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

FPL

March 13, 2003

L-2003-069
10 CFR 50.4

U. S. Nuclear Regulatory Commission
Attn: Document Control Desk
Washington, DC 20555

RE: St. Lucie Units 1 and 2
Docket Nos. 50-335 and 50-389
Generic Letter 96-06 Supplemental Response
Resolution of Waterhammer Issues

By letter L-2002-149 dated July 29, 2002, Florida Power & Light Company (FPL) provided the FPL plans for resolution of the remaining Generic Letter (GL) 96-06 waterhammer actions identified in NRC letter dated April 25, 2002. In their letter dated April 25, 2002, the NRC requested that FPL complete the remaining actions regarding GL 96-06, *Assurance of Equipment Operability and Containment Integrity During Design-Basis Accident Conditions.* The remaining GL 96-06 action for St. Lucie Units 1 and 2 was to address waterhammer.

Below is a summary of FPL commitments to close the GL 96-06 waterhammer concerns for the St. Lucie Plant. These actions are consistent with those committed to by FPL within L-2002-149.

- FPL to complete the St. Lucie Unit 2 CCW pump motor EDG loading sequence modification during the spring 2003 (SL2-14) refueling outage. The Unit 1 modification was completed during the fall 2002 (SL1-18) outage.
- FPL to complete all remaining corrective actions for St. Lucie Unit 1 prior to return to power following the spring 2004 refueling outage (SL1-19).
- FPL to complete all remaining corrective actions for St. Lucie Unit 2 prior to return to power following the fall 2004 refueling outage (SL2-15).

Please contact George Madden at 772-467-7155 if there are any questions about this submittal.

Very truly yours,

Donald E. Jernigan
Vice President
St. Lucie Plant

DEJ/GRM

Attachment

A072

St. Lucie Units 1 and 2
Resolution of Generic Letter 96-06 Waterhammer Issues

Summary

NRC letter dated April 25, 2002 informed Florida Power & Light Company (FPL) that Electric Power Research Institute (EPRI) Report TR-113594[1] for evaluating Generic Letter (GL) 96-06 waterhammer issues was acceptable to the extent specified and within the limitations delineated in the report and the NRC safety evaluation report (SER). FPL was requested to complete actions to address GL 96-06 and submit information referred to in Section 3.3 of the NRC safety evaluation.

FPL letter L-2002-149 dated July 29, 2002 stated that the St. Lucie Unit 1 and 2 Component Cooling Water (CCW) pump motors would be moved to an earlier emergency diesel generator (EDG) loading block to establish water pressure and water flow to the containment fan coolers (CFC) as a means to resolve the waterhammer issue. FPL committed to performing the EDG load block modifications during the SL1-18 and SL2-14 refueling outages. To reduce the modeling uncertainty for the time-to-boil and void size calculations, FPL stated an intent to benchmark the hydraulic model against CFC flow and pressure responses measured during CCW pump stop and start transients. FPL would then complete the waterhammer evaluation and, should piping support or other plant modifications be required, they would be completed by the subsequent SL1-19 and SL2-15 outages. FPL committed to complete the waterhammer evaluation and update our response by March 15, 2003.

This response addresses the field information developed during benchmarking activities during the SL1-18 outage and the conclusions of the waterhammer evaluation. Predicted results generally matched field benchmarking data and increased confidence in the hydraulic modeling effort. Testing results indicate that system pressure fluctuations occur following pump stop, and that pressure initially drops on the suction side of the pump following pump start prior to system pressure being re-established. This understanding affects FPL's previous position that CFC boiling can be prevented by EDG load block changes.

The test results have been helpful in benchmarking the voiding and waterhammer analysis. FPL will meet previous commitments for performing any additional corrective actions during the SL1-19 and SL2-15 refueling outages to resolve the remaining GL 96-06 waterhammer issue.

Background

FPL letter L-98-276 dated October 30, 1998 indicated that GL 96-06 waterhammer could be accommodated under existing functionality rules and St. Lucie Units 1 and 2 remained operable. FPL stated an intention to join utilities working with EPRI to develop design-based waterhammer evaluation criteria.

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[1] EPRI adopted a new report numbering system after the original report numbers (TR-113594, Volume 1 and 2) were assigned. The final report numbers and publication dates are provided in References 14 and 15. The EPRI reports include the NRC SER for the EPRI waterhammer methodology.

