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

FPL

March 25, 2012

L-2012-116
10 CFR 50.90

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

Re: St. Lucie Plant Unit 2
Docket No. 50-389
Renewed Facility Operating License No. NPF-16

Response to Request for Additional Information Identified During Audit of the Reactor Systems Branch (SRXB) Fluid System Analyses for the Extended Power Uprate License Amendment Request

References:

(1) R. L. Anderson (FPL) to U.S. Nuclear Regulatory Commission (L-2011-021), "License Amendment Request for Extended Power Uprate," February 25, 2011, Accession No. ML110730116.

(2) NRC Reactor Systems Branch Audit Conducted at Westinghouse Electric Company Facilities in Rockville, MD, February 14 and 15, 2012.

By letter L-2011-021 dated February 25, 2011 [Reference 1], Florida Power & Light Company (FPL) requested to amend Renewed Facility Operating License No. NPF-16 and revise the St. Lucie Unit 2 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 staff audit conducted at the Westinghouse Electric Company (Westinghouse) facilities in Rockville, MD on February 14 and 15, 2012 [Reference 2], the NRC staff requested additional information to support the review of selected fluid system analyses performed for the St. Lucie Unit 2 EPU license amendment request (LAR).

The fluid system analyses reviewed during the audit included; 1) low temperature overpressure protection (LTOP), 2) boric acid delivery, 3) natural circulation cooldown, and 4) shutdown cooling system performance. This response provides the additional information requested to address fluid system audit items 1, 2, and 4. The additional information requested for the natural circulation cooldown audit item will be provided in a separate submittal.

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NRR

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-2011-021 [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.

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 25-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 Request for Additional Information
Identified During Audit of the EPU LAR
Reactor Systems Branch Fluid System Analyses

The following information is provided by Florida Power & Light (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 Unit 2 submitted to the NRC by FPL via letter L-2011-021 dated February 25, 2011, Accession Number ML110730116.

The NRC Reactor Systems Branch (SRXB) conducted an audit of selected St. Lucie Unit 2 EPU fluid system analyses at the Westinghouse Electric Company (Westinghouse) facility in Rockville, MD on February 14 and 15, 2012. The fluid system analyses reviewed during the audit included; 1) low temperature overpressure protection (LTOP), 2) boric acid delivery, 3) natural circulation cooldown, and 4) shutdown cooling system performance. This response provides the additional information requested to address fluid system audit items 1, 2, and 4. The additional information requested for the natural circulation cooldown audit item will be provided in a separate submittal.

<u>SRXB-46 Follow-Up (Low Temperature Overpressure Protection (LTOP) Analysis)</u>

1. **Describe the methods used to perform the LTOP transient analysis, if possible refer to previously submitted and approved documents.**

2. **Demonstrate that limiting initial pressures and temperature values are used in the transient analyses across the full range of LTOP conditions.**

3. **Clarify the basis for not exceeding a 400 psia Shutdown Cooling (SDC) system pressure.**

4. **Ensure RT_{NDT} value used in the enable temperature calculation is consistent with the value used in the fracture mechanics section of the EPU LAR Attachment 5, Section 2.1.2, Table 2.1.2-2 and Table 2.1.2-6.**

5. **Describe how LTOP transient results are compared to the Appendix G Pressure-Temperature (P-T) limits. Include descriptions of:**

   a) **Applicable Technical Specification (TS) controls and how they relate to the range of applicability of the various LTOP transient results. Specifically over what temperature ranges are the various transient results applicable.**
   b) **The application of instrument uncertainty.**

6. **Describe how the analysis accounts for instrument uncertainty in LTOP calculations and TS limits.**

<u>Response</u>

1. The methods used to perform the LTOP transient analysis for the EPU are consistent with the current LTOP transient analysis methodology. Analyses were redone with updated inputs for EPU operating conditions (EPU LAR Attachment 5, Section 2.8.4.3.2.3). Generally, an EPU results in an increase in peak transient pressure for the Mass Addition

and Energy Addition events due to the increase in core decay heat (EPU LAR Attachment 5, Section 2.8.4.3.2.3)

The current LTOP licensing basis is documented in Enclosure 1 of Reference 1. This document was submitted and reviewed by NRC (Reference 2) in support of the extension of St. Lucie Unit 2 P-T limits to 55 Effective Full Power Years (EFPY). Section 3 of Enclosure 1 of Reference 1 provides a description of the St. Lucie Unit 2 LTOP transient analysis methodology.

2. Two types of limiting LTOP transient events are analyzed in Enclosure 1 of Reference 1; an energy addition to the reactor coolant system (RCS) during a reactor coolant pump (RCP) start with the secondary side steam generator inventory at a higher temperature than the reactor coolant and a mass addition to the RCS during operation of high pressure safety injection (HPSI) pumps and charging pumps. Both the mass and energy addition transients conservatively include the additional pressurization effects of pressurizer heaters and decay heat. For the mass addition transient, two different events are analyzed depending on RCS operating conditions, one with 1 HPSI pump and 3 charging pumps delivering flow to the RCS and a more severe event with 2 HSPI pumps and 3 charging pumps delivering flow to the RCS.

   For the mass addition transient, two methods are used to calculate peak pressure; the equilibrium method which determines the pressure at which the flow inputs match the relief valve discharge (Reference 1, Enclosure 1, Figure 7 and Figure 8) and a power operated relief valve (PORV) transient analysis method which calculates RCS pressure over time steps until an equilibrium condition is reached between the flow into the RCS and relief valve discharge (Reference 1, Enclosure 1, Section 3.3-2).

   The PORV transient analysis method is required for cases where the equilibrium pressure method results in a pressure below the valve setpoint. This method accounts for additional RCS pressurization above the valve setpoint due to valve opening time. For cases where the mass input exceeds the valve capacity when the valve initially reaches the full open position, the transient method results match the equilibrium method results. Both methods assume decay heat input. A bounding high temperature and a bounding high cooldown rate were assumed for each transient to maximize the decay heat input. With the exception of the decay heat input, the equilibrium pressure method is independent of assumed initial RCS temperature. The equivalent volumetric flow rate attributed to pressurizer heaters is determined assuming saturation conditions in the pressurizer at the initial RCS pressure. The PORV transient analysis method assumes an initial RCS temperature. An initial temperature of 300°F was assumed in the mass addition calculations supporting Reference 1 and EPU LAR Attachment 5. To conservatively cover all possible initial temperature conditions, an additional case with an initial RCS temperature of 80°F was analyzed for the limiting initial RCS pressure. These temperatures bound the LTOP temperature range.

