Tennessee Valley Authority, 1101 Market Street, Chattanooga, Tennessee 37402

CNL-16-152

September 12, 2016

10 CFR 50.90

ATTN: Document Control Desk
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555-0001

Browns Ferry Nuclear Plant, Units 1, 2, and 3
Renewed Facility Operating License Nos. DPR-33, DPR-52, and DPR-68
NRC Docket Nos. 50-259, 50-260, and 50-296

Subject: **Proposed Technical Specifications (TS) Change TS-505 - Request for License Amendments - Extended Power Uprate (EPU) - Supplement 32, Revised Responses to Requests for Additional Information**

References:

1. Letter from TVA to NRC, CNL-15-169, "Proposed Technical Specifications (TS) Change TS-505 - Request for License Amendments - Extended Power Uprate (EPU)," dated September 21, 2015 (ML15282A152)

2. Letter from NRC to TVA, "Browns Ferry Nuclear Plant, Units 1, 2, and 3 - Request for Additional Information Related to License Amendment Request Regarding Extended Power Uprate (CAC Nos. MF6741, MF6742, and MF6743)," dated June 13, 2016 (ML16146A635)

3. Letter from TVA to NRC, CNL-16-114, "Proposed Technical Specifications (TS) Change TS-505 - Request for License Amendments - Extended Power Uprate (EPU) - Supplement 24, Responses to Requests for Additional Information and Containment Accident Pressure Credit Elimination Updates," dated August 3, 2016 (ML16216A699)

4. Letter from TVA to NRC, CNL-16-105, "Proposed Technical Specifications (TS) Change TS-505 - Request for License Amendments - Extended Power Uprate (EPU) - Supplement 22, Responses to Requests for Additional Information," dated June 24, 2016 (ML16179A348)

By the Reference 1 letter, Tennessee Valley Authority (TVA) submitted a license amendment request (LAR) for the Extended Power Uprate (EPU) of Browns Ferry Nuclear Plant (BFN) Units 1, 2 and 3. The proposed LAR modifies the renewed operating licenses to increase the maximum authorized core thermal power level from the current licensed thermal power of 3458 megawatts to 3952 megawatts. In Reference 2, the Nuclear Regulatory Commission (NRC) provided Requests for Additional Information (RAIs) related to containment systems and in Reference 3, TVA provided responses to the Reference 2 RAIs.

The enclosure to this letter provides revisions to the responses for NRC RAIs SCVB-RAIs 1, 24, 25, and 26 provided in the Reference 3 letter. These revisions to the responses to NRC RAIs SCVB-RAIs 1, 24, 25, and 26 are as a result of additional reviews. The enclosure to this letter also provides a revision to the response to NRC RAI SCVB-RAI 16 provided in the Reference 4 letter. The submitted response to NRC RAI SCVB-RAI 16 reflects BFN Units 2 and 3 analysis results, which are different than the BFN Unit 1 analysis results. The revision to the response to NRC RAI SCVB-RAI 16 is made to accurately reflect the associated BFN analysis basis for each of the units. This condition, requiring a revision to the response to NRC RAI SCVB-RAI 16, has been entered in the TVA Corrective Action Program. The revisions to the responses to NRC RAIs SCVB-RAIs 1, 16, 24, 25, and 26, included in the enclosure to this letter, supersede the previous submitted RAI responses.

TVA has reviewed the information supporting a finding of no significant hazards consideration and the environmental consideration provided to the NRC in the Reference 1 letter. The supplemental information provided in this submittal does not affect the bases for concluding that the proposed license amendment does not involve a significant hazards consideration. In addition, the supplemental information in this submittal does not affect the bases for concluding that neither an environmental impact statement nor an environmental assessment needs to be prepared in connection with the proposed license amendment. Additionally, in accordance with 10 CFR 50.91(b)(1), TVA is sending a copy of this letter to the Alabama State Department of Public Health.

There are no new regulatory commitments associated with this submittal. If there are any questions or if additional information is needed, please contact Edward D. Schrull at (423) 751-3850.

I declare under penalty of perjury that the foregoing is true and correct. Executed on the 12th day of September 2016.

Respectfully,

J. W. Shea

Digitally signed by J. W. Shea
DN: cn=J. W. Shea, o=Tennessee Valley Authority, ou=Nuclear Licensing, email=jwshea@tva.gov, c=US
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J. W. Shea
Vice President, Nuclear Licensing

Enclosure

cc: See page 3

Enclosure: Revised Responses to NRC Requests for Additional Information SCVB-RAIs 1 (Revision 2), 16 (Revision 1), 24 (Revision 1), 25 (Revision 1), and 26 (Revision 1)

cc:

NRC Regional Administrator - Region II
NRC Senior Resident Inspector - Browns Ferry Nuclear Plant
State Health Officer, Alabama Department of Public Health

ENCLOSURE
Revised Responses to NRC Requests for Additional Information
SCVB RAIs 1 (Revision 2), 16 (Revision 1), 24 (Revision 1), 25 (Revision 1), and 26 (Revision 1)

ENCLOSURE

SCVB-RAI 1

During the review of Attachment X of the LAR regarding National Fire Protection Association (NFPA) 805 Transition Report (Reference 1), the NRC staff requested in an RAI (SCVB-RAI-5) that TVA describe the revised BFN, Units 1, 2, and 3, residual heat removal (RHR) heat exchanger performance monitoring program, which will assure that its fouling factor and tube plugging would not exceed their worst values assumed in calculating a K-value of 284.5 British thermal unit (BTU)/sec-degrees Fahrenheit (°F). In response to this RAI (Reference 2), TVA stated, "The revised performance monitoring program has not been developed at this time ... ", and made a commitment to revise the program that monitors the RHR heat exchanger performance.

In the approval of the NFPA 805 LAR, the NRC imposed the following license condition, which was accepted by TVA as implementation Item No. 49 in Reference 3:

> *Revise the program that monitors BFN Residual Heat Removal (RHR) heat exchanger performance for consistency with the assumptions of the NFPA 805 Net Positive Suction Head (NPSH) analysis. The monitoring program shall include verification that the tested worst fouling resistance, with measurement uncertainty added, of all BFN Units 1, 2, and 3 RHR heat exchangers is less than the design value of 0.001517 hr-ft^2-°F/BTU and the worst tube plugging is less than 4.57 percent.*

In Attachment 6 (Reference 4) and Attachment 39 (Reference 5) to the extended power uprate (EPU) LAR, at the EPU design-basis accident (DBA) loss-of-coolant accident (LOCA) statepoint, the RHR heat exchanger K-value for one heat exchanger is reported to be 265 BTU/sec-°F for a design fouling resistance of 0.001521 hr-ft^2-°F/BTU, which supersedes the fouling factor of 0.001517 hr-ft^2-°F/BTU reported in the NFPA 805 LAR.

Section 2.1 of Reference 5 provides the following EPU RHR heat exchanger K-values used in the analyses:

- *265 BTU/sec-°F (DBA-LOCA, Small Break LOCA, Loss of Shutdown Cooling, Stuck Open Relief Valve and SBO [Station Blackout]), 302 BTU/sec-°F (Shutdown of Non-Accident Unit), and 287 BTU/sec-°F (fire event defense-in-depth demonstration case) are based on the EPU design fouling resistance, 0.001521 hr-ft^2-°F/BTU.*

- *307 BTU/sec-°F (fire event licensing basis) is based on the EPU nominal fouling resistance, 0.001097 hr-ft^2- °F/BTU.*

- *277 BTU/sec-°F for the ATWS-MSIVC-EOC event corresponds to a nominal fouling resistance of 0.001220 hr-ft^2-°F/BTU.*

Describe the performance monitoring program to monitor the as-found worst RHR heat exchanger fouling factor and plugged tubes. As mentioned above, the description of this program was previously requested for the NFPA 805 LAR approval and is being again requested for the EPU LAR submittal. The monitoring program must verify the EPU design fouling resistance, 0.001521 hr-ft^2-°F/BTU and EPU nominal fouling resistance and 0.001097 hr-ft[^{2}]-°F/BTU, as given above.

The description of the program should include the following:

(a) Scope of monitoring
(b) Frequency of monitoring
(c) Acceptance criteria for the fouling factor should be less than nominal fouling resistance of 0.001097 hr-ft^2-°F/BTU (for fire event) with uncertainty included
(d) Acceptance criteria for plugged tubes - must be less than or equal to 4.57 percent tubes
(e) Accepted industry standards and guidelines used for heat exchanger performance testing
(f) Test setup
(g) Instrumentation with its accuracy
(h) Method of suppression pool heatup
(i) Data acquisition system
(j) Uncertainty analysis
(k) Data reduction method for calculation of the fouling factor
(l) Method of as-found heat-exchanger inspection for determining the number of plugged tubes and the effective heat transfer area

REFERENCES

1 Tennessee Valley Authority (TVA), Browns Ferry Nuclear Plant (BFN) Units 1, 2 and 3, "Transition to 10 CFR 50.48(c) - NFPA 805 Performance-Based Standard for Fire Protection for Light Water Reactor Electric Generating Plants, 2001 Edition, Transition Report," dated March 2013 (ADAMS Accession Number ML13092A392).

