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

FPL

September 29, 2003

L-2003-244
10 CFR 50.4

US Nuclear Regulatory Commission
Attn: Document Control Desk
Washington, DC 20555

RE: St. Lucie Units 1 and 2
Docket Nos. 50-335 and 50-389
Response to NRC Request for Additional Information
Generic Letter 96-06 Waterhammer Issues

The Florida Power & Light Company (FPL) supplemental response to Generic Letter 96-06, for St. Lucie Units 1 and 2 is attached. This supplement provides a response to the NRC second request for additional information (RAI) dated August 1, 2003.

GL 96-06 concerns whether the cooling water system for containment air coolers is susceptible to waterhammer or two phase flow conditions during postulated design basis accidents and whether piping systems that penetrate the containment are susceptible to overpressurization from thermal expansion of entrapped fluid. Under previous correspondence:

- NRC accepted FPL's responses and actions concerning two-phase flow and thermal pressurization issues and has closed these issues.
- NRC accepted FPL deferment of the waterhammer issue pending review and approval of an EPRI developed design-basis approach to waterhammer evaluation.

NRC letter dated April 3, 2002 documented acceptance of EPRI Report TR-113594 for use in evaluating GL 96-06 waterhammer issues and requested FPL response to the remaining waterhammer issues.

FPL Letter L-2002-149 dated July 29, 2002, provided a schedule for completing GL 96-06 analysis and modifications and indicated that FPL intended to preclude containment fan cooler (CFC) voiding by moving the component cooling water (CCW) pumps to an earlier emergency diesel generator (EDG) load block. To reduce modeling uncertainty for the time-to-boil and void size calculations, FPL subsequently performed benchmark testing of the CCW pump stop and start transients. These tests indicated that CFC voiding could be expected within Unit 1 Train B for the design bases accident with loss of offsite power (DBA/LOOP) scenario.

FPL Letter L-2003-069 dated March 13, 2003 responded to the NRC using an analysis based on the method of characteristics (MOC) methodology to determine waterhammer occurrence and magnitude as described in the EPRI Report.

A072

On August 1, 2003, the NRC issued an RAI with respect to this response requesting clarification of specific issues and additional analysis information.

As discussed by phone with the NRC staff on July 30, 2003, FPL will update Question 6 & 7 responses to address final design information within 30 days after return to power following the Unit 1 spring 2004 refueling outage (SL1-19). Please contact George Madden at 772-467-7155 if there are any questions about this submittal.

Very truly yours,

William Jefferson, Jr.
Vice President
St. Lucie Plant

WJ/GRM

Attachment

Attachment
St. Lucie Units 1 and 2 Response
NRC Request for Additional Information Dated August 1, 2003
Regarding GL 96-06 Waterhammer Issues

NRC Question 1 - Page 2 of the March 13, 2003, submittal discussed benchmark testing of Component Cooling Water (CCW) system pump coastdown and recovery following restart. Provide a comparison between these tests to a postulated loss of offsite power (LOOP) event at St. Lucie. Provide comparisons of steam formation within the CCW piping, number of pumps starting, maximum flow rates within the system after pump restart and waterhammer produced. Also, identify the location of the test section, discussed on page 3, relative to the CCW pumps and the containment coolers.

FPL Response

Benchmark testing was performed to confirm HYTRAN's velocity predictions following pump shutdown were reasonable (heat transfer analysis indicated sensitivity to pressure and flow transients) and to confirm HYTRAN's predicted water-solid dynamic pressure oscillations on pump stop and start were real. Benchmark testing results showed the HYTRAN analysis predictions were accurate.

The St. Lucie Units employ a closed loop CCW System for cooling containment fan coolers (CFCs) and other essential cooling loads. Without containment heating from a Loss of Coolant Accident (LOCA) or main steam line break (MSLB), the LOOP-only event for St. Lucie represents a water-solid transient associated with pump coastdown and pump start.

GL 96-06 modeling for St. Lucie Units 1 & 2 considered combinations of LOOP with containment heating scenarios (LOOP/LOCA, LOOP/MSLB). As discussed with NRC staff by phone on July 30, 2003, no analysis of the LOOP-only event was performed by FPL in response to GL 96-06. It is FPL's understanding that a LOOP-only event analysis is not required by the GL 96-06 work scope and, based on discussion with the NRC staff, is not required with respect to this RAI.

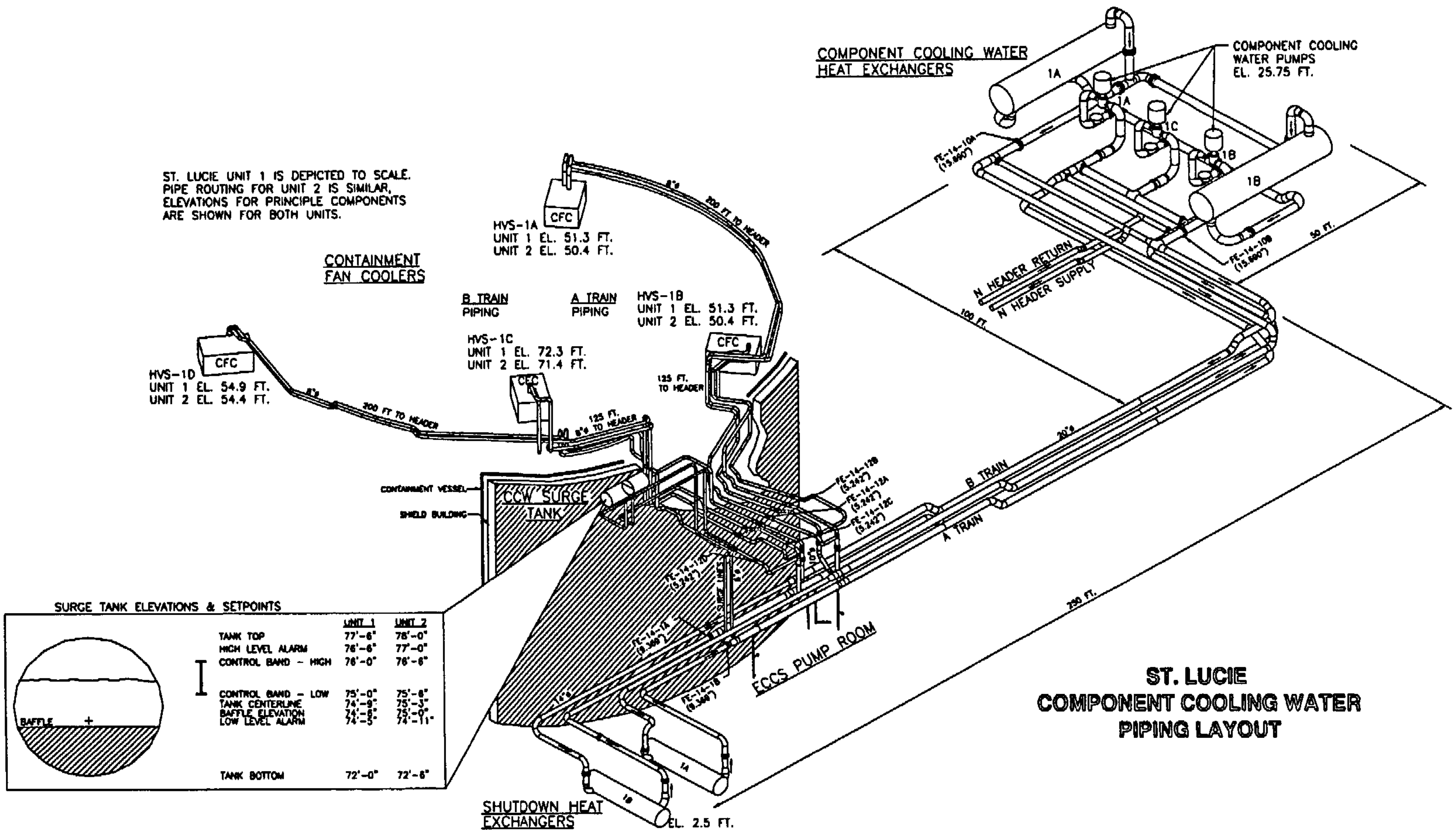
While the LOOP-only condition was not modeled, a water-solid response would be expected without steam formation within the CCW piping. Pump coastdown for benchmark testing would approximate the expected hydraulic transient for a LOOP event. Primary differences would stem from differences in the hydraulic resistance and inertial aspects of the LOOP-only scenario vs. the tested scenario.