   The initial temperature used for the energy addition transients is 290°F (Reference 1, Enclosure 1, Section 3.3-1) which bounds the LTOP enable temperatures of 246°F during heatup and 224°F during cooldown (EPU LAR Attachment 3, Table 3.4-3). The energy addition analysis uses the decay heat value determined for the mass addition transient. Since the rate of change of specific volume with temperature increases with increasing temperature, a higher temperature is conservative. This was demonstrated explicitly by running an additional energy addition case with an initial RCS temperature of 200°F. The results are shown in Figure 1. The 200°F initial RCS temperature case resulted in a lower peak pressure than the 290°F initial temperature case.

Historically, and in the calculations supporting Enclosure 1 of Reference 1, a 300 psia initial RCS pressure was used for all LTOP transient analyses as a reasonable value based on operational considerations and offsetting conservatisms.

Per Reference 3, Table 1.2 and Limiting Condition for Operation (LCO) 3.5.3, only one HPSI pump is operable when RCS temperature is less than or equal to 200°F (Mode 5). Therefore, for cold leg temperatures ≤ 200°F only the 1 HPSI and 3 charging pump mass addition transient needs to be evaluated.

Per Reference 3 LCO 3.4.9.3 and EPU LAR Attachment 3, Table 3.4-4, the PORVs can be used for transient mitigation for the entire LTOP temperature range for heatup and above an RCS temperature of 132°F for cooldown. Otherwise, the shutdown cooling relief valves (SDCRVs) must be used.

Based on shutdown cooling system operating pressure limits, the 300 psia initial pressure condition assumption for the energy addition analysis was justified. In order to achieve the conditions for the energy addition transient, secondary side steam generator inventory at a higher temperature than the reactor coolant, the shutdown cooling system must be operated.

The most significant effect of initial RCS pressure on the LTOP transients is the temperature of the fluid at the PORV inlet. The pressurizer is assumed to be saturated at the initial RCS pressure and the saturation temperature is used as the PORV inlet temperature for the entire transient. As the valve inlet temperature increases, the amount of subcooling at the valve inlet decreases and the valve flow capacity decreases.

The plant normal heatup and cooldown procedures maintain RCS pressure less than 275 psia when the RCS is water solid. Therefore, if the RCS were water solid as assumed for the LTOP transient analyses (Reference 1, Enclosure 1, Section 3.2), the 300 psia initial pressure condition is justified.

There is a 275 psia operating limit on RCS pressure for shutdown cooling initiation. This limit is to prevent overpressurization of the shutdown cooling system. Adding a pressurizer pressure instrument uncertainty of 21.0 psia yields a maximum pressurizer pressure for shutdown cooling initiation of 275 psia + 21 psia = 296 psia. It then follows that a bounding upper limit on initial pressurizer pressure of 300 psia is justified based on operational controls for all LTOP transients initiated when the shutdown cooling system is aligned.

At least one shutdown cooling loop shall be operable when RCS temperature is less than or equal to 200°F (Reference 3, Table 1.2 and LCO 3.4.1.4.1).

Per the normal cooldown procedure, the shutdown cooling system is placed in service before RCS temperature is below the LTOP enable temperature. Therefore, for a normal cooldown, a 300 psia initial transient pressure is justified for the entire LTOP temperature range.

Per the normal plant heatup procedure, RCPs are started in Mode 5 prior to exceeding a RCS temperature of 200°F. The preferred RCPs are started (2B1 and 2B2) and RCS pressure is maintained between 255 psia and 265 psia for the pump start and the subsequent heatup above 200°F. Therefore, for a plant heatup where the preferred RCPs are started, the 300 psia initial pressure is justified when RCS temperature is below 200°F for all transients.

The plant heatup procedure also allows the non-preferred option of starting opposite loop RCPs. If the non-preferred RCPs are started then shutdown cooling is removed from service and RCS pressure is raised to 325 psia prior to starting the RCPs. The RCS pressure is maintained between 310 psia and 325 psia for the subsequent heatup above 200°F. For the non-preferred pump start option the initial RCS pressure would be above 300 psia.

For PORV mitigated LTOP transients, it is possible to have initial pressures higher than 300 psia, specifically on heat-up. Operating procedures are written to prevent inadvertent lifting of the PORVs and restrict RCS pressure to 450 psia when the PORVs are in the LTOP mode during heat-up. Adding instrument uncertainty (21 psia) yields a pressurizer pressure of 471 psia. Therefore, the highest actual initial pressurizer pressure at the start of the transient would be 471 psia.

To conservatively cover possible initial pressure conditions, additional PORV mitigated transient sensitivity cases were analyzed with initial RCS pressures of 471 psia and 250 psia. Additional SDCRV mitigated transient sensitivity cases were run with an initial RCS pressure of 250 psia, a pressure below 300 psia. Since the PORVs can be used for the entire LTOP temperature range during heat-up (EPU LAR Attachment 3, Table 3.4-4) and the PORV mitigated transient results are limiting, SDCRV sensitivity cases with initial RCS pressure above 300 psia were not analyzed.

The results of the LTOP transient analyses along with the initial pressure and temperature conditions are summarized in Table 1 through Table 5. For mass addition cases where the equilibrium method results are limiting, the result is not dependent on initial temperature. Table 1 summarizes the transient results applicable to heatup with RCS temperature < 200°F. Table 2 summarizes the transient results applicable to heatup with RCS temperature ≥ 200°F and ≤ 246°F (LTOP enable temperature for heatup). Only 2 HPSI and 3 charging pump cases are shown since they will bound the results of the 1 HPSI and 3 charging pump cases. Table 3 summarizes the transient results applicable to cooldown with RCS temperature < 132°F (minimum temperature for PORV use on a cooldown). Table 4 summarizes the transient results applicable to cooldown with RCS temperature ≥ 132°F and < 200°F. Table 5 summarizes the transient results applicable to cooldown with RCS temperature ≥ 200°F and ≤ 224°F (LTOP enable temperature for cooldown). Only 2 HPSI and 3 charging pump cases are shown since they will bound the results of the 1 HPSI and 3 charging pump cases. The limiting or controlling peak transient pressures from Table 1 through Table 5 are summarized in Table 6. These controlling pressures are compared to and shown not to exceed the allowable pressure temperature limits in the response to question 5.