2 Letter from TVA to NRC, dated June 13, 2014, "Response to NRC Request for Additional Information Regarding the License Amendment Request to Adopt NFPA 805 Performance-Based Standard for Fire Protection for Light Water Reactor Electric Generating Plants for the Browns Ferry Nuclear Plant, Units 1, 2, and 3 (TAC Nos. MF1185, MF1186, and MF1187) - Attachment X and Fire Modeling" (ADAMS Accession Number ML14167A175).

3 Letter from TVA to NRC, dated October 20, 2015, "Update to License Amendment Request to Adopt NFPA 805 Performance-Based Standard for Fire Protection for Light Water Reactor Electric Generating Plants for the Browns Ferry Nuclear Plant, Units 1, 2, and 3 (TAC Nos. MF1185, MF1186, and MF1187) - Revised Implementation Item 49" (ADAMS Accession No. ML15293A527).

4 Attachment 6 to EPU LAR, NEDC-33860P, Revision 0, "Safety Analysis Report for Browns Ferry Nuclear Plant, Units 1, 2, and 3, Extended Power Uprate (proprietary)" (ADAMS Accession No. ML15282A264 (non-public)).

5 Attachment 39 to EPU LAR, "RHR Heat Exchanger K-values Utilized in EPU Containment Analyses" (ADAMS Accession No. ML15282A235).

TVA Response (Revision 2):

General Description:
Beginning in January 2012, Residual Heat Removal (RHR) heat exchanger performance tests were performed in conjunction with quarterly Reactor Core Injection Cooling (RCIC) surveillance testing (see item h, below, for further details). The RHR heat exchanger testing involves installation of temporary temperature and temporary differential pressure instruments (connected to instrument taps from permanently installed Residual Heat Removal Service Water (RHRSW) flow orifices or RHR flow nozzles) to collect the data necessary to compute heat exchanger tube side and shell side heat transfer rates. The RHR heat exchanger testing uses a Tennessee Valley Authority (TVA)-approved procedure to perform the test. Under contract, an outside vendor operating under a 10 CFR 50 Appendix B Quality Assurance (QA) program provides the test instrumentation, including data acquisition system, collects and processes the data, and provides test reports documenting the results. The data analysis and preparation of vendor test reports are performed by a vendor also operating under a 10 CFR 50 Appendix B Quality Assurance Program in accordance with approved procedures. The procedures include steps to compare process and tube side heat transfer rates and to statistically evaluate test data such that results conservatively account for the uncertainties associated with each test. Thus, the accuracy of each test, which varies from one test to another, is reflected in the test results which are then compared to the acceptance criteria.

This RAI response describes how the Browns Ferry Nuclear Plant (BFN) Generic Letter (GL) 89-13 program incorporates the National Fire Protection Association (NFPA) 805 license condition requirements. The GL 89-13 program has been revised through incorporation of NFPA 805 licensing condition requirements into applicable implementing procedures. ~~Copies of these implementing procedures, 0-TI-322, “RHR Heat Exchanger Performance Testing,” and 0-TI-522, “Program for Implementing NRC Generic Letter 89-13,” are being provided in Attachments 1 and 2, respectively, of this RAI response.~~

A more detailed response addressing each specific item is provided below:

(a) The Current Licensed Thermal Power (CLTP) scope of monitoring complies with the NFPA 805 license condition. Extended Power Uprate (EPU) implementation will not require any changes to the CLTP scope of monitoring. In both cases, the scope of monitoring includes verification that: (1) tested worst fouling resistance of all BFN Units 1, 2, and 3 RHR heat exchangers is less than the design value acceptance criteria; (2) worst tube plugging is less than the tube plugging acceptance criteria.

(b) An RHR Heat Exchanger Performance Monitoring Program will be maintained through the BFN Preventive Maintenance (PM) program. Prior to implementation of the RHR Heat Exchanger Performance Monitoring Program required by the NFPA 805 license condition, the GL 89-13 commitment for the RHR heat exchangers was met through BFN PM Program routine cleaning and inspection. Each RHR heat exchanger was tested at least once by June 16, 2016. Subsequent testing of each RHR heat exchanger will be performed periodically at an interval that is nominally four years, but will not exceed five years. ~~Additionally, the heat exchangers will be cleaned on an 8-year frequency at a maximum. This 8-year cleaning frequency is based on supporting PM-required RHR heat exchanger tube eddy current testing. More frequent RHR heat exchanger cleaning will occur if the fouling rate, as trended, indicates the need to take corrective actions in order to maintain the heat exchanger condition within the fouling resistance acceptance criteria (see item (c) response, below).~~

For EPU implementation, the inspect and clean frequency for the RHR heat exchangers is in accordance with the current Generic Letter 89-13 commitment (i.e., inspect and clean the cooling water side of these heat exchangers periodically as determined by the preventative maintenance (PM) program). The current maximum interval for performing RHR heat exchanger inspection and cleaning is procedurally limited to five years (four years + 25%). Any increase in the inspect and clean interval beyond five years would be evaluated in accordance with PM program procedures, GL 89-13 program implementing procedures and TVA programmatic procedure change requirements. Changes to the PM performance interval (frequency) are procedurally controlled and require a technical justification for any increase of the PM performance interval. Consecutive satisfactory as-found inspections where the inspection acceptance criteria was satisfied have been used to technically justify extending the inspect and clean interval. For EPU implementation, inspection results and performance testing results would be used to technically justify extending the inspect and clean interval. The as-found inspection acceptance criteria is currently less than 77 tubes obstructed (sum of the number of tubes mechanically plugged and the number of tubes obstructed by macrofouling); this acceptance criteria is unchanged for EPU.

Additionally, plant operation at EPU conditions does not change RHR or RHRSW normal operating conditions. Consequently, the RHR heat exchangers will not experience any change in fouling resistance or fouling rates during normal operation at EPU conditions. As described in BFN EPU LAR Attachment 39, the acceptance criterion for fouling resistance at EPU conditions is increased from the CLTP criterion of 0.001521 hr-ft^2-°F/Btu to 0.001562 hr-ft^2-°F/Btu. Therefore, upon EPU implementation, the margin between actual heat exchanger fouling resistances and the fouling resistance acceptance criterion will be increased and consequently, RHR heat exchanger CLTP inspect and clean PM performance intervals will remain applicable for plant operation at EPU conditions. Changes to the RHR heat exchanger inspect and clean PM performance intervals are not required to support operation at EPU conditions.

CLTP or EPU	Frequency of Monitoring - Performance Testing
CLTP	Each RHR heat exchanger has been performance tested at least once and will be tested periodically at an interval that initially will not exceed five years.
EPU Implementation	Each RHR heat exchanger will be tested periodically at an interval that is nominally four years, but will not exceed five years.

CLTP or EPU	Frequency of Monitoring - Visual Inspection and Cleaning
CLTP	Each RHR heat exchanger will be ~~cleaned on an 8-year frequency~~inspected and cleaned periodically as determined by the PM program.
EPU Implementation	For EPU implementation, the inspect and clean frequency for the RHR heat

	exchangers will be in accordance with the current Generic Letter 89-13 commitment (i.e., inspect and clean the cooling water side of these heat exchangers periodically as determined by the preventative maintenance (PM) program). The current maximum interval for performing RHR heat exchanger inspection and cleaning is procedurally limited to five years (four years + 25%). Any increase in the inspect and clean interval beyond five years would be evaluated in accordance with PM program procedures, GL 89-13 program implementing procedures and TVA programmatic procedure change requirements. Changes to the PM performance interval (frequency) are procedurally controlled and require a technical justification for any increase of the PM performance interval. Consecutive satisfactory as-found inspections where the inspection acceptance criteria was satisfied have been used to technically justify extending the inspect and clean interval. For EPU implementation, inspection results and performance testing results will be used to technically justify extending the inspect and clean interval. The as-found inspection acceptance criteria is currently less than 77 tubes obstructed (sum of the number of tubes mechanically plugged and the number of tubes obstructed by macrofouling) and this acceptance criteria is unchanged for EPU. ~~Each RHR heat exchanger will be cleaned once every 8-years at a maximum. More frequent RHR heat exchanger cleaning will occur if the fouling rate, as trended, indicates the need to take corrective actions in order to maintain the heat exchanger condition within the fouling resistance acceptance criteria.~~

(c) CLTP fouling resistance acceptance criteria was established upon implementation of the NFPA 805 license condition. Upon EPU implementation, the fouling resistance acceptance criteria will be changed, as described in EPU License Amendment Request (LAR) Attachment 39. Specifically, the NFPA 805 design fouling resistance of 0.001517 hr-ft^2-°F/Btu (corresponding to Design Basis Accident-Loss of Coolant Accident (DBA-LOCA) event with RHR heat exchanger K of 265 Btu/sec-°F) will be replaced with the EPU design fouling resistance of 0.001562 hr-ft^2-°F/Btu (corresponding to the limiting EPU NFPA 805 fire event with RHR heat exchanger K of 290 Btu/sec-°F).