In the LOOP scenario, the non-essential CCW header (N-header) would remain in service and the restart of the two CCW pumps would produce flow in the A, B, and N-headers. For the test condition, the N-header was isolated and the shutdown cooling (SDC) heat exchanger was valved in service. The hydraulic resistance of the SDC heat exchanger flow circuit is somewhat less than the N-header while the inertia of the N-header is likely greater than the SDC heat exchanger flow circuit.

Information concerning the number of pumps starting in the benchmark test and LOOP-only scenario, and maximum flow rates expected within the system after pump restart is provided as follows:

Parameter	Test Condition	LOOP Only Condition
Number of Pumps Starting	1 (half system w/SDC Hx)	2 (N-header not isolated)
Maximum flow rates	~7640 gpm per pump	~5700 gpm per pump
Flow rate at the CFC	~1350 gpm	~1400 gpm

Benchmark test measurements were taken at pipe penetrations adjacent to the outside containment shield building wall. Relative locations to system components are shown on the following figure.



ST. LUCIE
COMPONENT COOLING WATER
PIPING LAYOUT

NRC Question 2 - Figures on page 3 of the submittal indicate that a CCW system hydraulic (HYTRAN) code predicts higher waterhammer pressures when a reduced speed of sound is used. It is the U.S. Nuclear Regulatory Commission (NRC) staff's understanding that when a reduced speed of sound is used in waterhammer calculations, lower waterhammer pressures should result. Explain this discrepancy.

FPL Response

As discussed in the response to Question 1, the water-solid dynamic pressure response shown in the figures on page 3 of the submittal do not represent column closure waterhammer conditions following heating of the containment. The water-solid dynamic pressure oscillations occur as a result of pump shutdown and startup.

FPL concurs with the NRC staff's understanding that when a reduced speed of sound is used in waterhammer calculations, lower transient pressures would be expected. The Sargent & Lundy (S&L) HYTRAN code also predicts lower waterhammer pressures with a reduced speed of sound (following the Joukowski equation).

The following additional information is provided to place the submittal's comment concerning the speed of sound into context. The benchmark testing showed the predicted pressure oscillations were real and the magnitude of the oscillations was well represented. However, the wave frequency was over-predicted and the oscillation's rate of decay was under-predicted as shown in the top figure on page 3 of the submittal. It was noted that by changing the speed of sound used within the HYTRAN analysis, there was much better congruence of wave's period and rate of decay in this water-solid condition.

The comment on page 3 of the submittal indicated that air coming out of solution may act to locally reduce the speed of sound and account for this field test result. This conclusion was offered as an observation for the likely cause of the phase shift in the calculated water-solid dynamic pressure response. The shift of the periodic pressure oscillation to coincide with the pressure rise of the pump start did result in a higher calculated maximum pressure indicated in the second figure on page 3 of the submittal. This can be explained by in-phase reinforcement of the water-solid pressure oscillation with the water-solid pump start pressure transient.

The speed of sound criteria contained within the EPRI Report was used for all HYTRAN runs made in support of the formal GL 96-06 response for St. Lucie Unit 1 & 2 LOOP/LOCA and LOOP/MSLB scenarios.

NRC Question 3- The submittal states that the HYTRAN code was used to predict peak pressure produced in the waterhammer analysis. The NRC staff has not previously reviewed the HYTRAN code for waterhammer analysis within CCW piping. Provide either the HYTRAN code for staff review, or provide an analysis of the most severe waterhammer postulated within the CCW piping using the Electric Power Research Institute (EPRI) methodology that the staff has approved. If you choose to apply the EPRI methodology rather than submitting the HYTRAN code for staff review, provide the following information:

a. The maximum CCW velocity following pump restart.
b. Mass of gas in the void. Provide justification that the minimum noncondensible mass for use of the EPRI methodology will be present.
c. Amount of cushioning credited. Reference the nomograph used to determine cushioning.
d. Assumptions regarding pressure pulse shape.
e. Assumptions regarding pressure pulse duration.
f. Transmission coefficients used to track the pressure wave through the CCW piping.
g. Pressure pulse clipping.

FPL Response

In correspondence dated April 3, 2002 (Reference 1), the NRC accepted use of EPRI Report TR-113594[1] and provided a safety evaluation presenting the bases for their acceptance. NRC Safety Evaluation Report (SER) acceptance was based on general agreement with EPRI's testing and analytical approaches, stipulation of limitations, and a risk perspective analysis of potential pipe failure as a consequence of a postulated GL 96-06 waterhammer event.

EPRI provided two acceptable methods for calculating GL 96-06 Column Closure Waterhammer (CCWH) loads within Reference 2. The first of these methods, the Method of Characteristics (MOC) method, is provided in Chapter 8 of Reference 2. The second EPRI method, the Rigid Body Method (RBM), is a simplified, approximating approach explained in Chapter 9 of Reference 2 and in more detail within Reference 3.

The NRC SER indicates on page 7 that use of either MOC (Method of Characteristics) or RBM (Rigid Body Method) methodology requires that licensees first perform an evaluation sufficient to obtain the necessary analytical inputs for the methodology and that certain specified conditions must be met.

As discussed in FPL Letter L-2002-149 dated July 29, 2002, Sargent & Lundy (S&L) performed a plant specific MOC analysis to model the St. Lucie CCW pump coastdown and CCW pump start phase of the DBA/LOOP event to determine the necessary analytical inputs for entry into one of the two EPRI test methodologies. FPL

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1 EPRI adopted a new report numbering system after the original report numbers (TR-113594, Volumes 1 and 2) were assigned. The final report numbers and publication dates are provided in References 2 & 3. The reports include the NRC safety evaluation for the EPRI waterhammer methodology.

subsequently elected to continue the St. Lucie analysis of the CCWH event using the more accurate EPRI MOC methodology. As discussed in FPL Letter L-2003-069 dated March 13, 2003, the HYTRAN/MOC analysis was performed in accordance with the NRC SER limitations and restrictions provided and a risk perspective analysis demonstrated the overall risk of piping failure was similar to that contained within the SER.

Based on discussion with the NRC Staff on September 2, 2003, it is FPL's understanding that use of the MOC methodology by S&L within their HYTRAN code requires further review to ensure the analysis correctly implements the EPRI MOC method. Per discussion with the NRC staff, the following material is prepared to assist in the review.

- Further information will be provided to demonstrate that the HYTRAN CCWH analysis correctly implements the EPRI MOC method.
- The HYTRAN MOC results will be compared to EPRI RBM results to show consistency.

EPRI MOC METHOD/HYTRAN

HYTRAN is a Sargent Lundy, LLC (S&L) proprietary computer program designed to model transient hydraulic phenomena in piping systems. It has been the standard analysis tool for virtually all single phase transient analyses at S&L over the past 30 years. Use of this code has been proven in the design of major piping systems (e.g., feedwater, main steam, circulating water, etc.) on numerous nuclear and fossil power stations. The HYTRAN code is listed as an analysis tool in several UFSARs (e.g., Clinton).

