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

FPL

March 15, 2012

L-2012-105
10 CFR 50.90

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

Re: St. Lucie Plant Unit 1
Docket No. 50-335
Renewed Facility Operating License No. DPR-67

Response to Nuclear Performance and Code Review Branch Request for Additional Information Identified During an Audit of Analyses Supporting the Extended Power Uprate License Amendment Request

References:

(1) R. L. Anderson (FPL) to U.S. Nuclear Regulatory Commission (L-2010-259), "License Amendment Request (LAR) for Extended Power Uprate," November 22, 2010, Accession No. ML103560419.

(2) NRC Nuclear Performance and Code Review Branch Audit Conducted at Westinghouse Electric Company Facilities in Rockville, MD, February 22 and 23, 2012.

By letter L-2010-259 dated November 22, 2010 [Reference 1], Florida Power & Light Company (FPL) requested to amend Renewed Facility Operating License No. DPR-67 and revise the St. Lucie Unit 1 Technical Specifications (TS). The proposed amendment will increase the unit's licensed core thermal power level from 2700 megawatts thermal (MWt) to 3020 MWt and revise the Renewed Facility Operating License and TS to support operation at this increased core thermal power level. This represents an approximate increase of 11.85% and is therefore considered an Extended Power Uprate (EPU).

During the course of the NRC audit conducted at the Westinghouse Electric Company facilities in Rockville, MD on February 22 and 23, 2012 [Reference 2], the NRC staff requested additional information related to the EPU analyses for boron precipitation. The attachment to this letter provides the requested information.

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

This submittal does not alter the significant hazards consideration or environmental assessment previously submitted by FPL letter L-2010-259 [Reference 1].

In accordance with 10 CFR 50.91(b)(1), a copy of this letter is being forwarded to the designated State of Florida official.

A001
NRR

Should you have any questions regarding this submittal, please contact Mr. Christopher Wasik, St. Lucie Extended Power Uprate LAR Project Manager, at 772-467-7138.

I declare under penalty of perjury that the foregoing is true and correct to the best of my knowledge.

Executed on 15-March-2012

Very truly yours,

Richard L. Anderson
Site Vice President
St. Lucie Plant

Attachment

cc: Mr. William Passetti, Florida Department of Health

Response to NRC Nuclear Performance and Code Review Branch Request for Additional Information

The following information is provided by Florida Power & Light Company (FPL) in response to the U. S. Nuclear Regulatory Commission's (NRC) Request for Additional Information (RAI). This information was requested to support the review of the Extended Power Uprate (EPU) License Amendment Request (LAR) for St. Lucie Nuclear Plant Unit 1 that was submitted to the NRC by FPL via letter (L-2010-259) dated November 22, 2010, Accession Number ML103560419.

As part of the NRC's LAR review process, an audit of supporting analyses was conducted at the Westinghouse Electric Company facilities in Rockville, MD on February 22 and 23, 2012. During this audit the NRC staff requested additional information related to the EPU analyses for boron precipitation. Although the Westinghouse audit was predominantly in support of the St. Lucie Unit 2 EPU, the NRC reviewer indicated that the information requested is also applicable to St. Lucie Unit 1. The St. Lucie Unit 1 responses to the NRC request are documented below.

Item 1

Document core and sump boric acid concentrations versus time post-LOCA.

Response

Table 1 documents the requested results from the case of 229 gpm hot leg injection (HLI) begun at 6 hours post-LOCA.

Table 1
St. Lucie Unit 1
229 gpm HLI Begun at 6.0 Hours Post-LOCA

Time, hours	Core Boric Acid Concentration, wt%	Sump Boric Acid Concentration, wt%
0.28	3.27	0.00
2.18	11.34	0.00
2.30	11.78	1.29
3.00	13.96	1.27
3.10	14.25	1.26
3.20	14.55	1.26
3.30	14.84	1.26
3.40	15.13	1.25
3.50	15.41	1.25
3.60	15.70	1.25
3.70	15.98	1.24

Table 1
St. Lucie Unit 1
229 gpm HLI Begun at 6.0 Hours Post-LOCA

Time, hours	Core Boric Acid Concentration, wt%	Sump Boric Acid Concentration, wt%
3.80	16.26	1.24
3.90	16.53	1.24
4.00	16.81	1.24
4.10	17.08	1.23
4.20	17.35	1.23
4.30	17.62	1.23
4.40	17.89	1.22
4.50	18.15	1.22
4.60	18.41	1.22
4.70	18.67	1.21
4.80	18.93	1.21
4.90	19.19	1.21
5.00	19.44	1.21
5.10	19.70	1.20
5.20	19.95	1.20
5.30	20.20	1.20
5.40	20.45	1.20
5.50	20.70	1.19
5.60	20.95	1.19
5.70	21.19	1.19
5.80	21.43	1.18
5.90	21.68	1.18
6.00	21.92	1.18
6.10	22.16	1.18
6.20	22.39	1.17
6.30	22.63	1.17
6.40	22.87	1.17
6.50	23.10	1.17
6.60	23.33	1.16
6.70	23.56	1.16
6.80	23.79	1.16
6.90	24.02	1.16
7.00	24.25	1.15
7.10	24.48	1.15
7.20	24.71	1.15
7.30	24.93	1.15
7.40	25.15	1.14
7.50	25.38	1.14