DBA-LOCA event

CLTP or EPU	Fouling Resistance Acceptance Criteria
EPU Implementation	EPU: 0.001562 hr-ft^2-°F/Btu*

*The EPU DBA-LOCA design and licensing basis minimum required heat removal rate ~~(System Operability Limit per American Society of Mechanical Engineers (ASME) Operation and Maintenance (OM)-2015, Part 21, Section 9.1)~~ is 80,136,000 Btu/hr per heat exchanger, with two heat exchangers in service. The RHR heat exchanger testing program fouling resistance acceptance criteria is based on the limiting EPU NFPA 805 fire event.

The RHR heat exchanger performance test result fouling resistance (including test uncertainty) will be compared to the fouling resistance acceptance criterion (fouling resistance of 0.001562 hr-ft^2-°F/Btu). This acceptance criterion was determined from a deterministic containment analysis based on conservative inputs. ~~Upon EPU implementation, BFN will follow the guidance from the ASME OM-2015, Part 21, Section 9.1, System Operability Limits. Specifically, the EPU design and licensing basis minimum required heat removal rate will be the System Operability Limit. Additionally, RHR heat exchanger performance test fouling resistance, including test uncertainty, will be trended for comparison to the fouling resistance acceptance criterion, in a manner consistent with ASME OM-2015, Part 21, Section 6.10, except for the second paragraph of Section 6.10.2. Because the BFN testing program will compare the test results to the acceptance criteria at the time the program is established, BFN will take specific exception to the second paragraph of Section 6.10.2 which requires "trending these parameters for a minimum of three test or monitoring points" prior to comparison to the applicable acceptance criteria (i.e., trending will be performed prior to having a minimum of three test or monitoring points). This is the only exception to Section 6.10.~~

Fire Event

CLTP or EPU	Fouling Resistance Acceptance Criteria
CLTP	CLTP Fire event: 0.001517 hr-ft^2-°F/Btu
EPU Implementation	EPU Fire event: 0.001562 hr-ft^2-°F/BTU*

*The EPU fire event design and licensing basis minimum required heat removal rate is 124,966,800 Btu/hr with one heat exchanger in service. The RHR heat exchanger testing program fouling resistance acceptance criteria for the fire event at EPU conditions is based on the EPU fire event design and licensing basis minimum required heat removal rate.

The RHR heat exchanger performance test result nominal fouling resistance (including test uncertainty) will be compared to the fire event acceptance criterion (fouling resistance of 0.001562 hr-ft^2-°F/Btu*).

(d) The CLTP allowable tube plugging acceptance criteria (4.57%) applicable to the NFPA 805 licensing condition was established in applicable implementing program procedures. Upon EPU implementation, the RHR Heat Exchanger Performance Monitoring Program tube plugging limit acceptance criteria will remain at 77 tubes (4.57% of 1700 tubes) mechanically plugged.

(e) Accepted industry standards and guidelines used for heat exchanger performance testing are identified in applicable CLTP program documents. EPU will not require any change from the standards and guidelines used for CLTP heat exchanger performance testing.

CLTP or EPU	Accepted Industry Standards/Guidelines
CLTP	Performance testing is conducted consistent with the guidance described in Electric Power Research Institute (EPRI) 3002005340, Service Water Heat Exchanger Testing Guidelines, May 2015. Testing performed between January, 2015 and May 2015 was conducted consistent with the guidance provided in the previous version of this document, EPRI TR-107397, Service Water Heat Exchanger Testing Guidelines, Final Report, March 1998. Testing conducted in January 2012 also followed the EPRI TR-107397 guidelines as well as EPRI NP-7552, “Heat Exchanger Performance Monitoring Guidelines,” dated December 1991.
EPU Implementation	Performance testing will be conducted consistent with the guidance described in EPRI 3002005340, Service Water Heat Exchanger Testing Guidelines, May 2015. ~~Parameter (fouling resistance) trending and comparison to the acceptance criteria will be performed consistent with the guidance provided in ASME OM-2015, Part 21, Section 6.10, Parameter Trending, except as noted in response (c).~~

(f) Test set-up included installation of temporary surface mounted temperature sensors on the heat exchanger process (RHR) and cooling water (RHRSW) inlet and outlet pipes. The piping insulation was removed and eight temporary surface-mounted temperature sensors were uniformly spaced at 45° increments around the circumference of each outlet pipe. Piping insulation was also removed from each inlet pipe and four temporary surface-mounted temperature sensors were uniformly spaced at 90° increments around the circumference of each inlet pipe. The pipe insulation was then reinstalled over the temporary surface-mounted temperature sensors to reduce the influence from external environmental conditions. The temporary surface-mounted temperature sensor leads were bundled and routed to the data acquisition unit.

Dimensions of the system piping where RHRSW and RHR temperature sensors were mounted are contained in the detailed vendor test report. RHRSW inlet temperature sensors were mounted on 16” OD, 0.375” wall thickness, carbon steel pipe. RHRSW outlet temperature sensors were mounted on 12.75” OD, 0.375” wall thickness, carbon steel pipe. RHR inlet and outlet temperature sensors were mounted on 20” OD, 0.50” wall thickness, carbon steel pipe.

Temporary differential pressure instruments were connected to instrument taps from permanently installed RHRSW flow orifices and RHR flow nozzles.

The GL 89-13 implementing procedures require the following.

- Temporary surface mounted temperature instrumentation for RHR and RHRSW inlet and outlet piping shall meet the guidance identified in EPRI 3002005340, Service Water Heat Exchanger Test Guidelines, May 2015.
- Temporary differential pressure (DP) instrumentations connected to the instrument taps from the permanently installed RHRSW flow orifices and RHR flow nozzles shall meet the guidance provided in EPRI 3002005340, Service Water Heat Exchanger Test Guidelines, May 2015.

(g) Temporary test instrumentation (e.g., surface-mounted temperature sensors, delta-P meters, current converter and data acquisition system) and thus, the associated instrumentation accuracy, is provided to BFN under contract from an outside vendor where 10 CFR Part 50 Appendix B and 10 CFR Part 21 apply. The vendor’s Quality Assurance System complies with applicable requirements of International Standardization Organization (ISO)/International Electrotechnical Commission (IEC)-17025-2005, American National Standards Institute (ANSI)/National Conference of State Legislatures (NCSL) Z540-I-1994 and ISO 9001: 2008. The instruments are calibrated against standards traceable to the National Institute of Standards & Technology (NIST) or compared to nationally or internationally recognized consensus standards. The reported calibration uncertainty has a confidence level of 95% (k=2). The temporary surface-mounted temperature sensors used during the tests that have been performed to date had a calibration accuracy of 0.1 °F. Calibration certificates for the pre-test and post-test calibrations are included in the vendor test report.

Temporary delta-P meters were used to record the flow rates for RHR and RHRSW. The meters had a pre-test and post-test accuracy of 0.05% of full scale. The composite systematic uncertainty for the instruments used in measurement of RHRSW and RHR flow rates for the RHR heat exchanger performance tests performed since January 2012 is documented in each vendor test report. This value was calculated using 95% confidence analysis techniques. The resulting composite systematic uncertainty from each test for both RHRSW and RHR flow rates has been less than ±5% of measured flow.

Supplied temporary test instrumentation and associated instrumentation accuracy meets the Industry Standards/Guidelines identified in response (e), above. Specifically, EPRI 3002005340, Section 1.6.9 states, “ASME PTC 12.5, Single Phase Heat Exchangers was revised in 2005 and provides comprehensive guidance to plan, conduct and analyze results for accurate performance tests of single phase heat exchangers. The Code details information for calculation techniques and methods to determine steady state performance at both test conditions and reference conditions. Guidelines are also provided for instrumentation and accuracy." ASME PTC 12.5, Section 3.1.1 states, "As a benchmark, the calibration uncertainty for temperature measurements shall be less than ±0.2°F (±0.1°C), the total flow measurement uncertainty shall be less than ±5% of measured flow…" The instrumentation used in the tests performed to date meets these guidelines.

Installation of temporary test instrumentation is performed under an approved TVA procedure using the BFN work order process. The GL 89-13 implementing procedures require the following.

- Temporary instruments shall be calibrated against standards traceable to the National Institute of Standards and Technology or compared to nationally or internationally recognized consensus standards.

(h) One of the attributes of an effective RHR heat exchanger performance test is to maximize the heat exchanger heat removal rate. This requires maximizing the difference between the RHR (heat exchanger shell side) inlet temperature and the RHRSW (heat exchanger tube side) inlet temperature. The RHR (heat exchanger shell side) inlet temperature is dependent upon the suppression pool (torus) temperature while the RHRSW (heat exchanger tube side) inlet temperature is dependent upon the ultimate heat sink (river) temperature. These water bodies experience a maximum temperature differential during winter months, with a reduced temperature difference in spring and fall months, and a minimum temperature differential during summer months. Consequently, the best time of the year for maximizing the heat load on the RHR heat exchanger is to perform the test during winter months.