The EPRI work began in the fall of 1998 and was sponsored by a group of utilities, including FPL. Altran Corporation performed the work with independent oversight and review provided by a panel of industry experts. The NRC was also an active participant, monitoring and critiquing the work as the initiative progressed. EPRI issued a design document for NRC review in December 2000. NRC comments were extensive and led to additional empirical testing, refinement of the results and a reformatting of the output documents into a Technical Report and a User's Manual.

Recognizing that the ACRS did not fully agree with the proposed methodology for evaluating GL 96-06 waterhammer, EPRI proposed that the risk associated with the events and the results that would be achieved if the methodology were used could be an important factor. EPRI provided a review of the progression of events that could lead to an unacceptable condition to quantify the risk. The risk perspective became an integral part of the NRC safety evaluation.

EDG Load Block Changes

FPL letter L-2002-149 dated July 29, 2002 stated that the St. Lucie Unit 1 and 2 CCW pump motors would be moved to an earlier EDG loading block as a means to resolve the waterhammer issue. FPL committed to performing the EDG load block modifications during the SL1-18 and SL2-14 outages. Further, FPL stated an intent to benchmark the hydraulic model. FPL would then complete any additional required corrective actions by the subsequent SL1-19 and SL2-15 outages.

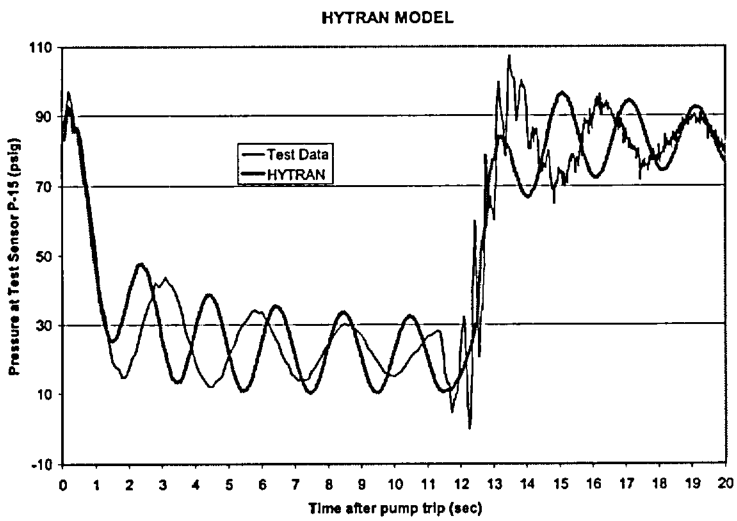
Field work to move the St. Lucie Unit 1 CCW pump motors to the 0 second EDG loading block was completed as committed during the fall 2002 (SL1-18) outage.

Field work to move the St. Lucie Unit 2 CCW pump motors to the 0 second EDG loading block will be completed as committed during the spring 2003 (SL2-14) outage.

Hydraulic Model Benchmarking

Benchmark testing was completed during the St. Lucie Unit 1 fall 2002 (SL1-18) outage following completion of the EDG load block change. This testing was intended to benchmark the accuracy of the Sargent & Lundy (S&L) CCW System hydraulic model (HYTRAN) with respect to prediction of system flow and pressure changes during pump coastdown and recovery following restart. The test was conducted with the St. Lucie Unit 1 CCW B Train in the post-accident alignment (i.e., isolated from the non-essential header with flow established through the shutdown cooling heat exchanger). Pressures were recorded at the containment penetrations for the HVS-1C and HVS-1D cooler supply and return lines. Four channels of information were recorded each millisecond via pressure transducers connected to a high-speed data acquisition system.

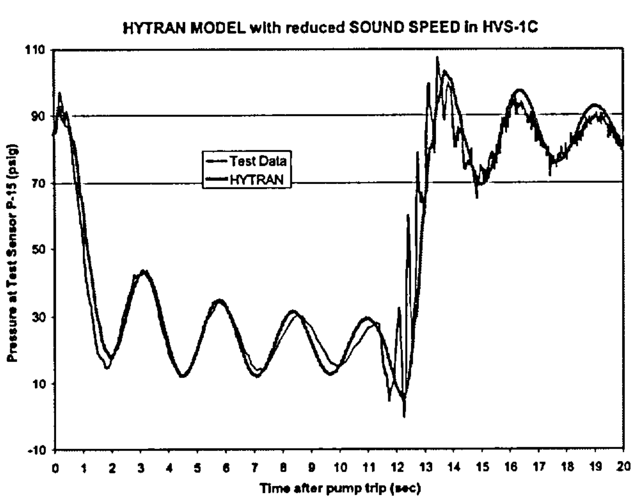
The hydraulic model's predicted results generally matched field-benchmarking data. To this end, the test results were useful for developing confidence in the hydraulic modeling effort. The testing confirmed a model prediction that pressure fluctuations within the system will adversely affect previous time-to-boil determinations. Test results also identified an unpredicted initial pressure drop in the pump suction side of the CCW system immediately following CCW pump start. These test results affect FPL's previous preliminary assessment that voiding within the Train B CFC coolers can be precluded by EDG load block changes.