3. The SDC system design pressure is 350 psig. The 400 psia value is 110% of the design pressure (1.1 x 350 psig + 14.7 psia = 400 psia).

4. The current (pre-EPU) LTOP enable temperature values are calculated by applying the ASME Boiler and Pressure Vessel Code Section IX, Appendix G methodology (Reference 1, Enclosure 1, Section 2.2) using an Adjusted Reference Temperature (ART) of 160°F (Reference 1, Enclosure 1, Section 2.8).

The pre-EPU ART was based on a peak neutron fluence at 55 effective full power years (EFPY) (Reference 1, Enclosure 1, Section 2.1).

In accordance with EPU LAR Attachment 5, Section 2.1.2.2.5, the ART values that form the basis for the pre-EPU P-T limits are lower than the ART values projected for 55 EFPY that account for the effects of the EPU. The existing P-T limits are projected to remain valid for approximately 47 EFPY and this necessitates a change in the period of applicability for the P-T limit curves in the plant Technical Specifications for EPU.

The required changes to the Technical Specification Figures 3.4-2 and 3.4-3 and Tables 3.4-3 and 3.4-4 are included in EPU LAR Attachment 3.

5. The LTOP transient results are developed to represent pressurizer pressure at the pressurizer pressure instrument location. The EPU LTOP transient results were compared to P-T limits hydraulically adjusted from the reactor vessel beltline location to the pressurizer pressure instrument location. Instrument uncertainty is not accounted for when adjusting the P-T limits for comparison to the transient results since analysis values are being compared to analysis values.

   PORV actuation loop instrument uncertainty is accounted for in the transient analyses and instrument uncertainty is accounted for when determining the range of applicability of the LTOP transient results when a LTOP control is dependent on operator action. No pressure instrument uncertainty is applied to the SDCRVs, since the actuation of these valves is by direct pressure without an instrument channel.

   The EPU P-T limits and LTOP controls are consistent with the current values. The updated EPU transient results were compared to these limits using the same methodology that was used for Enclosure 1 of Reference 1.

   Figure 2 shows a comparison of the controlling transient pressures from Table 6 with the P-T limits for heatup. Composite heatup P-T limits were created from Table 3 of Enclosure 1 of Reference 1, allowable heatup rate from EPU LAR Attachment 3, Figure 3.4-2, minimum pressure limit, minimum boltup temperature, and flange limit temperature from Section 2.7 of Enclosure 1 of Reference 1, and LTOP enable temperature without instrument uncertainty of 231.1°F for heatup. By inspection of Figure 2, it can be seen that the LTOP transient pressures are below the P-T limits for the entire LTOP temperature range.

   Figure 3 shows a comparison of the controlling transient pressures from Table 6 with the P-T limits for cooldown. Composite cooldown pressure temperature limits were created from Table 3 of Enclosure 1 of Reference 1 and allowable cooldown rates from Figure 3.4-3 of EPU LAR Attachment 3, minimum pressure limit, minimum boltup temperature, and flange limit temperature from Section 2.7 of Enclosure 1 of Reference 1. The LTOP enable temperature, without instrument uncertainty, is 210°F for cooldown. By inspection of Figure 3 it can be seen that the LTOP transient pressures are below the P-T limits for the entire LTOP temperature range.

6. The application of instrument uncertainty in LTOP calculations and TS limits is unchanged for EPU from the 55 EFPY P-T limit update (Reference 1).

The treatment of instrument uncertainty for LTOP transient evaluation and comparison of transient results to the P-T limits is discussed in the response to question 5.

The normal instrument loop uncertainty for LTOP actuation instrument channels is applied to the LTOP enable temperature calculation.

Application of instrument uncertainty to the Technical Specification P-T limit curves is not required since margin against violating the P-T limit curves is administratively maintained and controlled. However, narrow range temperature and pressure uncertainty is applied to the P-T curves so that operator actions take place at indicated pressure and temperatures on the P-T curve.

No pressure or temperature uncertainties are applied to the lowest service temperature limit or the Appendix G flange limit, since these limits are protected by the LTOP setpoints.

References:

1. Florida Power & Light Letter L-2007-198 (Accession Number ML080290135), "Update PT Curve and LTOP for 55 EFPY," January 23, 2008.

2. NRC Letter, "St. Lucie Plant, Unit No. 2 – Issuance of Amendment Regarding Pressure Vessel Fluence to 55 Effective Full-Power Years of Operation (TAC NO. MD8040)," Accession Number ML090060049, January 29, 2009.

3. St. Lucie Plant Unit No. 2 Technical Specifications, Amendment 158, May 31, 2010.

Table 1
LTOP Transient Results
Heatup with RCS Temperature < 200°F

Transient	Initial RCS Pressure (psia)	Initial RCS Temperature (°F)	Relief Valve -	Setpoint (psia)	Peak Pressure (psia)
Mass Addition (1 HPSI & 3 Charging Pumps)	250	300	PORV	490	530.0
Mass Addition (1 HPSI & 3 Charging Pumps)	300	300	PORV	490	531.0
Mass Addition (1 HPSI & 3 Charging Pumps)	471	300	PORV	490	537.0
Mass Addition (1 HPSI & 3 Charging Pumps)	471	80	PORV	490	546.0
Mass Addition (1 HPSI & 3 Charging Pumps)	250	N/A	SDCRV	350	368.0
Mass Addition (1 HPSI & 3 Charging Pumps)	300	N/A	SDCRV	350	368.0
Energy Addition	250	290	PORV	490	545.9
Energy Addition	300	290	PORV	490	546.5
Energy Addition	471	290	PORV	490	546.5
Energy Addition	250	290	SDCRV	350	362.8
Energy Addition	300	290	SDCRV	350	368.0