Beginning January 2012, RHR heat exchanger testing has been performed in accordance with an approved TVA procedure in conjunction with quarterly RCIC system surveillance testing. The intent of performing these tests in a back-to-back fashion was to allow the heat input rate from the RCIC turbine exhaust to the suppression pool (torus) to be matched to the removal rate from the suppression pool through the RHR heat exchanger while in the suppression pool cooling mode of operation. A perfect match of the heat input and removal rates would result in no change to the suppression pool temperature over the duration of the test data collection period. This condition would result in optimal steady state RHR (heat exchanger shell side) inlet temperatures during the test and would also serve to reduce the uncertainty associated with the test data. However, in practice, it is not feasible to match the heat input and heat removal rates exactly. Consequently, during the test data collection period there is some suppression pool heating or cooling, even though establishment of test conditions matches heat input and heat removal rates to the extent practical. In conclusion, there is actually no intent to change the suppression pool temperature during the RHR heat exchanger test data collection period.

Future RHR heat exchanger performance testing will be performed in a manner similar to or the same as that described above and performed to date.

(i) The data acquisition system for all tests performed since January 2012 was provided to TVA by an outside vendor operating under their own 10 CFR 50 Appendix B Quality Assurance program. This vendor provided the test instrumentation, including data acquisition system. The test instrumentation and data acquisition system is capable of instrumenting two heat exchangers at the same time and still have spares. All instruments and software are labeled and configured for specific use in each test location. This system complies with the requirements listed in the EPRI document TR-107397. A data acquisition software package works with the heat exchanger instrumentation system and produces data files that may be loaded directly into Proto-HX. Personal computers with data collection software are provided. The data collection software is written and validated under the vendor software Quality Assurance program. Time stamped data is collected from each sensor.

The GL 89-13 implementing procedures require the following.

- The data acquisition system, including the associated software, shall comply with the guidance in EPRI 3002005340, Service Water Heat Exchanger Test Guidelines, May 2015.
- Computer programs used in the thermal performance analysis shall meet the requirements of 10 CFR 50, Appendix B, and 10 CFR 21.

(j) The RHR heat exchanger performance testing that has been performed at BFN since January 2012 has used an outside vendor operating under a 10 CFR 50 Appendix B Quality Assurance program to provide the test instrumentation, collect and process the data, and provide test reports documenting the results. The data analysis and preparation of vendor test reports are performed by a vendor also operating under a 10 CFR 50 Appendix B Quality Assurance Program in accordance with approved procedures that include steps to compare process and tube side heat transfer rates and to statistically evaluate test data such that results account for the uncertainties associated with each test. The method of calculation follows the EPRI guidelines (see response (e), above) in terms of determining the uncertainty contributors of precision and bias errors for thermal performance test evaluations. The uncertainty analysis methodology in Proto-HX determines the sensitivity coefficients through a numerical approach using the central differencing method (i.e., symmetric uncertainties). The EPRI guideline (see response (e), above) provides an overview of this approach. The variables considered are the test data (flow rates and temperatures) and the film coefficients.

The GL 89-13 implementing procedures require the following.

- The uncertainty analysis methodology shall comply with the approach described in EPRI 3002005340, Service Water Heat Exchanger Test Guidelines, May 2015.
- Computer programs used in the thermal performance analysis shall meet the requirements of 10 CFR 50, Appendix B, and 10 CFR 21.

(k) The data reduction method for calculating the fouling resistance involves averaging the data from the RHR heat exchanger test to identify nominal values for each parameter. These nominal values are then analyzed to determine the condition of the heat exchanger with respect to the overall fouling factor. Further analysis of the test data identifies the uncertainty in each parameter measurement. These uncertainties are then used to establish the overall uncertainty in the test result. The test result is then compared to the acceptance criterion to determine if the test is satisfactory.

The data reduction is performed by the vendor under the same processes as described in item (j), above. In the testing that has been performed to date, the vendor calculation follows the heat transfer test method using the heat transfer at design limiting conditions as the performance parameter. This method is outlined in EPRI Test Report 107397, “Service Water Heat Exchanger Testing Guidelines,” dated March 1998.

These initial testing results (vendor test reports) have been revised to recompute the performance parameter, including the performance parameter (fouling resistance) uncertainty, so as to report results consistent with the units specified in the NFPA 805 license condition for the fouling resistance, hr-ft^2-°F/Btu. The GL 89-13 implementing procedures require the following.

- Data reduction shall comply with the approach described in the EPRI 3002005340, Service Water Heat Exchanger Test Guidelines, May 2015.

(I) In the context of the "method of as-found heat-exchanger inspection for determining the number of plugged tubes and the resulting effective heat transfer area," it is noteworthy how this information actually impacts the heat exchanger post-test analysis. The vendor test reports contain the following conservative assumption: "It is assumed that all tubes were unobstructed during the test (i.e., none of the tubes were plugged by macro fouling during the test). It is an inherent part of the PROTO-HX method of analysis to distribute the tube-side flow equally to all tubes and to use the specified heat transfer area in the fouling calculation. This assumption is acceptable since lost area due to unknown macrofouling will show up as extra fouling resistance."

The method of as-found heat-exchanger inspection for determining the number of unavailable tubes and the effective heat transfer area is performed in accordance with an approved TVA procedure. An attachment to the procedure provides a GL 89-13 Heat Exchanger Visual Inspection and Evaluation Form. The form requires recording the number of tubes plugged, the number of tubes fully blocked (>90%), and the number of tubes partially obstructed (75% - 90%). Guidance for determining the number of tubes equivalent blocked is that tubes found with >90% of the area obstructed are considered fully blocked and 50% of the tubes with 75% to 90% of the area obstructed are considered fully blocked. The acceptance criterion is the number of tubes plugged, fully blocked or equivalent blocked must be less than the maximum plugging limit. This information on as-found potential tube blockage is only applicable for consideration in determining heat exchanger past-operability for an event where the potential tube blockage was introduced into the system since the performance of the last heat exchanger test. In some cases, this same as-found blockage could have been present during previous heat exchanger testing. The consideration of the effects of potential blockages inside the heat exchanger prior to the last heat exchanger performance test is addressed in the first paragraph of this response (item (I)).

EPU implementation will not change the method of as-found heat-exchanger inspection for determining the number of unavailable tubes and the effective heat transfer area. ~~However, upon EPU implementation, acceptance criteria will be included in the Updated Final Safety Analysis Report (UFSAR), to identify, for any given fouling resistance, the maximum allowable number of tubes that could be plugged or otherwise obstructed and still meet the DBA-LOCA system operability limit minimum heat removal requirement. This determination will facilitate a more immediate assessment of the as-found condition of any RHR heat exchanger where the fouling resistance is known or can be projected based on the fouling rate and the as-found number of tubes determined to be fully blocked from the as-found heat exchanger inspection. This acceptance criteria, included in the UFSAR, would only be used for past-operability/functionality determinations.~~

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Section 2.6.1.5 of PUSAR states:

> *The Browns Ferry analysis of record at CLTP shows that the recirculation line break DBALOCA event causes boiling in the drywell cooling coils sooner than for steam line breaks at CLTP conditions. A comparison of the drywell temperature profiles during a DBA-LOCA for CLTP and EPU conditions shows a minor difference in temperature (less than 2°F) and lasting only seconds. Based on the minor differences in the drywell temperature profiles and the margin between the RBCCW pump start (40 seconds) and calculated time to boil (61 seconds), it is concluded that voiding will not occur under EPU conditions prior to the restart of a RBCCW [reactor building closed cooling water] pump.*

Table 2.6-1 of PUSAR shows peak drywell temperature of 297°F for Units 2 and 3, and 295.2 °F for Unit 1 in the current licensing basis analysis. Table 2.6-1 shows 336.9°F EPU long-term drywell gas temperature for the SSLB. In the current response to Generic Letter (GL) 96-06, the boiling time in the drywell cooling coils of 61 seconds should be based on the short-term drywell gas temperatures.

In the current response to GL 96-06, what are the drywell gas and the RBCCW temperatures used in the analysis to determine the boiling time of 61 seconds in the drywell cooling coils? State the basis for these temperatures and confirm that the both are limiting for the boiling time of 61 seconds in the RBCCW piping and the drywell cooler cooling coils. Provide the same temperature under the EPU conditions with justification that these are most limiting for the boiling time determination in the drywell cooling coils.

TVA Response (Revision 1):

1) The current licensing basis peak drywell temperature (297°F for Units 2 and 3, and 295.2°F for Unit 1) is based on the DBA-LOCA. The PUSAR Table 2.6-1 EPU peak drywell temperature of 336.9°F is based on a small steam line break. Note 8 of PUSAR Table 2.6-1, applied to the Current Licensed Thermal Power (CLTP) peak drywell temperature results, states, “This value is for a recirculation line liquid break. The Unit 2 and Unit 3 peak drywell airspace temperature for a steam line break is 336ºF (Reference 104). The Unit 1 peak drywell airspace temperature for a steam line break is 335.4ºF (Reference 105).” The recirculation line liquid break is the recirculation suction line DBA-LOCA.

   A comparison, based on the different LOCA events of CLTP versus EPU peak drywell temperature as follows.

