	As described in the Conditions and Limitations for WCAP-16530-NP (ADAMS ML073520891), the aluminum release rate equation used in WCAP-16530-NP provides a reasonable fit to the total aluminum release for the 30-day ICET tests but under-predicts the aluminum concentrations during the initial active corrosion portion of the test. To provide more appropriate levels of aluminum for the LOCADM analysis in the initial days following a LOCA, licensees shall apply a factor of two to the aluminum release as determined by the WCAP-16530-NP spreadsheet, although the total aluminum considered does not need to exceed the total predicted by the WCAP-16530-NP spreadsheet for 30 days. Alternately, licensees may choose to use a different method for determining the aluminum release, but in all cases licensees shall not use a method that under-predicts the aluminum concentrations measured during the initial 15 days of ICET 1.	The St. Lucie Unit 2 LOCADM calculation applied a factor of two to the aluminum release rate while maintaining the total aluminum release to that of the 30 day mission time,

Enclosure 3

(St. Lucie Unit 2 Updated Supplemental Response)

NRC Safety Evaluation Report

Limitations and Conditions for

WCAP 16406-P Revision 1

L&C No.	NRC Limitations & Conditions (WCAP-16406-P Rev. 1)	FPL (St. Lucie Unit 2) Response
1.	Where a TR WCAP-16406-P, Revision 1, section or appendix refers to examples, tests, or general technical data, a licensee should compare and verify that the information is applicable to its analysis.	General WCAP-16406-P examples and technical data were not used for site specific input. The wear equations developed in the WCAP-16406-P based on tests and general technical data were developed and benchmarked on equipment and with debris similar to that found at St. Lucie Unit 2. The wear equations were adjusted for the specific materials and debris concentration at St. Lucie Unit 2.
2.	A discussion of EOPs, AOPs, NOPs or other plant-reviewed alternate system line-ups should be included in the overall system and component evaluations as noted in the NRC staff's SE of NEI 04-07, Section 7.3 (Reference 13).	The downstream effects analysis for St. Lucie Unit 2 considered all procedural recirculation system line-ups that are used by the plant, including any alternate line-ups. Analysis of components in the alternate flowpaths was performed for the full recirculation mission time, like the primary flowpath components. The system evaluation discusses the procedures and alternate system line-ups.
3.	A licensee using TR WCAP-16406-P, Revision 1, will need to determine its own specific sump debris mixture and sump screen size in order to initiate the evaluation.	The downstream effects analysis uses a bounding site-specific sump debris mixture and the actual sump strainer hole size. Since site specific debris bypass test data were not available, the WCAP-16406-P methodology of strainer efficiency and retention size were utilized. The assumed maximum particulate size capable of passing the strainer was altered from the suggested WCAP-16406-P approach. Debris size distribution was determined based on experimental data (not site specific) and the St. Lucie Unit 2 specific debris types were used.
4.	TR WCAP-16406-P, Revision 1, Section 4.2, provides a general discussion of system and component mission times. It does not define specific times, but indicates that the defined term of operation is plant-specific. As stated in the NRC staff's SE of NEI 04-07, Section 7.3 (Reference 13), each licensee should define and provide adequate basis for the mission time(s) used in its downstream evaluation.	Recirculation operation is analyzed for 30 days post-LOCA. The mission time of all components is 30 days unless the plant's recirculation procedures limit the time that specific components are used. The 30 day recirculation duration is based on the SE of NEI 04-07, and was reviewed and found to be consistent with the St. Lucie Unit 2 design and licensing basis.
5.	TR WCAP-16406-P, Revision 1, Section 5.8, assumes that the coolant which is not spilled flows into the reactor system and reaches the reactor vessel downcomer. This would be true for most PWR designs except for plants with UPI. Therefore, the methodology of Section 5.8 may not be applicable to plants with UPI and its use should be justified on a plant-specific basis.	St. Lucie Unit 2 utilizes lower plenum injection.
6.	TR WCAP-16406-P, Revision 1, Section 5.8, provides equations which a licensee might use to determine particulate concentration in the coolant as a function of time. Assumptions as to the initial particulate debris concentration are plant-specific and should be determined by the licensee. In addition, model assumptions for ECCS flow rate, the fraction of coolant spilled from the break and the partition of large heavy particles which will settle in the lower plenum and smaller lighter particles which will not settle should be determined and justified by the licensee.	The initial particulate debris concentration was determined for St. Lucie Unit 2 based on a plant-specific limiting debris loads and sump water volumes. Debris depletion in the calculations is based on plant specific flows, debris types and debris concentrations. The size of debris subject to settling in the lower plenum was determined on a plant-specific basis; the ECCS flows and spillage assumed are the most conservative for this purpose.

