Florida Power & Light Company, 6501 S. Ocean Drive, Jensen Beach, FL 34957

FPL

July 30, 2009

L-2009-179
10 CFR 50.54(f)

U. S. Nuclear Regulatory Commission
ATTN: Document Control Desk
11555 Rockville Pike
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Florida Power & Light Company
St. Lucie Unit 1
Docket No. 50-335

Subject: Updated Supplemental Response to NRC Generic Letter (GL) 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 (ML042360586)

(2) 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)

(3) Letter L-2008-137 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 June 30, 2008 (ML081840513)

(4) Letter from B. L. Mozafari (U. S. Nuclear Regulatory Commission) to J. A. Stall (FPL) "St. Lucie Plant, Unit 1 – Request for Additional Information (RAI) Related to Generic Letter 2004-02, Potential Impact of Debris Blockage on Emergency Sump Recirculation at Pressurized-Water Reactors," (TAC NO. MC4710), dated September 17, 2008 (ML082610690)

(5) Letter L-2008-235 from G. L. Johnston, (FPL) to U. S. Nuclear Regulatory Commission, "Request for Extension of the Completion Date of the St. Lucie Unit 1 NRC Generic Letter 2004-02 Actions," dated October 29, 2008 (ML083080377)

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NRC Generic Letter (GL) 2004-02 (Reference 1) requested licensees to:

1) perform an evaluation of the emergency core cooling system and containment spray system recirculation functions in light of the information provided in GL 2004-02 and, if appropriate, take additional actions to ensure system function; and

2) provide a written response in accordance with 10 CFR 50, §50.54(f).

The Florida Power and Light Company (FPL) submitted preliminary supplemental responses (Reference 2) to the GL on February 27, 2008, and final supplemental responses (Reference 3) on June 30, 2008 for St. Lucie Units 1 and 2. FPL stated that plant specific strainer testing and analysis confirmed that the new strainers are of sufficient size to demonstrate acceptable emergency core cooling system (ECCS) pump net positive suction head (NPSH) margin when fully loaded with debris only, and when evaluated for potential chemical impacts, based on the results of the chemical testing that was performed.

By letter dated September 17, 2008 (Reference 4) the NRC stated that they had identified several critical issues with the test protocol used in the chemical effects testing at VUEZ, and requested a response to an attachment containing a request for additional information (RAI) for St. Lucie Unit 1. The NRC stated that an alternative approach to demonstrate adequate performance of the containment sump may need to be considered by FPL, and that should an alternate approach be utilized, response to the specific attached RAIs is not necessary.

In an October 3, 2008 teleconference with the NRC, FPL provided an overview of an alternative approach for St. Lucie Unit 1 for addressing the NRC's concern regarding the VUEZ test results. By letter dated October 29, 2008 (Reference 5), FPL stated that additional testing and analysis would be performed in order to validate adequate performance of the containment sump, and that the results would be provided to the NRC by July 30, 2009. FPL has completed the alternative approach activities.

The purpose of this submittal is to provide the results and conclusions of the debris transport analysis and chemical effects testing that have recently been completed for St. Lucie Unit 1. The format that has been chosen to present this information is to revise our June 30, 2008 supplemental response in its entirety.

Attachment 1 provides the St. Lucie Unit 1 GL 2004-02 Summary Description of Approach, including a discussion of conservatisms and margins.

Attachment 2 provides the St. Lucie Unit 1 Updated Supplemental Response for GL 2004-02.

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

Please contact Mr. 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 July 30, 2009.

Sincerely yours,

Gordon L. Johnston
Site Vice President
St. Lucie Plant

Attachments: (2)

Attachment 1

St. Lucie Unit 1

GL 2004-02

Summary Description of Approach

Summary Description Of Approach

This supplemental response to NRC Generic Letter (GL) 2004-02 updates information previously submitted in FPL letter L-2008-037, 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 June 30, 2008. Changes to the June supplemental response and new information are shown in the text with revision bars.

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 has been raised and is controlled at 32.5 feet to be consistent with the recently approved license amendment request to revise the plant Technical Specifications.

Process Changes:

- Specifications and procedures were updated to ensure that strainer design basis loads will not be exceeded.
- Walkdowns, the sump water level calculation, and 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.

Margins and Conservatisms Summary

1. Introduction

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

2. Design Basis Event Scenarios

- The piping break selected was based on selecting the break size and location that would result in debris generation that will maximize the head loss across the containment sump strainers. The design basis piping break is a break of the reactor coolant system (RCS) loop B hot leg at the base of the steam generator (42-inch ID). This break generates the greatest quantity of debris. Feedwater and main steam piping were not considered for potential break locations because the emergency core cooling system (ECCS) is not required to operate in the recirculation mode for main steam or feedwater line breaks.

- Following a potential RCS piping break, safety injection is automatically initiated upon a safety injection actuation signal (SIAS) which is produced by coincidence of two-of-four low pressurizer pressure signals or two-of-four high containment pressure signals. Low pressurizer pressure and high containment pressure are indicative of a loss of coolant accident (LOCA). The reactor is tripped by the reactor protective system and the turbine is tripped coincident with a reactor trip. The engineered safety features actuation system (ESFAS) containment isolation signal (CIS) is also initiated by a SIAS.

- System operation in the Injection Mode

  The following equipment is simultaneously activated:
  1) Both high pressure safety injection (HPSI) pumps start,
  2) Both low pressure safety injection (LPSI) pumps start,
  3) All eight high pressure and all four low pressure injection valves open,
  4) The four safety injection (SI) tank recirculation/drain valves receive a signal to close.

  The refueling water tank (RWT) provides a reservoir of borated water for the injection mode operation of the SI system.

  Once the RCS pressure drops below the SI tank pressure, the SI tanks discharge their contents into the RCS cold legs.

  Containment spray (CS) is automatically initiated by the containment spray actuation signal (CSAS) which is a coincidence of the SIAS and the high-high containment pressure signal. During the initial injection mode the CS system sprays borated water from the RWT into the containment.

Upon receipt of the CSAS, isolation valves open in the iodine removal system line to allow flow of sodium hydroxide (NaOH) from the NaOH storage tank into the suction of the containment spray pumps. Upon reaching low-low level in the NaOH storage tank, the caustic line isolation valves close to isolate the NaOH storage tank, thereby ending injection of NaOH.

- System Operation in Recirculation Mode

  The SI system and CS system transfer automatically from the injection mode of operation to the recirculation mode of operation on receipt of the recirculation actuation signal (RAS). The RAS is produced by a low level signal from the RWT.

  The recirculation mode of operation must not be initiated until at least 20 minutes have elapsed since initiation of safety injections. At this time the core decay heat will be less than the heat removal capacity of one HPSI pump taking suction from the containment sump. For this reason the injection mode of operation must be maintained for at least 20 minutes and sufficient RWT volume for this operation is provided.

  On receipt of the RAS, the containment sump isolation valves are opened and the RWT outlet valves are closed. Opening the sump isolation valves, results in a transfer of the SI and CS pump suction from the RWT to the containment sump.

  The RAS also acts to shut down the LPSI pumps. Recirculation flow is normally provided by at least one HPSI pump. Plant procedures require that, just prior to RAS, with at least one CS pump running, a portion of the cooled water from the CS system be directed to the HPSI pump suction.

- The containment sump strainer design flow rates are based on maximum pump flows (two HPSI pumps and two CS pumps) plus the flow from a LPSI pump which has failed to trip on RAS, plus margin for flow variability. This applies to the debris transport analysis, head loss testing, and net positive suction head (NPSH) analysis. Utilizing these high flow rates is very conservative because significantly more flow than design is accommodated with margin by the containment sump strainer system for this highly unlikely event.

3. <u>Debris Generation / Zone of Influence</u>

- In the debris generation analysis, the zone of influence (ZOI) used for Nukon Insulation is 17.0D. WCAP-16710-P testing confirmed that the ZOI could be reduced 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 that the debris generation calculation was conservative and to ensure inclusion of the entire volume of insulation.

- An additional margin of 10% has been applied to the fiber and calcium silicate insulation volume results.
- The limiting break on the 42 inch hot let at Steam Generator B generates by far the most debris of any break considered and is therefore very conservative for any other break location analyzed.

4. Latent Debris

- Significant margin has been applied to the amount of latent debris analyzed and tested for St. Lucie Unit 1. The latent debris quantity was based on St. Lucie Unit 2 walkdowns and analysis in accordance with NEI 04-07. The latent debris quantity conservatively determined for Unit 2 was doubled for conservatism for use for St. Lucie Unit 1.
- Significant margin has been applied to the amount of miscellaneous debris analyzed and tested for St. Lucie Unit 1. The miscellaneous debris quantity was based on St. Lucie Unit 2 walkdowns and analysis. The miscellaneous debris quantity determined for Unit 2 was increased by 25% for conservatism for use for St. Lucie Unit 1.

5. Debris Transport

- Debris Transportation calculations were performed based on flow rates due to a LPSI pump failure to trip. This is very conservative because these flow rates are much higher and would occur only in the unlikely event of the single failure and only until the operator could stop the pump flow.
- 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.
- All of the small debris that is blown into the upper level of containment is washed down during the containment spray transient. To add additional conservatism all of the small debris in the upper containment is washed down to zones outside of the biological shield wall. In addition, all debris generated during the limiting break is assumed to originate in proximity zones nearest the break .
- The percentage of debris assumed in the in active pool was conservatively calculated as 13.37% in accordance with NEI 04-07. However, at a pool depth of over approximately 6 inches, water will start to flow into the inactive pool. Since the containment pool velocities would be higher at a depth of 6 inches, a significant percentage of the debris is expected to be suspended and as such the flow streams are expected to direct debris into the inactive pool. Although only 13.37 % was credited, the higher velocities at the lower sump level would be expected to transport a higher fraction to the inactive pool. Once the inactive pool volume has flooded and equalized with the containment pool, the overall containment pool level will continue to increase as water inventory is released

from the LOCA break site. The velocities in the sump pool will decrease as the level increases, and as such any debris not transported to the inactive pool is expected to begin to settle. Note that the expected response described above is not credited in the debris transport calculation and represents additional conservatism in the analysis.