Parameter	CLTP - DBA LOCA	EPU -with EPU Model - DBA-LOCA	CLTP - Steam Line Break LOCA	EPU - with EPU Model - Steam Line Break LOCA
Peak Drywell Temperature (°F)	297 - U2, U3 295.2 - U1	297.5 (D) 295.8 (B) 295.2 (R)	336 - U2, U3 335.4 - U1	336.9

The initial drywell temperature conditions for the EPU DBA-LOCA (D), (B), and (R) results are stated in Note 7 below PUSAR Table 2.6-1. The CLTP DBA-LOCA peak drywell temperature values were determined by analyses that assumed an initial drywell temperature of 150°F. The above table shows that the peak drywell temperature at EPU increases by a maximum of 2.3°F (297.5°F - 295.2°F) for the DBA-LOCA and 1.5°F (336.9°F - 335.4°F) for the steam line break LOCA, which is not significant.

For Units 2 and 3, both the current licensing basis and the proposed EPU basis for the shortest time to boil are based on the drywell temperature response profile for the DBA-LOCA.

For Unit 1, both the current licensing basis and the proposed EPU basis for the shortest time to boil are based on the peak drywell temperature resulting from a steam line break.~~Both the current licensing basis and the proposed EPU basis for the time to boil are based on the drywell response profile for the DBA-LOCA. The current licensing basis analysis for determining the RBCCW time to boil for all three BFN units was based on the CLTP drywell temperature response profile associated with the Unit 2, Unit 3 peak drywell temperature of 297°F.~~

2) In both the current licensing basis and the proposed EPU GL 96-06 analysis, the RBCCW initial temperature is set at 150°F. This RBCCW temperature value is conservative for the following reasons: 1) the 150°F value is greater than the maximum abnormal temperature of 140°F for the RBCCW system; 2) the maximum normal operation drywell airspace temperature allowed by Technical Specifications is 150°F; therefore assuming RBCCW in thermal equilibrium to this maximum drywell temperature is reasonable; 3) the assumption of RBCCW temperature at 150°F also places this initial RBCCW liquid temperature closer to the boiling point.

The EPU DBA LOCA drywell gas temperature profiles with initial drywell temperature of 130°F (Bounding case) and 150°F (Reference case) were examined for the EPU evaluation for the time to boil. While the EPU DBA-LOCA design (D) case results in a slightly higher peak drywell temperature, this temperature profile was not used because the initial conditions for this case were designed to maximize the containment pressure response and the initial drywell temperature (70°F) to produce this peak pressure response are artificially low. Analyses show that the DBA-LOCA event causes boiling in the drywell cooling coils sooner than the main steam line break (MSLB) at CLTP conditions. The drywell temperature response in the first 80 seconds of the EPU steam line break LOCA analysis is essentially unchanged from the Units 2 and 3 CLTP steam line break analysis that was used in the CLTP boiling analysis. The drywell temperature profile generated from a DBA-LOCA with an initial temperature of 130°F produces a slightly higher temperature than the profile with an initial temperature of 150°F (slightly higher by less than 2°F between 10 and 14 seconds). However, establishing a bounding initial drywell temperature of 130°F with an RBCCW temperature of 150°F is not physically possible. If the RBCCW initial temperature were assumed to be 130°F for the Bounding case, the slightly higher resulting drywell temperature for such a short time period would not shorten the 61 seconds to boil time period as the water now has an additional 20°F to be heated. Therefore, the DBA-LOCA drywell gas temperature profile with an initial drywell gas temperature of 150°F was used in the GL 96-06 evaluation.~~Therefore, the initial drywell gas temperature of 150°F and the resulting DBA-LOCA drywell temperature profile was used in the GL 96-06 evaluation.~~

The GL 96-06 drywell cooler boiling analysis for steam line breaks conservatively assumes that the drywell atmosphere instantaneously increases at the start of the event from the initial drywell temperature (150°F) to the peak drywell temperature (336°F) . The drywell temperature is then assumed to remain at the peak temperature (336°F) for the duration of the event. Observation of PUSAR Figure 2.6-9 shows that the drywell temperature response for steam line breaks during the first 100 seconds does not exceed 330°F.

3) Figure SCVB-RAI 16-1 shows the drywell temperature profiles for a DBA LOCA with an initial drywell temperature of 150°F for both CLTP and EPU conditions. In comparing the drywell temperature profiles, the discussion is separated into the following three time periods:

- The largest difference in temperatures are seen in the first two seconds following a LOCA. The extent of the temperature difference ranges from approximately 6°F at 0.02 seconds to approximately 1°F at two seconds. When coupled with the small time duration, this difference is expected to have little effect on the drywell cooling time to boiling.
- From two seconds to eight seconds, the temperature difference continues to decrease until EPU conditions are bounded by the temperature profile in the CLTP calculation. The small temperature difference, combined with the small time duration is expected to have insignificant effect on the time to boiling.
- For the remainder of the time, the temperature profile associated with EPU conditions is either bounded by, or very close to, the temperature profile from the CLTP calculation.

For Units 2 and 3, both the current licensing basis and the proposed EPU basis for the time to boil are based on the drywell temperature response profile for the DBA-LOCA. Based on the minor differences in the drywell temperature profiles and the margin between the RBCCW pump start (~~40~~ 43 seconds) and calculated time to boil (61 seconds), it is concluded that voiding will not occur under EPU conditions prior to the restart of the RBCCW pump.

For Unit 1, both the current licensing basis and the proposed EPU basis for the time to boil are based on the peak drywell temperature resulting from steam line breaks. A peak drywell temperature of 336°F was used in the current licensing basis evaluation. At EPU conditions with an assumed initial drywell temperature of 150°F, the peak drywell temperature for steam line breaks is 335.2°F. The drywell temperature profile for steam line breaks at EPU conditions is bounded by the temperature profile used in the current licensing basis analysis. Therefore, the current licensing basis conclusion, an RBCCW pump would have been restarted (43 seconds) prior to voiding occurring (46 seconds) and that water hammer and two-phase flow in the RBCCW system are not a concern, is still valid at EPU conditions.

Changes to NEDC-33860P Revision 0 - BFN Power Uprate Safety Analysis Report (PUSAR):

NEDC-33860P, Section 2.5.3.3, the bottom paragraph of page 2-225 states the following:

Browns Ferry's current licensing basis regarding GL 89-13 is discussed in TVA's response to the NRC by letter dated March 16, 1990, "Response to Generic Letter 89-13 Service Water Problems Affecting Safety-Related Equipment." Browns Ferry's current licensing basis regarding GL 96-06 is discussed in TVA's response to the NRC, "Browns Ferry Revision 1-Response to Generic Letter 96-06 - Assurance of Equipment Operability and Containment Integrity During Design Basis Accident Conditions," dated October 23, 1997.

NEDC-33860P, Section 2.5.3.3, the bottom paragraph of page 2-225 will be revised as follows:

Browns Ferry's current licensing basis regarding GL 89-13 is discussed in TVA's responses to the NRC by letter dated March 16, 1990, "Response to Generic Letter 89-13 Service Water Problems Affecting Safety-Related Equipment." Browns Ferry's current licensing basis regarding GL 96-06 is discussed in TVA's response to the NRC, "Browns Ferry Revision 1-Response to Generic Letter 96-06 - Assurance of Equipment Operability and Containment Integrity During Design Basis Accident Conditions," dated October 23, 1997 and Browns Ferry Nuclear Plant (BFN) Unit 1 - Generic Letter 96-06, Assurance of Equipment Operability and Containment Integrity During Design Basis Accident Conditions," dated May 12, 2004.

NEDC-33860P, Section 2.6.1.5, the first four paragraphs state the following:

2.6.1.5 Generic Letter 96-06

GL 96-06 identified potential problems with equipment operability and containment integrity during design-basis accident conditions as a result of: (1) water hammer and/or two-phase flow conditions in cooling water systems serving the containment air coolers; and (2) thermally induced over-pressurization of isolated piping sections in containment.

The Browns Ferry response to GL 96-06 stated that in the event of a LOCA or MSLB with a coincident LOOP, the RBCCW pumps will be load shed at the start of the event. The first RBCCW pump will then be given a start signal 40 seconds after it was shed. Based on computed results, voiding in the RBCCW drywell atmosphere cooling coils will not occur for at least 60 seconds while the RBCCW pumps are stopped. As a RBCCW pump will have been restarted prior to voiding occurring, water hammer and/or two-phase flow in the RBCCW system are not a concern. EPU is not altering the RBCCW system serving the drywell atmosphere cooling coils.

The Browns Ferry analysis of record at CLTP shows that the recirculation line break DBA-LOCA event causes boiling in the drywell cooling coils sooner than for steam line breaks at CLTP conditions. A comparison of the drywell temperature profiles during a DBA-LOCA for CLTP and EPU conditions shows a minor difference in temperature (less than 2°F) and lasting only seconds. Based on the minor differences in the drywell temperature profiles and the margin between the RBCCW pump start (40 seconds) and calculated time to boil (61 seconds), it is concluded that voiding will not occur under EPU conditions prior to the restart of a RBCCW pump.