Table 1
St. Lucie Unit 1
229 gpm HLI Begun at 6.0 Hours Post-LOCA

Time, hours	Core Boric Acid Concentration, wt%	Sump Boric Acid Concentration, wt%
7.60	25.60	1.14
7.70	25.82	1.14
7.80	26.04	1.14
7.90	26.26	1.13
8.00	26.48	1.13
8.10	26.69	1.13
8.20	26.91	1.13
8.30	27.12	1.12
8.40	27.34	1.12
8.50	27.55	1.12
8.60	27.76	1.12
8.70	27.95	1.11
8.80	28.12	1.11
8.90	28.28	1.11
9.00	28.43	1.11
9.10	28.56	1.11
9.20	28.67	1.11
9.30	28.77	1.11
9.40	28.85	1.11
9.50	28.92	1.10
9.60	28.98	1.10
9.70	29.02	1.10
9.80	29.04	1.10
9.90	29.06	1.10
10.00	29.05	1.10
10.10	29.04	1.10
10.20	29.01	1.10
10.30	28.97	1.10
10.40	28.92	1.10
10.50	28.85	1.11
10.60	28.78	1.11
10.70	28.69	1.11
10.80	28.59	1.11
10.90	28.48	1.11
11.00	28.36	1.11
11.10	28.23	1.11
11.20	28.09	1.11
11.30	27.95	1.11

Table 1
St. Lucie Unit 1
229 gpm HLI Begun at 6.0 Hours Post-LOCA

Time, hours	Core Boric Acid Concentration, wt%	Sump Boric Acid Concentration, wt%
11.40	27.79	1.12
11.50	27.63	1.12
11.60	27.45	1.12
11.70	27.27	1.12
11.80	27.09	1.12
11.90	26.89	1.13
12.00	26.69	1.13
12.10	26.49	1.13
12.20	26.27	1.13
12.30	26.06	1.14
12.40	25.83	1.14
12.50	25.61	1.14
12.60	25.38	1.14
12.70	25.14	1.14
12.80	24.90	1.15
12.90	24.66	1.15
13.00	24.41	1.15
13.10	24.17	1.16
13.20	23.92	1.16
13.30	23.67	1.16
13.40	23.41	1.16
13.50	23.16	1.17
13.60	22.90	1.17
13.70	22.64	1.17
13.80	22.38	1.17
13.90	22.12	1.18
14.00	21.87	1.18
14.10	21.61	1.18
14.20	21.35	1.19
14.30	21.09	1.19
14.40	20.83	1.19
14.50	20.57	1.19
14.60	20.32	1.20
14.70	20.06	1.20
14.80	19.81	1.20
14.90	19.55	1.21
15.00	19.30	1.21
15.10	19.05	1.21

Table 1
St. Lucie Unit 1
229 gpm HLI Begun at 6.0 Hours Post-LOCA

Time, hours	Core Boric Acid Concentration, wt%	Sump Boric Acid Concentration, wt%
15.20	18.80	1.21
15.30	18.56	1.22
15.40	18.31	1.22
15.50	18.07	1.22
15.60	17.83	1.22
15.70	17.59	1.23
15.80	17.36	1.23
15.90	17.13	1.23
16.00	16.90	1.23
16.10	16.67	1.24
16.20	16.45	1.24
16.30	16.22	1.24
16.40	16.00	1.24
16.50	15.79	1.25
16.60	15.57	1.25
16.70	15.36	1.25
16.80	15.16	1.25
16.90	14.95	1.26
17.00	14.75	1.26
17.10	14.55	1.26
17.20	14.36	1.26
17.30	14.16	1.26
17.40	13.97	1.27
17.50	13.79	1.27
17.60	13.60	1.27
17.70	13.42	1.27
17.80	13.25	1.27
17.90	13.07	1.28
18.00	12.90	1.28
18.10	12.73	1.28
18.20	12.57	1.28
18.30	12.41	1.28
18.40	12.25	1.29
18.50	12.09	1.29
18.60	11.94	1.29
18.70	11.79	1.29
18.80	11.64	1.29
18.90	11.49	1.29

Table 1
St. Lucie Unit 1
229 gpm HLI Begun at 6.0 Hours Post-LOCA

Time, hours	Core Boric Acid Concentration, wt%	Sump Boric Acid Concentration, wt%
19.00	11.35	1.30
19.10	11.21	1.30
19.20	11.08	1.30
19.30	10.94	1.30
19.40	10.81	1.30
19.50	10.68	1.30
19.60	10.56	1.30
19.70	10.44	1.31
19.80	10.31	1.31
19.90	10.20	1.31
20.00	10.08	1.31

Item 2

Provide additional justification for reactor vessel bottom head temperature vs. time following initiation of simultaneous hot and cold leg injection, and explain how this could impact precipitation.