As indicated in the graph to the left, field test results for pressure changes within the CCW system showed close congruency with predicted model results with respect to the general drop-off in system pressure. Matching the field test pressures provides confidence in the flows calculated by analysis.

The trend of CFC pressure and flow are important with respect to predicting the onset of voiding and estimating void size. Flow affects the forced convection heat transfer coefficient while system pressure, in relation to the fluid saturation pressure/temperature, is important with respect to determining the onset of sub-cooled nucleate and pool boiling heat transfer mechanisms.

Benchmarking confirmed a HYTRAN model prediction of a pressure fluctuation following pressure decay and following pressure recovery on CCW pump stop and start. The model reasonably predicts the peak-to-peak pressure fluctuation at the time of CCW pump stop but over-predicts the fluctuation with time, as dampening of the fluctuation with time is under-predicted. Additionally, the actual frequency of the system pressure fluctuation is not as fast as predicted by HYTRAN. The fluctuation of pressure following pump trip is believed to stem from the release of stored energy within the system due to water compressibility.



To develop an understanding of the differences between the model and the field data, HYTRAN was modified to more closely model the frequency of the observed pressure fluctuation period and dampening (shown to the left) by modifying the speed of sound used within cooler HVS-1C. The close agreement with test results by this analytical modification may indicate the release of air within HVS-1C during depressurization following CCW pump stop.

The presence of small air bubbles within the return piping water is theorized to account for an apparent reduction in the velocity of sound and the observed fluctuation dampening. In order to maintain consistency with the methodology for calculating the speed of sound contained within the EPRI report, the HYTRAN GL 96-06 model was not modified to match this field test result.

The observed presence of a pressure fluctuation is important to the analysis of the GL 96-06 scenario as the approximate ±10 psi magnitude around the decaying mean value causes the local CFC pressure to repeatedly cross the saturation line during the post-trip pressure decay and pressure recovery following restart. The periodic pressure fluctuation is responsible for determining that multiple CFCs experience some degree of voiding despite a 6 second decrease in CCW pump recovery time afforded by the EDG load block change.

Of particular note during review of the St. Lucie Unit 1 field benchmarking results was the identification of a 70-200 psi pressure pulse on CCW pump restart. This transient on pump start appears to be related to previously reported hydraulic transients on CCW pump restart during St. Lucie Unit 2 Engineered Safeguards testing. These transients are independent of the GL 96-06 scenario. The St. Lucie Unit 2 transient as documented in the St. Lucie corrective action tracking system, is noticed by control room personnel due to their close proximity to water-cooled control room air conditioning (CRAC) equipment in this unit. The St. Lucie Plant Unit 1 transient was not heard by field or test personnel during the conduct of the test but was recorded by high speed pressure transducers installed for the benchmarking test. The pulse peaked at 70 psig in HVS-1C and at 200 psig in HVS-1D. The 200 psig pulse occurred over a 3 ms timeframe at 0.842 seconds after pump start. For very short duration transients, system inertia and flexibility result in insignificant loads imparted to the system.

System walkdowns associated with the previous Unit 2 events identified no piping or support degradation, deformation, or indications of displacement, such as scraped paint. No abnormal conditions on Unit 1 have been identified as a result of this condition. FPL concludes that the CCW system and support inertia and flexibility are such that the piping system does not respond to the observed transient in the timeframe the load is present. Consideration of the observed transient during restart following a LOOP event leads to the conclusion that the recorded and observed cold water results do not challenge the structural integrity of the CCW system.