6. Containment Coatings Evaluation

- In the transport analysis, 100% of qualified and unqualified coatings debris, regardless of types and location inside containment, were assumed to fail as particulates and all but that retained in inactive pools is assumed to transport to the screen. Electric Power Research Institute and industry testing indicates some unqualified coatings do not fail and some coatings fail as chips and may not transport to the sump.

7. Vortexing

- The vortexing determination was evaluated using three times the average strainer velocity. This is a much greater velocity than to the highest velocity strainer module.

8. NPSH

- A design flow rate of 8,530 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 of HPSI and CS pumps 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.

9. Downstream Effects – Ex-Vessel

- For the downstream effects wear analysis, the total debris load was determined for a bounding large break loss of coolant accident (LBLOCA) in accordance with NEI 04-07. A minimum sump water volume for recirculation was determined for a small break loss of coolant accident (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.

10. Downstream Effects – In-Vessel

- The results for the LOCADM calculations for the maximum sump volume, which include the required adjustments for the aluminum release rate increase and the fiber bump up factor, yielded a maximum fuel cladding temperature of 378.70 °F, which is 47.3% of the 800 °F acceptance criteria in WCAP-16793-NP Revision 0. This result is also well below the 750 °F acceptance criteria for using Option 2 in PWROG Letter OG-07-534. The thickest calculated post-LOCA scale (the scale formed by the concentration of chemical species after the LOCA) is 3.15 mils, which is 6.3% of the acceptance criteria of 50 mils. This result is also well below the 35 mils acceptance criteria for using Option 2 in PWROG Letter OG-07-534.

- The results for the LOCADM calculations for the minimum sump volume, which include the required adjustments for the aluminum release rate increase and the fiber bump up factor, yielded a maximum fuel cladding temperature of 378.70 °F, which is 47.3% of the 800 °F acceptance criteria in WCAP-16793-NP Revision 0. This result is also well below the 750 °F acceptance criteria for using Option 2 in PWROG Letter OG-07-534. The thickest calculated post-LOCA scale is 3.99 mils, which is 8% of the acceptance criteria of 50 mils. This result is also well below the 35 mils acceptance criteria for using Option 2 in PWROG Letter OG-07-534.

  The results of the LOCADM calculations are substantially below the WCAP limits for fuel cladding temperature and scale thickness and demonstrate that post-LOCA chemical effects will not challenge the ability of the ECCS to remove decay heat over the long term.

11. Chemical Effects

- Steps taken to minimize near-field effects in the head loss tests included batching debris and chemical precipitate in liquid slurries and adding the slurries to the test flume in discreet quantities to minimize agglomeration and/or saturation and early settling in the test flume. This maximized the amount of debris/precipitate on the screen and provided very conservative head loss results.

- The amount of chemicals calculated to form in 30 days were added to the test flume early in testing, and as such a 30 day chemical effect head loss 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.

- No credit was taken for silicate inhibition of aluminum

12. Screen Design/Strainer Structural Analysis

- The surface area for the recirculation sump strainers was increased from approximately 24 ft^2 to 8,275 ft^2. The replacement strainers have a nominal hole size of 0.0625 inch compared to the previous screens' openings of ¼ inch mesh size. These strainers are distributed around 260 degrees of containment which effectively lowers the approach velocities to the replacement strainers. The strainers have been designed for a crush pressure well above that expected under maximum head loss conditions.

13. Debris Source Term

- Specifications, design processes and procedures were updated to ensure that the strainer design basis debris and precipitate source loads will remain conservative. Specification updates ensure that strainer design basis coatings loads will not be exceeded.

14. Strainer Testing

- Less than half of the Calcium Silicate generated is calculated to be transported to the containment sump strainers. However, conservatively, 100% of the Calcium Silicate particulate calculated to be generated (91.1 cu ft) was assumed to transport to the sump strainers and used for the strainer debris head loss testing. No credit was taken for calcium silicate holdup in the inactive pool.

- The scaling factor for determining the test strainer size, test flow rates, and test debris quantities included significant conservatisms. For the purpose of scaling, four of the strainer modules were considered to be 100% blocked. Because of conservative reductions, the strainer area used for scaling was 6,527 ft^2. compared to the total strainer area of 8,187 ft^2

15. Conclusion

This combination of conservatisms and margins, together with the design modifications, the process changes, and the supporting analyses provides reasonable assurance that long-term core cooling is maintained. This submittal demonstrates compliance with the applicable GL 2004-02 regulatory criteria.

Attachment 2

St. Lucie Unit 1

Updated Supplemental Response GL 2004-02

UPDATED SUPPLEMENTAL RESPONSE TO GL 2004-02

This supplemental response to NRC Generic Letter (GL) 2004-02 updates information previously submitted in FPL letter L-2008-137, 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 June 30, 2008. Changes to the June supplemental response and new information are shown in the text with revision bars.

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 GL 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 were performed in 2008. Test results and conclusions were initially reported in the St. Lucie Unit 1 Supplemental Response to GL 2004-02 which was submitted to the NRC on June 30, 2008 under Topics 3.m, Downstream Effects – Components and Systems, 3.n, Downstream Effects – Fuel and Vessel, and 3.o, Chemical Effects.

Subsequently, FPL performed additional actions. The first action was to perform a full debris transport analysis using Computational Fluid Dynamics (CFD) for the design basis flow case to augment previous analysis. The second action was to perform flume head loss testing based on the revised transport data and flow rates. The analysis and test results and conclusions are discussed in this supplemental response under Topics 3.c, Debris Characteristics, 3.e, Debris Transport, and 3.o, Chemical Effects. Additionally, Topics 3.f, Head Loss and Vortexing, 3.g, Net Positive Suction Head (NPSH), 3.h, Coatings Evaluation, and Enclosure 1, Safety Evaluation Report, Limits and Conditions for WCAP 16530-NP Revision 0.

As noted in Topic 3.g, Net Positive Suction Head (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 determined that an amendment to the Technical Specifications, raising the minimum Refueling Water Tank (RWT) level, was required to correctly bound St. Lucie Unit 1 strainer test results and calculations. Hence, a proposed amendment to the St. Lucie Unit 1 Technical Specifications requesting the necessary increase in RWT level was submitted. This proposed amendment has been approved by the NRC. The existing administrative controls for maintaining a higher water level in the RWT will remain in effect until the amendment is implemented on-site.

GL 2004-02 Applicable Regulatory Requirements

10 CFR 50.46 requires that the emergency core cooling system (ECCS) have the capability to provide long-term cooling of the reactor core following a loss of coolant accident (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 approved 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. However, in response to concerns raised by the Advisory Committee on Reactor Safeguards regarding WCAP-16793-NP, Rev. 0, the Pressurized Water Reactor Owners' Group (PWROG) is performing additional testing and analyses to more realistically determine the potential downstream and chemical effects on the reactor core and the vessel/components. Corrective actions will be identified, if required for resolution of this item, and submitted to the NRC following the issuance of the revised WCAP-16793-NP and the associated NRC Safety Evaluation Report (SER).

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 been determined, based on a review of the Waterford audit results, that the current administratively controlled Refueling Water Tank (RWT) water level should be incorporated into the Technical Specifications. As discussed further in Topic 3.p *Licensing Basis*, the NRC has approved an amendment request to raise the Technical Specification minimum level for the Refueling Water Tank (RWT).

A full debris transport analysis using Computational Fluid Dynamics (CFD) for the design basis flow case has been performed. A summary is provided in the response to NRC Topic 3.e, Debris Transport.

Chemical effects testing has been performed by AREVA Inc. at Alden Labs. 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 RAIs.

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 relative to the location of the strainer modules is of secondary importance, and the primary consideration is the amount of 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] 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.

Table 3c-1: Debris Size Distribution –Inside 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%	--
Coatings (Particulates) 100	100%	--

Table 3c-2: Debris Size Distribution –Outside the ZOI

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 particulate debris used in the strainer performance testing for St. Lucie Unit 1 are consistent with NEI 04-07 (GR) and the NRC staff's SE.

The specific surface areas for fibrous and particulate debris are sometimes used in the prediction of head loss with the NUREG/CR-6224 correlation. However, St. Lucie Unit 1 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 deviate from USNRC-approved guidance.

The debris values for amounts, bulk densities, material densities and characteristic diameters for fibrous debris and particulate debris used in the strainer performance testing for St. Lucie Unit 1 are consistent with NEI 04-07 (GR) and the staff's SE.

The bulk densities that were used to ensure that the proper quantities of the surrogate materials were used in the head loss tests are provided in Table 3.c-3 below.

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

Debris Type	Bulk density
Cal-sil powder	14.5 lbs/ft^3
Fiber	2.4 lbs/ ft^3
Tin Powder (surrogate for zinc coatings)	457 lbs/ ft^3
Acrylic coating (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.

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

In order to determine the distribution of the 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. Note that additional details on the blowdown, washdown, and transport sequence are being provided in a letter from FPL to the NRC that provides additional responses to the NRC's RAIs dated January 22, 2009. This letter, L-2009-180, is also being submitted in July 2009.

[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-coolant-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 extent 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.

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.

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.

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 fluid flow and heat transfer.

The computational mesh generated in the model was approximately 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 1 containment sump flow patterns and velocity distributions. Each relevant physical boundary is listed followed by a discussion of the boundary condition applied at that surface.

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 23.86 ft. This water surface elevation is less than 1% higher than the minimum water level at the start of recirculation which was revised to account for containment atmosphere water content. This surface was modeled as a velocity inlet representing an even distribution of spray flow over the containment pool.