Response

Following a large break LOCA, safety injection is immediately injected into the RCS through the high pressure safety injection (HPSI) and low pressure safety injection (LPSI) pumps and safety injection tanks (SITs) to the cold legs. This pump injection initially comes from the refueling water tank (RWT). The RWT and SITs are at a relatively cold temperature, which leads to an initially subcooled condition for the downcomer. Once the RWT empties, injection switches to recirculation from the containment sump, which is at a hotter temperature than the RWT. After recirculation begins with relatively low HPSI flow, the fluid in the vessel is expected to approach saturation due to heat addition from the vessel walls and an essentially stagnant mass of fluid in the vessel, whose boil-off is replenished by HPSI flow.

The boric acid precipitation analysis does not explicitly calculate the temperature in the reactor vessel bottom head. The analysis assumes saturation conditions, which is conservative, as it maximizes core boil-off.

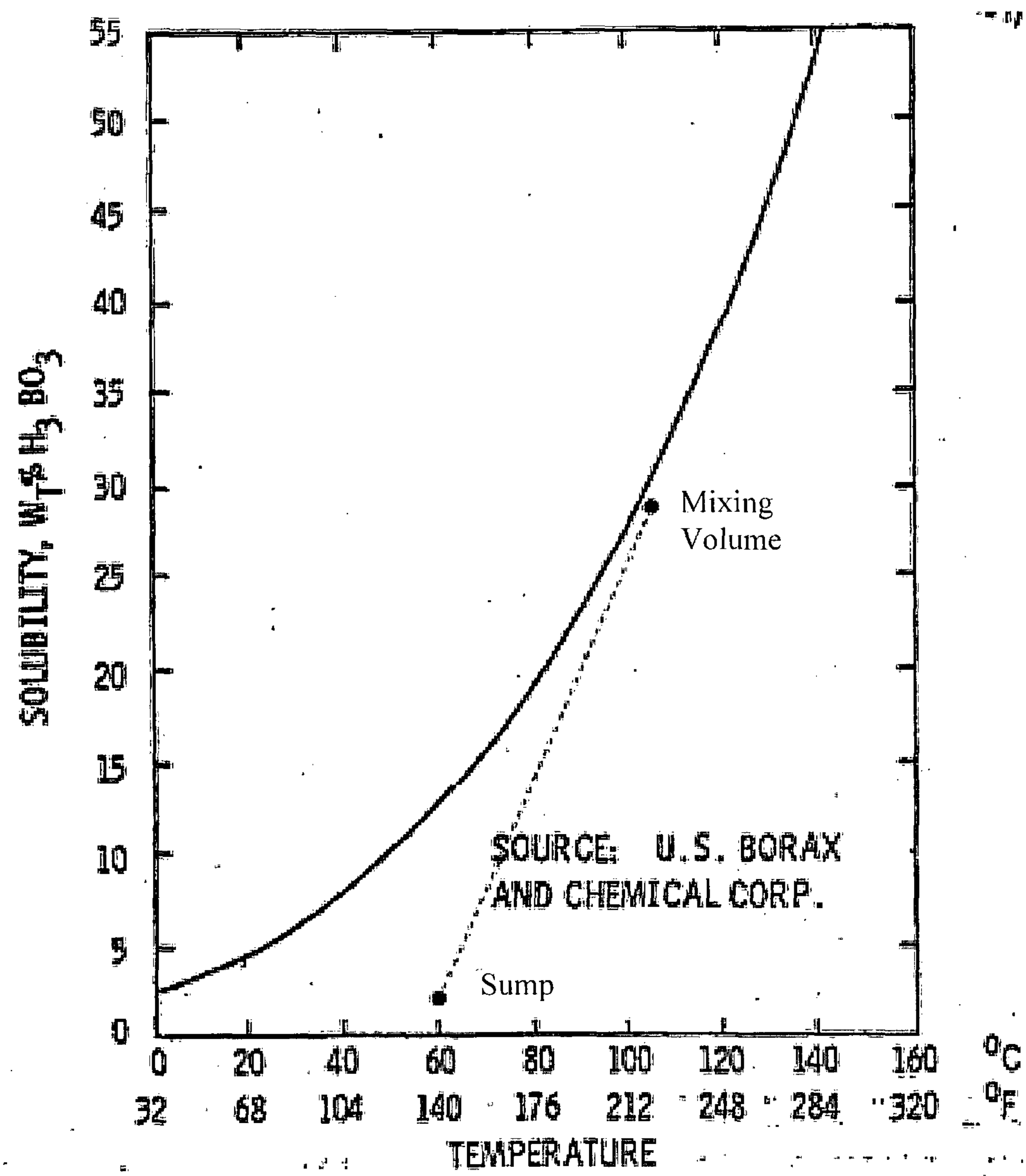
St. Lucie Unit 1 has several potential configurations for hot and cold leg injection. Injection through the LPSI pump is the preferred HLI method; however, provisions exist for HLI through either the containment spray (CS) or HPSI pumps. Cold leg injection (CLI) is primarily through the HPSI pump. For the configurations in which CS or HPSI pumps are used for injection, the injection flow will pass through the shutdown cooling heat exchanger (SDCHX).