Waterhammer Analysis

Void size prediction and waterhammer loads are developed using the EPRI GL 96-06 Method of Characteristics (MOC) methodology addressed in the EPRI technical report. The analysis of the St. Lucie Unit 1 HVS-1C CFC piping system was performed using the S&L HYTRAN model which implements the fixed-grid MOC solution technique to calculate pressures and flow velocities in a network of pipes. These quantities are then used to calculate the time-varying forces on the pipe segments that comprise the network.

In order to support the EPRI GL 96-06 waterhammer methodology, HYTRAN was modified by S&L to include an ability to handle the growth and collapse of a discrete steam and air filled cavity. A new node type was added in which the saturation pressure is specified as a function of time. The weight and temperature of steam in the cavity is calculated assuming the steam is saturated at the cavity pressure. The amount of dissolved air that has been released during boiling is included in the cavity's gaseous contents. The recommended amounts of air release due to boiling are given by EPRI as 50% of the air in the water in the CFC tubes, provided that the tube surface reaches a temperature that is 10°F hotter than the water saturation temperature, and 24% of the air in the water in the fan cooler headers, provided that steam passes through them.

After modification, HYTRAN was benchmarked against the MOC solutions provided within the EPRI report and with the EPRI tests themselves. These comparisons indicate the CFC boundary condition has been implemented correctly in HYTRAN. The HYTRAN results are somewhat higher (i.e. conservative) than the EPRI Method of Characteristics results but the differences are not large.

Using the following rationale, application of the HYTRAN model was made to the St. Lucie Unit 1 CCW Train B sub-system with a structural emphasis on the 8-inch and 10-inch return lines from the CFC to the 20-inch return header outside containment as the representative structural case:

- A and B CCW trains within each unit are isolated from each other with double isolation valves following DBA/LOOP.
- Pipe routing and support locations are similar for the A and B trains of St. Lucie Units 1 and 2.
- St. Lucie Unit 1 CCW Train B is bounding with respect to steam generation (due to post-DBA containment conditions and elevated position of the HVS-1C cooler).
- St. Lucie Unit 1 CCW Train B is expected to be representative of the remainder of the CCW System. EPRI methodology credits a fixed amount of air release following steam generation providing that the CFC tubes reach a temperature that is 10°F above the saturation temperature of the water within the tubes. Accordingly, smaller void sizes have similar amounts of air cushioning as large voids and can be expected to result in similar or reduced closure velocities and waterhammer loads on column closure. The EPRI methodology, however, also uses a constant heat transfer coefficient for steam condensation over a constant area equal to the sum of the pipe cross section areas at the end of the void. This results in more steam cushioning for larger voids, which reduces the column closure velocity. The overall result is that cavity size has relatively little effect on the calculated loads.
- Steam voids are expected to initially form in the CFCs and column rejoining is expected to occur at the highest elevation point in the piping downstream of the CFCs.
- After CCW pump restart, the void in the return piping collapses as the water column from the supply side rejoins the water column on the return side of the cooler. The resulting fluid loads in the 8-inch and 10-inch return piping from Train B HVS-1C and HVS-1D coolers are expected to be representative of the entire CCW system.

- Supply lines to the CFCs are expected to have pipe stresses and support loads that are less severe than for the return lines as the column closure pressure wave will be dissipated by traveling through the multiple tubes and flow paths within the coolers.
- The piping analysis ended at the intersection of the 10-inch return lines with the 20-inch return header outside containment. The loads in the 20-inch headers are expected to be reduced slightly relative to the loads in the 8-inch return piping due to the distance and friction between the point of void collapse, the tees where the 8-inch piping joins the 10-inch piping, and 10x20x20-inch tee at the 20-inch header. The intervening elbows, valves, and orifices would contribute to this effect. While the 20-inch headers supports have larger loads, their support systems are correspondingly stronger. Supports for the 20-inch header at the intersection of the 10-inch return piping were reviewed and were found adequate.

Development of the HYTRAN model is an iterative process. HYTRAN is used to calculate pump coastdown flow rates and pressures at the outlet nozzles of HVS-1C and HVS-1D prior to pump restart. The coastdown flows and pressures are then used as input to the CFC model to calculate the water heat-up transient. This heat up transient is then subsequently used as an input to HYTRAN.

The CCW System is normally operated with the SDC heat exchanger discharge valves closed and flow from the two CCW pumps is divided between the CFCs and other components on the two essential headers and the common non-essential header. On safety injection actuation signal, the non-essential header isolation valves close in approximately 4.1 to 10.6 seconds and the SDC heat exchanger discharge valves open in approximately 2.4 to 5.0 seconds to reconfigure the system to the accident alignment. The CCW pump restarts at about 11.5 seconds after it stops on loss of offsite power.