Table 2
LTOP Transient Results
Heatup with RCS Temperature ≥ 200°F and ≤ 246°F

Transient	Initial RCS Pressure (psia)	Initial RCS Temperature (°F)	Relief Valve -	Setpoint (psia)	Peak Pressure (psia)
Mass Addition (2 HPSI & 3 Charging Pumps)	250	N/A	PORV	490	561.0
Mass Addition (2 HPSI & 3 Charging Pumps)	300	N/A	PORV	490	586.0
Mass Addition (2 HPSI & 3 Charging Pumps)	471	N/A	PORV	490	677.0
Mass Addition (2 HPSI & 3 Charging Pumps)	250	N/A	SDCRV	350	387.0
Mass Addition (2 HPSI & 3 Charging Pumps)	300	N/A	SDCRV	350	387.0
Energy Addition	250	290	PORV	490	545.9
Energy Addition	300	290	PORV	490	546.5
Energy Addition	471	290	PORV	490	546.5
Energy Addition	250	290	SDCRV	350	362.8
Energy Addition	300	290	SDCRV	350	368.0

Table 3
LTOP Transient Results
Cooldown with RCS Temperature < 132°F

Transient	Initial RCS Pressure (psia)	Initial RCS Temperature (°F)	Relief Valve -	Setpoint (psia)	Peak Pressure (psia)
Mass Addition (1 HPSI & 3 Charging Pumps)	250	N/A	SDCRV	350	368.0
Mass Addition (1 HPSI & 3 Charging Pumps)	300	N/A	SDCRV	350	368.0
Energy Addition	250	290	SDCRV	350	362.8
Energy Addition	300	290	SDCRV	350	368.0

Table 4
LTOP Transient Results
Cooldown with RCS Temperature ≥ 132°F and < 200°F

Transient	Initial RCS Pressure (psia)	Initial RCS Temperature (°F)	Relief Valve -	Setpoint (psia)	Peak Pressure (psia)
Mass Addition (1 HPSI & 3 Charging Pumps)	250	300	PORV	490	530.0
Mass Addition (1 HPSI & 3 Charging Pumps)	300	300	PORV	490	531.0
Mass Addition (1 HPSI & 3 Charging Pumps)	471	300	PORV	490	537.0
Mass Addition (1 HPSI & 3 Charging Pumps)	471	80	PORV	490	546.0
Mass Addition (1 HPSI & 3 Charging Pumps)	250	N/A	SDCRV	350	368.0
Mass Addition (1 HPSI & 3 Charging Pumps)	300	N/A	SDCRV	350	368.0
Energy Addition	250	290	PORV	490	545.9
Energy Addition	300	290	PORV	490	546.5
Energy Addition	471	290	PORV	490	546.5
Energy Addition	250	290	SDCRV	350	362.8
Energy Addition	300	290	SDCRV	350	368.0

Table 5
LTOP Transient Results
Cooldown with RCS Temperature ≥ 200°F and ≤ 224°F

Transient	Initial RCS Pressure (psia)	Initial RCS Temperature (°F)	Relief Valve -	Setpoint (psia)	Peak Pressure (psia)
Mass Addition (2 HPSI & 3 Charging Pumps)	250	N/A	PORV	490	561.0
Mass Addition (2 HPSI & 3 Charging Pumps)	300	N/A	PORV	490	586.0
Mass Addition (2 HPSI & 3 Charging Pumps)	471	N/A	PORV	490	677.0
Mass Addition (2 HPSI & 3 Charging Pumps)	250	N/A	SDCRV	350	387.0
Mass Addition (2 HPSI & 3 Charging Pumps)	300	N/A	SDCRV	350	387.0
Energy Addition	250	290	PORV	490	545.9
Energy Addition	300	290	PORV	490	546.5
Energy Addition	471	290	PORV	490	546.5
Energy Addition	250	290	SDCRV	350	362.8
Energy Addition	300	290	SDCRV	350	368.0

Table 6
Controlling Pressures

Condition	Pressure (psia)
Cooldown, RCS Temp < 132°F (Table 3)	368.0
Cooldown, 132°F ≤ RCS Temp < 200°F (Table 4)	546.5
Cooldown, 200°F ≤ RCS Temp ≤ 224°F (Table 5)	677.0
Heatup, RCS Temp < 200°F (Table 1)	546.5
Heatup, 200°F ≤ RCS Temp ≤ 246°F (Table 2)	677.0

Figure 1
Energy Addition Temperature Sensitivity
PORV Mitigated Transient with PORV Setpoint = 490 psia