Sump Strainers

The strainers were modeled as velocity inlets, with uniform negative velocities applied to each face. Two cases of sump strainer flow distribution were considered. These cases correspond to flow distribution at maximum flow rate and minimum temperature with debris (Case 1) and with no debris (Case 4). Table 3.e-1 lists the strainer flow distribution for Case 1 and Case 4.

Table 3.e- 1: GE Strainer Flow Distribution (Units in GPM)

Strainer	Case 1	Case 4
STR-D7	414.41	160.75
STR-D6	414.55	164.61
STR-D5	416.13	203.43
STR-D4	419.63	280.35
STR-D3	391.85	388.18
STR-D2	434.89	592.41
STR-D1	403.67	911.11
STR-C6	408.04	176.40
STR-C5	334.63	166.83
STR-C4	410.25	241.00
STR-C3	413.30	322.24
STR-C2	418.83	460.60
STR-C1	427.49	674.86
STR-B6	362.03	111.01
STR-B5	361.15	90.60
STR-B4	360.94	84.10
STR-B3	395.43	390.93
STR-B2	375.69	391.70
STR-B1	353.90	557.72
STR-E2	506.47	1,043.00
STR-E1	506.76	1,118.00
TOTAL	8,530	8,530

The net flow through the sump strainer was equal to the sum of the spray and break flows. The design basis head loss and flow distribution calculation determined the flow through each strainer for Case 1 and Case 4 at a total flow of 8,530 gpm. In the simulation for the CFD, two scenarios (high and low break flow) were performed for each case. For high break flow (LPSI failure to trip), the sum of the spray and break flow was 11,630 GPM which was more than the total of the sump strainer flow distribution calculated in the design basis head loss and flow distribution calculation (8,530 GPM). To determine the flow distribution for the high flow case, the strainer flow distribution was adjusted by multiplying by the ratio of the high and low total flows (11,630/8,530 = 1.36342). Table 3.e-2 lists the adjusted strainer flow distribution for the high break flow scenario. For the low break flow scenario, the sum of the spray and break flow (8,530 GPM) was equal to the total of the sump strainer flow distribution (8,530 GPM). The flow distribution in the sump strainer for the low break flow scenario was not adjusted since the flow was already balanced.

Table 3.e- 2: GE Strainer High Flow Distribution (Units in GPM)

Strainer	Case 1	Case 4
STR-D7	565.01	219.17
STR-D6	565.20	224.43
STR-D5	567.36	277.37
STR-D4	572.13	382.24
STR-D3	534.26	529.25
STR-D2	592.94	807.71
STR-D1	550.37	1242.23
STR-C6	556.33	240.50
STR-C5	456.24	227.46
STR-C4	559.34	328.58
STR-C3	563.51	439.35
STR-C2	571.04	628.00
STR-C1	582.85	920.12
STR-B6	493.61	151.35
STR-B5	492.40	123.52
STR-B4	492.11	114.67
STR-B3	539.14	533.01
STR-B2	512.22	534.05
STR-B1	482.51	760.41
STR-E2	690.53	1,422.05
STR-E1	690.93	1,524.31
TOTAL	11,630	11,630

St. Lucie Unit 1 does not employ debris interceptors.

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 in the active pool, latent debris, signs, stickers, tags, tape, and other miscellaneous debris are conservatively assumed to transport 100% to the strainer modules.

Using the results of the 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)

Table 3.e-3 summarizes the results of the transport analysis:

Table 3.e-3 Debris at Sump Strainer Modules for Limiting Case Break S1

Debris Type	Quantity Generated	Quantity at Strainer
Mirror RMI	857.2 ft^2	153.54 ft^2
Cal-Sil	91.1 ft^3	37.35 ft^3
Fiberglass (Nukon/Knaupf)	1,366.6 ft^3	588.1 ft^3
Coatings	15.21 ft^3	13.18 ft^3

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

Less than half of the Calcium Silicate is calculated to transport to the strainers. However, for conservatism, the entire amount of Cal-Sil particulate generated was assumed to transport and was introduced to the test flume.

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 approximately 14 inches. At the minimum Small Break LOCA (SBLOCA) water level, the submergence of the highest opening in the strainer system is 6 inches less than for LBLOCA.

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 much higher than the flow to these modules. This evaluation is, therefore, considered bounding for the remainder of the strainer 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 approximately 14 inches for the LBLOCA, and 6 inches less 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 head loss and the module/plenum/piping head loss.

The strainer head loss, including chemical effects, is based on the head loss tests that were run specifically for St. Lucie Unit 1 (PSL-1) by AREVA at Alden Labs.

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.

[RAI 36] 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. The data provided was utilized to create a representative and bounding flow stream in the test flume. For all design basis and bypass tests performed for PSL-1, the debris quantities were scaled to the test flume based on expected flow rates in PSL-1 containment. Equation 3f-1 was used to scale the debris quantities.

Equation 3f-1: Debris Quantity Scaling Factor

$$\frac{TestFlumeFlowRate}{PSL-1FlowRate} = ScalingFactor(\%)$$

The PSL-1 strainer design flow rate is 8,530 gpm through the strainer modules within containment. For conservatism, a prototypical strainer module D2 with the fifth highest flow rate of the 21 strainer modules was used for scaling (592.4gpm). This flow rate was scaled up based on the total strainer area and sacrificial area as described below. The starting surface area of the strainer modules within PSL-1 was 8,187 ft^2 (8275 – 88.1 foreign material allowance). Assuming the highest flow strainer modules E1, E2, C1 and D1 are 100% blocked during a LOCA, the surface area for these strainers are subtracted from the total strainer surface. Another 100 ft^2 of surface area is sacrificed due to unexpected miscellaneous debris that may exist on the strainers at the start of a LOCA. Thus, the surface area used to determine the test flow rate is 6,527 ft^2. The following methodology was used to determine the test flume minimum flow rate shown below:

$$592.4gpm\frac{8{,}187ft^2}{6{,}527ft^2} = 743.1gpm$$

Utilizing Equation 3f-1, the scaling factor was calculated as shown below:

$$\frac{743.1gpm}{8{,}530gpm} = 8.71\%$$

A scaling factor of 8.71% was applied to all debris quantities for all of the tests based on the above methodology. Note that this scaling factor is extremely conservative as the scaling factor based on the test strainer area is approximately 4.8% with respect to the total strainer area.

Non-chemical debris was procured and produced in accordance with AREVA 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 1 strainer assemblies operating in containment. Non-chemical debris was introduced in accordance with NRC feedback;

namely, particulates first; then fine fibers; then smalls, etc.

Chemical debris was produced and accepted for use in accordance with 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.

Typically, a regression line is plotted for the head loss data collected during the last 15 flume turnovers of the test. This regression line is then used to provide an estimated head loss for a given mission time (usually 30 days). However, based on test data, it is apparent that the head loss depletes with respect to time. If a regression line is plotted using this data, the head loss would trend to zero. It is expected that the head loss would diminish to a constant value. Since the head loss depleted with respect to time at the end of the test, the maximum head loss value observed during the test bounds the postulated maximum head loss value.

Based on these test results, the Design Basis Tests head loss was taken at the absolute maximum and resulted in a final head loss across the screen and debris bed of 8.721 feet of water at an average temperature of 94.3 °F, and average flow of 752.7 gpm. Although this flow is higher than the scaled test target flow of 743.1 gpm, for conservatism, the head loss was not adjusted downward for flow.

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 materials used to represent the St. Lucie Unit 1 debris in the test are listed in Table 3.f-1 below.

The module/plenum/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 connection. 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 8,530 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.
- 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 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. For debris laden strainers, the piping/plenum head loss of 6.22 ft. is based on approximate evenly distributed strainer module flow and applied throughout the mission time. This is very conservative because these head losses would be much lower in the critical early stages of the transient. See Topic 3.j, Screen Modification Package, for the strainer size.

Table 3.f-1: Test Debris Materials

Debris Type	Material	Density
Fiber	Transco Thermal Wrap (shredded)	2.4 lb/ft^3
Cal-Sil	(Cal-Sil powder)	14.5 lb/ft^3
Qualified steel coatings	Tin Powder	457 lb/ft^3
Qualified concrete and unqualified coatings	Acrylic coating	94 lb/ft^3

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

Condition	Design Flow Rate (gpm)	Strainer Head Loss (ft)	Piping/Plenum Head Loss (ft)	Total Head Loss (ft)
Debris Laden (210 °F)	8,530	3.56	6.22	9.78
Debris Laden (94.3 °F)	8,530	8.721	6.22	14.94
Clean (105.1 °F, 757.4 gpm)	8,530	.313	3.06	3.37

St. Lucie Unit 1 head loss testing of a debris laden strainer section was conducted by AREVA at Alden Labs at final fluid temperatures of approximately 94 °F. Head loss values obtained 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 tests confirmed that for the St. Lucie Unit 1 limiting head loss test cases, no boreholes were observed. Flow sweeps were also conducted with head loss checks to verify the absence of boreholes. See the end of test flow sweep data on Figure 3.f-2.

For the limiting design case (lowest pool level and highest debris head loss) the minimum permissible partial pressure of air existing prior to the accident is credited in addition to vapor pressure for prevention of flashing at the immediate strainer/debris bed surface.