The HYTRAN GL 96-06 waterhammer simulation includes a Normal Mode of operation for a period of time to obtain stable entry conditions. The CCW pump is then stopped. CFC water inventory temperature is provided by CFC model data and CCW flows into the two CFCs are developed based on pump coastdown and hydraulic system changes for the 11.5 second delay before CCW pump restart. This pressure time history along with an estimate of the weight of dissolved air released during boiling are used as inputs to define a discrete cavity in the HYTRAN model at the piping high point just downstream of the HVS-1C cooler outlet. The CCW pump is started and system pressure recovery is modeled using pump inertia, torque and similar parameters that determine water acceleration and system pressure time lag.

In the HYTRAN model, the CFC discharge void starts its growth when the saturation pressure exceeds the line pressure and continues to grow to a maximum size at some time after the CCW pump restarts. The cavity then begins to reduce in size as the line pressure exceeds the saturation pressure. Following EPRI methodology, it is assumed that the void is filled with a mixture of saturated steam and a quantity of air that has been released during the boiling process. During this phase, the steam in the cavity is assumed to be saturated and to continue to condense on a condensing surface equal to the sum of the pipe cross section areas at the two ends of the cavity.

Analysis results indicated that a 7.4 cubic foot void formed within the HVS-1C cooler for the worst case scenario of loss of offsite power with a loss of coolant accident. The peak pressure generated for the waterhammer analysis was ~270 psig. The piping design pressure is 150 psig while the CFC cooling coils were designed to withstand a pressure of 225 psig. Peak forces generally occur 5 to 6 seconds after pump restart. The uncushioned velocity and pressure are less than 40% higher than the cushioned values.

Use of EPRI Report Methodology

NRC acceptance of EPRI Report TR-113594, "Resolution of Generic Letter 96-06 Waterhammer Issues, Volumes 1 and 2," is documented in Reference 12. While the NRC safety evaluation accepted the EPRI methodology for addressing the GL 96-06 waterhammer issue, the evaluation indicated the perceived risk-to-plant-safety was an important consideration in the NRC review, evaluation, and acceptance of the methodology.

Section 3.3 of the NRC SER, dated December 2000, requires:

> *"Certification that the EPRI methodology, including clarifications, was properly applied, and that plant-specific risk considerations are consistent with the risk perspective that was provided in the EPRI letter dated February 1, 2002. If the uncushioned velocity and pressure are more than 40 percent greater than the cushioned values, also certify that the pipe failure probability assumption remains bounding."*

FPL response:

FPL certifies that the EPRI methodology, including the clarifications, was properly applied in work performed for the St. Lucie GL 96-06 response. The waterhammer evaluation methodology complies with the EPRI methodology, including clarifications, based on the following:

- A St. Lucie Plant analysis consistent with Section 2.2 of the EPRI report identified system design characteristics, operating modes, initial plant configuration and failure modes to establish the limiting GL 96-06 scenarios.
- A Method of Characteristics solution was used to address column closure water hammer (CCWH). The program was benchmarked against the EPRI tests and the EPRI MOC solutions used to validate the EPRI Rigid Body Method and found to be conservative by 3 to 22%.
- Condensation induced waterhammer (CIWH) was not reviewed as CCWH will be bounding (system pressure at the time of the postulated CIWH $\leq$ 20 psig, CCW Systems are not degassed, piping has been shown by analysis to be able to withstand a CCWH following LOOP/LOCA without significant degradation).
- The weight and temperature of the steam in the cavity at the start of compression is calculated assuming it is saturated at the cavity pressure.
- The amount of air released during boiling is developed based on 50% of air in the water in the tubes that is exposed to tube temperatures that are at least 10°F

above the saturation point and 24% of air in water in the CFC headers and attached piping provided steam passes through them.

- Free air in water upstream and downstream of void was not credited for reducing sonic velocity. Free air is lumped into the void and was found to exceed (60 mg)$(ID/2)^2$ at the location of the potential waterhammer.
- Condensing surface area is taken as the sum of pipe cross sectional areas at the two void ends.
- Condensing surface temperature is taken as initial void temperature and remains constant, as does the condensing coefficient.
- A conservative condensing heat transfer coefficient (72,000 BTU/hr ft^2 F) was used during the column closure waterhammer analysis for steam and air cushioning. The calculated void temperature exceeded 200^0F.
- The uncushioned velocity and pressure are not more than 40% greater than the cushioned values.