For steam line break LOCAs, including the MSLB, the DW temperature at EPU conditions (335.2°F as shown on Note 6 of Table 2.6-1) is bounded by the CLTP peak DW temperature of 336°F used in the analysis of record (using the same initial DW temperature of 150°F at both CLTP and EPU). The peak DW temperature at EPU using a conservatively low initial DW temperature (70°F) to maximize the containment pressure response is 336.9°F (see Table 2.6-1), which slightly exceeds the peak temperature value used in the analysis of record. The slightly higher peak temperature will result in a slight reduction in the time to boil and a subsequent reduction in margin between the time to boil and the time that the RBCCW pumps restart and return flow to the drywell atmosphere cooling coils. This reduction in margin is considered negligible and does not affect the conclusion that voiding will not occur under EPU conditions prior to the restart of the RBCCW pump.

NEDC-33860P, Section 2.6.1.5, the first four paragraphs will be revised as follows:

2.6.1.5 Generic Letter 96-06

GL 96-06 identified potential problems with equipment operability and containment integrity during design-basis accident conditions as a result of: (1) water hammer and/or two-phase flow conditions in cooling water systems serving the containment air coolers; and (2) thermally induced over-pressurization of isolated piping sections in containment.

The calculation that supports the Browns Ferry responses to GL 96-06 states that in the event of a DBA-LOCA or steam line break event with a coincident LOOP, the RBCCW pumps will be load shed at the start of the event. The first RBCCW pump will then be given a start signal 40 seconds after it was shed. Should the first pump fail to start, the second pump will be given a start signal 3 seconds later. Based on computed results, voiding in the RBCCW drywell atmosphere cooling coils will not occur for at least:

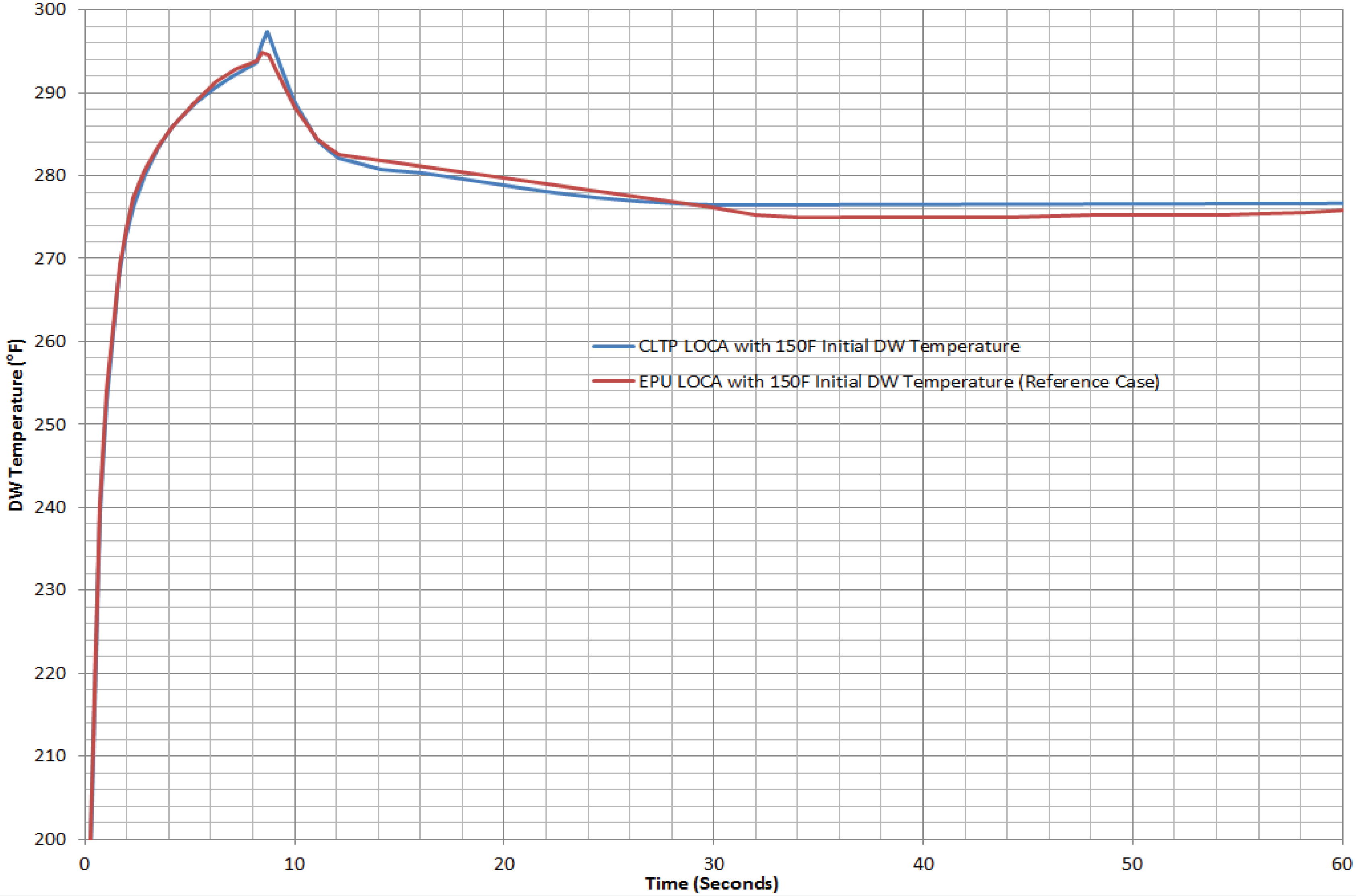
- 61 seconds on Units 2 and 3 for the DBA LOCA,
- 62 seconds on Units 2 and 3 for the steam line break.
- 46 seconds on Unit 1 for the steam line break.
- 49 seconds on Unit 1 for the DBA-LOCA.

As an RBCCW pump will have been restarted prior to voiding occurring, water hammer and/or two-phase flow in the RBCCW system are not a concern. The resultant time to boil is less in the Unit 1 analyses primarily due to two factors: (1) the drywell coolers were replaced in Unit 1 and the tubes in the Unit 1 replacement drywell coolers have a smaller inner diameter than the tubes used in the drywell coolers installed in Units 2 and 3, and 2) the modeling of the Unit 1 drywell cooler response was revised to more accurately represent the heat transfer by the drywell cooler tube fins.

A comparison of the drywell temperature profiles, during a DBA LOCA for current licensing basis and EPU conditions, shows a minor difference in temperature (less than 2°F) and lasting only seconds. Based on the minor differences in the drywell temperature profiles and the margin between the RBCCW pump start (43 seconds) and calculated time to boil (61 seconds for Units 2 and 3 and 49 seconds for Unit 1), it is concluded that voiding will not occur under EPU conditions prior to the restart of an RBCCW pump.

The maximum drywell temperature for the steam line break event at EPU conditions is bounded by the maximum drywell temperature used in the drywell cooler voiding analysis for the steam line break event at current licensing basis conditions. The drywell cooler voiding analysis for steam line breaks conservatively assumes that the drywell atmosphere instantaneously increases at the start of the event from the initial drywell temperature (150°F) to the peak drywell temperature (336°F). The drywell temperature is then assumed to remain at the peak temperature (336°F) for the duration of the event. Observation of Figure 2.6-9 shows that the drywell temperature response for steam line breaks during the first 100 seconds does not exceed 330°F. Therefore, the conclusion that an RBCCW pump will have been restarted prior to voiding occurring and that water hammer and two-phase flow in the RBCCW system are not a concern, is still valid. EPU is not altering the RBCCW system serving the drywell atmosphere cooling coils."

Figure SCVB-RAI 16-1: CLTP/EPU LOCA DW TEMP Starting at 150°F



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Section 2.5.3.2 of PUSAR under heading "Browns Ferry Current Licensing Basis" states:

> *Browns Ferry's current licensing basis regarding GL 89-13 is discussed in TVA's response to the NRC by letter dated March 16, 1990, "Response to Generic Letter 89-13 Service Water Problems Affecting Safety-Related Equipment.*

In the TVA response letter to GL 89-13, dated March 16, 1990, the response to NRC recommended action II states:

> *Inspect and clean the cooling water side of the RHR heat exchangers at least once per cycle.*

In Reference 7, response to SCVB-RAI 1 (b), under title "Frequency of Monitoring – Performance Testing," states:

> *Each RHR heat exchanger will have been performance tested at least once and will be tested periodically at an interval that initially will not exceed five years.*

In Reference 7, response to SCVB-RAI 1 (b), under title "Frequency of Monitoring - Visual Inspection and Cleaning" for EPU implementation states:

> *Each RHR heat exchanger will be cleaned once every 8-years or more frequently if the trended fouling rate indicates the need to take corrective actions in order to maintain the heat exchanger condition within the fouling resistance acceptance criteria.*

As stated above, the inspection and cleaning interval of the RHR heat exchangers in TVA's response to GL 89-13 was at least once every cycle (i.e., at least 2 years) as committed in TVA letter dated March 16, 1990. Currently the inspection and cleaning is interval is 4 years. The inspection and cleaning interval after EPU implementations is being proposed to increase to 8 years.

a. *Provide the basis for increasing the inspection and cleaning interval from 2 years to the current interval of 4-years, and*

b. *Provide the basis for the proposed increase in interval from 4 years to 8 years after EPU implementation. Justify the increase in intervals based on the <u>trending history</u> of the previous as-found inspection and cleanliness condition results of the RHR heat exchangers, such as the as-found number of partial and wholly plugged tubes, and/or any other parameter that reflected the cleanliness of the as-found heat exchanger.*

TVA Response (Revision 1):

a. The basis for increasing the inspection and cleaning interval for the RHR heat exchangers as provided in the commitment change described in Enclosure 5 of Reference 1 ~~was~~ is as follows.