From 6-9 hours post-LOCA, sump water temperature, based on a double-ended break in the discharge leg with a failure of an emergency diesel generator, is on average 185 °F. When sent through the SDCHX, this liquid temperature will drop to on average 140 °F. For this evaluation, it is then assumed that the liquid remains at 140 °F when injected into the cold leg (only CLI is looked at here, as any HLI that eventually ends up in the lower plenum will have passed through the core, where it will heat up significantly due to decay heat). This is conservative, as it ignores any increase in temperature due to pump heat or heat transfer from the walls of the injection piping.

Figure 1 documents the effect that this colder injection liquid can have on the boric acid concentration and the potential for precipitation. As seen in Figure 1, the injection flow is at a cold temperature, but it is also at the boric acid concentration of the sump (maximum of 1.2 wt% from 6-9 hours post-LOCA). The mixing volume is assumed to be at saturation conditions for a boric acid solution (i.e., saturation temperature of 218 °F). Once the liquid from the sump enters the lower plenum, mixing will begin to occur. As the sump liquid mixes with the mixing volume liquid, both the temperature and boric acid concentration of that liquid will increase. At 6-9 hours post-LOCA, the mixing volume maximum boric acid concentration is 28.4 wt%. Figure 1 illustrates these values for the injected flow (sump) and the mixing volume, and as shown, both remain under the solubility limit. The dotted line seen in Figure 1 illustrates how the boric acid concentration of the liquid will change as mixing occurs, until the liquid is fully mixed into the mixing volume. Again, looking at this line shows that the maximum concentration will never cross the solubility limit, and therefore, boric acid precipitation is precluded.

Figure 1

Solubility of Boric Acid vs. Temperature



Item 3

Calculate the depressed elevation of liquid in the outlet plenum when taking into account water in the loop seal, and discuss how this effects the calculation of the mixing volume.

Response

The justification of the selection of the top of the mixing volume is documented in LR Section 2.8.5.6.3.5.2 of Attachment 5 to the EPU LAR. Portions of this section are repeated here, with the following changes to satisfy responding to Item 3:

1) The hydrostatic head due to water in the loop seal is subtracted from calculated hydrostatic head of the downcomer.
2) The density of saturated liquid in the core and outlet plenum is no longer assumed to be that of pure water, but instead of a saturated boric acid solution.

The method used to justify the top of the mixing volume at the top of the hot legs is to show that the hydrostatic head of the liquid in the mixing volume used in this analysis is less than the Inner Vessel (IV) hydrostatic head, where the IV hydrostatic head equals the hydrostatic head in the downcomer minus the head associated with the core-to-break steam flow pressure drop and the head associated with the hydrostatic head of water in the loop seal. This calculation is performed at 1 hour post-LOCA. The following equation describes the calculation:

$$\Delta P_{MV} < \Delta P_{IV} = \Delta P_{DC} - \Delta P_{STM} - \Delta P_{LS} \text{ (at 1 hour)}$$

The available ΔP can be used to calculate the top of the available mixing volume. If it is greater than the assumed height used (i.e., from the top of the active core to the top of the Core Support Barrel (CSB) nozzles), then this selection is valid.

The density of liquid used to calculate the liquid level in the core and outlet plenum is based on a saturated boric acid solution. This is conservative, as this solution is denser than pure water, and thus will decrease the amount of hydrostatic head available to support the static head of liquid in the outlet plenum.