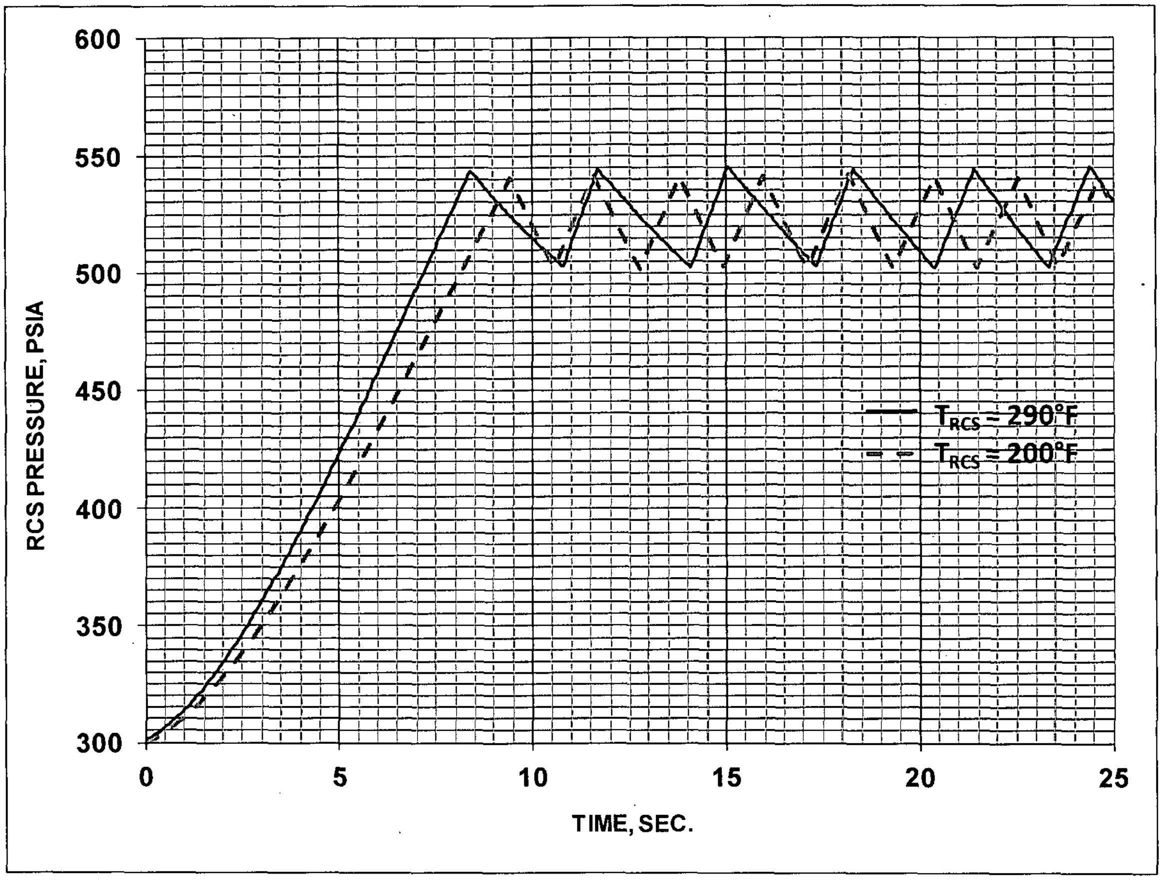


Figure 2
Transient Result / Pressure-Temperature Limit Comparison (Heatup)

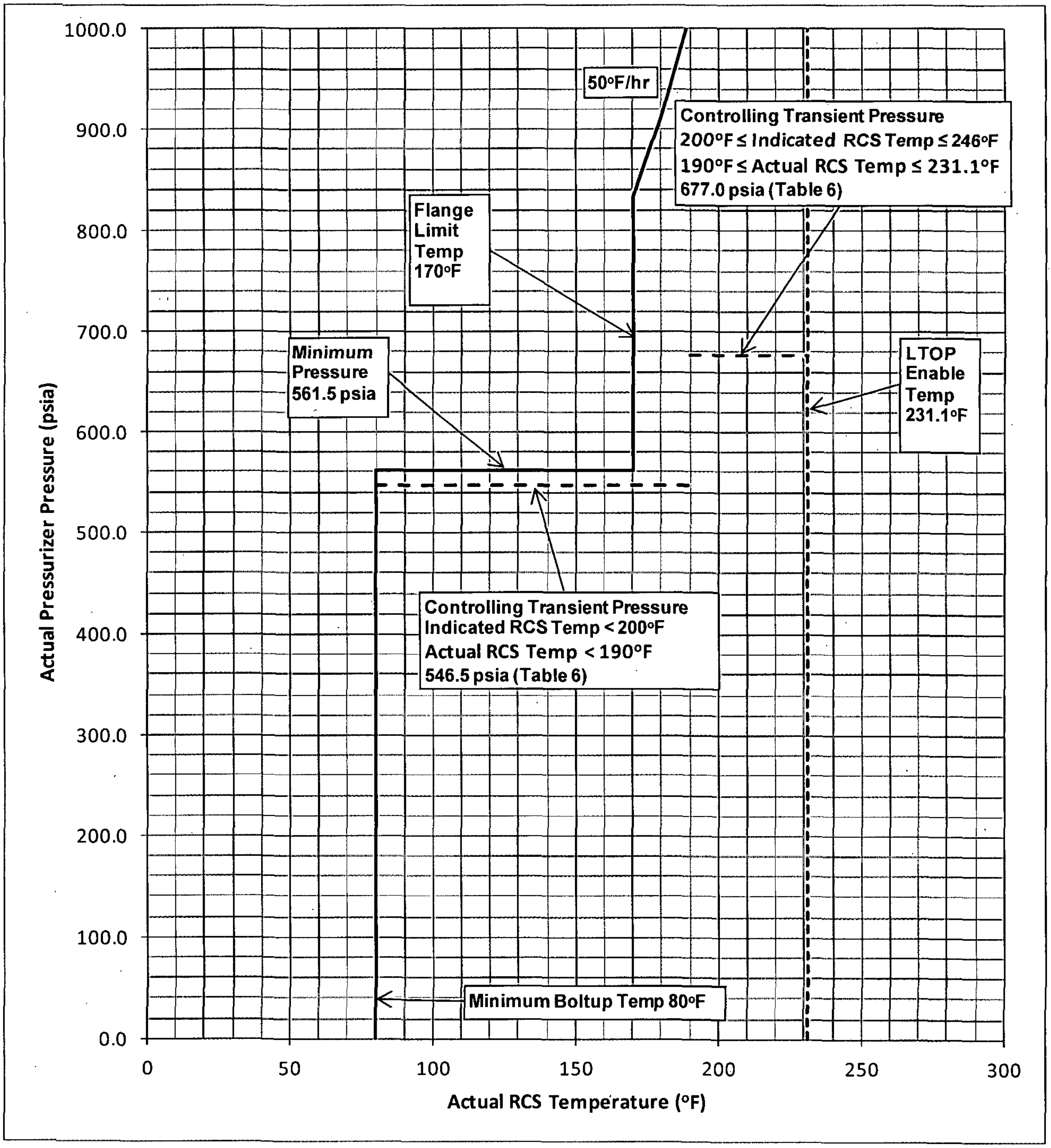
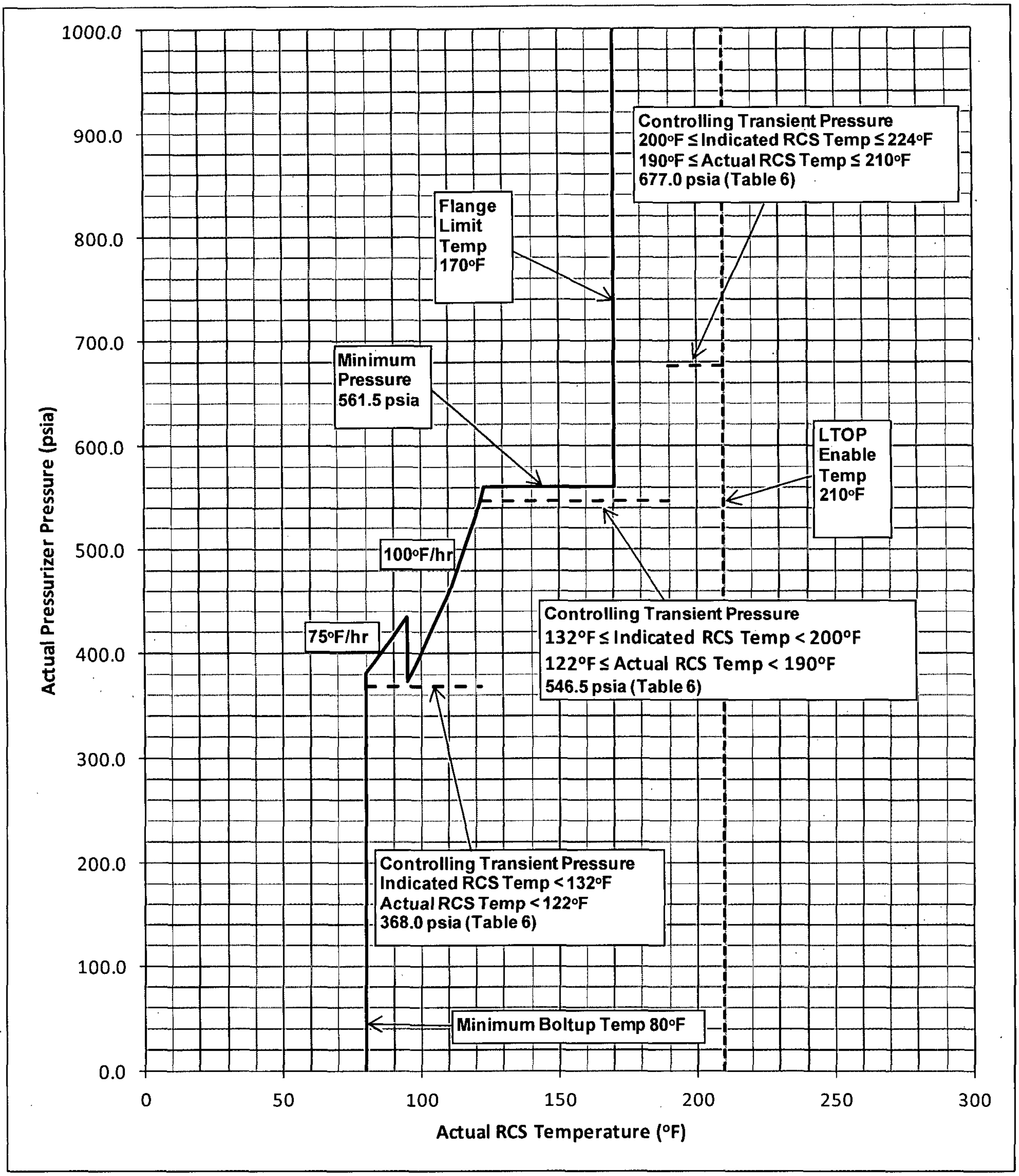


