Progress Energy

Crystal River Nuclear Plant
Docket No. 50-302
Operating License No. DPR-72

Ref: 10 CFR 50.90

August 12, 2005
3F0805-06

U.S. Nuclear Regulatory Commission
Attn: Document Control Desk
Washington, DC 20555-0001

Subject: Crystal River Unit 3 – License Amendment Request #290, Revision 1 Probabilistic Methodology to Determine the Contribution to Main Steam Line Break Leakage Rates for the Once-Through Steam Generator from the Tube End Crack Alternate Repair Criteria

Reference: PEF to NRC letter dated January 27, 2005, Crystal River Unit 3 – License Amendment Request #290, Revision 0, "Probabilistic Methodology to Determine the Contribution to Main Steam Line Break Leakage Rates for the Once-Through Steam Generator from the Tube End Crack Alternate Repair Criteria"

Dear Sir:

Florida Power Corporation, doing business as Progress Energy Florida, Inc. (PEF), hereby submits License Amendment Request (LAR) #290, Revision 1. This Revision to LAR #290 proposes to incorporate Crystal River Unit 3 (CR-3) specific Addenda B and C to BAW-2346P, Revision 0 into the CR-3 Improved Technical Specification (ITS) 5.6.2.10.2.f.

Attachments A and B have been updated to discuss the proposed ITS change provided in Attachments C (shadowed format) and D (revision bar format). CR-3 considers that the No Significant Hazards Consideration Determination conclusion provided in LAR #290, Revision 0, does not need to be re-noticed in the Federal Register due to the inclusion of Addenda B and C into the CR-3 ITS.

This LAR is proposing to utilize a probabilistic methodology to determine the contribution to Main Steam Line Break (MSLB) leakage rates for the Once-Through Steam Generator (OTSG) from the Tube End Crack (TEC) Alternate Repair Criteria (ARC) described in CR-3 Improved Technical Specifications (ITS) 5.6.2.10.2.f. The probabilistic methodology is being provided in Attachment E as Addendum B to Topical Report BAW-2346P, Revision 0.

Attachment F to this submittal contains Addendum C to Topical Report 2346P, Revision 0, which provides the method for projecting the TEC leakage that may develop during the next operating cycle. This method will be applied to each subsequent operating cycle after inspection results are obtained from the previous operating cycle.

A001

Enclosure does not contain Proprietary Info per Licensee

Progress Energy Florida, Inc.
Crystal River Nuclear Plant
15760 W. Powerline Street
Crystal River, FL 34428

Attachment G provides the CR-3 response to an NRC Request for Additional Information (RAI) regarding LAR #290. The RAI was provided to CR-3 by electronic mail and was discussed with the NRC staff on July 7, 2005.

PEF respectfully requests NRC review of LAR #290, Revision 1, be performed to support an approval date of October 1, 2005.

This letter establishes no new regulatory commitments.

The CR-3 Plant Nuclear Safety Committee has reviewed this request and recommended it for approval.

If you have any questions regarding this submittal, please contact Mr. Sid Powell, Supervisor, Licensing and Regulatory Programs at (352) 563-4883.

Sincerely,

Dale E. Young
Vice President
Crystal River Nuclear Plant

DEY/lvc

Attachments:

A. Background, Description of Proposed Change, Reason for Request and Evaluation of Request
B. Regulatory Analysis (No Significant Hazards Consideration Determination, Applicable Regulatory Requirements and Environmental Impact Evaluation)
C. Proposed Improved Technical Specification Page – Shadowed format
D. Proposed Improved Technical Specification Page – Revision Bar Format
E. Addendum B Dated August 10, 2005 to Topical Report BAW-2346P, Revision 0, Probabilistic Leakage Assessment of Crystal River Unit 3 Steam Generator (SG) Tube End Cracks
F. Addendum C Dated August 12, 2005 to Topical Report BAW-2346P, Revision 0
G. Response to Request for Additional Information (RAI) Regarding License Amendment Request #290, Revision 0

xc: NRR Project Manager
Regional Administrator, Region II
Senior Resident Inspector

STATE OF FLORIDA

COUNTY OF CITRUS

Dale E. Young states that he is the Vice President, Crystal River Nuclear Plant for Florida Power Corporation, doing business as Progress Energy Florida, Inc.; that he is authorized on the part of said company to sign and file with the Nuclear Regulatory Commission the information attached hereto; and that all such statements made and matters set forth therein are true and correct to the best of his knowledge, information, and belief.