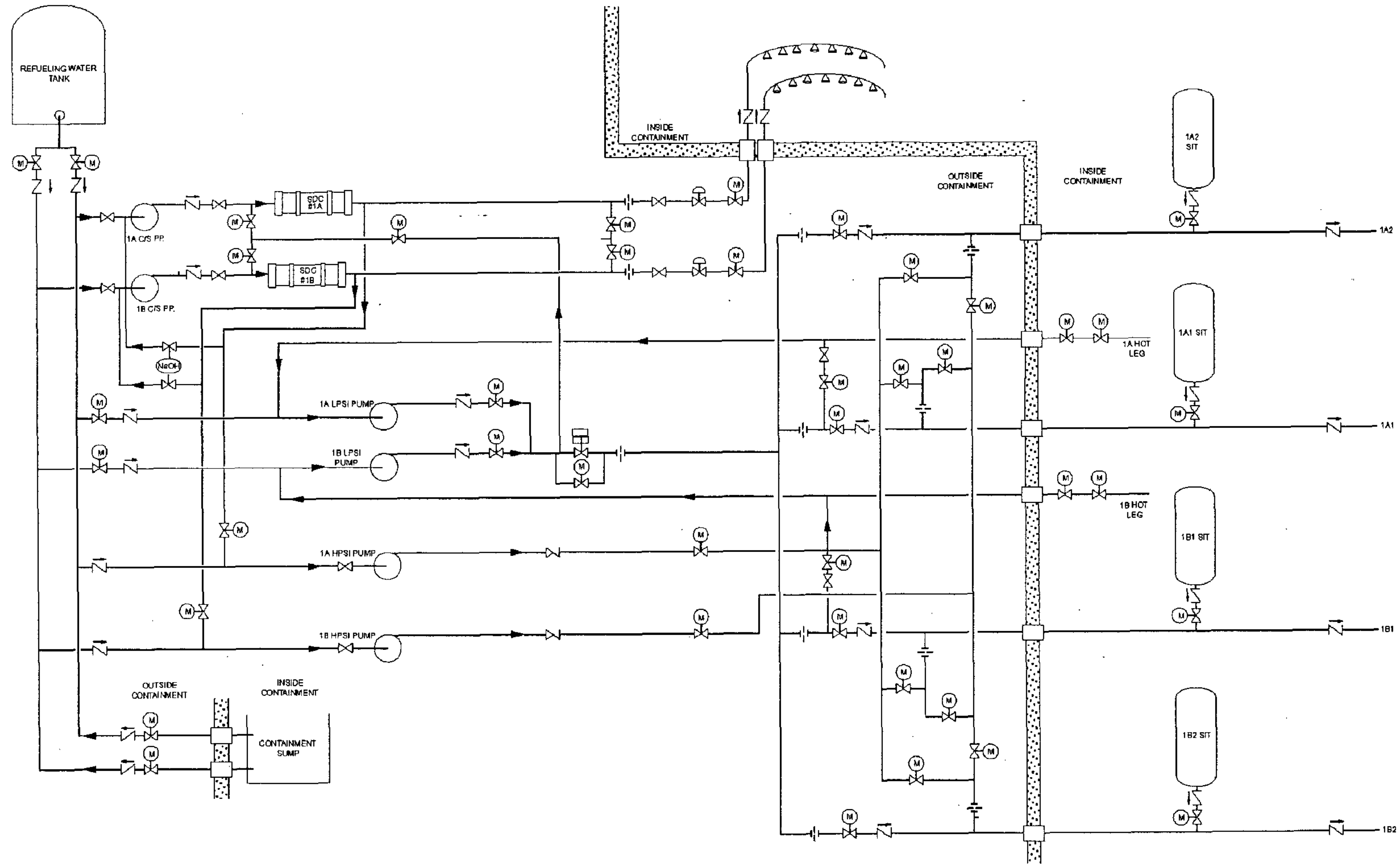
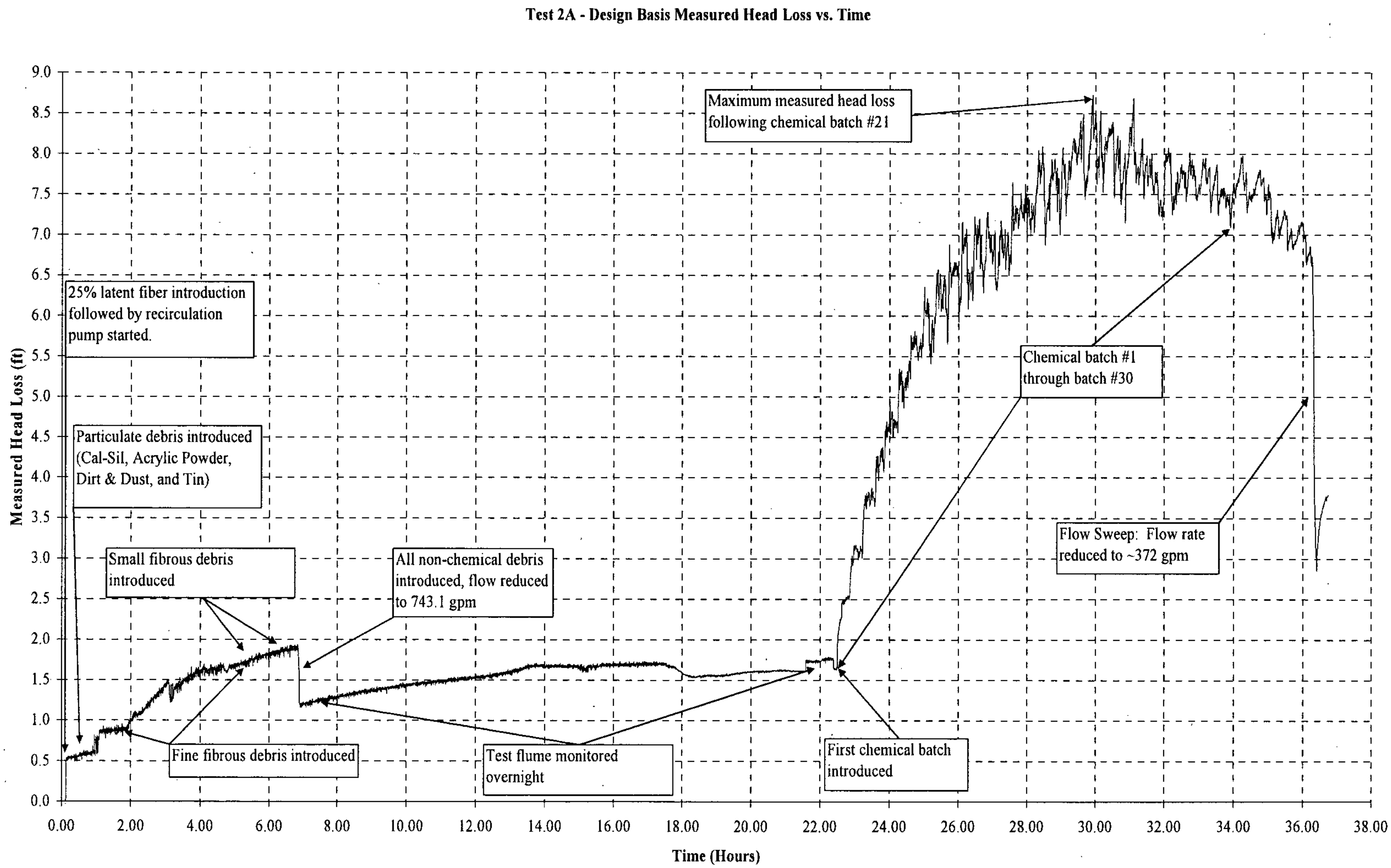


Figure 3.f-1: ECCS/CSS Piping Schematic



<u>**Figure 3.f-2: ECCS/CSS Strainer Head Loss Test**</u>

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

FPL Response

The minimum LBLOCA post LOCA containment water level will reach an elevation of 23.81 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 23.31 ft (assuming an RWT level of 32.5 ft and minimum levels assumed in other injected tanks).

The LBLOCA flow rates used to calculate the NPSH margin are 8,530 gpm and 11,630 gpm (LPSI failure to trip), which are 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. The lower 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 for hot leg recirculation 400 gpm
- Total 8,530 gpm

And

- Two Containment Spray System (CSS) pumps 8,130 gpm
- One Low Pressure Safety Injection (LPSI) pump failure to trip 3,500 gpm
- Total 11,630 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 6.8 ft for the LBLOCA, and 6.3 ft for the SBLOCA. Note that the minimum NPSH margin for the CS pump for the LPSI failure to trip (described below) is 2.8 ft for the LBLOCA. 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, including chemical effects, was determined by testing.
- Plenum and piping head losses were determined by calculation based conservatively on evenly distributed strainer module flow for the entire mission time.

- 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. The Technical Specification for the minimum RWT level has recently been increased, 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 also showed there is sufficient NPSH margin for the CS pumps to continue operating (2.8 ft for a LBLOCA). However, there is marginally insufficient NPSH to support continued LPSI pump operation after RAS. Should this condition lead to damage of the failed to trip LPSI pump (pump not stopped in time by operators), this pump is already considered to be the single failure. 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 calculated 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	15,779 ft^3	5,618 ft^3
RAS initiation		
Refueling Water Storage Tank: (Note 1)		
411,264 gal/7.4805 =	54,978 ft^3	54,978 ft^3
Total minimum volume inside containment at RAS =	70,757 ft^3	60,596 ft^3

Note 1: RWT usable volume at minimum level of 32.5 ft.

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.