HYTRAN was originally developed at S&L in the period 1971 through 1972. Using the fixed grid Method of Characteristics (MOC) solution procedure as given in Streeter and Wylie (References 4 & 5), HYTRAN is able to simulate a wide variety of hydraulic transients such as pump start or column closure in liquid systems and steam hammer on stop valve closure in gaseous systems. Over the years the program has been modified to add new boundary conditions and to update the solution procedure to conform to the latest methods. HYTRAN falls under the S&L QA Program, which complies with 10CFR50, Appendix B. HYTRAN is validated and verified (V&V) against a standard problem set, primarily from Reference 4, which tests significant modeling within the code.

Further, as part of a V&V effort for acquisition of software, results from a commercially available code (AFT Impulse™) were compared to HYTRAN results. This work was completed in 2002 and showed accurate agreement between the codes.

For FPL's St. Lucie GL 96-06 analysis, a Containment Fan Cooler boundary condition (steam-air filled void) was added to HYTRAN. This version of HYTRAN complies with the EPRI MOC methodology described in Reference 2, including the modeling of heat transfer within the steam-air void. To demonstrate this, HYTRAN was benchmarked and validated against the test and analysis results EPRI provided in Reference 2.

The V&V compares HYTRAN to three EPRI test cases and to EPRI's MOC simulations of the test cases. Further, the V&V compares HYTRAN MOC simulations to EPRI's MOC simulations of two Rigid Body Method cases. For all five cases, HYTRAN results correlate well with the EPRI results.

Within the next section, a comparison between the HYTRAN MOC and RBM maximum pipe segment loads for the St. Lucie specific analysis also demonstrates that the loads calculated by HYTRAN are reasonable. In addition, the CCWH pressure pulse calculated by HYTRAN at the point of column closure is shown to correlate well with the RBM peak pressure and shape.

The HYTRAN calculation is available for NRC staff review at the St. Lucie site. The HYTRAN source code is available for NRC staff review at the S&L corporate office in Chicago.

EPRI RBM METHOD

The EPRI RBM approach is a simplified, standard approach approved by the NRC. As such, it can be compared to other methods of calculating CCWH loads. The intent of comparing loads from the EPRI RBM approach with HYTRAN, is to demonstrate that the HYTRAN results are reasonable and can be used as input to qualify the subject piping for CCWH loading resulting from a postulated GL 96-06 event.

The EPRI Rigid Body Method (RBM) is used below to calculate GL 96-06 CCWH maximum pipe segment loads and pressures downstream of St. Lucie Unit 1, Loop B CFCs HVS-1C and HVS-1D, including the CFC HVS-1C return manifold piping. These loads are then compared to those formally calculated using the EPRI MOC approach, developed using the HYTRAN computer program. The HVS-1C & HVS-1D return piping is representative of piping in both loops and units of the St. Lucie Component Cooling Water Systems.

The EPRI RBM approach (References 2 & 3) is used to calculate the peak pressure, rise and duration of a pressure pulse, and the associated maximum pipe segment loads, resulting from a worst case CCWH GL 96-06 scenario. Application of the RBM approach to estimate maximum pipe leg forces in constant diameter legs adjacent to the point of column rejoining is straightforward, assuming that the water column differential velocity is known.

The maximum differential velocity of the two water columns from an uncushioned HYTRAN analysis is equated to $V_{initial}$ in the RBM approach delineated in the EPRI User's Manual. The uncushioned HYTRAN analysis does not include the effect of either steam or air cushioning. However, the steam pressure in the cavity corresponding to the flashing point of the hot water is considered, and the downstream water column velocity prior to column rejoining results from the steam cavity pressure.

The cavity closure point is located at a 10 inch by 8 inch reducer, which is at the high point of the CCW system downstream of the HVS-1C outlet. To be conservative, the RBM calculation is based on the minimum air requirement for a 10 inch pipe and the maximum differential velocity for an 8 inch pipe. From an uncushioned HYTRAN analysis, the maximum differential velocity of the two water columns in an 8 inch diameter pipe is approximately 9.5 feet per second ($V_{initial}$). The requirement that the differential water column velocities be less than 30 feet per second is met, which allows use of the nomographs in the EPRI User's Manual.

Based on the volume of boiling water in the tubes of approximately 11.28 cubic feet, an initial water temperature of 100F and the EPRI Methodology (pages 5-5, 5-6, and 5-7 of Reference 3), 2.87 grams of air from water in the cooler tubes can be credited in calculating the air cushioning effect.

The EPRI Methodology also credits a percentage of the gas in the mass of water in the heat exchanger headers and attached piping through which steam passes. The steam reaches the high point of the attached piping just downstream of HVS-1C prior to CCWH. The steam passes through an estimated 5 feet of 3 inch nominal diameter piping for each of 6 coils, and an estimated 24 feet of 6 inch nominal diameter piping, and over 2 feet of 10 inch diameter piping. The total water mass that steam passes through is estimated to be 464 pounds. Taking credit for a portion of the air in this water mass per EPRI, another 0.95 grams of air can be credited in calculating the air cushioning effect. While some steam will likely pass through the supply side headers, no credit was taken for this effect.

The total amount of air that can be credited for cushioning the GL 96-06 CCWH event initiated by the HVS-1C cavity is 3.82 grams of air compared to 1.5 grams of air needed in a 10 inch diameter pipe and 0.960 grams of air needed in an 8 inch pipe. Note that the HYTRAN analysis credited 2.8 grams of air in order to provide a calculation margin.

For the purposes of this RBM comparison, 2.8 grams of air will also be credited. Since L_{wo} is approximately 200 feet, the Figure A40 nomograph, with K = 40, is used to obtain $V_{cushion}/V_{initial} = 0.84$. Therefore, $V_{cushion} = 8.0$ feet per second.

Peak pressure = $\frac{1}{2}\rho C V_{cushion} = (\frac{1}{2} * 1.93\ ^{slugs}/_{ft^3} * 4200\ ^{ft}/_{sec} * 8.0\ ^{ft}/_{sec})/(144\ in^2/ft^2) = 224$ psi

Pressure rise time = 33.6 milliseconds, using Equation 9 -11 of Reference 2

The pressure pulse duration time is twice the distance from the point of column rejoining to the nearest downstream header (about 290 feet) divided by the water sound speed (about 4200 feet per second) for a 69 millisecond duration time. To be conservative, the duration time is increased by adding the rise time. Therefore the pressure pulse is calculated to be a trapezoid with a peak pressure of 224 psi having a linear rise time of 33.6 milliseconds, a dwell time of 35 milliseconds and a linear decay time of 33.6 milliseconds. The RBM peak pressure and shape correlate well with the HYTRAN/MOC peak pressure and shape as shown in the figure at the end of this response.

The method for calculating pipe segment forces provided in Figure 6-4 and associated text of Reference 3 is used to calculate the maximum leg forces. The longest straight pipe segment downstream of HVS-1C is leg name 107 at 20.2 feet. Using the RBM approach, the maximum force in this leg is 1605 pounds.

At pipe area changes, such as tees and reducers, transmission factors using the methodology of References 2 & 3 are applied. In order to simplify the calculation, pressure pulse clipping is not credited except as noted below for the junction of the return piping from HVS-1D. Not crediting pressure pulse clipping is conservative as clipping acts to reduce the magnitude of the pressure wave. These transmission and clipping factors, where applied, are tabulated in the following table.

The 8-inch lines from the HVS-1C and HVS-1D coolers join together outside containment and then the combined line joins the 20 inch header to return to the CCW pump suction. The 20 inch header is within 17 feet of the tee joining the HVS-1C and HVS-1D return lines. This header reduces the pipe pressure transmitted from the tee upstream to Cooler HVS-1D. Without considering the effect of the 20 inch header the transmission factor at the tee is 0.667. Using Equation 9.2 of the EPRI Technical Basis Report (Reference 2), the transmission factor is reduced to 0.366.

The following Load Comparison Table compares RBM and HYTRAN/MOC maximum leg forces. The accompanying Node Point/Leg Sketches indicate the locations of the legs.