____

Dale E. Young
Vice President
Crystal River Nuclear Plant

The foregoing document was acknowledged before me this _____ day of _______________, 2005, by Dale E. Young.

____

Signature of Notary Public
State of Florida

____

(Print, type, or stamp Commissioned
Name of Notary Public)

Personally Known ______ -OR- Produced Identification ______

PROGRESS ENERGY FLORIDA, INC.

CRYSTAL RIVER UNIT 3

DOCKET NUMBER 50-302/LICENSE NUMBER DPR-72

ATTACHMENT A

LICENSE AMENDMENT REQUEST #290, REVISION 1

Background, Description of Proposed Change, Reason for Request and Evaluation of Request

Background

On October 1, 1999, the NRC issued License Amendment No. 188 for Crystal River Unit 3 (CR-3) approving an alternate repair criteria to be applied to steam generator tubes with crack-like indications within the upper and lower tubesheet areas. The technical basis for the alternate repair criteria is contained in a Babcock and Wilcox Owners Group topical report, "Alternate Repair Criteria for Tube End Cracking in the Tube-to-Tubesheet Roll Joint of Once Through Steam Generators," BAW-2346P, Revision 0 (Proprietary).

The leakage integrity of the steam generator tubes was demonstrated in the topical report by leak testing. Before leak testing, a finite element model to analyze structural behavior of the tubes was used to determine test parameters that would give the least tight test roll joints, which in turn would give maximum possible leak rates in the leakage tests.

Topical Report BAW-2346P, Revision 0, specifies a number of requirements and limitations in order to implement the alternate repair criteria on tubes having Tube End Crack indications (TEC). Calculation of the combined total leakage from all primary-to-secondary sources, including TEC indications left in service, is one of the requirements contained in the topical report. The approved Alternate Repair Criteria (ARC) required that the combined total leakage from all primary-to-secondary sources, including TEC indications left in service, shall not exceed the main steam line break (MSLB) accident leakage limit (one gallon per minute for CR-3) minus operational leakage (150 gallons per day per steam generator). For tubes with multiple indications, a separate leak rate for each indication must be used.

The current CR-3 TEC leakage assessment is based on a deterministic relationship of tube location in the bundle (tubesheet radius) and tubesheet hole dilation during a Main Steam Line Break (MSLB) event. Probabilistic estimates plus actual tube loading are more realistic and provide better predictions for actual leakage.

The condition monitoring evaluation performed as part of the steam generator inspection conducted during Refueling Outage 13 (October 2003), identified the postulated leakage from the as-found indications did exceed the MSLB limit. CR-3 reported that condition in LER 50-302/2004-004-00.

Use of the probabilistic method and actual tube loading will result in increased margin to total MSLB leakage. The increased margin in combination with a more conservative method to project TEC leakage for the subsequent cycle (Attachment F) will ensure future CR-3 MSLB leakage results remain within required ITS limits.

The actual operating primary-to-secondary leakage values for CR-3 are significantly under the 5 gallon per day threshold limit from the Electrical Power Research Institute (EPRI) Primary-to-Secondary Leak Guidelines.

Description of the Proposed License Amendment Request

License Amendment Request (LAR) #290, Revision 1, is proposing to utilize a probabilistic methodology to determine the contribution to the MSLB leakage rates for the Once-Through Steam Generator (OTSG) from the TEC ARC described in the CR-3 Improved Technical Specifications (ITS) 5.6.2.10.2.f. Attachment E to this submittal contains Addendum B to Topical Report 2346P, Revision 0, which is the basis of the proposed probabilistic methodology.