A Chemical Treatment Program was put into service in September of 1996. The chemicals are dispersed throughout the RHRSW System to control corrosion, clam infestation, and water fouling. Inspections conducted, after implementation of the Chemical Treatment Program and prior to submittal of the commitment change described in Reference 1, showed a relatively small amount of debris and indicated that the heat transfer surfaces were in good condition. Based on the Chemical Treatment Program and the previous inspection results, TVA revised the inspection and cleaning commitment, as described in the Reference 1 letter, to the following, "Inspect and clean the cooling water side of these heat exchangers periodically as determined by the preventive maintenance (PM) program." Four years was chosen to be the new inspection and cleaning frequency for the RHR heat exchangers at that time based on the PM program results.

Upon implementation of EPU, the frequency of inspection and cleaning will be as described in the response to SCVB-RAI 24b. below.

b. For EPU implementation, the inspect and clean frequency for the RHR heat exchangers will be in accordance with the current Generic Letter 89-13 commitment (i.e., inspect and clean the cooling water side of these heat exchangers periodically as determined by the preventative maintenance (PM) program). The current maximum interval for performing RHR heat exchanger inspection and cleaning is procedurally limited to five years (four years + 25%). Any increase in the inspect and clean interval beyond five years would be evaluated in accordance with PM program procedures, GL 89-13 program implementing procedures and TVA programmatic procedure change requirements. Changes to the PM performance interval (frequency) are procedurally controlled and require a technical justification for any increase of the PM performance interval. Consecutive satisfactory as-found inspections where the inspection acceptance criteria was satisfied have been used to technically justify extending the inspect and clean interval. For EPU implementation, inspection results and performance testing results will be used to technically justify extending the inspect and clean interval. The as-found inspection acceptance criteria is currently less than 77 tubes obstructed (sum of the number of tubes mechanically plugged and the number of tubes obstructed by macrofouling) and this acceptance criteria is unchanged for EPU. ~~The inspection and cleaning frequency will be determined by a Residual Heat Removal (RHR) Heat Exchanger Performance Monitoring Program being developed for implementation following EPU and will be maintained through the BFN PM Program. Each RHR heat exchanger has been tested at least once prior to June 16, 2016. Subsequent performance testing of each RHR heat exchanger will be performed periodically at an interval of nominally four years, not to exceed five years. The performance testing acceptance criteria will be used to demonstrate margin between the actual heat removal capability assumed in the containment analyses because it assumes more heat exchanger tubes are plugged in a given heat exchanger. Performance test results, in conjunction with trended fouling rate, will be used to determine if the margin to the acceptance criteria will be exceeded before the next scheduled inspection and cleaning. The heat exchangers will be cleaned on a maximum frequency of 8 years. This 8-year cleaning frequency is based on supporting PM-required eddy current testing of the RHR heat exchanger tubes. More frequent RHR heat exchanger inspection and cleaning will occur if the fouling rate, as trended, indicates the need to take corrective actions in order to maintain the heat exchanger condition within the fouling resistance acceptance criteria. These requirements will be~~

~~included in the Updated Final Safety Analysis Report as described in the response to SCVB-RAI 26.~~

Reference

1. Letter from TVA to NRC, "Browns Ferry Nuclear Plant (BFN) - Units 1, 2, and 3 - Summary Report for January 1, 1998, through May 31, 1999," dated November 8, 1999 (ML993270093)

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In Reference 4, the implementation Item 49, which is a license condition states:

> *Revise the program that monitors BFN Residual Heat Removal (RHR) heat exchanger performance for consistency with the assumptions of the NFPA [National Fire Protection Association] 805 Net Positive Suction Head (NPSH) analysis. The monitoring program shall include verification that the tested worst fouling resistance, with measurement uncertainty added, of all BFN Units 1, 2, and 3 RHR heat exchangers is less than the design value of 0.001517 hr-ft^2 – °F/BTU and the worst tube plugging is less than 4.57 percent.*

Provide the proposed revision to the above licensee condition for EPU implementation including the frequency of cleaning and testing of the RHR heat exchangers.

TVA Response (Revision 1):

The NFPA 805 license condition associated with implementation item 49 is proposed to be deleted. The RHR Heat Exchanger Performance Monitoring Program has already been established as required by the NFPA 805 license condition. These NFPA 805 licensing condition requirements have been incorporated into the applicable implementing procedures. ~~Copies of these implementing procedures, 0-TI-322, "RHR Heat Exchanger Performance Testing," and 0-TI-522, "Program for Implementing NRC Generic Letter 89-13," are provided as part of the revised response to SCVB-RAI 1, included in this EPU LAR supplement.~~

In order to support deletion of the NFPA 805 license condition associated with implementation item 49, it is proposed to add RHR Heat Exchanger Performance Monitoring Program requirements to the Administrative Controls section of the BFN Technical Specifications (TS). Specifically, a new TS 5.5.14, "Residual Heat Removal (RHR) Heat Exchanger Performance Monitoring Program, is proposed to be added. This TS would require the establishment of a program to ensure the RHR heat exchangers are maintained in a condition that meets or exceeds the minimum performance capability assumed in the EPU containment analyses, which support not taking credit for containment accident pressure in the NPSH analyses. The TS would require RHR heat exchanger performance testing and overall uncertainty in the fouling resistance to be performed in accordance with the guidelines in the EPRI report, EPRI 3002005340, "Service Water Heat Exchanger Guidelines," dated May 2015. The TS requires the program to include the following.

a. Provisions for periodically monitoring RHR heat exchanger performance, including frequency of monitoring and methodology for considering uncertainty of the result.
b. Acceptance criteria for RHR heat exchanger worst fouling resistance and number of plugged tubes.
c. Limitations and compensatory actions if degraded performance is observed.
d. Controls for changes to program requirements.

The TS would require the details of the program to be described in the UFSAR.

Placing the RHR Heat Exchanger Performance Monitoring Program in the BFN TS, with detail of the program included in the UFSAR, provides assurance BFN RHR heat exchanger performance will be maintained consistent with BFN analysis and licensing bases. Changes to the BFN analysis and licensing bases associated with the RHR Heat Exchanger Performance Monitoring Program details included in the UFSAR will be controlled in accordance with 10 CFR 50.59, "Changes, tests, and experiments." The proposed program details to be included in the UFSAR are provided in the response to SCVB-RAI 26.

Including the fouling resistance and tube plugging acceptance criteria in the UFSAR enables BFN to address the impact of potential heat exchanger degraded conditions, associated fouling resistance or tube plugging, on past operability/functionality within the TVA CAP. ~~For example, basing thermal performance evaluations supporting past operability/functionality could be based on actual plant conditions that existed in the past (e.g., number of tubes plugged).~~ The current NFPA 805 license condition, with explicit limits, does not facilitate this type of past thermal performance evaluation.

The proposed Technical Specification 5.5.14 wording is as follows.

5.5.14 <u>Residual Heat Removal (RHR) Heat Exchanger Performance Monitoring Program</u>

This program is established to ensure that the RHR heat exchangers are maintained in a condition that meets or exceeds the minimum performance capability assumed in containment analyses, which support not taking credit for containment accident pressure in the NPSH analyses. The RHR heat exchanger testing and determination of overall uncertainty in the fouling resistance shall be in accordance with the guidelines in EPRI report, EPRI 3002005340, Service Water Heat Exchanger Test Guidelines, May 2015. This program establishes the following attributes.

a. The program establishes provisions to periodically monitor RHR heat exchanger thermal performance. The program includes frequency of monitoring and the methodology considers uncertainty of the result.

b. The program establishes and controls acceptance criteria for RHR heat exchanger worst fouling resistance and number of plugged tubes.

c. The program establishes limitations and allows for compensatory actions if degraded performance is observed.

d. Changes to the program shall be made under appropriate administrative review.

e. Details of the program including program limitations, compensatory actions for degraded performance, testing method, data acquisition method, data reduction method, overall uncertainty determination method, thermal performance analysis, acceptance criteria, and computer programs used that meet the 10 CFR 50 Appendix B, and 10 CFR 21 requirements are described in the UFSAR.

SCVB-RAI 26

Provide the proposed revision to the GL 89-13 response applicable to the RHR heat exchanger for EPU implementation.

TVA Response (Revision 1):

The Browns Ferry Nuclear Plant (BFN) maintains a residual heat removal (RHR) Heat Exchanger Performance Monitoring Program designed to ensure the heat transfer capability of the RHR heat exchangers meet or exceed the minimum performance capability assumed in containment analyses, which support not taking credit for containment accident pressure in the NPSH analyses. The scope of the RHR Heat Exchanger Performance Monitoring Program is limited to the RHR heat exchangers. The program is implemented by the associated Generic Letter (GL) 89-13 program procedure. Requirements of the GL 89-13 program procedure are implemented through the BFN preventive maintenance (PM) program.