The CCWH MOC pressure pulse from the HYTRAN analysis at the point of closure is compared to the peak pressure and shape of the RBM pressure pulse in a following figure.

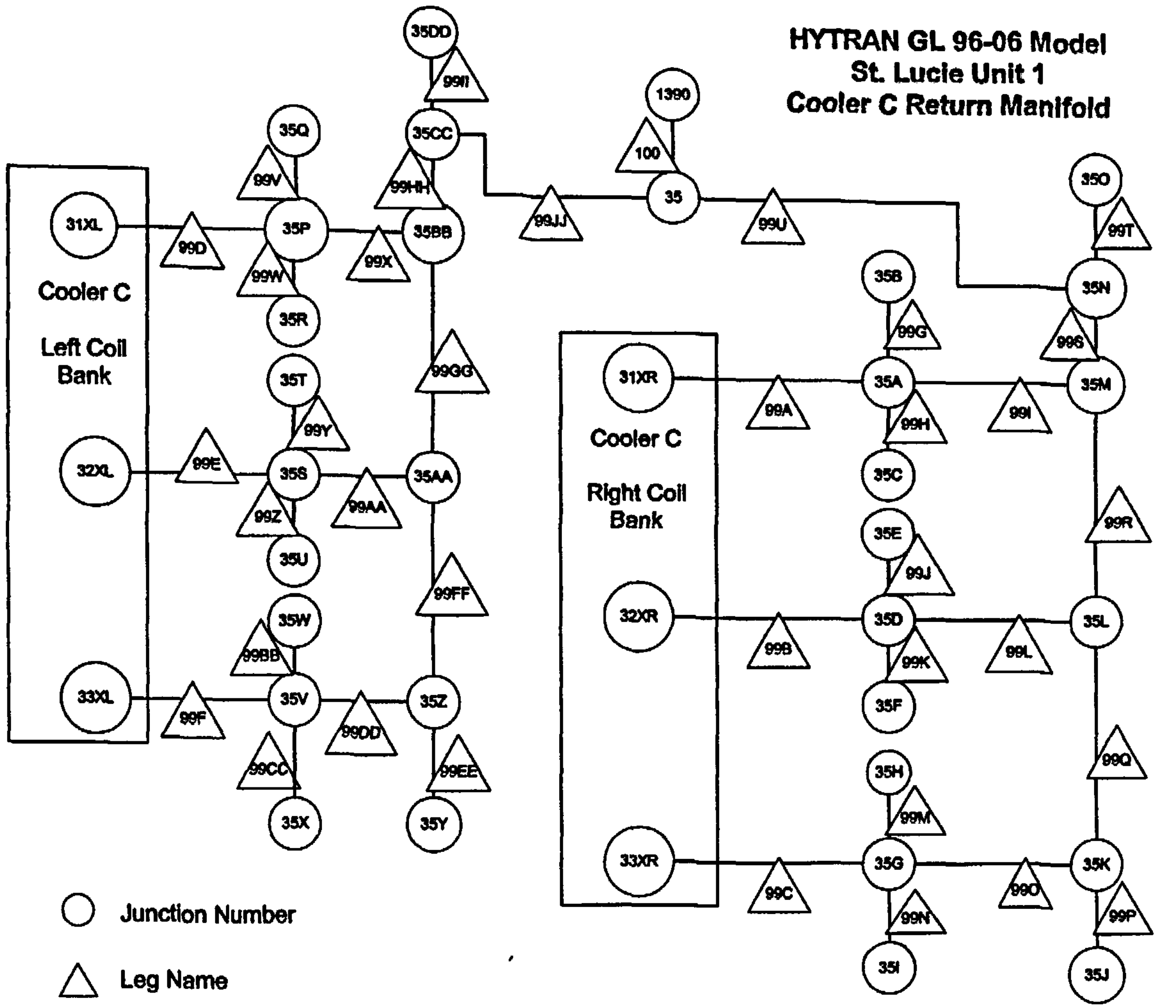
Load Comparison Table of RBM and HYTRAN/MOC Maximum Leg Forces

HYTRAN Leg Name	Leg Area (sq. in)	Leg Length (feet)	RBM Max Load (pounds)	HYTRAN Max Load (pounds)	RBM Max Pressure Pulse (psi)	Transmission Factor/Pressure Clipping
Point of Column Combining is at System High Point just Outboard of Cooler C - 10"x8" Red/Leg 100 to 101						
101	50	7.8	620	864	224	1.000
102	50	3.3	262	406	224	1.000
103	50	16.8	1335	1315	224	1.000
104	50	3	238	412	224	1.000
105	50	2.3	183	431	224	1.000
106	50	6.8	540	854	224	1.000
107	50	20.2	1605	1877	224	1.000
108	50	1.7	135	358	224	1.000
109	50	14	1112	1281	224	1.000
110	50	3.1	246	438	224	1.000
111	50	11.7	930	1228	224	1.000
112	50	2	159	351	224	1.000
113	50	5.7	453	329	224	1.000
114	50	2	159	375	224	1.000
115	50	13.4	1065	1341	224	1.000
116	50	2.7	215	464	224	1.000
117	50	12.5	993	1320	224	1.000
118	50	2.3	183	412	224	1.000
119	50	10.3	818	962	224	1.000
Leg Name 119 ends at C & D Return Tee - Leg Name 48 starts outboard of Cooler D						
48	50	1.6	46	139	82	0.366
49	50	33	959	1042	82	0.366
50	50	11.5	334	415	82	0.366
51	50	1.4	41	131	82	0.366
52A	50	11.4	331	435	82	0.366
52	50	9.8	285	302	82	0.366
53	50	1.8	52	148	82	0.366
54	50	1.6	46	148	82	0.366
55	50	32.3	938	945	82	0.366
56	50	1.4	41	129	82	0.366
57	50	5.6	163	138	82	0.366
58	50	8.1	235	315	82	0.366
59	50	9.8	285	355	82	0.366
60	50	9.8	285	353	82	0.366
61	50	5.3	154	161	82	0.366
62	50	4.9	142	151	82	0.366
63	50	13.5	392	410	82	0.366
64	50	11	320	553	82	0.366
65	50	8.4	244	408	82	0.366
66	50	2	58	205	82	0.366
67	50	14.4	418	610	82	0.366
68	50	2.6	76	187	82	0.366
69	50	12.6	366	591	82	0.366
70	50	2.3	67	200	82	0.366
Leg Name 70 ends at C & D Return Lines Tee - Leg Name 71 Provides C & D Return Water to Header						
71	50	13.2	383	1509	82	0.366
72	50	3.6	105	542	82	0.366
Leg Name 72 Flows into 20" Return Header - Leg Name 73 is 20" Header Return						
73	278	47.0	3659	4042	40	0.176
74	278	5.0	389	391	40	0.176