Attachment F to this submittal contains Addendum C to Topical Report 2346P, Revision 0, which provides the method and the technical justification for projecting the TEC leakage that may develop during the next operating cycle following each inservice inspection of the CR-3 OTSGs.

This LAR revision involves a change to ITS 5.6.2.10.2.f to incorporate the methodologies of Addenda B and C which are provided in Attachments E and F of this submittal.

The methodology change for TEC leakage calculation proposed in this LAR, and provided in Addendum B, utilizes the same probabilistic process approved by the NRC Generic Letter (GL) 95-05, "Voltage-Based Repair Criteria for Westinghouse Steam Generator Tubes Affected by Outside Diameter Stress Corrosion Cracking."

Description of the Proposed ITS 5.6.2.10.2.f Text Change

The following text will be added to ITS 5.6.2.10.2.f to incorporate the methodologies in Addenda B and C:

"The contribution to MSLB leakage rates from TEC indications shall be determined utilizing the methodology in Addendum B dated August 10, 2005 to Topical Report BAW-2346P, Revision 0. The projection of TEC leakage that may develop during the next operating cycle shall be determined using the methodology in Addendum C dated August 12, 2005 to Topical Report BAW-2346P, Revision 0."

Reason for Request

The process described in Topical Report BAW-2346P, Revision 0, and approved in License Amendment No. 188 for calculating leakage and currently used by CR-3 uses a very conservative, deterministic method. CR-3 is seeking approval for a leakage calculation method (Addendum B, Attachment E of this submittal) which removes some of the excessive conservatism inherent in the current approach while providing conservative results at a high level of confidence. The process described in Topical Report BAW-2346P, Revision 0, does not include the method to project the TEC leakage that may develop during the next operating cycle other than accounting for POD of undetected indications. CR-3 is providing this method and its technical justification in Addendum C (Attachment F of this submittal).

Evaluation of Request

Current TEC Leak Rate Calculation Methodology

Tubesheet distortion caused by differential thermal and pressure effects during a MSLB alters the tightness of the roll expanded tube-to-tubesheet joint. During the initial development of BAW-2346P, Revision 0, finite element analyses were performed to conservatively determine key parameters including joint tightness and axial tube load under MSLB conditions. It was determined that joint tightness and axial tube load vary with the distance from the center of the tubesheet. Consequently, a number of concentric tubesheet zones were defined for use in determining TEC leakage based upon the tightness of the joint.

A series of bounding leak tests using 100% through-wall (TW) Electrical Discharge Machined (EDM) notches confirmed that there is a correlation between leakage and joint tightness. Based upon the leakage tests and the defined zones, a leakage value was assigned to all tubes within each zone. The assigned value is the maximum leakage for any tube within that zone. Under the current leakage calculation method, each TEC within a particular zone is assigned that zone's leakage value. The total leakage for all zones is the estimated OTSG leakage resulting from TEC under MSLB conditions.

This approach conservatively assumes that every TEC has perforated the tube wall and will leak, when in fact, many TEC have not advanced to that depth. It also conservatively assumes that multiple TEC within a particular tube will each contribute to the overall TEC leakage, when in fact, the leakage from a tube is limited not by the number of cracks present but by the tightness of the joint. Finally, it assumes that the axial tube load applied during the tests was representative of the load which would occur during a CR-3 MSLB, while the CR-3 MSLB loads are much lower than the tests. These assumptions yield very conservative leakage estimates.