L&C No.	NRC Limitations & Conditions (WCAP-16406-P Rev. 1)	FPL (St. Lucie Unit 2) Response
7.	TR WCAP-16406-P, Revision 1, Sections 5.8 and 5.9, assumes that debris settling is governed by force balance methods of TR Section 9.2.2 or Stokes Law. The effect of debris and dissolved materials on long-term cooling is being evaluated under TR WCAP-16793-NP (Reference 12). If the results of TR WCAP-16793-NP show that debris settling is not governed by force balance methods of TR Section 9.2.2 or Stokes Law, then the core settling term determined from TR WCAP-16793-NP should be used.	The site specific debris settling size is determined in calculations which were according to force balance methods. The methodology uses empirical friction factors based on the debris shape. This methodology is benchmarked against the NRC-sponsored testing of paint chip settling reported in NUREG/CR-6916.
8.	TR WCAP-16406-P, Revision 1, Section 7.2, assumes a mission time of 720 hours for pump operation. Licensees should confirm that 720 hours bounds their mission time or provide a basis for the use of a shorter period of required operation.	Analysis was performed for a mission time of thirty days following initiation of LBLOCA event. No reduction in mission time is credited in this analysis. The use of a full thirty day mission time is consistent with NEI 04-07 and its NRC SER, and the UFSAR. Additionally, use of a 30 day mission time is consistent with the time periods anticipated in NUREG 0800, Section 9.2.5, Ultimate Heat Sink. Reasonable and prudent management and operator action is credited for any actions required beyond thirty days to ensure continued safe operation of needed ECCS and CSS pumps. The mission time of individual components was a full 30 days except where the plant's recirculation procedures limit the time that specific components are used.
9.	TR WCAP-16406-P, Revision 1, Section 7.2, addresses wear rate evaluation methods for pumps. Two types of wear are discussed: 1) free-flowing abrasive wear and 2) packing-type abrasive wear. Wear within close-tolerance, high-speed components is a complex analysis. The actual abrasive wear phenomena will likely not be either a classic free-flowing or packing wear case, but a combination of the two. Licensees should consider both in their evaluation of their components.	The downstream effects calculation considers the maximum of either free-flow or packing type abrasive wear until a wear ring clearance of 50 mils diametral is reached. Beyond that time, the packing is assumed expelled and free-flow wear (abrasive and erosive) is modeled.
10.	TR WCAP-16406-P, Revision 1, Section 7.2.1.1, addresses debris depletion coefficients. Depletion coefficients are plant-specific values determined from plant-specific calculations, analysis, or bypass testing. Licensees should consider both hot-leg and cold-leg break scenarios to determine the worst case conditions for use in their plant specific determination of debris depletion coefficient.	Debris depletion coefficients in the calculations are based on plant specific flows, debris types and debris concentrations and the strainer design. The ECCS flows and spillage assumed are the most conservative for this purpose of either cold or hot-leg break scenarios. The calculated plant-specific depletion coefficient is only utilized where it is lower than (i.e., more conservative) the WCAP-16406-P lower-limit values.
11.	TR WCAP-16406-P, Revision 1, Section 7.3.2.3, recognizes that material hardness has an effect on erosive wear. TR WCAP-16406-P, Revision 1, suggests that "For elastomers, the wear rate is at least one order of magnitude less than steel. Therefore, for soft-seated valves, divide the estimated wear rate of steel from above equations by 10 per Appendix F." The NRC staff agrees that the wear rates of elastomers are significantly less than for steels. However, the wear coefficient should be determined by use of a suitable reference, not by dividing the steel rate by a factor of 10.	Wear of elastomeric materials, reduced by a factor of 10, is not applicable to any of the downstream effects wear calculations.