As stated above, the Reactor Coolant System (RCS) is broken into four major regions over which the pressure drops are determined:

1) hydrostatic head of the downcomer, ΔP_{DC}
2) hydrostatic head of the loop seal, ΔP_{LS}
3) the core-to-break steam flow pressure drop, ΔP_{STM}
4) hydrostatic head of the IV, ΔP_{IV}

The hydrostatic head is equal to the height of liquid divided by the specific volume, v, (and multiplied/divided by the appropriate conversion factors), given as follows:

$$\Delta P\text{, psi} = (\text{Height of Liquid, ft}) / v\text{, ft}^3/\text{lbm} / 144 \text{ in.}^2/\text{ft}^2 * g/g_c$$

The enthalpies and specific volumes of saturated steam and liquid for pure water at 14.7 psia are as follows:

- enthalpy of saturated steam = 1150.28 Btu/lbm
- enthalpy of saturated liquid = 180.18 Btu/lbm
- specific volume of saturated steam = 26.7952 ft^3/lbm
- specific volume of saturated liquid = 0.016714 ft^3/lbm

The density of a saturated boric acid solution in water is 1.016 g/cm^3, which converts to a specific volume of 0.015765 ft^3/lbm.

Hydrostatic Head of the Downcomer, ΔP_{DC}

This value is unchanged from what is documented in LR Section 2.8.5.6.3.5.2. The hydrostatic head of the downcomer from the bottom elevation of the active core to the bottom elevation of the reactor coolant pump (RCP) discharge legs remains 6.53 psi.

Hydrostatic Head of the Loop Seal, ΔP_{LS}

Using the geometric information in LR Table 2.8.5.6.3-10, the height of the loop seal (from top of cross-over leg to bottom of discharge leg) is 3.5 ft for St. Lucie Unit 1. The static head associated with the height of liquid in the cold leg above the loop seal inlet to the reactor coolant pump is offset by the added static head for the downcomer from this liquid. The hydrostatic head, ignoring the head of steam in the downflow side of the loop seal, associated with this level of liquid in the loop seal is calculated as follows:

$$\Delta P_{LS} = 3.5 \text{ ft} / 0.016714 \text{ ft}^3/\text{lbm} / 144 \text{ in.}^2/\text{ft}^2 * g/g_c = 1.454 \text{ psi}$$

Core-to-break steam flow pressure drop, ΔP_{STM}

This value is unchanged from what is documented in LR Section 2.8.5.6.3.5.2. The core-to-steam flow pressure drop remains 0.593 psi at 1 hour post-LOCA.

Hydrostatic Head of the Inner Vessel, ΔP_{IV}

The hydrostatic head of the mixing volume is made up of two parts; the hydrostatic head of the core, ΔP_{CORE}, and the outlet plenum, ΔP_{OP}, the latter of which is ultimately being solved for.

Hydrostatic Head of the Core, ΔP_{CORE}

The head of the collapsed liquid in the core is dependent upon the liquid volume, which in turn is dependent on the void fraction of the core, and thus is time dependent. The liquid volume in the core at 1 hour post-LOCA is determined to be 160.43 ft^3 and the core flow area is 54.00 ft^2. As documented above, the specific volume of saturated boric acid solution is 0.015765 ft^3/lbm. Based on these data, the core hydrostatic pressure drop, ΔP_{core} is:

$$\Delta P_{core} = (160.43\ ft^3 / 54.00\ ft^2) / 0.015765\ ft^3/lbm / 144\ in.^2/ft^2 * g/g_c = 1.31\ psi$$

Hydrostatic Head of the Outlet Plenum, ΔP_{OP}

The ΔP available to support the inner vessel liquid volume (i.e., the core and outlet plenum portion of the mixing volume) is the difference between the downcomer hydrostatic ΔP and the steam flow ΔP.

From this relationship, the hydrostatic head of the outlet plenum can be calculated as follows:

$$\Delta P_{IV} = \Delta P_{DC} - \Delta P_{STM} - \Delta P_{LS}$$

$$\Delta P_{OP} + \Delta P_{CORE} = \Delta P_{DC} - \Delta P_{STM} - \Delta P_{LS}$$

$$\Delta P_{OP} = \Delta P_{DC} - \Delta P_{STM} - \Delta P_{LS} - \Delta P_{CORE}$$

$$\Delta P_{OP} = 6.53 - 0.593 - 1.454 - 1.31$$

$$\Delta P_{OP} = 3.173\ psi$$

This equation gives the amount of hydrostatic head available to support the static head of the outlet plenum. In other words, the static head of the outlet plenum that yields this ΔP_{OP} is the height necessary to balance the system effects. It needs to be shown this height, which represents the collapsed height of the outlet plenum, is greater than the height used in the calculation of the mixing volume, i.e., the distance from the top of the active core to the top of the hot legs. Thus,

$$\Delta P_{MV} < \Delta P_{IV}$$

In other words, it needs to be shown that the hydrostatic ΔP of the selected mixing volume is less than the actual hydrostatic ΔP of the inner vessel. Restated, this relationship is:

$$(\Delta P_{OP\_MV} + \Delta P_{CORE\_MV}) < (\Delta P_{OP\_ACTUAL} + \Delta P_{CORE\_ACTUAL})$$

where ΔP_{CORE_MV} equals ΔP_{CORE_ACTUAL} since the liquid core volume used in determining ΔP_{CORE_ACTUAL} follows the same methodology used in calculating the liquid core volume for the mixing volume (Note: the liquid volume of the core for the mixing volume was calculated at a time of 6 hours, though this sample calculation is performed at 1 hour. This is conservative, as an earlier time corresponds to a higher steam flow rate and hence pressure drop through the system).