The initial submittal of LAR #249, Revision 0, indicated that CR-3 would use specific leak rates for CR-3 based on the MSLB tube loads. These were to be included in an addendum to BAW-2346P. Addendum A was submitted on May 28, 1999. The submittal stated that the Addendum included the CR-3 plant specific MSLB tube loads. In actuality, the Addendum leak rates were partially based upon the bounding laboratory test results with an applied axial load of 3,060 pounds. The increased effect of this laboratory applied axial load on tube tubesheet hole dilation (i.e., change from round to oval) has been neglected in Topical Report BAW-2346P, Revision 0, and the subsequent Addendum A. Similarly, this effect was neglected in the development of the CR-3 delta dilations in the topical report and addendum. Neglecting this effect produces overly conservative leakage estimates because the axial load applied during the tests (3,060 pounds) was significantly larger than the maximum axial load which would occur during a CR-3 MSLB (663 pounds). This submittal includes an accounting of the affect of the reduced axial load on tube dilation for both the laboratory test results and the CR-3 MSLB conditions, and provides a more realistic result yet remains conservative.

Probabilistic Methodology

The methodology described in Framatome ANP, "Probabilistic Leakage Assessment of Crystal River Unit 3 Steam Generator (SG) Tube End Cracks," (Attachment E), reduces some of the conservatisms in the current approach while generating appropriately conservative, high confidence leakage estimates.

The methodology relies on the same accident analyses described in Topical Report BAW-2346P, Revision 0, and License Amendment Request #249, Revision 0, and utilizes the same leakage test data and leakage limit. The methodology preserves the assumption that multiple cracks within the same tube will multiply the leakage from that tube. Unlike the GL 95-05 approach, which assumes that some cracks are not capable of leaking (probability of leakage), the probabilistic approach described herein, assumes that every crack leaks.

The currently approved method for calculating leakage assumes that all cracks within a given zone will leak at the maximum level for that zone. In the proposed methodology, each crack is evaluated with respect to its radial position in the tubesheet. The difference in axial loads between CR-3 and the leakage test program are accounted for in this approach. One significant difference between the current method of TEC leakage calculation and the new method proposed herein, is that instead of assigning each crack a fixed quantity of leakage based on its position in the tubesheet, the proposed method assigns individual leakage values probabilistically.

Consistent with the NRC-approved GL 95-05, "Voltage-Based Repair Criteria for Westinghouse Steam Generator Tubes Affected by Outside Diameter Stress Corrosion Cracking," dated August 3, 1995, the probabilistic approach for TEC leakage calculation accounts for the uncertainties associated with the leakage correlation, in this case, the correlation of leakage to joint tightness during a MSLB. Total OTSG leakage is determined by summing the individual probabilistic leakage for each crack. Thousands of estimates of OTSG leakage are developed and processed to determine the upper 95^{th} percentile/95% confidence estimate for total OTSG leakage. This proposed statistical method concludes, with a 95% confidence, that there is a 95% probability the actual leakage will be less than the calculated value.

Conclusion

The results in Attachment E show that the proposed methodology estimates a lower total leak rate for the CR-3 OTSGs than the deterministic method. Although the proposed methodology preserves conservatisms not assumed in the GL 95-05 approach, it employs the same GL 95-05 calculational methodology which provides a realistic bounding approach to leakage calculation and a high level of confidence.

References

1. CR-3 to NRC letter, 3F0599-02, dated May 5, 1999, "License Amendment Request #249, Revision 0, Once Through Steam Generator Tube Surveillance Program, Alternate Repair Criteria for Axial Tube End Crack Indications" (includes BAW-2346P, Revision 0)

2. CR-3 to NRC letter, 3F0599-21, dated May 28, 1999, "License Amendment Request #249, Revision 0, Once Through Steam Generator Tube Surveillance Program (TAC No. MA5395), Addendum to Babcock & Wilcox Owners Group Topical Report BAW 2346P" (includes BAW-2346P, Revision 0, Addendum A)

3. NRC to CR-3 letter, 3N1099-01, dated October 1, 1999, "Crystal River Unit 3 – Issuance of Amendment Regarding Alternate Repair Criteria for Steam Generator Tubing" (TAC No. MA5395)

4. Generic letter 95-05, "Voltage-Based Repair Criteria for Westinghouse Steam Generator Tubes Affected by Outside Diameter Stress Corrosion Cracking," dated August 3, 1995

5 Licensee Event Report 50-302/2004-004-00 dated November 22, 2004

6. CR-3 to NRC letter, 3F0105-03, dated January 27, 2005, "Crystal River Unit 3 – License Amendment Request #290, Revision 1, Probabilistic Methodology to Determine the Contribution to Main Steam Line Break Leakage Rates for the Once-Through Steam Generator from the Tube End Crack Alternate Repair Criteria"

PROGRESS ENERGY FLORIDA, INC.