L&C No.	NRC Limitations & Conditions (WCAP-16406-P Rev. 1)	FPL (St. Lucie Unit 2) Response
12.	TR WCAP-16406-P, Revision 1, Section 8.1.1.2, "Evaluation of ECCS Pumps for Operation with Debris-Laden Water from the Containment Sump," states that "Sufficient time is available to isolate the leakage from the failed pump seal and start operation of an alternate ECCS or CSS train." Also, Section 8.1.3, "Mechanical Shaft Seal Assembly," states: "Should the cooling water to the seal cooler be lost, the additional risk for seal failure is small for the required mission time for these pumps." These statements refer only to assessing seal leakage in the context of pump operability and 10 CFR Part 100 concerns. A licensee should evaluate leakage in the context of room habitability and room equipment operation and environmental qualification, if the calculated leakage is outside that which has been previously assumed.	Non-mechanistic failure of an ECCS or CSS pump seal is considered as a single-failure in the plant design basis and is acceptable. The WCAP-16406-P attempts to justify failure of the seals due to recirculation debris, which is a potential common-mode failure. The pump seals at St. Lucie Unit 2 have been evaluated as not susceptible to failure by debris-laden water because they recirculate seal cavity fluid. Therefore the only potential failure that must be considered is an assumed single failure, which again is part of the existing design basis of the plant (bounded by a moderate energy line break in the pump room). The potential effect of debris causing an increased leakage flow through the disaster bushing following that single-failure has been evaluated and determined to be acceptable
13.	TR WCAP-16406-P, Revision 1, Section 8.1.3, discusses cyclone separator operation. TR WCAP-16406-P, Revision 1, generically concludes that cyclone separators are not desirable during post-LOCA operation of HHSI pumps. The NRC staff does not agree with this generic statement. If a licensee pump contains a cyclone separator, it should be evaluated within the context of both normal and accident operation. The evaluation of cyclone separators is plant-specific and depends on cyclone separator design and the piping arrangement for a pump's seal injection system.	The HPSI and CSS pump seal configuration at St. Lucie Unit 2 was modified to utilize recirculated seal cavity fluid in the seal, which included removal of the cyclone separators. The resulting seal configuration is consistent with that utilized on the St. Lucie-1 ECCS and CSS pumps.
14.	TR WCAP-16406-P, Revision 1, Section 8.1.4, refers to pump vibration evaluations. The effect of stop/start pump operation is addressed only in the context of clean water operation, as noted in Section 8.1.4.5 of TR WCAP-16406-P, Revision 1. If an ECCS or CSS pump is operated for a period of time and builds up a debris "packing" in the tight clearances, stops and starts again, the wear rates of those areas may be different due to additional packing or imbedding of material on those wear surfaces. Licensees who use stop/start operation as part of their overall ECCS or CSS operational plan should address this situation in their evaluation.	The pump wear analysis assumes 30 days of continuous wear. St. Lucie Unit 2 procedure does not direct to stop then start the ECCS/CSS pumps during recirculation. In the event the pumps must be stopped and restarted, the Archard wear model assumed the highest friction factors and eccentricity postulated by the WCAP-16406-P. Therefore, any "additional packing" that could be caused by stopping and starting the pumps is bounded by the Archard model used.
15.	TR WCAP-16406-P, Revision 1, Section 8.1.4, states: "should the multistage ECCS pumps be operated at flow rates below 40% of BEP during the containment recirculation, one or more of the pumps should be secured to bring the flow rate of the remaining pump(s) above this flow rate." The NRC staff does not agree with this statement. System line-ups and pump operation and operating point assessment are the responsibility of the licensee. Licensees must ensure that their ECCS pumps are capable of performing their intended function and the NRC has no requirements as to their operating point during the recirculation phase of a LOCA.	The plant's procedures were not changed to reflect the WCAP-16406-P concerns. The St. Lucie Unit 2 multistage pumps performed adequately with respect to pump design and plant design basis before GSI-191 concerns. The pump assessment concludes that the HPSI pumps continue to be capable of performing their intended design basis functions based on the pump's hydraulic characteristics after 30 days of wearing.
16.	TR WCAP-16406-P, Revision 1, Section 8.1.5, makes a generic statement that all SI pumps have wear rings that are good "as new" based solely upon "very little service beyond in-service testing." A stronger basis is needed to validate this assumption, if used (e.g., maintenance, test and operational history and/or other supporting data).	The pump wear analysis assumed a starting wear ring clearance as the average of the vendor recommended gap range. The combination of low run time and very clean fluids would justify an assumption that the wear rings are "as good as new" and thus closer to the low end of the recommended ring clearance, but the wear calculation conservatively assumes that the wear rings are mid-way between the lower and the upper ring clearance recommended by the pump manufacturers.