Figure 3
Transient Result / Pressure-Temperature Limit Comparison (Cooldown)



SRXB-33 and SRXB-34 Follow-Up (Boric Acid Delivery Analysis)

The response to SRXB-34 provides the bases for the required water volumes and boron concentrations in the boric acid makeup tank (BAMT) specified in TS Figure 3.1-1 for Modes 1 though 4 for maintaining the required shutdown margin. It indicates that the TS Figure 3.1-1 requirements are established from a boric delivery analysis. The analysis assumes that the operator initiates actions, after 30 minutes into a NRC BTP 5-4 plant cooldown event, to cool down the plant "with makeup for liquid shrinkage first from the boric acid make (BAM) tank and then the refueling water tank (RWT) once the BAM tank is exhausted. This provides boration to the RCS."

Please provide the following information:

1. **Discuss the models and computer codes used in the BTP 5-4 cooldown event and shows the acceptability of the models and codes used in the analysis. The discussion should include the thermal hydraulic and neutronic models, as well as the boron mixing model.**

2. **Discuss the plant procedures for the operator actions credited in the boric delivery analysis for the RCS makeup from the sources of the BAMT and RWT, and show that the operator using safety grade systems and equipment can initiate the required actions in 30 minutes following the plant cooldown.**

3. **Specify the maximum value of the RCS water volume shrinkage resulting from the analysis of the BTP 5-4 cooldown event and show that the required makeup water volumes in TS Figure 3.1-1 added to the RCS in accordance with the applicable plant procedures will not result in pressurizer overfill, if the required makeup water volume are greater than the calculated maximum RCS water shrinkage volume.**

4. **This followup RAI is also applicable to the boric acid delivery analysis discussed in the response to SRXB-33 addressing the bases for TS 3.1.2.7, "Borated Water Sources – Shutdown". As stated in the SRXB-33 response, the required "boration capability to maintain shutdown margin for Modes 5 and 6 cooldown is based on a cooldown scenarios that meets the safe shutdown requirements of NRC BTP 5-4, and consists of two cases based on the borated water sources. The first uses only the boric acid makeup (BAM) tank, the second uses only the refueling water tank (RWT)." The analysis values of the borated water volumes and boron concentrations are listed in Table SRXB-33-1 and Table 33-2 for the BAMT and RWT, respectively. Explain why the analysis values of the borated water volume are about the same for the BAMT and RWT, while the boron concentration are 5320 ppm for the water in the BAMT, and 1800 ppm in the RWT water for maintaining the required shutdown margin.**

Response

1. The boric acid delivery analysis is a stand-alone analysis that makes conservative assumptions consistent with the natural circulation cooldown analysis to meet the safe shutdown requirements of BTP 5-4. The boric acid delivery analysis makes conservative assumptions to determine a limiting chemical and volume control system (CVCS) boric acid delivery capability. The boric acid delivery analysis assumes loss of letdown during the

cooldown and makeup for fluid shrinkage is sourced first from the BAMTs followed by the RWT to maintain pressurizer level.

The boric acid delivery analysis methodology is based on the current analysis method for St. Lucie Unit 2, previously approved by the NRC in Amendment No. 40 to Facility Operating License No. NPF-16 (ADAMS Accession No. ML013600491). The boric acid delivery calculations are performed using commercially available spreadsheet software using the same analysis methodology currently approved for St. Lucie Unit 2. The methodology is summarized below in the discussion of the neutronic, thermal hydraulic, and boron mixing models.