CRYSTAL RIVER UNIT 3

DOCKET NUMBER 50-302/LICENSE NUMBER DPR-72

ATTACHMENT B

LICENSE AMENDMENT REQUEST #290, Revision 1

Regulatory Analysis

No Significant Hazards Consideration Determination
Applicable Regulatory Requirements
Environmental Impact Evaluation

No Significant Hazards Consideration Determination

License Amendment Request (LAR) #290, Revision 0, proposed change consists of a change in methodology for Tube End Crack (TEC) leakage calculation and the addition of a method to project the number of TEC indications that may initiate during the next operating cycle.

This LAR proposes to utilize a probabilistic methodology (Addendum B dated August 10, 2005 to Topical Report BAW-2346P, Revision 0) to determine the contribution to the Main Steam Line Break (MSLB) leakage rates from the Once-Through Steam Generator (OTSG) TEC Alternate Repair Criteria (ARC) approved in License Amendment No. 188. This LAR also proposes to add the methodology provided in Addendum C dated August 12, 2005, to Topical Report BAW-2346P, Revision 0, to project the TEC leakage that may develop at Crystal River Unit 3 (CR-3) during the next operating cycle. Reference to Addenda B and C has been added to Improved Technical Specifications (ITS) 5.6.2.10.2.f.

1. *Does not involve a significant increase in the probability or consequences of an accident previously evaluated.*

This LAR proposes to change the method to determine the projected MSLB leakage rates for TEC. Potential leakage from OTSG tubes, including leakage contribution from TEC, is bounded by the MSLB evaluation presented in the CR-3 Final Safety Analysis Report (FSAR) and testing performed during the development of Topical Report BAW-2346P, Revision 0. The inspection required by the ARC will continue to be performed as required by CR-3 ITS 5.6.2.10. This inspection provides continuous monitoring of tubes with TEC indications remaining in service, and ensures that degradation of new tubes containing TEC indications is detected. The proposed change in method to determine MSLB leakage rates for TEC and the addition of a method to project the TEC leakage that may develop during the next operating cycle do not change any accident initiators.

Therefore, granting this LAR does not involve a significant increase in the probability or consequences of an accident previously evaluated.

2. *Does not create the possibility of a new or different type of accident from any accident previously evaluated.*

This LAR proposes to change the method to determine the projected MSLB leakage rates for TEC and the addition of a method to project the TEC leakage that may develop during the next operating cycle. The changes introduce no new failure modes or accident scenarios. The proposed changes do not change the assumptions made in Topical Report BAW-2346P, Revision 0, which demonstrated structural and leakage integrity for all normal operating and accident conditions for CR-3. The addition of a method to project the TEC leakage provides an additional means to monitor the initiation of TEC. The design and operational characteristics of the OTSGs are not impacted by the use of a probabilistic methodology to determine MSLB leakage rates.

Therefore, the proposed change will not create the possibility of a new or different kind of accident from any previously evaluated.

3. *Does not involve a significant reduction in the margin of safety.*

This LAR proposes to change the method to determine the projected MSLB leakage rates for TEC and the addition of a method to project the TEC leakage that may develop during the next operating cycle. The resulting leakage estimates will be lower than the estimates from the old method. However, the estimates from the proposed method will be more realistic and do not impact the acceptance criteria. The methodology relies on the same accident analyses described in Topical Report BAW-2346P, Revision 0, and License Amendment Request #249, Revision 0, and utilizes the same leakage test data and leakage limit. The CR-3 FSAR analyzed accident scenarios are not affected by the change and remain bounding. The limits established in CR-3 ITS 3.4.12 and 5.6.2.10.2.f have not been changed. The addition of a method to project the TEC leakage that may develop during the next operating cycle provides an additional means to monitor the initiation of TEC. Therefore, the proposed change does not reduce the margin of safety.