Load Comparison Table of RBM and HYTRAN/MOC Maximum Leg Forces

HYTRAN Leg Name	Leg Area (sq. in)	Leg Length (feet)	RBM Max Load (pounds)	HYTRAN Max Load (pounds)	RBM Max Pressure Pulse (psi)	Trans-Mission Factor
Leg Name 99A starts at Cooler C Tubing						
99A	10.2	12.0	118	285	136	0.606
99B	10.2	12.0	104	283	120	0.537
99C	10.2	12.0	166	277	192	0.855
99D	10.2	12.0	118	285	136	0.606
99E	10.2	12.0	104	283	120	0.537
99F	10.2	12.0	166	277	192	0.855
Leg Name 99F ends Cooler C Tubing - Leg Name 99G starts 3" Manifold to 6" Manifold						
99G	7.3	1.5	11	86	136	0.606
99H	7.3	1.5	11	73	136	0.606
99I	7.3	2.5	18	81	136	0.606
99J	7.3	1.5	9	21	120	0.537
99K	7.3	1.5	9	30	120	0.537
99L	7.3	2.5	16	78	120	0.537
99M	7.3	1.5	15	50	192	0.855
99N	7.3	1.5	15	26	192	0.855
99O	7.3	2.5	25	78	192	0.855
99P	28.8	0.8	20	21	120	0.537
99Q	28.8	3.3	81	95	120	0.537
99R	28.8	3.3	92	186	136	0.606
99S	28.8	1.3	41	300	153	0.684
99T	28.8	0.8	25	129	153	0.684
99U	28.8	5.9	185	251	153	0.684
Leg Name 99U is 6" Return to 6"x6"x10" Tee - Leg Name 99V starts 3" Manifold to 6" Manifold						
99V	7.3	1.3	9	86	136	0.606
99W	7.3	1.5	11	73	136	0.606
99X	7.3	1.5	11	81	136	0.606
99Y	7.3	1.3	8	21	120	0.537
99Z	7.3	1.5	9	30	120	0.537
99AA	7.3	1.5	9	78	120	0.537
99BB	7.3	1.3	13	50	192	0.855
99CC	7.3	1.5	15	26	192	0.855
99DD	7.3	1.5	15	78	192	0.855
99EE	28.8	0.8	20	21	120	0.537
99FF	28.8	3.3	81	95	120	0.537
99GG	28.8	3.3	92	186	136	0.606
99HH	28.8	1.3	41	300	153	0.684
99II	28.8	0.8	25	129	153	0.684
99JJ	28.8	4.4	138	251	153	0.684
Leg Name 99JJ is 6" Return to 6"x6"x10" Tee - Leg Name 100 is 10" Return Leg from 6"x6"x10" Tee						
100	78.9	2.8	272	823	174	0.776

HYTRAN GL 96-06 Model
St. Lucie Unit 1
Cooler C Return Manifold



HYTRAN 96-06 Model – St. Lucie Unit 1

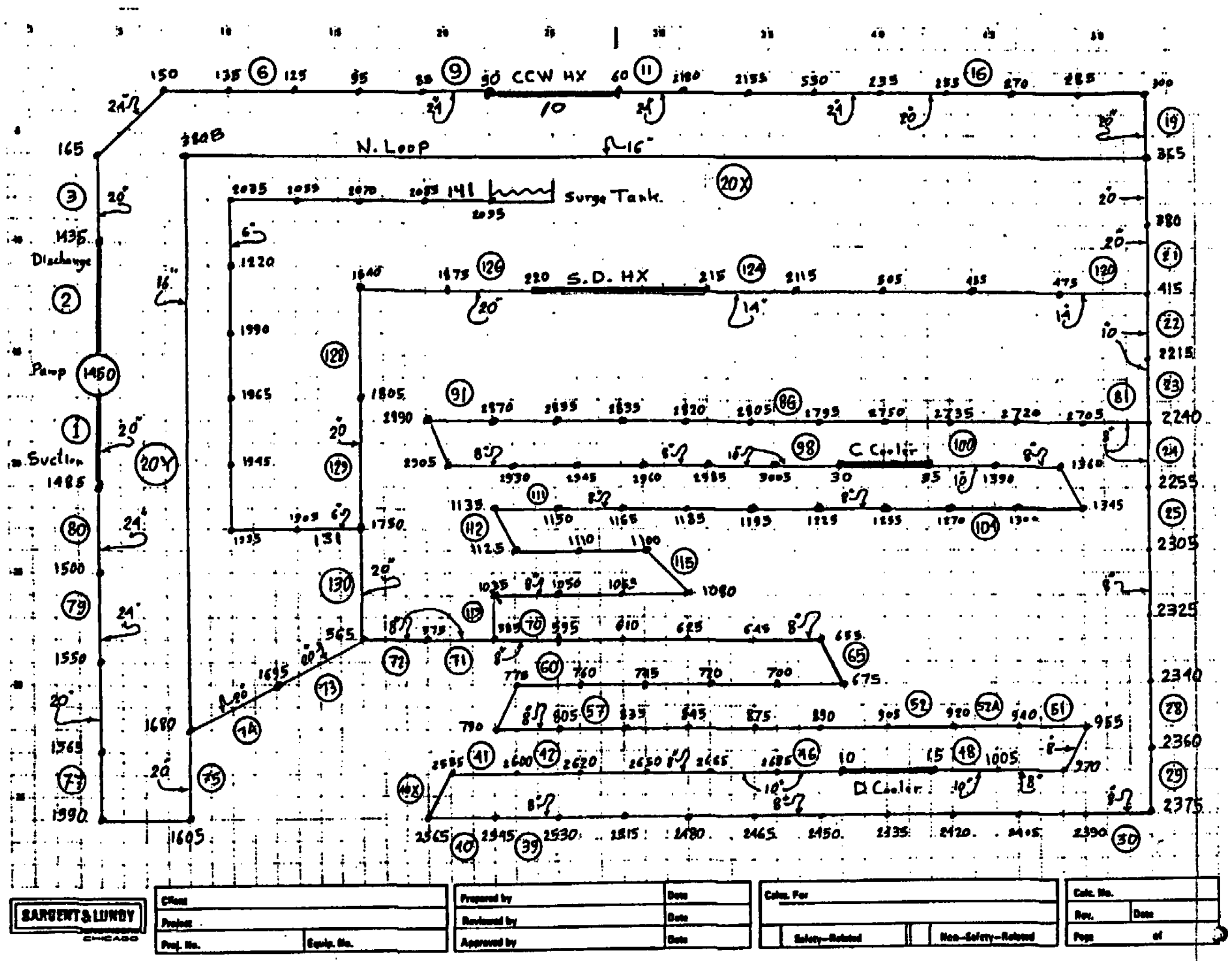
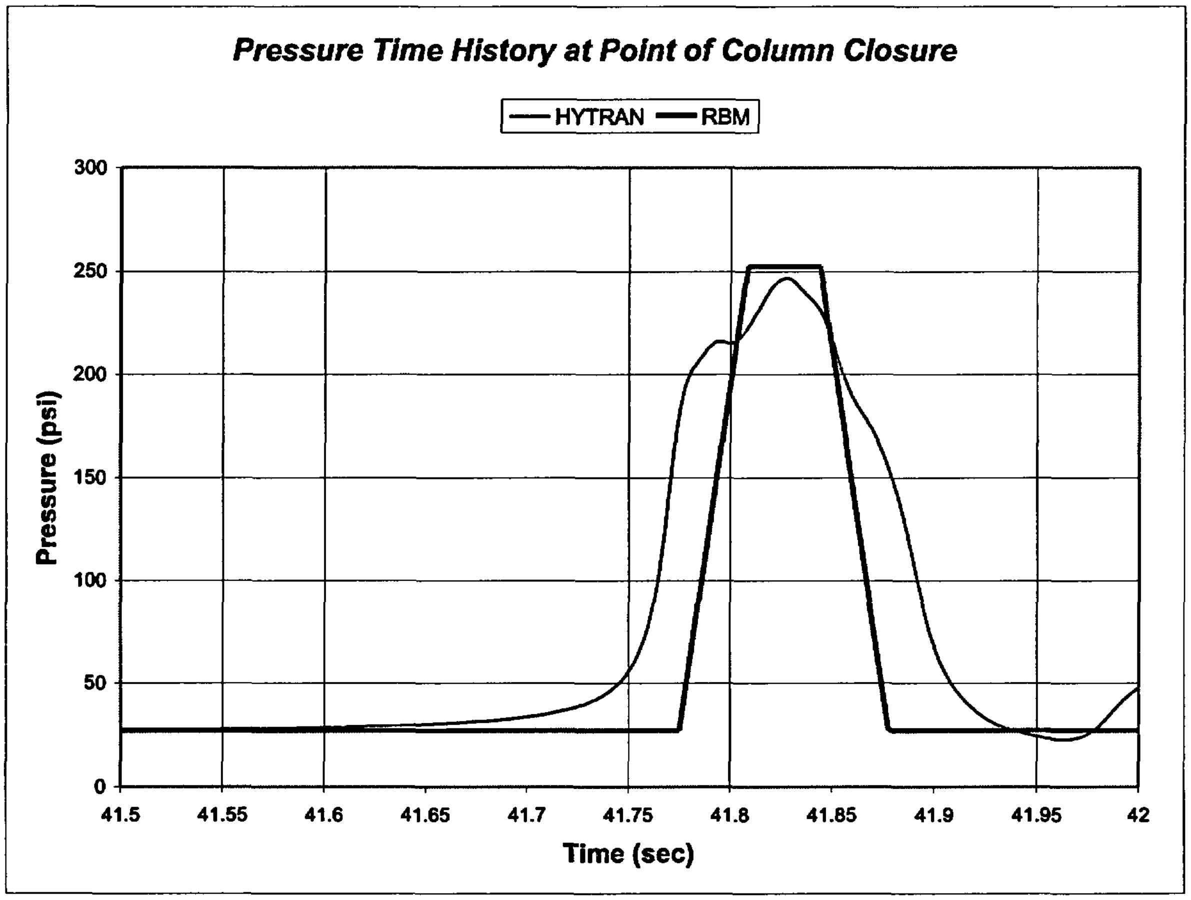