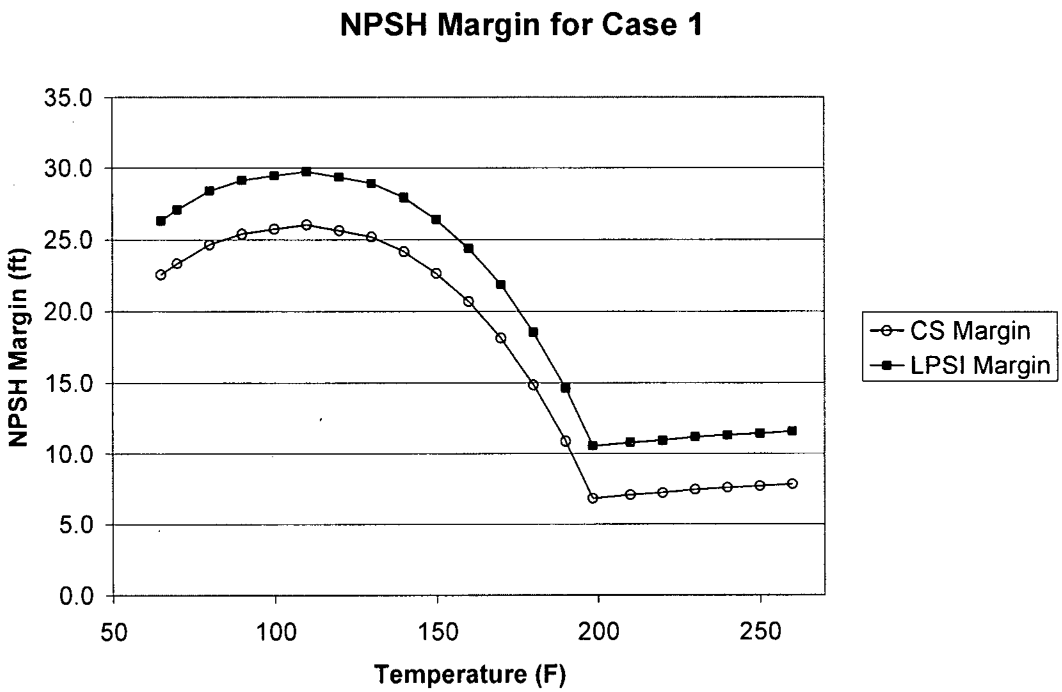
The NPSH calculation was performed consistent with Regulatory Guide 1.1

The containment sump strainer design temperature of 210 °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 chemical precipitant) is applied near 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 plot of NPSH margin versus temperature for the containment spray and low head safety injection pumps are provided below for the design basis LBLOCA case.



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. However, flume head loss testing performed at Alden labs concluded that a thin bed did not form. All coating debris was treated as particulate with 100% transportation of generated coatings in the active pool to the sump screen. Acrylic coating powder 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. Tin powder was used as the surrogate for inorganic zinc. .

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 reduced to 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 use of 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.

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 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 2,200 °F in 10 CFR 50.46, the acceptance criterion 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 °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.

In response to concerns raised by the Advisory Committee on Reactor Safeguards regarding WCAP-16793-NP, Rev. 0, the Pressurized Water Reactor Owners' Group (PWROG) is performing additional testing and analyses to more realistically determine the potential downstream and chemical effects on the reactor core and the vessel/components. Corrective actions will be identified, if required for resolution of this item, and submitted to the NRC following the issuance of the revised WCAP-16793-NP and the associated NRC Safety Evaluation Report (SER).

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 March 2008 Revised Content Guide for Generic Letter 2004-02 Supplemental Responses specifies specific areas to be addressed which are outlined below. Additionally, FPL will provide an overall summary of the integrated testing performed at Alden Labs.

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 March 28, 2008 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 should be 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 complete details 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 of the amount calculated for the plant).

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: Licensees should 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.

Overall Description of Integrated Head Loss Testing

Description of Test Facility

Integrated head loss testing was conducted by AREVA at Alden Labs. The test apparatus includes a test flume, two pumps (a main operating pump and a back up pump if the main pump fails. Both pumps do not operate in parallel), a prototype strainer, instrumentation & controls, and the associated piping and valves needed to complete a recirculation loop. The chemical injection system consists of: chemical mixing tanks, a peristaltic pump designated to pump the chemical debris into the test flume, and associated piping/tubing. To conservatively maintain a steady water level at or below the submergence water level during testing, an over flow weir (water management overflow Figure 3.o-1) was installed at the upstream end of the test flume. Debris which may have transported past the overflow weir was captured by 5 and 10 micron bag filters located downstream of the overflow weir. The net "effective surface area" of the test strainer was 390 ft^2.

Figures 3.o-1 through 3.o-3 depict the test configuration utilized for St. Lucie Unit 1.

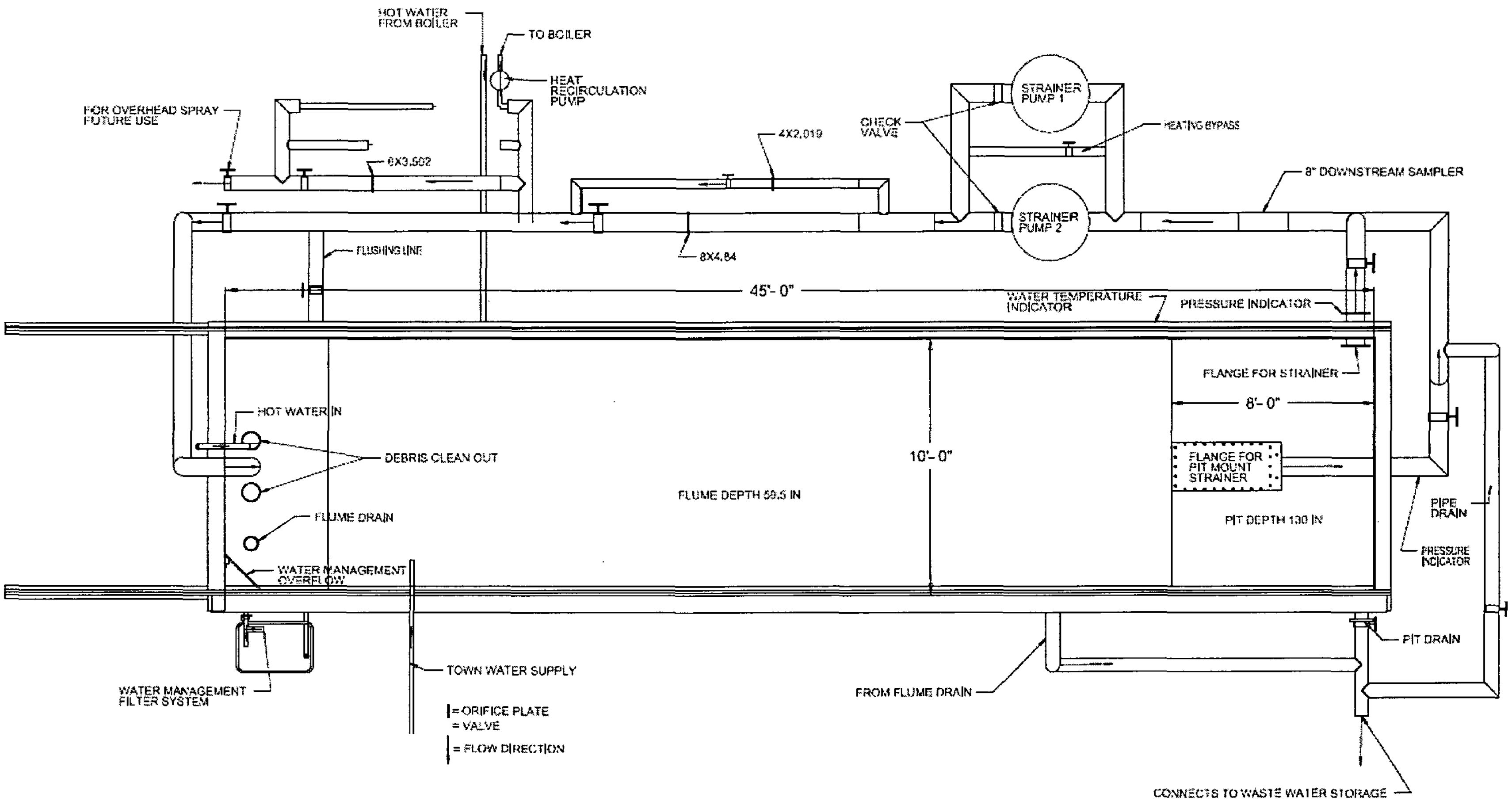
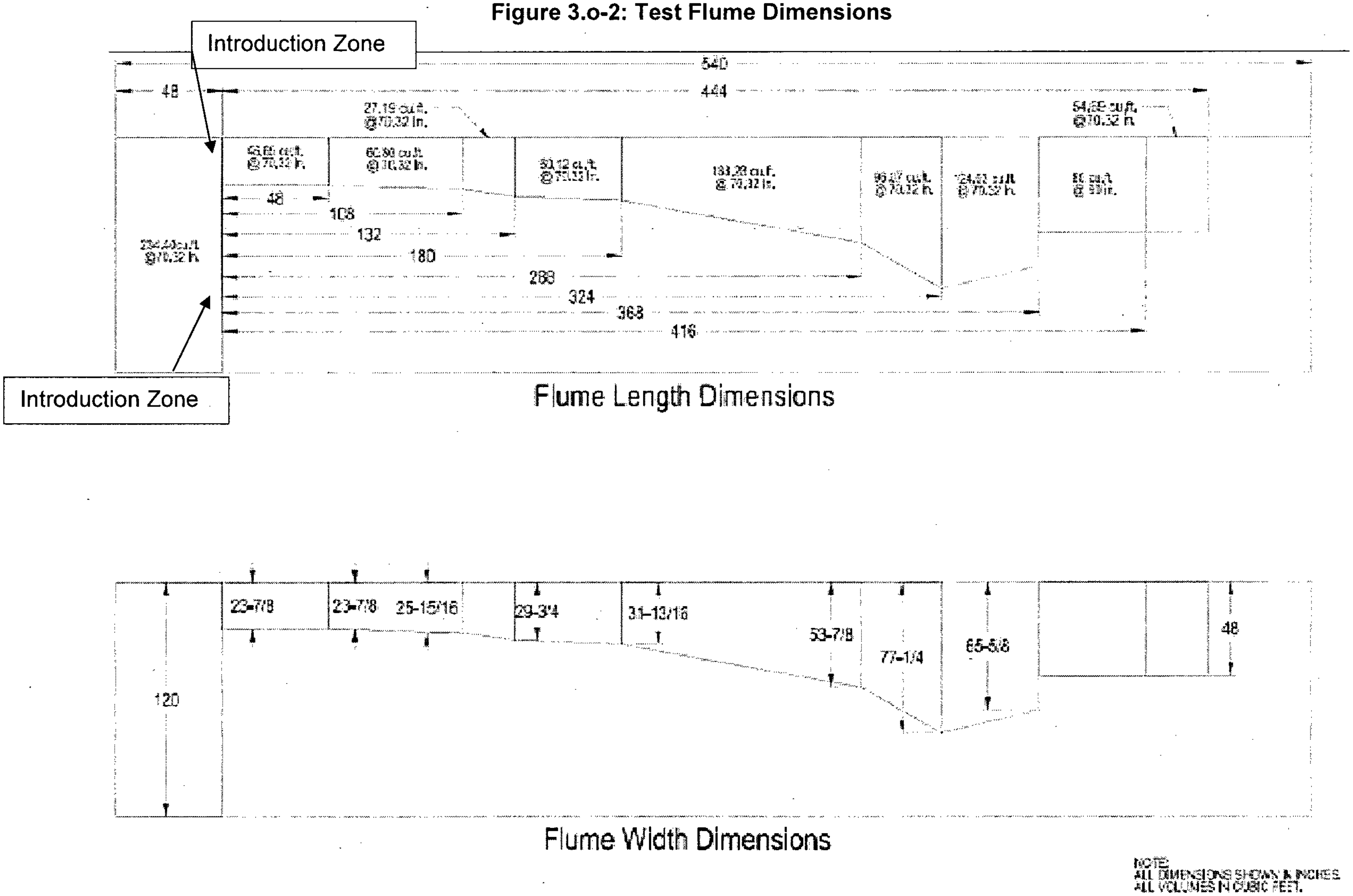