L&C No.	NRC Limitations & Conditions (WCAP-16406-P Rev. 1)	FPL (St. Lucie Unit 2) Response
17.	TR WCAP-16406-P, Revision 1, Section 8.3, identifies criteria for consideration of tube plugging. Licensees should confirm that the fluid velocity going through the heat exchanger is greater than the particle settling velocity and evaluate heat exchanger plugging if the fluid velocity is less than the settling velocity.	The minimum heat exchanger tube velocity was calculated and compared to the bounding particle settling velocity. No heat exchangers were found to be susceptible to debris settling within the tubes.
18.	TR WCAP-16406-P, Revision 1, Section 8.6, refers to evaluation of instrumentation tubing and system piping. Plugging evaluations of instrument lines may be based on system flow and material settling velocities, but they must consider local velocities and low-flow areas due to specific plant configuration.	The evaluation of instrumentation tubing was based primarily on the instrument line's specific configuration, and then upon the local flow velocity for instrument lines oriented below the horizontal datum. Plant-specific layout and actual local flow velocities were used in all cases.
19.	TR WCAP-16406-P, Revision 1, Sections 8.6.7, 8.6.8, 8.6.9, and 8.6.10 describe, in general terms, the Westinghouse, CE, and B&W RVLIS. TR WCAP-16406-P, Revision 1, recommends that licensees evaluate their specific configuration to confirm that a debris loading due to settlement in the reactor vessel does not effect the operation of its RVLIS. The evaluation of specific RVLIS design and operation is outside the scope of this SE and should be performed in the context of a licensees reactor fuel and vessel evaluations.	The St. Lucie Unit 2 RVLIS design was compared to the generic designs reviewed and deemed acceptable by the WCAP-16406-P. St. Lucie Unit 2 utilizes a Heated Junction Thermocouple System consisting of eight pairs of heated/unheated thermocouples. Since the probes are not in the lower plenum where debris could potentially settle, debris settling will not affect the operation of its RVLIS.
20.	TR WCAP-16406-P, Revision 1, Section 8.7, refers to evaluation of system piping. Plugging evaluations of system piping should be based on system flow and material settling velocities. Licensees should consider the effects of local velocities and low-flow areas due to specific plant configuration. A piping wear evaluation using the free-flowing wear model outlined in Section 7 should be performed for piping systems. The evaluation should consider localized high-velocity and high-turbulence areas. A piping vibration assessment should be performed if areas of plugging or high localized wear are identified.	ECCS and CSS system piping was checked for potential plugging due to debris settling. At each control valve in the recirculation systems, the minimum expected system flow rates in each line were used to minimize the flow velocity and compared to the bounding settling velocity. The evaluation at control valve locations considered the local flow velocities of all the various line sizes and flow rates used for recirculation in the St. Lucie Unit 2 ECCS and CSS. All lines were found acceptable with respect to plugging. Regarding wear, the material wear of the bounding ECCS/CSS orifice, which sees much higher wear than system piping, was compared to the pipe wall thicknesses in the recirculation lines. The material wear was found to be insignificant compared to the pipe wall thickness. Therefore, all pipes were determined to have sufficient wear margin, and the erosion was considered so slight as to not require vibration analysis.
21.	TR WCAP-16406-P, Revision 1, Section 9, addresses reactor internal and fuel blockage evaluations. This SE summarizes seven issues regarding the evaluation of reactor internal and fuel. The PWROG indicated that the methodology presented in TR WCAP-16793-NP (Reference 15) will address the seven issues. Licensees should refer to TR WCAP-16793-NP and the NRC staff's SE of the TR WCAP-16793-NP, in performing their reactor internal and fuel blockage evaluations. The NRC staff has reached no conclusions regarding the information presented in TR WCAP-16406-P, Section 9.	Reactor internal and fuel blockage was evaluated utilizing WCAP-16793-NP and is discussed in NRC Topic 3.n, Downstream Effects – Fuel and Vessel.
22.	TR WCAP-16406-P, Revision 1, Table 4.2-1, defines a plant Category based on its Low-Head / Pressure Safety Injection to RCS Hot-Leg Capability. Figure 10.4-2 implies that Category 2 and 4 plants can justify LHSI for hot-leg recirculation. However, these categories of plants only have one hot-leg injection pathway. Category 2 and Category 4 plant licensees should confirm that taking credit for the single hot-leg injection pathway for their plant is consistent with their current hot-leg recirculation licensing basis.	This WCAP-16406-P guidance was not utilized. St. Lucie Unit 2 has single-failure tolerant hot-leg recirculation capability as part of the existing design and licensing basis. No credit was taken for a single hot-leg injection pathway as suggested by the WCAP-16406-P.