Based on the above, Progress Energy Florida, Inc. (PEF) concludes that the proposed LAR presents a no significant hazards consideration under the standards set forth in 10 CFR 50.92(c), and accordingly, a finding of "no significant hazards consideration" is justified.

Applicable Regulatory Requirements

PEF has evaluated the Regulatory Requirements applicable to the proposed changes. PEF has determined that the proposed changes do not require any exemptions or relief from regulatory requirements other than the change in methodology for TEC leakage calculation. The probabilistic methodology is being provided as Addendum B to Topical Report BAW-2346P, Revision 0. Addendum B supersedes the previously approved Addendum A. Addendum C to Topical Report BAW-2346P, Revision 0, provides the method to project the TEC leakage that may develop during the next operating cycle.

Environmental Impact Evaluation

10 CFR 51.22(c)(9) provides criteria for identification of licensing and regulatory actions eligible for categorical exclusion from performing an environmental assessment. A proposed amendment to an operating license for a facility requires no environmental assessment if operation of the facility in accordance with the proposed amendment would not:

(i) involve a significant hazards consideration,

(ii) result in a significant change in the types or significant increase in the amounts of any effluents that may be released offsite, and

(iii) result in a significant increase in individual or cumulative occupational radiation exposure.

PEF has reviewed proposed License Amendment Request #290, Revision 1, and concludes it meets the eligibility criteria for categorical exclusion set forth in 10 CFR 51.22(c)(9). Pursuant to 10 CFR 51.22(c), no environmental impact statement or environmental assessment needs to be prepared in connection with this request.

PROGRESS ENERGY FLORIDA, INC.

CRYSTAL RIVER UNIT 3

DOCKET NUMBER 50-302/LICENSE NUMBER DPR-72

ATTACHMENT C

LICENSE AMENDMENT REQUEST #290, REVISION 1

PROPOSED IMPROVED TECHNICAL SPECIFICATION PAGE

Shadowed Format

Shadowed Text Indicates Added Text

5.6 Procedures, Programs and Manuals

5.6.2.10 OTSG Tube Surveillance Program (continued)

The inspection data for tubes with axially oriented TEC indications shall be compared to the previous inspection data to monitor the indications for growth.

Tubes with axially oriented TEC may be left in-service using the method described in Topical Report BAW-2346P, Revision 0, provided the combined projected leakage from all primary-to-secondary leakage, including axial TEC indications left in-service, does not exceed the Main Steam Line Break (MSLB) accident leakage limit of one gallon per minute, minus 150 gallons per day, per OTSG. The contribution to MSLB leakage rates from TEC indications shall be determined utilizing the methodology in Addendum B dated August 10, 2005 to Topical Report BAW-2346P, Revision 0. The projection of TEC leakage that may develop during the next operating cycle shall be determined using the methodology in Addendum C dated August 12, 2005 to Topical Report BAW-2346P, Revision 0.

If the plant is required to shut down due to primary-to-secondary leakage and the cause is determined to be degradation of the TEC portion of the tubes, 100% of the tubes with TEC in that OTSG shall be examined in the location of the TEC. If more than 1% of the examined tubes are defective tubes, 100% of the tubes with TEC in the other OTSG shall be examined in the location of the TEC.

Tubes with crack-like indications within the carbon steel portion of the tubesheet shall be repaired or removed from service using the appropriate approved method. Tubes with circumferentially oriented TEC or volumetric indications within the Inconel clad region of the tubesheet shall be repaired or removed from service using the appropriate approved method.