FPL certifies that the plant-specific risk considerations are consistent with the risk perspective that was provided in the EPRI letter dated February 1, 2002. This certification is based on the following discussion.

The NRC acceptance of the EPRI GL 96-06 waterhammer methodology is based on a risk-informed review of the scenario's events and the results that would be achieved if the EPRI methodology were used. The EPRI report considered the risk of an unacceptable event occurring as a result of a loss of coolant accident (LOCA)/LOOP or main steam line break (MSLB)/LOOP event. Assurance that St. Lucie Unit 1 and 2 specific risk considerations are consistent with the NRC accepted risk perspective as developed within the EPRI report is provided below.

EPRI described a progression of events that could lead to an unacceptable condition, which was defined as the breach of the system pressure boundary. The unacceptable condition defined is applicable to St. Lucie Unit 1 and 2 as the containment fan cooler's cooling water system function is to provide water flow to the coolers and provide a containment boundary. The EPRI defined event progression with a comparison to plant specific St. Lucie conditions are:

1. **Occurrence of a LOCA or MSLB**

   NUREG/CR-5750 states that for a PWR, the mean frequency of occurrence of a large LOCA is 5E-6/yr, a medium LOCA is 4E-05/yr, and a MSLB is 1E-3/yr.

   The total St. Lucie Plant initiating event frequency for the events of concern (large LOCA or MSLB in containment) is less than 7E-04/yr and thus consistent with the EPRI evaluation.

2. **Occurrence of a LOOP following a LOCA or MSLB**

   NUREG/CR-6538 and other NRC studies indicate that the dependent probability of a LOOP event following a LOCA in a pressurized water reactor (PWR) is 1.4E-2/demand.

The dominant St. Lucie Plant demand failures related to LOOP following a trip due to a LOCA or MSLB is failure of the startup transformer breaker to close and the startup transformer being unavailable due to maintenance. The estimated LOOP probability following a LOCA or MSLB is estimated as:

Failure of startup breaker to close	4E-03/demand
Startup transformer unavailable	3.7E-03/demand

Total LOOP probability for both trains = 2 *(4E-03 + 3.7E-03) = 1.5E-02/demand

St. Lucie Plant probability for a LOOP following a LOCA or MSLB is consistent with the EPRI evaluation.

3. **Occurrence of a Simultaneous LOCA/LOOP or MSLB/LOOP Event**

The frequency of the combined event depends on the probability of a LOCA or MSLB and the dependent probability of the LOOP given that the LOCA or MSLB has occurred. Using the values in each of the NUREGs referenced above, the probability of the combined event is on the order of 1.5E-5/yr while EPRI assumed 1E-05/yr.

For comparison to St. Lucie Plant, large LOCA and MSLB initiating events are assumed:

(5.85E-05/yr + 6.3E-04/yr) * 1.5E-02/demand = 1E-05/yr

St. Lucie Plant frequency of a simultaneous LOOP/LOCA or LOOP/MSLB is consistent with the EPRI evaluation.

4. **Void Formation**

The EPRI report concluded that, in a closed loop plant, void formation will depend on the specific plant characteristics and a void may or may not form. If a void does not form, a waterhammer will not occur.

The St. Lucie Plant thermal-hydraulic evaluation indicates voids will form in specific coolers for certain event scenarios and will not form in other scenarios. Voids will form in the elevated HVS-1C cooler in CCW Train B for both St. Lucie Units 1 and 2. Voids are expected in both St. Lucie Unit 1 Train A coolers during the LOOP/LOCA but are not expected during LOOP/MSLB. Voids are not expected in St. Lucie Unit 2 Train A coolers for either LOOP/LOCA or LOOP/MSLB.

For St. Lucie Plant risk estimation purposes, it is accepted that a void will occur on design basis accident (DBA)/LOOP and a waterhammer will result.

5. **Pump Restart**

The EPRI report stated that the cooling water pumps will restart with certainty and the velocity in the pipe, immediately prior to closing the void, will be defined by the pressure in the void, the piping geometry, and the pump characteristics. This velocity will not be higher than the rate at which the pumps, once started, can pump water. The calculation of the water velocity prior to void closure is a plant specific analysis that can be conservatively performed.

The St. Lucie Plant situation is similar.