L&C No.	NRC Limitations & Conditions (WCAP-16406-P Rev. 1)	FPL (St. Lucie Unit 2) Response
23.	TR WCAP-16406-P, Revision 1, Appendix F, discusses component wear models. Prior to using the free-flowing abrasive model for pump wear, the licensee should show that the benchmarked data is similar to or bounds its plant conditions.	The debris and wear models were conservatively applied to ensure that they conservatively predict expected wear. Actual pump dimensions, characteristics, and materials, and the actual plant debris concentration was utilized in predicting pump wear.
24.	TR WCAP-16406-P, Revision 1, Appendix H, references American Petroleum Institute (API) Standard 610, Annex 1 eighth edition. This standard is for newly manufactured pumps. Licensees should verify that their pumps are "as good as new" prior to using the analysis methods of API-610. This validation may be in the form of maintenance records, maintenance history, or testing that documents that the as-found condition of their pumps.	The pump calculations all assume that the starting point for the wear rings is the midpoint of the manufacturers recommended ring clearance (see #16, above). Since the pumps rings are in new condition, the analysis methods of API-610 are applicable.
25.	TR WCAP-16406-P, Revision 1, Appendix I, provides guidelines for the treatment, categorization and amount of DBA Qualified, DBA Acceptable, Indeterminate, DBA Unqualified, and DBA Unacceptable coatings to be used in a licensee's downstream sump debris evaluation. A technical review of coatings generated during a DBA is not within the scope of this SE. For guidance regarding this subject see the NRC staff's SE of NEI-04-07 (Reference 13) Section 3.4 "Debris Generation."	This SER limitation is simply a statement of the limit of the NRC's review; no action is required. For reference, however, the amount of specific types of coatings used in the downstream effects analysis was determined on a plant-specific basis considering the types of coatings actually in use in the St. Lucie Unit 2 containment.
26.	TR WCAP-16406-P, Revision 1, Appendix J, derives an approach to determining a generic characteristic size of deformable material that will pass through a strainer hole. This approach is only applicable to screens and is not applicable to determining material that will pass through other close tolerance equipment.	This approach that is "only applicable to screens" was only applied to the sump screens (strainers in the case of St. Lucie Unit 2). The characteristic size of debris that can pass through the sump strainer was calculated and then compared to the smallest passages of downstream components. The component was deemed acceptable where the smallest passage is larger than this characteristic size, in other words the deformation of the debris was not credited to allow it to pass the downstream close tolerances.
27.	TR WCAP-16406-P, Revision 1, Appendix O, Section 2.2, states that the wear coefficient, K, in the Archard Model is determined from testing. The wear coefficient (K) is more uncertain than the load centering approach and K may vary widely. Therefore, licensees should provide a clear basis, in their evaluation, for their selection of a wear coefficient.	The Archard model wear coefficient utilized in the St. Lucie Unit 2 HPSI pump wear analysis is the "conservative upper bound" suggested by the WCAP-16406-P and 5 times larger than the value actually used in the WCAP-16406-P example. Its use resulted in calculated wear greater than the amount seen in the Davis-Besse testing. The materials, debris types and concentrations are comparable. Therefore, the K-value used appears to be the best conservative information available on ECCS pump wear when exposed to insulation and coating debris.
28.	TR WCAP-16406-P, Revision 1, Appendix P, provides a method to estimate a packing load for use in Archard's wear model. The method presented was benchmarked for a single situation. Licensees are expected to provide a discussion as to the similarity and applicability to their conditions. The licensee should incorporate its own specific design parameters when using this method.	The methodology of Appendix P was not used in the determination of packing loads. The St. Lucie Unit 2 calculation utilized the methodology discussed in Appendix O of WCAP-16406-P (centering load) for defining loads to be used in the packing wear model, and specific design parameters were applied to that methodology.