Fig 1 HYTRAN Model of Loop B Piping – Schematic

RBM to HYTRAN/MOC Comparison



Pressure Time History for Cavity Closure Point

Conclusion of the HYTRAN/MOC vs. RBM Method Review

The correlation of maximum pipe segment loads between EPRI RBM and HYTRAN/EPRI MOC is good, especially in the HVS-1C return line downstream of the point of water column closure. In the remaining part of the system, HYTRAN calculates consistently higher maximum pipe segment loads than the RBM approach, except for isolated cases. One reason for this in the CFC manifold region is that with a one millisecond calculation time, HYTRAN internally treats legs shorter than 4 feet (sound speed*time step) as being 4 feet long. This causes HYTRAN to overestimate the associated pipe segment loads.

The RBM peak pressure at the point of water column closure correlates well with HYTRAN/MOC, as does the overall shape of the pressure pulse.

The RBM to MOC comparison demonstrates that the St. Lucie GL 96-06 CCWH loads calculated by HYTRAN are suitable for qualification of the CCW System under CCWH loads resulting from a postulated GL 96-06 event. A significant advantage of using HYTRAN in an MOC approach is that the pressure time histories of each pipe leg are calculated and used as input into a dynamic piping analysis program to calculate pipe support loads. This approach results in more accurate modeling of piping response than applying the simplified approaches provided in the EPRI User's Manual.

References
1. NRC Letter dated April 3, 2002, NRC Acceptance of EPRI Report TR-113594, *Resolution of Generic Letter 96-06 Waterhammer Issues,* Volumes 1 and 2.
2. EPRI, Generic Letter 96-06 Waterhammer Issues Resolution: Technical Basis Report – Proprietary, EPRI, Palo Alto, CA; Report Number 2002.1003098.
3. EPRI, Generic Letter 96-06 Waterhammer Issues Resolution: User's Manual – Proprietary, EPRI, Palo Alto, CA; Report Number 2002.1006456.
4. Streeter, V. L., and Wylie, E. B., *Hydraulic Transients*, McGraw Hill, New York, NY 1967.
5. Wylie, E. B., and Streeter V. L., *Fluid Transients in Systems*, Prentice Hall, 1993.

NRC Question 4 - The submittal states, on page 6 that calculated results from a water heatup transient are used as input into HYTRAN. Describe the assumptions and equations used in this calculation and justify whether the methodology is conservative.

FPL Response

The assumptions and correlation equations used within the heat transfer analysis and justification of their use were previously provided in FPL's response L-97-18 dated January 28, 1997.

In summary, heat transfer on the outside of tubes accounts for fins, condensing heat transfer (4x Uchida), and forced convective heat transfer (Hilpert - for the MSLB event). Heat transfer on the inside of tubes accounts for the forced convection (Dittus-Boelter), natural convection (Catton), subcooled nucleate boiling (Rohsenow), and bulk pool boiling (Chen) regimes. The methodologies employed are standard formulations utilized within commercial and nuclear industries for many years and are considered applicable to the case-in-point. Assumptions within the heat transfer modeling were selected to conservatively determine the time-to-boil.

Based on phone conversations with the NRC staff, it is FPL's understanding that the previous L-97-18 response adequately addresses this question.

<u>NRC Question 5</u> – The submittal states, on page 7, that the peak pressure generated in the analysis is 270 psig, the piping design pressure is 150 psig, and that the Component Fan Cooler cooling coils have a design pressure of 225 psig. Provide justification that these components will not fail under the calculated waterhammer load.

<u>FPL Response</u>

CCW system piping and the CFC cooler manifolds are constructed of A-106 Gr B standard wall or greater material in sizes ranging from ½-inch to 24-inch diameter. Larger sizes of piping generally have a lower maximum working pressure.

- The location of column closure occurs within 8 and 10 inch Schedule 40 piping. Published maximum working pressure (NAVCO Piping Datalog, 11th Edition) for 10-inch A-106 Gr B Schedule 40 piping is 912 psig.

- The bounding CCW system pipe size of 24-inch Schedule 20 has a tabulated maximum working pressure of 415 psig while the peak pressure expected at this remote location (CCW pump) is 112 psig for the 24-inch suction piping and 200 psig for the 24-inch discharge piping.

The containment fan cooler cooling coils are constructed of 3-inch copper pipe and 5/8-inch tubes. The fabricated cooling coil assembly (coils and headers) was hydrostatically tested at a pressure of 300 psig.

Maximum pipe stresses for the waterhammer conditions are addressed within Question 6 and provides the formal justification that the piping and fittings will not fail under the calculated waterhammer load. An additional consideration, not included within the stress analysis, is that the elevated containment pressure at the time of the event effectively reduces the pressure stress.

<u>NRC Question 6</u> - *Provide the maximum loads calculated for the CCW piping, supports, orifices, bends, and penetrations for the worst case column closure waterhammer. Also, provide the ratios of the maximum loads within the service water system to the loads required for failure.*

<u>FPL Response</u>

The load combinations utilized for the CCW piping and supports under GL 96-06 are as defined in the St. Lucie Unit 1 & 2 UFSAR Sections 3.9. Specifically, the piping and components are evaluated for pressure, dead weight, thermal, and the square root sum of the squares (SRSS) of seismic DBE and waterhammer. Pipe supports, nozzles, and containment penetrations are evaluated for dead weight, thermal, seismic anchor movement, and the SRSS of seismic DBE and waterhammer.

Waterhammer loads were developed from the HYTRAN generated pressure time histories of each pipe leg and input into a dynamic piping analysis program to calculate pipe stress and support loads. These dynamic loads were appropriately combined with other piping code of record loads to evaluate the integrity of the piping. The results of these analyses indicate the piping and in-line components comply with ASME Section III Code requirements, with a maximum stress ratio of 0.52. In addition, the pipe supports, with some limited modifications, and penetrations were found structurally adequate for the applied loads.

The following table provides a summary of the affected pipe supports and penetrations, support type, maximum calculated waterhammer load, resulting design load, and design margin (either component load rating or limiting stress ratio of structural steel frame or weld). In addition, the table identifies those supports that require modification for the revised loads.

This table does not specifically address orifices and bends as these components fall under the scope of the piping stress analysis and are evaluated therein. As discussed with the NRC staff on July 30, 2003, the stress analysis demonstrates compliance with ASME Section III Code requirements and such demonstration is adequate to respond to this question.