Figure 3.o-1: Generic Test Flume Configuration)

Figure 3.o-2: Test Flume Dimensions



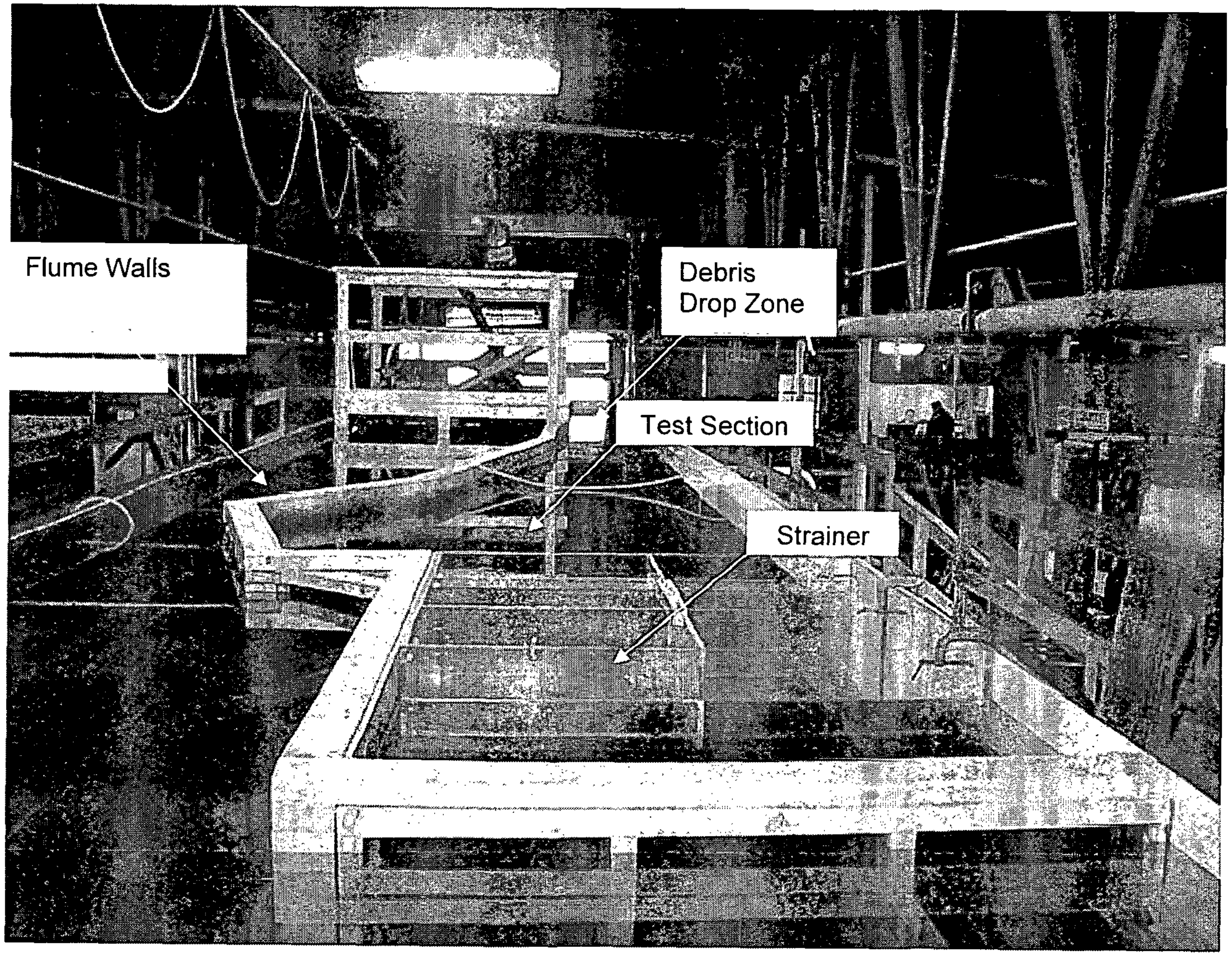


Figure 3.o-3: Test Flume Configuration Looking Upstream of Strainer

General procedure for conducting the tests.

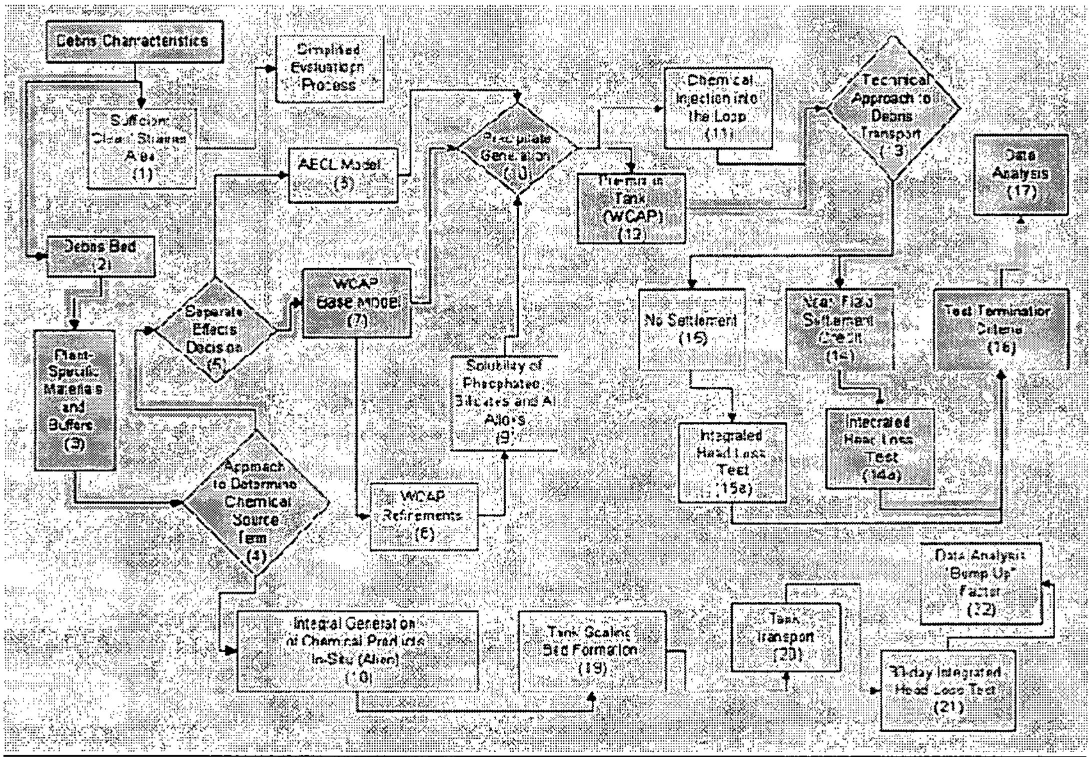
The general procedure for conducting the debris laden strainer test is summarized below based on the AREVA Test Plan.

- 25% of the latent fibrous debris was introduced through the length of the test flume with the pump turned off for 5 minutes.
- The pump was turned on and the design flow rate is achieved in the test flume.
- All fine particulate debris was introduced into the test flume upstream of the strainer module.
- Following the fine particulate, the fine fibrous debris was introduced into the test flume upstream of the strainer module.
- After 5 flume turnovers all of the small fibrous debris was introduced into the test flume. Note a flume turnover was approximately 10 minutes.
- Once all of the particulate and fibrous debris is introduced into the test flume, at least five flume turnovers are required between the non-chemical and chemical debris introductions.
- The chemical surrogate was added into the flume at the debris introduction point indicated on Figure 3.o-2. Chemical batches consisted of Aluminum Oxyhydroxide (ALOOH) only.
- Run the test until the change in head loss is less than 1% in 30 minutes.
- Measure flow, temperature, and head loss and record the time.

FPL Response to Issue 3.o.1:
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 conducted by AREVA at the Alden Research Lab. The testing program implemented assumed chemical precipitates form in accordance with the WCAP 16530-NP methodology. The effect 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 the strainer users group. The results of the chemical effects testing have been incorporated into the NPSH calculations as discussed in Topic 3.g, Net Positive Suction Head (NPSH), above.

FPL Response to Issue 3.o.2.
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 3.o-4, to highlight the process approach taken for testing and evaluation.

Figure 3.o-4 Chemical Effects Evaluation Process Flow Chart



FPL Response to Issue 3.o.2.1
St. Lucie Unit 1 did not perform a “simplified” chemical effects evaluation.

FPL Response to Issue 3.o.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 3.o.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 (9.8) after early in 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 UFSAR temperature curves for accident analysis. The temperature profiles presented in the UFSAR are conservative since the safety analyses assume single failures of portions of ECCS/CS supply to yield higher containment pressures and temperatures.