L&C No.	NRC Limitations & Conditions (WCAP-16406-P Rev. 1)	FPL (St. Lucie Unit 2) Response
29.	TR WCAP-16406-P, Revision 1, Appendix Q, discusses bounding debris concentrations. Debris concentrations are plant-specific. If 9.02E-5 (mils/hr)/10 PPM is to be used as the free flowing abrasive wear constant, the licensee should show how it is bounding or representative of its plant.	9.02E-5 (mils/hr)/10 PPM was not used as the free flowing abrasive wear constant at the plant. The wear rate was calculated for each pump's actual material hardness and actual debris concentrations, including application of the bounding debris penalty as required.
30.	TR WCAP-16406-P, Revision 1, Appendix R, evaluates a Pacific 11-Stage 2.5" RLIJ pump. The analysis was performed by the PWROG using specific inputs. ECCS pumps with running clearance designs and dimensions significantly different than those covered by the analysis should be subjected to pump-specific analysis to determine the support stiffness based on asymmetric wear. If licensees use the aforementioned example, a similarity evaluation should be performed showing how the example is similar to or bounds their situations.	Acceptance criteria and stiffness values from Appendix R were not used. All pump calculations utilize plant specific information and data to perform wear calculation and shaft stiffness evaluations. Example data from the WCAP-16406-P is not used in any calculation. The designs and dimensions of the St. Lucie Unit 2 HPSI pumps were reviewed and found to not be significantly different than those covered by the WCAP-16406-P analysis. Multi-stage pumps were evaluated by finding the shaft stiffness at a symmetric increase in wear ring clearance equal to 2X as the as-new clearance. The stiffness of the pumps after debris induced wear was then calculated. The stiffness of the pumps after recirculation asymmetric wear was compared to the allowed stiffness equivalent to a uniform 2X initial clearance to judge the acceptability of the pump.
31.	Licensees should compare the design and operating characteristics of the Pacific 2.5" RLIJ 11 to their specific pumps prior to using the results of Appendix S in their component analyses.	The criteria and analysis specific for Pacific 2.5" RLIJ 11 as shown in Appendix S were not used. As stated in response 30 above, all pump calculations utilize plant specific information and data to perform wear calculation and shaft stiffness evaluations. Example data from the WCAP-16406-P is not used in any calculation. Multi-stage pumps were evaluated by finding the shaft stiffness at a symmetric increase in wear ring clearance equal to 2X as the as-new clearance. The stiffness of the pumps after debris induced wear was then calculated. The stiffness of the pumps after recirculation asymmetric wear was compared to the allowed stiffness equivalent to a uniform 2X initial clearance to judge the acceptability of the pump