The static head of the outlet plenum at 1 hour post-LOCA can be solved as follows:

$$H_{OP}\text{, ft} = \Delta P_{OP}\text{, psi} * v\text{, ft}^3/\text{lbm} * 144 \text{ in.}^2/\text{ft}^2 * g/g_c$$

$$H_{OP}\text{, ft} = 3.173 \text{ psi} * 0.015765 \text{ ft}^3/\text{lbm} * 144 \text{ in.}^2/\text{ft}^2 * g/g_c = 7.20 \text{ ft}$$

Since this height was derived from the pressure drop, it represents the collapsed height of the outlet plenum that can be supported. It can be converted to a froth height since the void fraction of the outlet plenum and volume is known. The outlet plenum void fraction of 0.4621. When this void fraction is applied to the calculated collapsed height of liquid in the outlet plenum, the froth height is calculated as follows:

$$H_{froth}\text{, ft} = H_{OP} / (1 - \text{Void Fraction})$$

$$H_{froth}\text{, ft} = 7.20 \text{ ft} / (1 - 0.4621) = 13.39 \text{ ft}$$

It can be seen that when crediting voiding in the outlet plenum, the available height of two-phase liquid (13.39 ft) is much greater than the actual height of the outlet plenum region currently credited in the mixing volume calculation (7.60 ft). Thus, this calculation justifies the selection of the top of the CSB nozzles as the top elevation of the mixing volume and there should be no change to the mixing volume used in the St. Lucie Unit 1 boric acid precipitation analysis for EPU.

Item 4

Look at all St. Lucie Unit 1 and Unit 2 RAIs related to boron precipitation analyses and ensure that all RAIs are responded to for each unit.

Response

The following St. Lucie Unit 2 RAIs have not been answered for Unit 1.

SRXB-80 (Unit 2)

The mixing volume in the inner vessel includes the mixture level in the upper plenum to the top of the hot leg. Since vapor generation in the core exits the vessel through the hot legs, the mixture level cannot rise to the top of the hot leg, particularly since the upper plenum pressure will increase sufficiently to depress the two-phase level low enough below the hot leg top elevation to allow the steam to vent through the loop. The mixture volume is expected to decrease to 0.5 to one foot below the top of the hot leg to allow the vapor to vent. What is the impact on precipitation time assuming the mixture level remains at least one foot below the top of the hot leg? Please also clarify that only the volume in the upper plenum to this elevation is credited in the mixing volume.

Response (Unit 1)

The current analysis credits the volume in the upper plenum to an elevation to the top of the hot leg for the mixing volume calculation. Based on the recalculation of the height of collapsed liquid in the outlet plenum, taking into account liquid in the loop seal and the density of a boric acid solution in the core and outlet plenum, the actual height of liquid available for the mixing volume remained above the top of the hot leg. However, for the purposes of responding to this question, this calculation is performed with the top of the mixing volume at a height of 0.5 ft below the top of the hot leg. As it has been shown that there is still a two-phase mixture above the top of the hot leg in the outlet plenum, reducing the mixing volume 1 ft below the top of the hot leg is judged to be overly conservative. To evaluate the impact of crediting a mixing volume height of 0.5 ft below the top of the hot leg, the mixing volume calculation was redone, reducing the height of the outlet plenum by 0.5 ft. Crediting the volume in the upper plenum to only the elevation specified above resulted in about a 2% reduction in the mixing volume. This has a small effect on the results of the boric acid precipitation analysis. Specifically, with no hot side injection, the time to reach the solubility limit of 29.27 wt% has decreased from 9.3 hours to 9.0 hours. Additionally, slight changes were seen in the results of the case when hot side injection of 229 gpm is initiated 6 hours post-LOCA; these changes are documented below. The biggest change is in the required hot side injection flow rate. To achieve successful results, the required hot side injection flow rate was increased from 229 gpm to 230.5 gpm. With a reduced mixing volume, beginning simultaneous hot and cold side injection between 4-6 hours post-LOCA with a hot side injection of 230.5 gpm provides acceptable results that preclude boric acid precipitation.