6. **Column Closure**

The EPRI report stated that the water columns will refill the void and the velocity at closure cannot be larger than the largest calculated differential velocity for the upstream and downstream water columns.

The St. Lucie Plant situation is similar. The St. Lucie thermal-hydraulic evaluation is consistent with the EPRI report Method of Characteristics solution.

7. **Maximum Waterhammer Pressure**

EPRI stated that it is certain that the waterhammer pressure will be equal to or less than that developed by the Joukowski pressure. The EPRI report assumes that the Joukowski pressure is attained for the calculated cushioned velocity, although it is very likely that the pressure will be less than the maximum experienced.

The St. Lucie Plant situation is similar.

8. **Cushioned Waterhammer:**

EPRI indicated that the steam/gas cushioned velocity is expected to be on the order of 30-40% lower than the maximum uncushioned velocity for open loop plants. The waterhammer that is predicted would then be 30% to 40% less than the pressure calculated by Joukowski as the relationship between pressure and velocity is linear. For closed loop plants, EPRI predicted a 10%-15% decrease in closure velocity and peak pressure for the cushioned case relative to the uncushioned case.

EPRI reasoned that LOOP-only events tend to bound the events of concern discussed in GL 96-06 for open-loop cooling water systems. As over 100 LOOP-only events have occurred without loss of system pressure integrity, EPRI concluded that the likelihood of pipe failure given a waterhammer event is on the order of 1E-2 or less.

In an alternate approach, EPRI estimated the probability of piping failure if ASME code limits were exceeded by approximately 40%. EPRI assumed the probability of failure for an assumed stress distribution that is 40% larger than the faulted allowable and compared this to the actual tested material strengths for A-106 Grade B piping. Based on actual margins available in the ASME Code, EPRI estimated the actual probability of pipe failure to be 1E-4 or less. For the purpose of continuing the event progression, EPRI estimated the probability of pipe failure if the cushioned waterhammer were exceeded, to be on the order of 1E-2 and probably much less.

The St. Lucie Plant situation is similar.

9. **Likelihood of an Unacceptable Event**

EPRI indicated the low frequency (1E-5/yr) of the initiating events and the low, but conservative, probability of piping failure (1E-2), with use of the EPRI methodology in the User's Manual and the Technical Basis Report, will lead to a likelihood of a breach of the service water system pressure boundary that is on the order of 1E-7. This probability is below the threshold for significant risk to the plant.

The St. Lucie Plant initiating event frequencies for the events of concern (large LOCA or MSLB in containment) are consistent with that used in the EPRI evaluation and the likelihood of piping failure is similar to that assumed by EPRI. From a risk-informed perspective, the methods proposed in the EPRI Technical Basis report and User's Manual are considered appropriate for use in the St. Lucie Plant evaluation of GL 96-06 events.

"The additional information that was requested in RAIs that were issued by the NRC staff with respect to the GL 96-06 two phase flow issue (as applicable)."

FPL Response:

As the two-phase flow issue for St. Lucie Units 1 and 2 was closed within Reference 10, this item is not applicable.

"A brief summary of the results and conclusions that were reached with respect to the waterhammer and two-phase flow issues, including problems that were identified along with corrective actions that were taken. If corrective actions are planned but have not been completed, confirm that the affected systems remain operable and provide the schedule for completing any remaining corrective actions."

FPL Response:

A brief summary of the results and conclusions that were reached with respect to the waterhammer, problems that were identified, and corrective actions that have been taken to date has been provided in the body of this attachment. Remaining FPL actions to closeout GL 96-06 waterhammer issues for the St. Lucie Plant are provided below.

Piping, pipe support and cooler structural analysis for the design basis case is ongoing and has not been formally completed. FPL will utilize ASME Section III Appendix F criteria, as appropriate, in structural evaluations to finalize required modifications. Appropriate system structural modifications will be completed in accordance with current commitments. The preliminary structural analysis for the design case has confirmed that the affected systems remain operable. FPL's waterhammer evaluation and analysis of resulting piping stress and support loads addresses the CFCs return lines of Unit 1 Train B whose cooler HVS-1C has the highest expected steam generation during GL 96-06 DBA/LOOP events. Unit 1 Train B pipe stresses and pipe support loads will be representative of the stresses that would result from analyses of other units/trains. FPL will review emergency operating procedures with respect to providing guidance with respect to GL 96-06 scenarios.