Upon EPU implementation, the RHR Heat Exchanger Performance Monitoring Program is proposed to be included in the BFN Technical Specifications. RHR Heat Exchanger Performance Monitoring Program requirements will be described in the UFSAR. The changes to the RHR Heat Exchanger Performance Monitoring Program for EPU are summarized below and are reflective of the revised EPU LAR Attachment 39. The following details will be reflected in the UFSAR.

1. The EPU DBA-LOCA minimum required heat removal rate is 80,136,000 Btu/hour (hr) per heat exchanger with two heat exchangers in service. The EPU fire event minimum required heat removal rate is 124,966,800 Btu/hr with one heat exchanger in service.

2. The EPU thermal performance ~~test~~ acceptance criteria for an RHR heat exchanger is less than or equal to 0.001562 hr-ft^2-F/Btu with no more than 77 tubes (4.57% of 1700 tubes) ~~mechanically~~ plugged. ~~The test acceptance criteria is used to demonstrate margin between actual heat removal capability and minimum required heat removal capability assumed in the containment analyses because it assumes more tubes plugged than the actual number of tubes plugged in the given heat exchanger. Performance test results in conjunction with trended fouling rate, is used to determine if the margin to the acceptance criteria will be exceeded before the next scheduled inspection and cleaning.~~

3. The nominal (measured) test result (fouling resistance) including the test and measurement uncertainty will be used for comparison to the EPU thermal performance acceptance criteria.

4. The program includes the following requirements:

   a. Each RHR heat exchanger was performance tested at least once prior to the NFPA 805 implementation date, June 16, 2016.

   b. Upon EPU implementation, each RHR heat exchanger will be performance tested at a nominal interval of four years, not to exceed five years.

c. The RHR heat exchangers will be periodically inspected and cleaned~~cleaned at an interval that will not exceed 8 years. This 8-year cleaning frequency is based on supporting PM-required eddy current testing of the RHR heat exchanger tubes. More frequent RHR heat exchanger inspection and cleaning will occur if the fouling rate (as trended) indicates the need to take corrective actions in order to maintain the heat exchanger condition within the fouling resistance acceptance criteria~~. The inspect and clean interval for the RHR heat exchangers will be in accordance with the Generic Letter (GL) 89-13 commitment (i.e., inspect and clean the cooling water side of these heat exchangers periodically as determined by the preventative maintenance (PM) program). The current maximum interval for performing RHR heat exchanger inspection and cleaning is procedurally limited to five years (four years + 25%). Any increase in the inspect and clean interval beyond five years would be evaluated in accordance with PM program procedures, GL 89-13 program implementing procedures and TVA programmatic procedure change requirements. Changes to the PM performance interval (frequency) are procedurally controlled and require a technical justification for any increase of the PM performance interval. Inspection results and performance testing results will be used to technically justify extending the inspect and clean interval. The as-found inspection acceptance criteria is less than 77 tubes obstructed (sum of the number of tubes mechanically plugged and the number of tubes obstructed by macrofouling).

~~5. Thermal performance testing results, including uncertainty, is trended consistent with ASME OM 2015, Part 21, Section 6.10, to facilitate determining fouling rate. BFN takes exception to the second paragraph of Section 6.10.2 in that the test program currently compares the test fouling resistance results to the acceptance criteria. BFN did not trend the fouling resistance for a minimum of three tests or monitoring points prior to comparison to the acceptance criteria.~~

5~~6~~. Temporary surface mounted temperature instrumentation for RHR and RHRSW inlet and outlet piping meets the guidance provided in EPRI 3002005340, Service Water Heat Exchanger Test Guidelines, May 2015.

6~~7~~. Temporary differential pressure (DP) instrumentations connected to the instrument taps from the permanently installed RHRSW flow orifices and RHR flow nozzles meet the guidance provided in EPRI 3002005340, Service Water Heat Exchanger Test Guidelines, May 2015.

7~~8~~. Temporary instrumentation includes a temporary data acquisition system (DAS). The DAS software translates instrument output into data files that may be loaded into analytical software. Time stamped data is collected from each temporary instrument sensor. The DAS, including the associated software, complies with the guidance provided in EPRI 3002005340, Service Water Heat Exchanger Test Guidelines, May 2015.

8~~9~~. Temporary instruments are calibrated against standards traceable to the National Institute of Standards and Technology or compared to nationally or internationally recognized consensus standards.

9~~10~~. Test data is analyzed in accordance with EPRI 3002005340, Service Water Heat Exchanger Test Guidelines, May 2015. The analysis determines the overall fouling resistance for the heat exchanger and also determines the associated uncertainty in the test result (fouling resistance).

10~~1~~. The uncertainty analysis methodology complies with the approach described in EPRI 3002005340, Service Water Heat Exchanger Test Guidelines, May 2015.

11~~2~~. Data reduction complies with the approach described in EPRI 3002005340, Service Water Heat Exchanger Test Guidelines, May 2015.

12~~3~~. Computer programs used in the thermal performance analysis are required to meet the 10 CFR 50 Appendix B, and 10 CFR 21 requirements. PROTO-HX is the computer program used for thermal performance analyses in the RHR Heat Exchanger Performance Monitoring Program.

~~14. Test results in conjunction with trended fouling rate are projected and compared to the test fouling resistance acceptance criterion to schedule the next performance of the cleaning or testing PM in a manner consistent with ASME OM 2015, Section 9, Acceptance Criteria.~~

13~~5~~. Compensatory measures will be established based upon actual plant conditions. Compensatory measures include entering the condition into the TVA CAP, cleaning of the heat exchangers after inspections, determining if more frequent inspections and cleaning are required, and evaluating past operability/functionality when tube plugging and macrofouling acceptance criteria from inspection procedures are not met. The methodology for performing as-found and as-left inspections are provided in TVA Standard Programs and Processes procedures. As-left inspections are procedurally required and ensure that tubes found blocked/obstructed by macrofouling will not be left in the as-found condition. ~~The number of tubes found obstructed by macrofouling during heat exchanger (as-found) inspections is compared to acceptance criteria for the total number of tubes that can be mechanically plugged, which is identified in implementing procedures. Upon EPU implementation acceptance criteria will also be provided for the total number of tubes that can be blocked/obstructed (includes tubes mechanically plugged and tubes obstructed by macrofouling) for a given fouling resistance (see Table SCVB-RAI 26). These acceptance criteria are used to determine whether a subsequent engineering evaluation is required and are limited to use in evaluating only as-found conditions. Degraded conditions are entered into the TVA CAP.~~

14~~6~~. Changes to the program requirements above will be controlled in accordance with 10 CFR 50.59, “Changes, tests, and experiments.” Change to the program requirements may be made without prior NRC approval provided the changes do not require a change to the Technical Specification requirements and the changes do not require NRC approval pursuant to 10 CFR 50.59.

~~Table SCVB-RAI 26: RHR Heat Exchanger - Fouling Resistance and Total Tube Plugging Allowed~~

~~Fouling Resistance*~~	~~Total Number of Tubes Allowed Blocked (Number of Tubes Mechanically Plugged + Number of Tubes Blocked by Macrofouling)~~
~~(hr-ft^2-°F/Btu)~~	~~(each)~~
~~0.001694~~	~~0~~
~~0.001677~~	~~10~~
~~0.001660~~	~~20~~
~~0.001648~~	~~27~~
~~0.001643~~	~~30~~
~~0.001626~~	~~40~~
~~0.001609~~	~~50~~
~~0.001592~~	~~60~~
~~0.001575~~	~~70~~
~~0.001558~~	~~80~~
~~0.001541~~	~~90~~
~~0.001524~~	~~100~~
~~0.001507~~	~~110~~
~~0.001490~~	~~120~~
~~0.001473~~	~~130~~
~~0.001456~~	~~140~~
~~0.001439~~	~~150~~
~~0.001422~~	~~160~~
~~0.001405~~	~~170~~
~~0.001389~~	~~180~~
~~0.001372~~	~~190~~
~~0.001355~~	~~200~~
~~0.001338~~	~~210~~
~~0.001321~~	~~220~~
~~0.001304~~	~~230~~
~~0.001287~~	~~240~~
~~0.001270~~	~~250~~
~~0.001253~~	~~260~~
~~0.001236~~	~~270~~
~~0.001219~~	~~280~~
~~0.001203~~	~~290~~
~~0.001186~~	~~300~~
~~0.001169~~	~~310~~
~~0.001152~~	~~320~~
~~0.001135~~	~~330~~
~~0.001118~~	~~340~~
~~0.001101~~	~~350~~
~~0.001085~~	~~360~~
~~0.001068~~	~~370~~
~~0.001051~~	~~380~~
~~0.001034~~	~~390~~
~~0.001017~~	~~400~~
~~0.001001~~	~~410~~
~~0.000984~~	~~420~~
~~0.000975~~	~~425~~

ENCLOSURE

~~*For fouling resistances less than 0.000975 hr-ft^2-°F/Btu the total number of tubes allowed blocked without an engineering evaluation is limited to no more than 425 tubes, which is one-half of the number of tubes in the heat exchanger inlet pass (850 tubes).~~