Description	HSI Start Time (hr)	HSI Flow Rate (gpm)	Max. Core Boric Acid Concentration (wt%)	Margin to Solubility Limit (wt%)	Time of Maximum Concentration (hr)
Original Mixing Volume (7800 gallons)	6.0	229	29.1	0.17	9.9
New Reduced Mixing Volume (7646 gallons)	6.0	230.5	29.15	0.12	9.7

SRXB-81 (Unit 2)

Is the mixing volume assumed to be a fixed volume in the method? Since decay heat is higher early in the event, the loop pressure drop will be higher and limit the growth of the mixing volume with time from the initiation of the LOCA. As such, the mixing volume cannot be fixed (constant) parameter until hot side injection is aligned. Also, please show the mixture height vs. time and the core and upper plenum void distributions at one hr intervals until the switch to hot side injection is made?

Response (Unit 1)

The boric acid precipitation analysis assumes a fixed mixing volume. The mixing volume was calculated throughout the window for starting simultaneous hot and cold side injection (i.e., at 4, 5, and 6 hours) and it was found that the volume does not vary greatly. Additionally, boric acid precipitation in the core is more of a concern at later times (> 6 hours), and the use of a slightly larger mixing volume when the boric acid concentration in the core (at 4 and 5 hours) is lower, will have negligible impact on the final results. In other words, the later end of the window is still the limiting time for boric acid precipitation concerns.

Regardless of time, the height of the outlet plenum credited for the mixing volume is assumed to be constant and always credited to the top of the CSB nozzle (the outlet plenum height is 7.60 feet). Table 2 documents the core and upper plenum void distributions for 1-6 hours.

Table 2
Void Fractions

Mixing Volume Region*	Height, feet	Time, hours					
		1	2	3	4	5	6
1	10.1875	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
2	1.1392	0.4658	0.4231	0.3985	0.3814	0.3684	0.3578
3	1.1392	0.6356	0.5946	0.5699	0.5522	0.5385	0.5270
4	1.1392	0.7235	0.6875	0.6653	0.6491	0.6364	0.6256
5	1.1392	0.7772	0.7458	0.7261	0.7115	0.7000	0.6902
6	1.1392	0.8134	0.7857	0.7681	0.7551	0.7447	0.7358
7	1.1392	0.8395	0.8148	0.7990	0.7872	0.7778	0.7697
8	1.1392	0.8592	0.8370	0.8226	0.8119	0.8033	0.7959
9	1.1392	0.8746	0.8544	0.8413	0.8314	0.8235	0.8167
10	1.1392	0.8870	0.8684	0.8564	0.8473	0.8400	0.8337
11	1.1392	0.8971	0.8800	0.8689	0.8604	0.8537	0.8478
12	7.6000	0.8262	0.7999	0.7831	0.7706	0.7607	0.7522

*Mixing Volume Region 1 is the lower plenum, and Region 12 is the outlet plenum

SRXB-87 (Unit 2)

If the RCS refills and disperses the boric acid ~~for~~ breaks less than 0.036 ft^2 shown in Fig. 2.8.5.6.3-75, please explain the last column that shows breaks 0.012 ft^2 and smaller uncovering.

Response (Unit 1)

Before responding to the question, it must be noted that for St. Lucie Unit 1, the RCS refills and disperses the boric acid for breaks less than 0.024 ft^2. The CELDA analysis shows that breaks 0.012 ft^2 and smaller need to be cooled down with the shutdown cooling system and cannot be cooled down with simultaneous hot and cold side injection. That is, these breaks are small enough that they do not have the capacity by themselves to remove the decay heat energy from the system. The system will pressurize and require shutdown cooling for long term decay heat removal.

There are two basic procedures in the long-term cooling plan, namely simultaneous hot and cold side injection (large break procedure) and shutdown cooling (small break procedure). For the long term cooling analysis, using the CELDA code, if the break is small enough for the RCS to refill with safety injection water, then shutdown cooling is applicable. In shutdown cooling, the RCS is cooled down via the steam generators to the shutdown cooling entry temperature and shutdown cooling is initiated. Decay heat is then removed by the shutdown cooling system. The largest small break for shutdown cooling is 0.024 ft^2 according to the CELDA analysis.

The CELDA analysis also shows that breaks 0.013 ft^2 and larger can be cooled down with simultaneous hot and cold side injection. Simultaneous hot and cold side injection is applicable when the break flow is large enough to remove the decay heat from the RCS in the long term with simultaneous hot and cold side injection. The HPSI pump replenishes the RCS inventory that is lost out of the break. Steam generator heat transfer may need to be maintained for a period of time until decay heat drops sufficiently and the energy flow out the break is sufficient to remove decay heat. Then the system will reach an equilibrium pressure in which the break flow rate equals the simultaneous hot and cold side injection flow rate. In this case, the flow out the break is capable of removing the total energy added to the system by decay heat.