As discussed with the NRC staff on July 30, 2003, FPL identified several analytical discrepancies within the stress analyses of record for the affected CCW piping that are unrelated to GL 96-06. These discrepancies included incorrect seismic response spectra and omission of or incorrect seismic anchor and thermal accident movements. FPL's review of this condition determined the system remains operable. FPL is currently revising the affected Unit 1 CCW supply and return piping stress analysis to correct these discrepancies, while taking into consideration the GL 96-06 waterhammer loads. Unit 2 CCW system stress analyses are not affected by this issue.

As discussed by phone with the NRC staff on July 30, 2003, FPL will provide results of the final CCW piping and support design analyses within 30 days of return to power following Unit 1 Spring 2004 SL1-19 refueling outage (new commitment).

Calculated Loads for Pipe Supports - 1C & 1D CFC Coolers - Return Piping Inside Containment to RAB CCW B Return Header

Stress Calc	Pipe Support Mark No.	Support Type	Dynamic Loads Water Hammer (lbs)			New Combined Design Loads Faulted (lbs)			Margin		Remarks
			X Horizontal	Y Vertical	Z Transverse	X Horizontal	Y Vertical	Z Transverse	Catalog Items Capacity (lbs)	Limiting Stress Ratio Frames/Welds	
1D Containment Cooler to Penetration P-17 (Inside Containment)	CCH-212	Strut		±169			+1853 -873		4000	0.05	Modification- Replace Rod Hanger to Strut
	CC-1899-6210	Frame		±295	±741		-1498	±857	N/A	0.155	
	CC-1899-2208	Snubber	±3263			±3293			15000	0.08	
	CC-1899-6208	Frame		±489	±1615		-1490	±2407	N/A	0.233	
	CC-1899-6206	Frame		±1496	±1158		-2472	±1231	N/A	0.566	
	CC-1899-6204	Frame		±693	±1880		-1763	±2657	N/A	0.307	
	CC-1899-6202	Strut		±528			-1650		3000	0.22	
	CC-1899-29	Strut			±610			±1267	3000	0.22	
	CC-1899-2200	Snubber			±577			±744	6000	0.24	
	CCH-169	Frame		±881	±257		-2075	±788	N/A	0.19	
	CC-1899-6173	Frame	±762	±454	±484	±1417	-2185	±1981	N/A	0.627	
	CCH-184	Frame		±833			-2142		N/A	0.78	Modification- Replace U-bolt to Frame
	CC-1899-2184	Strut			±277			±564	3000	0.01	
	CC-1899-48	Snubber			±262			±335	6000	0.01	
	CC-1899-1187	Strut		±501			-1257		3000	0.02	
	CC-1899-6187	Strut			±1047			±1530	3000	0.04	

Calculated Loads for Pipe Supports - 1C & 1D CFC Coolers - Return Piping Inside Containment to RAB CCW B Return Header

Stress Calc	Pipe Support Mark No.	Support Type	Dynamic Loads Water Hammer (lbs)			New Combined Design Loads Faulted (lbs)			Margin		Remarks
			X Horizontal	Y Vertical	Z Transverse	X Horizontal	Y Vertical	Z Transverse	Catalog Items Capacity (lbs)	Limiting Stress Ratio Frames/Welds	
1C Containment Cooler to Penetration P-15 (Inside Ctmt)	CC-1883-6198	Rigid Bar		±2306			-4086 +756		6000	0.13	
	CC-1883-1198	Strut			±2735			±3380	6000	0.14	
	CCH-196	Strut		±805			-1095 +773		4000	0.04	Modification- Replace Rod Hanger to Strut
	CC-1883-6196	Strut			±1461			±1673	3000	0.04	
	CC-1883-6194	Frame		±444	±933		-1845	±1130	N/A	0.114	
	CC-1883-6192	Strut			±1338			±2080	3000	0.32	
	CCH-192	Strut		±350			-1437		4000	0.11	Modification- Replace Rod Hanger to Strut
	CC-1883-6190	Frame	±848	±2768	±605	±2240	-7557 +1225	±1131	N/A	0.54	
Penetration P-15 & P-17 to Common Header (RAB)	CCH-47	Strut		±1399			-6881		25000	0.32	Modification- Replace Rod Hanger to Strut
	CCH-51	Strut		±492			-1518		25000	0.12	Modification- Replace Rod Hanger to Strut
	CC-23-1	Strut			±1273			±4790	10000	0.14	
	CC-23-3	Frame		±172	±865		-54 +2870	±2434	N/A	0.17	
	CC-23-4	Frame		±196	±680		-350 +1300	±876	N/A	0.96	
	CCH-46	Spring Can	Dead load support only – evaluation not required								
	CCH-50	Spring Can	Dead load support only – evaluation not required								

	Penetration ID	Type	Dynamic Loads Water Hammer (lbs/ft-lbs)			New Combined Design Loads Faulted (lbs/ft-lbs)			MARGIN Limiting Stress Ratio
			Fx/Mx	Fy/My	Fz/Mz	Fx/Mx	Fy/My	Fz/Mz	
	P-15 & P-17	Ctmt Pen Type II	3109/432	496/2698	472/1128	4721/916	2686/4139	960/3156	0.7

<u>NRC Question</u> *7 - Page 11 of the submittal states that the piping, pipe support, and cooler structural analysis for the design basis case were ongoing. Provide the results of the structural analysis and include a summary of the licensing basis load combination along with the results of the stress analysis.*

<u>FPL Response</u>

A summary of the licensing basis load combinations, piping and pipe support analysis, and its status was addressed in the response to Question 6. The response to Question 7 will summarize the cooler structural analysis and its status.

The cooler analysis addresses the copper cooling coils, cooler manifold piping up to the 10 inch diameter flanges on both the supply and return lines and the cooling coil and manifold supports. The 10 inch piping flanges are the interface points between the cooler analysis and the CCW piping analysis.

As discussed by phone with the NRC staff on July 30, 2003, the cooler analysis completed thus far has developed the waterhammer loads but has not formally combined them with pressure, deadweight, thermal, and seismic loading in an analysis which would support the FSAR design basis loading combination. The following information is provided to indicate the results of the dynamic analysis completed to date.

CFC Layout

The containment fan cooler is a 12 x 11 x 24 ft assembly constructed of structural steel members and sheet metal to support a fan, motor, ducting, cooling coils and supply/return manifold piping connected to the CCW System. The steel manifold piping serving the 6 cooling coils consists of 6 x 10 inch tee in a horizontal run serving two 6-inch vertical risers which supply flow to 3 coils each via three nominal 3-inch flanged branch connections. The supply manifold and return manifold have a nearly identical layout and are supported by two supports on the horizontal run and two supports on each vertical leg. The 5/8 inch copper cooling coils are of a serpentine construction supported by a radiator type fins in a steel frame. Each coil has 44 copper tubes, which make 4 passes and each of the tube passes is approximately 80 inches in length. The outside diameter of each copper tube is 0.64 inches, and the tube thickness is approximately 0.049 inches, leaving the copper tube inside diameter at approximately 0.542 inches. Three inch nominal diameter copper pipe headers are drilled to accept the 5/8 inch copper tubing. The copper pipe headers have a brazed joint for steel or 90/10 copper/nickel stub and flange for connection to the steel manifold piping.

Cooling Coil Nozzle Loads

The limiting condition for the cooling coils is governed by the piping nozzle allowable value, which is expressed in a six-factor interaction equation by the coil manufacturer. Fluid transient piping loads acting on the 3-inch flanges are compared to the faulted nozzle allowable values provided in vendor documentation with adjustment for actual tube wall thickness and for plant specific stress allowable values (3.0 S_m). The nozzle allowable criterion is met for each of the 6 coils connecting to the manifold on the return line piping. Suitable margin is provided for additional consideration of combined loads.