Neutronic Model

In order to confirm that the boric acid delivery analysis will support EPU fuel cycles, a physics analysis was performed to provide a target for adequate boration capability at EPU conditions. This physics analysis calculated required RCS boron concentrations as a function of both post-shutdown time and RCS temperature, and showed that the boric acid delivery requirements were met with adequate margin for future cycles. While the neutronic model used for the physics analysis is outside the scope of the boric acid delivery analysis, the physics analysis was performed using the same methods as currently employed for the St. Lucie Unit 2 reload safety analysis checklist (RSAC). The boric acid delivery requirements are verified for every core design as part of the cycle specific RSAC.

Thermal Hydraulic Model

The analysis methodology to determine the available boron concentration assumes that the borated water added to the RCS is equal to the fluid volume contraction due to the cooldown while the pressurizer water level is maintained constant.

The quantity of fluid shrinkage over a particular temperature step is determined based on the initial and final thermodynamic states of interest. Once temperature, pressure, and volume are known, the mass added to the RCS through makeup is calculated. Mass is added to the RCS via the charging pumps. Once the cooldown is commenced, the pressurizer level is held constant with makeup initially sourced from the BAMT. The cooldown continues until the available inventory from one BAMT is exhausted. Makeup is then sourced from the RWT. The use of both the BAMT and RWT is consistent with Technical Specification 3.1.2.8.

The determination of the temperature cooldown rate, RCS pressure reduction rate, and fluid shrinkage per time step is consistent with the analysis of record. The following two conservative analysis changes are made for EPU conditions.

First, the RCS temperature for Modes 1 through 4 is assumed to decrease by an average cooldown rate of 11.0°F per hour. This cooldown rate results in an overall cooldown period of 32 hours. Using a minimal value for the cooldown rate is conservative because the longer the duration of the cooldown, the more positive reactivity is added due to the xenon decay. The analysis of record used an average cooldown rate of 12.5° per hour.

Second, the initial RCS mass is determined at the RCS hot zero power (HZP) temperature prior to the loss of offsite power (LOOP). The RCS temperature is then assumed to rise by 25°F during the 30 minutes prior to operators initiating a natural circulation cooldown. The analysis of record determined the initial RCS mass at the RCS HZP temperature plus 25°F due to the RCS coolant heat-up following the LOOP. The cooldown initiation temperature is used to determine the fluid mass in the RCS at the start of the cooldown based on a fixed reactor coolant pressure boundary (RCPB) volume. An increase in temperature would yield a smaller calculated RCS fluid mass. Since additional fluid mass acts as a diluent in the boric acid delivery calculation, it is non-conservative to assume a smaller initial fluid mass. Since there is no justification to assume a higher RCS fluid temperature prior to the loss of letdown, the analysis for EPU uses the most conservative temperature for the determination of the initial RCS fluid mass which is at HZP.

Boron Mixing Model

Consistent with the analysis of record methodology, the RCS is treated as achieving instantaneous equilibrium with the fluid injected from either the BAMT or RWT. From the standpoint of the thermal properties of the fluids, it is conservative to make this assumption since the borated water sources are of significantly higher density than the RCS fluid. As such, the non-expanded volume would yield higher mass additions from the boration sources yielding higher RCS boron concentrations per time step. From the standpoint of the mixing of chemical species, it is also conservative to assume complete instantaneous mixing throughout the entire RCS, including the pressurizer. The most important location for boration is the reactor vessel, which is also the most likely site for concentration of the boron, especially during a natural circulation cooldown scenario as described in the natural circulation cooldown tests performed at San Onofre Nuclear Generating Station (SONGS). By assuming instantaneous distribution of the boron to all locations in the RCS including the pressurizer, the overall concentration in the vessel is reduced to the minimum value.

Two boron mixing tests were performed at SONGS to 1) confirm sufficient mixing of borated water added prior to or during cooldown can be achieved under NCC conditions with loss of letdown, and 2) estimate times required to achieve such mixing. The testing at SONGS showed the boron concentration in the hot legs increased smoothly and rapidly following injection, and complete boron mixing occurred within 5 to 6 loop transient times (approximately 30 minutes). Based on the similarity in pipe geometry and cold leg and charging fluid velocity at SONGS and St. Lucie Unit 2, the 1 hour time step, which assumes complete instantaneous boron mixing in the RCS coolant, is determined to be acceptable for the St. Lucie Unit 2 boron delivery analysis.

2. The boric acid delivery analysis for EPU conditions was performed consistent with the current methodology. The boric acid delivery capability of the CVCS credits only safety-related systems. The operator action to cooldown the plant 30 minutes following the LOOP is consistent with the current analysis assumption approved by the NRC in Amendment No. 40 to the Facility Operating License No. NPF-16 (ADAMS Accession No. ML013600491). No changes to plant procedures or operator actions are required for operation at EPU conditions.

3. The makeup volume to the RCS, sourced first from the BAMT followed by the RWT, is the same as the required volume determined in the boric acid delivery analysis. This results in the pressurizer level being maintained constant with no pressurizer overfill. The required fluid mass for makeup due to coolant contraction is approximately 124,000 lbm. The equivalent required volume is dependent on the density of the boration source, where the fluid density is a function of the boron concentration. As an example, for the configuration

with the BAMT boron concentration equal to 3.1 wt% (5420 ppm), 7325 gal is injected from the BAMT and 7492 gal is injected from the RWT.

4. The boric acid delivery analysis is based on the assumption that injection from either the BAMT or RWT is equal to the RCS liquid shrinkage due to cooldown in order to maintain constant pressurizer level. The borated water volumes injected from the RWT and BAMT are approximately the same for the Mode 5 and 6 cooldown due to the same RCS volume shrinkage and calculated injected fluid mass for a cooldown from cold shutdown to refueling conditions (200°F to 135°F). The small difference in consumed volume (1432 gal from the BAMT and 1443 gal from the RWT) is due to the difference in density of the two boron injection sources. It should be noted the boration of the RCS does vary based on the boration source, and the limiting requirement is based on the scenario where borated coolant is sourced from the RWT. A higher RCS boron concentration will be achieved if makeup coolant is sourced from the BAMT.

<u>SRXB-47 Follow-Up (Shutdown Cooling System Analysis)</u>

1. **Table SRXB 47-1 indicates that for the normal and emergency cooldown analyses, the SDC system was assumed to be initiated 3.5 hours after shutdown. It also shows that for the emergency cooldown analysis, the cooldown with most limiting failure was assumed.**

   Provide the bases for the 3.5 hours after shutdown to initiate the SDCS, and specify the most limiting single failure assumed for cooldown in the emergency cooldown analysis.