The operability evaluation for St. Lucie Units 1 and 2 GL 96-06 waterhammer concerns was previously provided to the NRC under letter FPL L-98-276 (Reference 9). The evaluation addressed the CCW pump's original 6 second EDG loading sequence and concluded the CFC cooling water systems were susceptible to steam generation during DBA/LOOP. The evaluation identified the amount of CCW System voiding expected within the CFC coolers for the LOCA/LOOP and MSLB/LOOP scenarios and concluded the St. Lucie Unit 1 Train B HVS-1C cooler was bounding with respect to void development and waterhammer loads.

The evaluation concluded the expected waterhammer stresses and loads on piping, coolers, supports, containment penetrations and nozzles were acceptable under functionality review criteria. Consistent with the NRC request for additional information dated July 28, 1998, the FPL response L-98-276 (Reference 9) provided increased detail with respect to evaluation methodology, inputs, assumptions, engineering judgement and failure modes.

The existing St. Lucie Unit 1 and 2 functionality determinations remain valid, as the methodology was reasonable and the underlying assumptions within the evaluation remain valid.

Plant modifications have been implemented for St. Lucie Unit 1 and will be implemented for St. Lucie Unit 2 to move the CCW pump motors to the 0 second EDG load block to decrease the CCW System repressurization time and initiate flow some 6 seconds earlier than that currently evaluated. The EDG load block change does not adversely affect the previous conclusion that the St. Lucie Unit 1 and 2 CCW systems remain operable.

Evaluation of the GL 96-06 transient using the EPRI methodology indicates that waterhammer piping stresses and support loads are not sensitive to void size. The support loads developed using the EPRI methodology are consistent with and are less than those previously developed within the functionality analysis.

FPL concludes that the St. Lucie Unit 1 and 2 CCW systems remain operable with respect to GL 96-06 waterhammer concerns.

FPL Commitments to Close the GL 96-06 Waterhammer Concerns

FPL actions required to closeout GL 96-06 waterhammer issues for the St. Lucie Plant are:

- Complete the St. Lucie Unit 2 CCW pump motor EDG loading sequence modification during the spring 2003 (SL2-14) refueling outage. The Unit 1 modification was completed during the fall 2002 (SL1-18) outage.
- Complete modifications to St. Lucie Unit 1 as required prior to return to power following the spring 2004 refueling outage (SL1-19).
- Complete modifications to St. Lucie Unit 2 as required prior to return to power following the fall 2004 refueling outage (SL2-15).

These actions are consistent with those committed to by FPL within Reference 16.

References:

1. NRC GL 96-06, Assurance of Equipment Operability and Containment Integrity During Design-Basis Accident Conditions, September, 30, 1996
2. NRC GL 96-06 Sup 1, Assurance of Equipment Operability and Containment Integrity During Design-Basis Accident Conditions, November 13, 1997
3. FPL letter L-96-280 to NRC dated October 28, 1996
4. FPL letter L-97-18 to NRC dated January 28,1997
5. NRC letter to FPL dated April 21, 1997
6. FPL letter L-97-114 to NRC dated April 22, 1997
7. NRC letter to FPL dated November 17, 1997
8. NRC RAI for Generic Letter 96-06 dated July 28, 1998
9. FPL letter L-98-276 to NRC dated October 30, 1998
10. NRC letter to FPL dated March 27, 2000, Review of FPL Responses to GL 96-06 Concerning Waterhammer, Two-Phase Flow, and Thermal Overpressurization (TAC Nos. M96870 and M96871)
11. NRC letter to EPRI dated April 3, 2002, NRC Acceptance of EPRI Report TR-113594, "Resolution of Generic Letter 96-06 Waterhammer Issues, Volumes 1 and 2"
12. NRC letter to FPL dated April 25, 2002, EPRI Report TR-113594, "Resolution of Generic Letter 96-06 Waterhammer Issues, Volumes 1 and 2"
13. EPRI Report TR-113594, Resolution of GL 96-06 Waterhammer Issues (reissued with new numbers)
14. EPRI, Generic Letter 96-06 Waterhammer Issues Resolution: User's Manual – Proprietary, EPRI, Palo Alto, CA: April 2002. 1006456
15. EPRI, Generic Letter 96-06 Waterhammer Issues Resolution: Technical Basis Report – Proprietary, EPRI, Palo Alto, CA: April 2002. 1003098
16. FPL letter L-2002-149 to NRC dated July 29, 2002