- 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, Cal-Sil, and NaOH were utilized as input the analysis.

<u>FPL Response to Issue 3.o.2.4,</u>
The effects of the sump chemical environment were evaluated in an integrated chemical effects head loss test conducted by AREVA at the Alden Research Lab.

<u>FPL Response to Issue 3.o.2.5</u>
The effects of the sump chemical environment were evaluated in an integrated chemical effects head loss test by AREVA at the Alden Research Lab. The testing program implemented assumed chemical precipitates form in accordance with the WCAP-16530-NP methodology.

<u>FPL Response to Issue 3.o.2.6</u>
St. Lucie Unit 1 does not use the AECL based models for testing.

<u>FPL Response to Issue 3.o.2.7</u>
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 993.9 kg. The types and quantities of chemical precipitates expected to form in the St. Lucie Unit 1 containment sump and reactor coolant system following a Design Basis LOCA are as follows; 757.7 kg. of sodium aluminum silicate ($NaAlSi_3O_8$), and 236.2 kg. of aluminum oxyhydroxide (AlOOH). This analysis was comprised of the bounding set of inputs. Testing utilized an amount of precipitate greater than predicted to form.

<u>FPL Response to Issue 3.o.2.8</u>
The chemical precipitates were calculated utilizing the base methodology in WCAP-16530-NP. No refinements to WCAP-16530-NP were utilized in the chemical effects analysis.

<u>FPL Response to Issue 3.o.2.9</u>
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.

<u>FPL Response to Issue 3.o.2.10</u>
Precipitates used in testing are formed in a separate mixing tank and subsequently introduced into the test loop.

<u>FPL Response to Issue 3.o.2.11</u>
Chemical injection into the test loop was not used for St. Lucie Unit 1 testing.

<u>FPL Response to Issue 3.o.2.12</u>
The chemical precipitates were generated utilizing the methodology in WCAP-16530-NP 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) was introduced based on the predicted chemical formation.

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 3.o.2.13

Prior to testing, CFD analyses were implemented to define a "bounding" flow stream to the screen as described in Topic 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. Note that additional details on the blowdown, washdown, and transport sequence are being provided in a letter from FPL to the NRC that provides additional responses to the NRC's RAIs dated January 22, 2009. This letter is also being submitted in July 2009. The plant strainer approach velocities were calculated in the AREVA debris transport calculation. The following was extracted from that calculation:

"The calculation of the St. Lucie Nuclear Power Plant Unit 1 (PSL1) Sure Flow Strainer qualification test program flume configuration utilizes the results of the CFD debris transport study to define the average approach velocities to the strainer. The following methodology is applied:

1. *Use the CFD post-processing software to numerically seed each active module train face with massless tracer particles (massless tracer particles show the direction of the flow at every point along their path).*
2. *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.*
3. *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, along the paths defined in (2).*
4. *Trim each plane such that the velocities within that plane are those which convey water to the module.*
5. *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 bifurcated path individually. Record these averages over a total of 30 ft back from the module train.*
6. *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.*
7. *Create a plot of the calculated weighted average velocity defined in (6) vs. incremental distance back from the module train.*
8. *Using engineering judgment, create up to 9 linear line segments which conservatively represent the velocity trends over the 30 ft distance.*

9. *Calculate the width of the test flume at each line segment break using the following expression:*

   Q = VA

   Where:
   Q = Total flow to test module (ft^3/s)
   A = Flume cross sectional area (ft^2)
   V = Weighted cross sectional average velocity (ft/s)

   And:
   A = WH

   Where:
   W = Flume width (ft)
   H = Water surface height in the test flume (ft)

10. *Create a table of flume width vs. line segment length to be used in defining the shape of the flume."*

The results of this method are provided in the form of a graph below. NOTE: the WT AVG Velocity is the weighted average plant approach velocity.

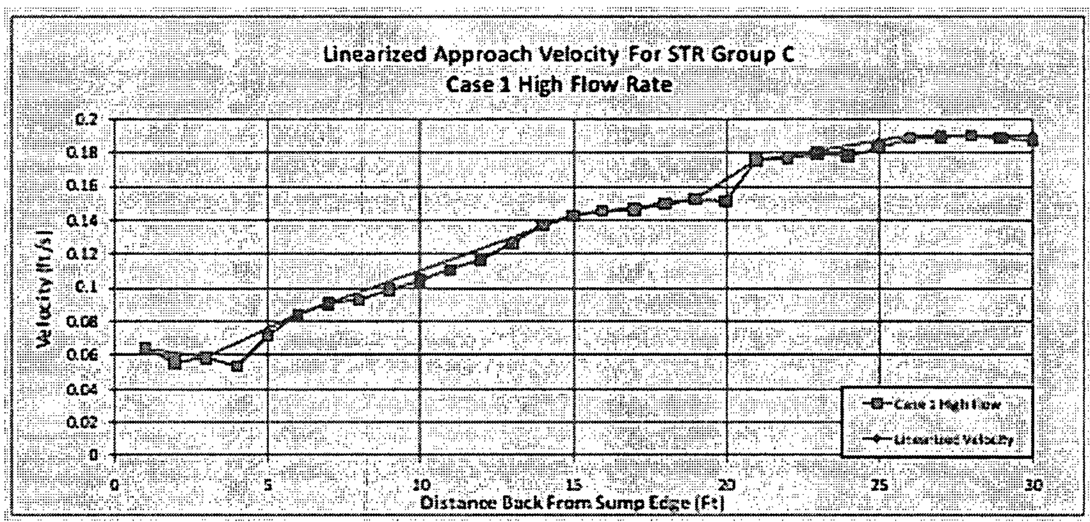


Figure 3.o-5: Test Flume Approach Velocities for High Flow

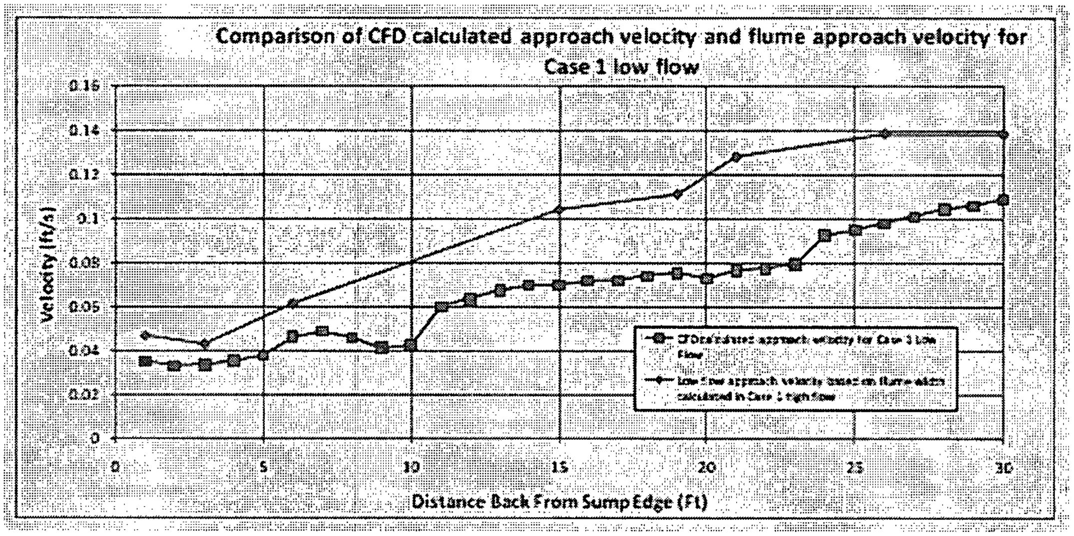


Figure 3.o-6: Test Flume Approach Velocities for Low Flow

Conclusion: The test flume width was constructed such that, for a given water level and test module flow, the approach velocities at each cross section were bounded by the plant conditions calculated from a conservative CFD model.

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

<u>FPL Response to Issue 3.o.2.15</u>
St. Lucie Unit 1 utilized near field settling. Therefore, this section is not applicable.

<u>FPL Response to Issue 3.o.2.16</u>
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.

<u>FPL Response to Issue 3.o.2.17</u>
Typically, a regression line is plotted for the head loss data collected during the last 15 flume turnovers of the test. This regression line is then used to provide an estimated head loss for a given mission time (usually 30 days). However, based on Figure 3.o-7 it is apparent that the head loss depletes with respect to time. If a regression line is plotted using this data, the head loss would trend to zero. It is expected that the head loss would diminish to a constant value. Since the head loss continually depleted with respect to time, the maximum