2. **Page 14 of the SRXB-47 response lists assumptions used to determine the longest time from reactor tip to SDCS initiation for the 10 CFR 50 Appendix R SDCS cooldown analysis.**

   Provide a discussion of operating procedures, and training programs and records to demonstrate that each of the following assumptions can be met in the 10 CFR Appendix R conditions:

   a) **The RCS charging system requires two hours for initiation.**
   b) **The plant requires an additional two hours to align for plant cooldown.**
   c) **The maximum cooldown rate is 25°F per hour.**

   Provide the calculated longest time from the reactor trip to SDCS initiation based on the page 14 assumptions discussed above and show that it meets the applicable cooldown time limit.

3. **Provide a discussion of the thermal hydraulic computer codes or models used in the SDC system analyses discussed in the SRXB-47 response and justify acceptance of the codes or models for the SDC system analysis in support of the St. Lucie Unit 2 EPU application.**

<u>Response</u>

1. The basis for the 3.5 hours SDCS initiation time value is that this is a historical parameter used in the performance design basis of the SDCS. It is a value currently described in the

St. Lucie Unit 2 UFSAR, Section 5.4.7. The value is not based on safety analysis assumptions. Using 3.5 hours as the start time is conservative because it maximizes decay heat; therefore, it prolongs the cooldown time.

The most limiting single failure assumed for the emergency cooldown is the failure of an emergency diesel generator. Failure of an emergency diesel generator results in the loss of a complete train of SDCS forcing a single train cooldown. This failure is more limiting than the loss of any single active component.

2. The St. Lucie Unit 2 safe shutdown analysis (SSA) confirms that the plant complies with the requirements of Appendix R to 10 CFR 50. Specifically, the Appendix R SSA shows that, for a single fire in any fire area, the plant can be brought to cold shutdown conditions within 72 hours. For the current pre-EPU conditions, a SSA timeline has been developed to show the 72 hour cold shutdown time requirement can be met.

   Critical operator action timing inputs into the SSA timeline are described in the EPU LAR Attachment 5, Section 2.5.1.4.2.3.5.2. The times include:

   a) Two hours to initiate charging flow for reactor coolant system (RCS) makeup in preparation for plant cooldown. Note that the SSA requires that RCS makeup be provided within one hour. Thus, the 2 hour time delay assumption in the SSA timeline to initiate charging is conservative. Use of a 2 hour timing requirement is consistent with the current SSA timeline and remains unchanged for EPU.

   b) An additional 2 hours (for 4 hours total) is included in the analysis before the start of the plant cooldown. This time delay is consistent with the current SSA timeline and remains unchanged for EPU. Also, this delay in the initiation of plant cooldown is consistent with the requirements of Branch Technical Position (BTP) 5-4.

   c) The SSA timeline for EPU continues with the conservative assumption that the plant cooldown uses only one atmospheric dump valve (ADV) and one steam generator (SG). Note that there are two ADVs per SG. The cooldown rate using one ADV is initially limited to a maximum rate of 25°F/hr. However, as the RCS temperatures decreases, the ADV can no longer maintain this cooldown rate. Accordingly, the EPU calculation assumes the cooldown rate decreases over time as a function of valve capacity to a minimum value of 1°F/hr. The elapsed time for the cooldown to shutdown cooling entry conditions is 20.35 hours. Once the shutdown cooling entry temperature is achieved, an additional 7.15 hour hold time is assumed to allow for cooling of the reactor vessel upper head (RVUH). Using these conservative timing assumptions, the total time to reach shutdown cooling entry conditions for the Appendix R scenario is 31.5 hours (i.e. 4 hr + 20.35 hr +7.15 hr).

   The analysis then considers that the shutdown cooling system (SDCS) is placed in service assuming only one train of equipment is available. The SDCS performance model is used to calculate the time required to cool the RCS to 200°F (cold shutdown). The model, which is limited to a maximum cooldown rate of 25°F/hr, calculates a total cooldown time of 16.6 hours, or an average cooldown rate of approximately 7.5°F/hour.

   Therefore, the total Appendix R SSA cooldown time for EPU has been conservatively calculated to be 48.1 hours (i.e. 31.5 hr + 16.6 hr). This is well within the Appendix R cold shutdown time requirement of 72 hours and results in an overall cooldown margin of 23.9

hours. Accordingly, there is adequate margin available for EPU to accommodate minor variations in the assumed operator action times.

3. The SDCS performance analysis for the EPU project was performed using an analysis tool that models SDCS performance and is essentially a heat exchanger model. The tool is the same as used in establishing the existing SDCS performance statements in the St Lucie Unit 2 UFSAR. This model is the standard method for modeling SDCS performance for many of the Combustion Engineering Nuclear Steam Supply Systems. The tool is a heat exchanger model with St. Lucie Unit 2 shutdown cooling heat exchanger (SDCHX) specific parameters. The RCS cooldown process is modeled as a transfer of heat from the primary loop (RCS hot leg) to the secondary loop (component cooling water, CCW) via the SDCHX. The model uses a time incremental analysis which accounts for primary heat (time dependant core decay heat input, pump heat input, RCS metal and coolant heat capacity) that is compared to the SDCHX heat removal ability. At each time step a series of equations are used in an iterative process to establish the maximum amount of heat removed. Maximum heat removal rate is an input variable. The model uses a standard mathematical heat exchanger relationship that accounts for shell (CCW) and tube (SDCS) side flow rate, inlet temperature and heat transfer coefficients to determine a tube side outlet temperature. Shell side flow and inlet temperature are fixed input parameters. Tube side inlet temperature is calculated based on the previously noted primary system heat parameters. For each time step the maximum HX tube side flow rate is determined consistent with the permissible heat removal rate to a maximum input value. The time step tube side flow and outlet temperature are combined with the total SDCS flow rate (a fixed input parameter) to determine the return temperature and ultimately the HX tube side inlet temperature for the next time increment. Time steps are a variable input parameter. This process is repeated until the desired final temperature is reached. This model is a PC based software tool maintained to appropriate Quality Assurance program Verification & Validation procedures.