Item 5

Provide additional justification for SDC single failure capability.

Response

The shutdown cooling (SDC) system utilizes the safety related and redundant 1A and 1B low pressure safety injection (LPSI) pumps and the 1A and 1B shutdown cooling heat exchangers; however, the flow path for SDC operation is not single failure proof. Consistent with the St.

Lucie Unit 1 licensing basis, cooldown to hot standby/hot shutdown conditions can be accomplished via safety related structures, systems and components, namely use of the main steam and auxiliary feedwater systems. For large break and small break scenarios, emergency core cooling single failure requirements are met for both the injection and recirculation phases of these events. The ability to proceed from "safe shutdown" to SDC system operation and cold shutdown is predicated on the availability and functionality of the SDC system. Also, under post-LOCA circumstances, the Technical Support Center (TSC) and Emergency Operations Facility (EOF) would be providing specific recommendations, in addition to the EOPs, to control room operators to ensure that the plant is brought to a safe and stable condition including the potential initiation of normal shutdown cooling system operation. These recommendations would be based on a number of factors including indications from monitoring instrumentation for the reactor coolant system and containment, onsite and offsite dose, the status and capability of various systems and components, and the availability of offsite power.

Item 6

Identify conservative analysis assumptions used in the boric acid precipitation analysis.

Response

The following list documents the notable conservative analysis assumptions from the boric acid precipitation analysis:

- Containment Pressure is assumed to be 14.7 psia in the analysis, when in actuality, the pressure would be, at a minimum, 20 psia. Assuming a conservatively low pressure reduces the boric acid solubility limit quite significantly. If a containment pressure of 20 psia was credited, the solubility limit would increase to approximately 32 wt%.

- 20% uncertainty (in the form of a 1.2 multiplier) is added to the calculation of decay heat for all times post-LOCA.

- There are several conservatisms in the calculation of the mixing volume, including:

    - The steam flow rate is maximized by assuming that saturated water enters the mixing volume.
    - A locked rotor k-factor is used to maximize the steam flow pressure drop.
    - Frictional losses in the loop pressure drop calculation were increased by roughly 60%.
    - Frictional pressure drops include 10% uncertainty, and geometric pressure drops include 10% uncertainty inside the reactor vessel and 20% uncertainty outside the reactor vessel.
    - Crediting only 50% of the lower plenum volume in the mixing volume is conservative based on the results of the Mitsubishi Heavy Industries' BACCHUS mixing tests, which showed that the entire lower plenum contributed to mixing.

- The calculated active core volume based on core area and height used in the mixing volume calculation is smaller than the cited liquid volume in the core (PSL-ENG-SEMS-08-029, Revision 15, page 38), which leads to a smaller mixing volume.
- Justification for the selection of the top of the mixing volume height calculations were performed at 1 hour post-LOCA, while the mixing volume calculation was done at 6 hours post-LOCA. This is conservative, as an earlier time translates to a higher steam flow rate, which equals a higher pressure drop through the system, and ultimately, a lower outlet plenum pressure drop (and height), leaving less available margin in the calculation of the top of the mixing volume.
- Credit was not taken for a 2-phase liquid in calculating the height of liquid in the outlet plenum (i.e., a collapsed liquid height, not a froth height, was used).

- The charging pumps are assumed to inject into 2 intact RCP discharge legs, as opposed to injecting into 1 intact leg and 1 broken leg.

- No credit is taken for subcooling of injection flow, which maximizes core boil-off, and thus, maximizes the boric acid concentration in the core.

- Steam exiting the core is assumed to not contain any boric acid, thus maximizing the concentration in the core.

- Entrainment of liquid from the core during the initial injection phase was neglected. The entrainment removes large amounts of liquid in the early time period following reflood of the core, which minimizes the boric acid build-up during this period.

- Minimum HPSI, LPSI, and containment spray pump flow rates were modeled in the boric acid precipitation calculation in order to maximize the duration of injection flow from the RWT.

- A worst single failure of the loss of an emergency diesel generator is assumed.

- Maximum tank volumes are used for the boric acid makeup tanks (BAMTs), RWT, and SITs, to maximize the boric acid concentration.

- Minimum tank temperatures are used for the BAMTs, RWT, and SITs, to calculate the minimum specific volume, which will maximize the actual tank volumes.

- Maximum boric acid concentrations are used throughout the analysis for the BAMTs, RWT, SITs, and RCS, including a minimum of 100 ppm of uncertainty.

- Minimum number of HPSI, LPSI and containment spray pumps is used in order to maximize the duration of injection flow from the RWT.

- At least an hour margin is maintained between the latest time to initiate switchover to simultaneous hot and cold side injection and the time when the boric acid solubility limit will be reached with no HLI.