Manifold Piping Stresses

Carbon steel and copper piping stresses are compared to a Faulted Condition allowable of 3.0 S_m, where S_m is the applicable material allowable stress in the hot condition. Suitable margin is provided for additional consideration of combined loads.

Manifold Support Evaluation

Piping supports are qualified using the acceptance criteria based on ASME Appendix F stress allowable values. The location with the maximum faulted stress interaction is in the 3x3x1/4-inch tube steel member; consistent with the critical member identified in the vendor seismic stress analysis. Suitable margin is provided for additional consideration of combined loads.

Coil Support Structure

Loads applied to the cooling coil nozzles are transmitted to the frame of the cooling coil, which are in turn transmitted through structural members to the cooler foundations. As discussed in the vendor's original seismic design report, the construction of the cooler is made of substantial members. The limited nozzle loads allowed from the cooling coils, precludes the need for rigorous analysis of the cooler structural members.

Summary – Cooler Analysis for Waterhammer Loading

- Piping nozzle allowable values adjusted for the actual tube wall thickness and faulted stress allowable are met for each of the six coils connected to the return piping. As the tubing connected to the copper header is the weakest location of the CFC and the nozzle loads are controlled based on this criterion, the CFC coil design is adequate to withstand GL 96-06 CCWH loading.

- Return side manifold piping is shown to meet Appendix F allowable values. Due to the location of the column closure, the supply side piping is expected to have similar or lower GL 96-06 CCWH loads than the return side piping. Since the supply side piping routing is nearly identical to the return side piping, the supply side piping is also acceptable. The manifold pipe supports meet their stress allowable values under the GL 96-06 CCWH loading.

As previously mentioned, the analysis performed to date has not formally combined deadweight, thermal, seismic and dynamic (waterhammer) stresses and loads. This analysis will be completed prior to making the GL 96-06 piping system modifications committed for completion during SL1-19 (existing commitment). The available margin in the cooler analysis indicates the expected load combination will be acceptable without the need for further CFC manifold support modifications. Should manifold support modifications be required, they will be completed on the same schedule previously committed for piping support modifications.

As discussed by phone with the NRC staff on July 30, 2003, FPL will provide final design information with respect to the cooler structural analysis within 30 days of return to power following Unit 1 Spring 2004 SL1-19 refueling outage (new commitment).

NRC Question 8 - Page 11 of the submittal states that the loads and stresses are "not sensitive to void size." Explain.

FPL Response

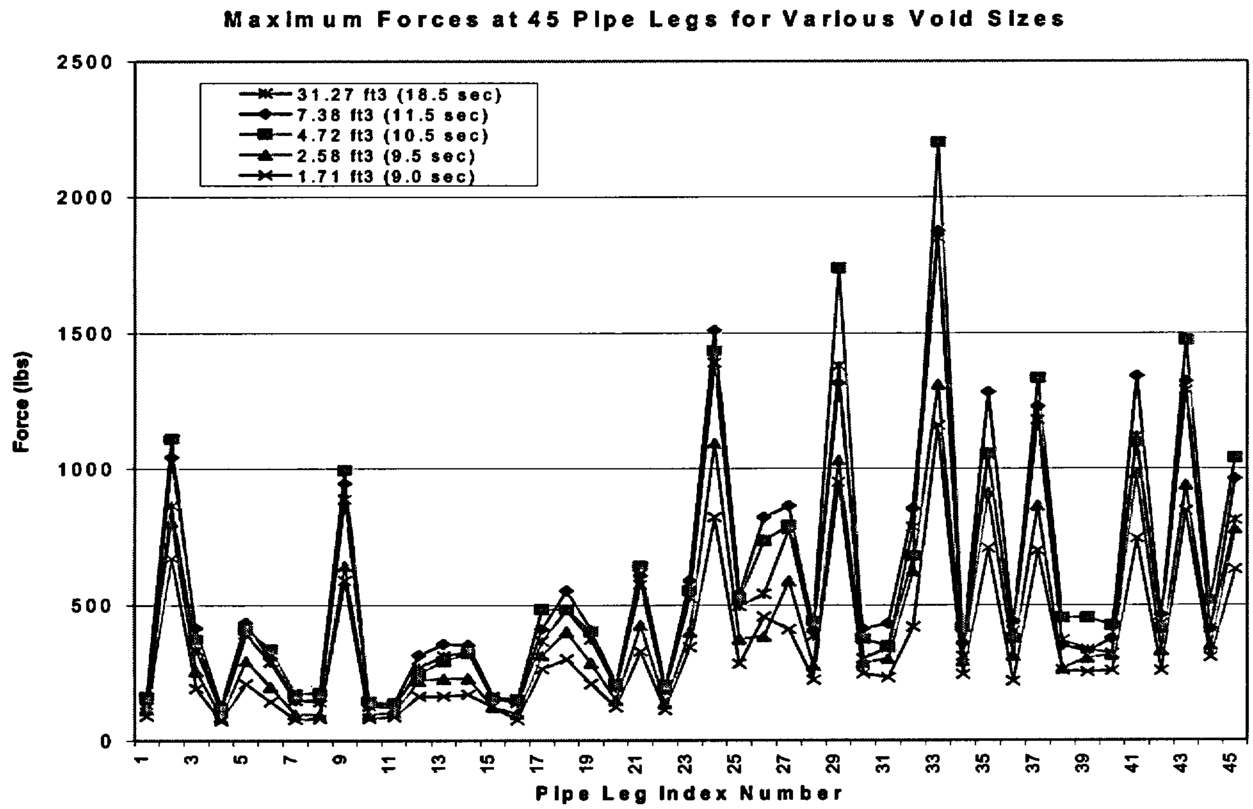
From a qualitative viewpoint, review of the EPRI methodology indicates:

- Release of a fixed percentage of the dissolved gas (air) in the total mass of CFC water is credited if the water is exposed to a tube temperature satisfying a temperature criterion, plus a fixed percentage of the dissolved gas from the total mass of header water is credited assuming the steam passes through the volume. Accordingly, smaller cavity sizes would generally be expected to be associated with reduced column closure velocities and reduced waterhammer loads, since various void sizes result in similar credited air cushions.

- A constant heat transfer coefficient is assumed over a constant area regardless of steam mass. The effect of this at St. Lucie is that larger voids have more credited steam cushioning.

For St. Lucie, the combination of these two effects limits the variance in the column closure velocity with void size and hence limits the variance in waterhammer forces with void size.

A parametric review was performed with respect to the affect of void size on maximum pipe segment loads for the 45 legs in the CFC return lines within the Unit 1 B CCW train for five arbitrary void volumes. The effect of void size on pipe segment loads is shown below. The results indicated that the loads were very small at low void size (1.71 ft^3), increased as void size increased (2.58 ft^3 to 4.72 ft^3), decreased slightly at 7.38 ft^3 and dropped off again at a void size of 31.37 ft^3. The variance in the maximum loads between the analyzed case (7.38 ft^3) and other void sizes reviewed ranged from 10% to 25%.



NRC Question 9 - Page 13 of the submittal establishes commitments for completing modifications that are necessary for resolving the waterhammer issue. Provide a status update for these items.

FPL Response

- Modifications to implement Unit 1 EDG load block changes were completed during SL1-18 as committed.
- Modifications to implement Unit 2 EDG load block changes were completed during SL2-14 as committed.
- Support modifications for Unit 1 will be implemented during the SL1-19 refueling outage (currently scheduled for spring 2004). Design package development is currently underway to support this existing commitment.
- Update RAI Question 6 & 7 responses to address final design and provide within 30 days of return to power following SL1-19. Final design analysis of the CCW piping and CFC is currently underway to support this new commitment.

- Support modifications for Unit 2 will be implemented during the SL2-15 refueling outage (currently scheduled for fall 2004). Design package development is planned to support this existing commitment.