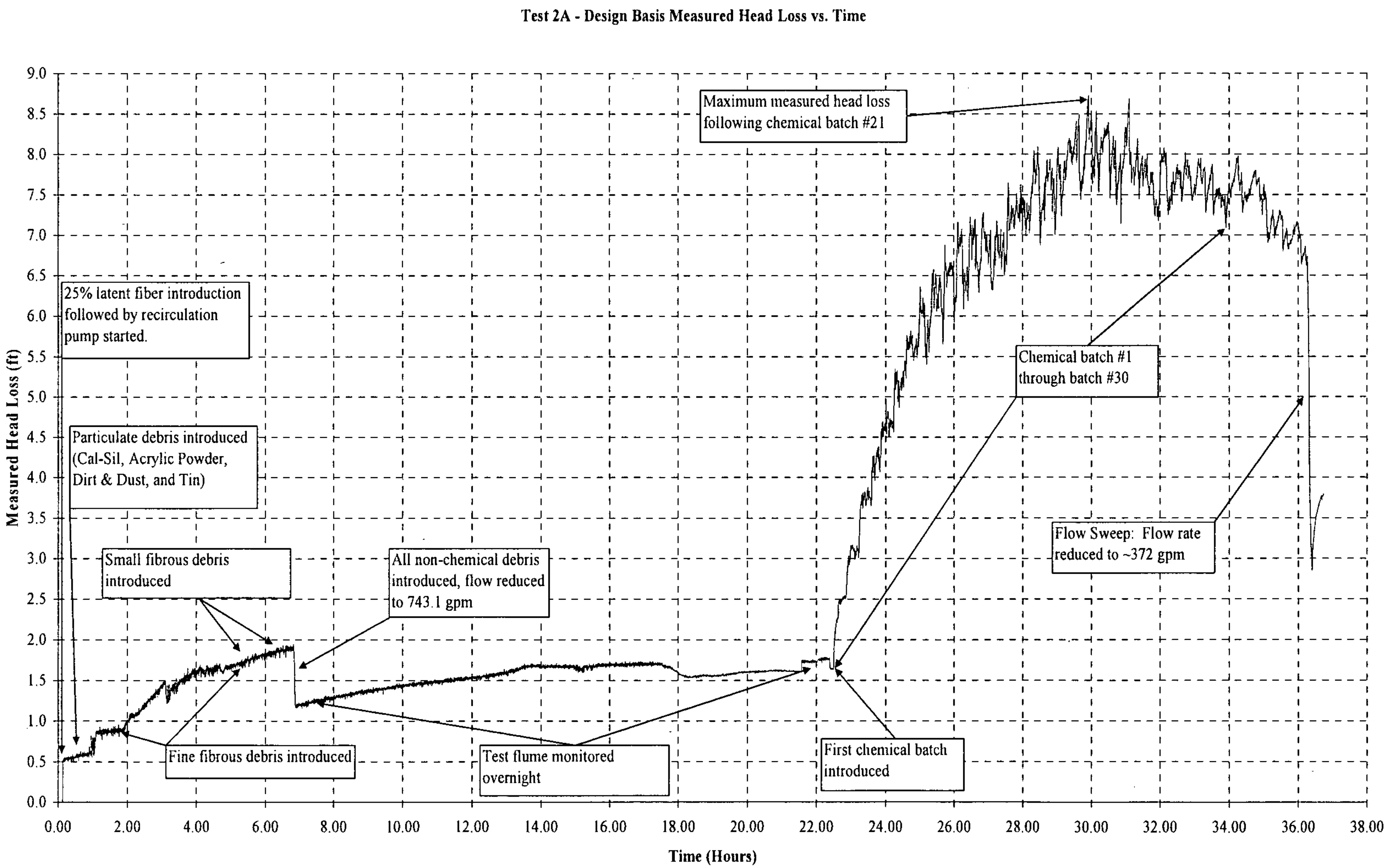


Figure 3.o-7: ECCS/CSS Strainer Head Loss Test

head loss value observed during the test is bounding of the postulated maximum head loss value. Therefore, for conservatism, the absolute maximum head loss measured during the entire test at 94.3 °F and 752.7 gpm of 8.721 ft was used for the design basis case. Also, for conservatism, this head loss was not corrected downward for flow to the target rate of 743.1 gpm. Pressure drop was recorded in data tables and documented in the test report. Pressure drop was recorded in data tables and documented in the test report.

FPL Response to Issue 3.o.2.18 through 3.o.2.22
The most recent St. Lucie Unit 1 testing 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

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 213.79 Unsubmerged 4,061.9 Total 4,275.7
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 1,300
Copper total surface area	*Submerged and Unsubmerged (ft^2)*	61,407.6

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 ft^2. 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 23.81 ft. The scaffold poles are stored in a horizontal position (2,000 linear-feet) and the vertical position (1,000 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 ft^2. The ladders are evaluated for storage in the vertical position with the legs on the 23 ft elevation. The maximum submerged area would be approximately 7 ft^2 with all 10 ladders stored on the 23 ft elevation based on the 23.81 ft flood level.

Storage for 1 Stainless Steel Access ladder to be stored on the 62 ft elevation of the containment building is approved. The total square footage of the ladder surface area is 50 ft^2. The ladder is stored in the horizontal position. This amount is negligible when compared to containment totals.

[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 23.81 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 2,700 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	2,600 ppm	2,800 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 materials inside St. Lucie Unit 1 and ICET#4.

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[1]	ft^3/ft^3
Calcium Silicate	0.0017	ft^3/ft^3		ft^3/ft^3

However, the chemical effects evaluation for St. Lucie Unit 1 utilized the methodology published

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

in WCAP-16530-NP. The chemical effects evaluation did not take credit for any independent chemical effects based benchmark testing results such as ICET#4. Therefore, this question is not applicable to the St. Lucie Unit 1 chemical effects evaluation or related strainer performance testing activities.

[RAI 7] The time until ECCS external recirculation initiation is a minimum of approximately 20 minutes, see Topic 3.g, Net Positive Suction Head (NPSH). The sump and containment temperature profiles are provided below. The pool volume including hold up is provided in the table in Topic 3.g, Net Positive Suction Head (NPSH).

Sump and Containment Temperature Profiles]

Time (sec)T	Time (days)	Sump Temperature (°F)	Containment Temperature (°F)
1	1.16E -05	145	165
10	1.16E -04	232	252
40	4.63E -04	233	253
100	1.16E -03	236	256
200	2.31E -03	238	258
300	3.47E -03	236	256
400	4.63E -03	230	250
500	5.79E -03	227	247
1000	0.012	218	238
1002	0.012	218	238
1200	0.014	215	235
1260	0.015	215	235
2000	0.023	205	225
3000	0.035	200	220
3600	0.042	198	218
4000	0.046	197	217
7000	0.081	191	211
10000	0.116	184	204
20000	0.231	173	193
30000	0.347	165	185
50000	0.579	152	172
90000	1.042	144	164
100000	1.157	140	160
200000	2	129	149
300000	3	121	141
400000	5	118	138
700000	8	111	131
900000	10	106	126
1000000	12	105	125
1200000	14	104	124
1400000	16	102	122
2000000	23	101	121
2200000	25	100	116
2600000	30	100	116

[RAI-8] This RAI requested information regarding the FPL chemical effects testing program. This information is provided in Topic 3.g, Net Positive Suction Head (NPSH), and this Topic.

[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 is not utilizing bench top testing for input to the flume head loss testing performed by AREVA at Alden Labs. Therefore this RAI topic is not applicable to St. Lucie Unit 1.

[RAI 11] 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 accordance with Performance Contract Inc. (PCI) standards; also in accordance with discussions held with the NRC staff over the same review period. Non-chemical debris was introduced in accordance with NRC feedback; namely, particulates first; then fine fibers; then smalls, etc.

Chemical debris was produced and accepted for use in accordance with 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 AREVA implemented 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 accordance with WCAP 16530-NP and NRC feedback; the effect of the post-LOCA environment is bounded in the implemented test protocol. See also Topic 3o, Chemical Effects.

[RAI 12] This RAI requested FPL to 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 (debris and the maximum chemical precipitate) is applied near 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 locations contained calcium silicate insulation and ensure some silica in solution.
The impact of chemical effects for 30 days and the associated head loss effects down to the minimum plant temperature of 65 °F have been evaluated. The full measure of chemical precipitate predicted to be generated by WCAP 16530-NP without refinement has been introduced to the test flume and evaluated for head loss and NPSH impact for St. Lucie Unit 1.

[RAI 17] St. Lucie Unit 1 is not relying on the ICET#4 results to address plant specific conditions or chemical effects. The WCAP-16785-NP investigations into silicate inhibition are also corroborated by the results of the ICET#4 results but have not been credited in the St. Lucie Unit 1 analysis. The St. Lucie Unit 1 testing utilized plant specific values for calcium silicate which were less than ICET#4. No credit has been taken for silica inhibition in the St. Lucie Unit 1 chemical effects analysis or testing. Therefore, this represents a potentially significant conservatism with respect to metallic corrosion.

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 (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 has been approved by the NRC, and is being 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.	The St. Lucie Unit 1 chemical effects testing program was performed by AREVA/Alden Labs which implemented WCAP-16530-NP to define the quantities and types of chemical precipitates to be formed post-LOCA. St. Lucie Unit 1 did not apply a time based chemical margin criteria. That is, the total quantity of generated precipitants (30 day chemical loading) was tested in a 1-2 day test period; the time is conservatively compressed to measure the full effect 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.	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.	The St. Lucie Unit 1 chemical effects testing program was performed by AREVA/Alden Labs 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 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	The St. Lucie Unit 1 chemical effects testing program was performed by AREVA/Alden

L&C No.	NRC Limitations & Conditions (WCAP 16530-NP Revision 0)	FPL (St. Lucie Unit 1) Response
	environment, the total amount of sodium aluminum silicate added to the test shall account for the solubility of sodium aluminum silicate in this environment.	Labs which did not use sodium aluminum silicate precipitates for testing.

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.

L&C No.	NRC Limitations & Conditions (WCAP 16793-NP Revision 0)	FPL (St. Lucie Unit 1) Response
	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

L&C No.	NRC Limitations & Conditions (WCAP 16406-P Revision 1)	FPL (St. Lucie Unit 1) Response
	(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

L&C No.	NRC Limitations & Conditions (WCAP 16406-P Revision 1)	FPL (St. Lucie Unit 1) Response
	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 8.6.10 describe, in general terms, the Westinghouse, CE, and B&W RVLIS. TR WCAP-16406-P, Revision 1, recommends that	The St. Lucie Unit 1 RVLIS design was compared to the generic designs reviewed and deemed acceptable by the WCAP-16406-P. St.

L&C No.	NRC Limitations & Conditions (WCAP 16406-P Revision 1)	FPL (St. Lucie Unit 1) Response
	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.	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 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 pump 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	This SER limitation is simply a statement of the

L&C No.	NRC Limitations & Conditions (WCAP 16406-P Revision 1)	FPL (St. Lucie Unit 1) Response
	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."	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 clearance. The stiffness of the pumps after debris induced wear was then calculated. The

L&C No.	NRC Limitations & Conditions (WCAP 16406-P Revision 1)	FPL (St. Lucie Unit 1) Response
		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