The results of each bobbin coil sample inspection shall be classified into one of the following three categories:

------------------------- NOTE -------------------------
In all inspections, previously degraded tubes whose degradation has not been spanned by a sleeve must exhibit significant (>10%) further wall penetrations to be included in the below percentage calculations.

------------------------- NOTE -------------------------
For the inspection conducted in accordance with 5.6.2.10.2.f, only tubes with TEC indications identified after the 1997 inspection will be included in the below percentage calculations.

Category	Inspection Results
C-1	Less than 5% of the total tubes inspected are degraded tubes and none of the inspected tubes are defective.
C-2	One or more tubes, but not more than 1% of the total tubes inspected are defective, or between 5% and 10% of the total tubes inspected are degraded tubes.

(continued)

PROGRESS ENERGY FLORIDA, INC.

CRYSTAL RIVER UNIT 3

DOCKET NUMBER 50-302/LICENSE NUMBER DPR-72

ATTACHMENT D

LICENSE AMENDMENT REQUEST #290, REVISION 1

PROPOSED IMPROVED TECHNICAL SPECIFICATION PAGE

Revision Bar Format

5.6 Procedures, Programs and Manuals

5.6.2.10 OTSG Tube Surveillance Program (continued)

The inspection data for tubes with axially oriented TEC indications shall be compared to the previous inspection data to monitor the indications for growth.

Tubes with axially oriented TEC may be left in-service using the method described in Topical Report BAW-2346P, Revision 0, provided the combined projected leakage from all primary-to-secondary leakage, including axial TEC indications left in-service, does not exceed the Main Steam Line Break (MSLB) accident leakage limit of one gallon per minute, minus 150 gallons per day, per OTSG. The contribution to MSLB leakage rates from TEC indications shall be determined utilizing the methodology in Addendum B dated August 10, 2005 to Topical Report BAW-2346P, Revision 0. The projection of TEC leakage that may develop during the next operating cycle shall be determined using the methodology in Addendum C dated August 12, 2005 to Topical Report BAW-2346P, Revision 0.

If the plant is required to shut down due to primary-to-secondary leakage and the cause is determined to be degradation of the TEC portion of the tubes, 100% of the tubes with TEC in that OTSG shall be examined in the location of the TEC. If more than 1% of the examined tubes are defective tubes, 100% of the tubes with TEC in the other OTSG shall be examined in the location of the TEC.

Tubes with crack-like indications within the carbon steel portion of the tubesheet shall be repaired or removed from service using the appropriate approved method. Tubes with circumferentially oriented TEC or volumetric indications within the Inconel clad region of the tubesheet shall be repaired or removed from service using the appropriate approved method.

The results of each bobbin coil sample inspection shall be classified into one of the following three categories:

------------------------- NOTE -------------------------
In all inspections, previously degraded tubes whose degradation has not been spanned by a sleeve must exhibit significant (>10%) further wall penetrations to be included in the below percentage calculations.

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For the inspection conducted in accordance with 5.6.2.10.2.f, only tubes with TEC indications identified after the 1997 inspection will be included in the below percentage calculations.

Category	Inspection Results
C-1	Less than 5% of the total tubes inspected are degraded tubes and none of the inspected tubes are defective.
C-2	One or more tubes, but not more than 1% of the total tubes inspected are defective, or between 5% and 10% of the total tubes inspected are degraded tubes.

(continued)

PROGRESS ENERGY FLORIDA, INC.

CRYSTAL RIVER UNIT 3

DOCKET NUMBER 50-302/LICENSE NUMBER DPR-72

ATTACHMENT E

LICENSE AMENDMENT REQUEST #290, REVISION 1

Addendum B Dated August 10, 2005 to Topical Report 2346P, Revision 0
Probabilistic Leakage Assessment of Crystal River Unit 3
Steam Generator (SG) Tube End Cracks

Non-proprietary

AREVA

ENGINEERING INFORMATION RECORD

Document Identifier 51 - 5053331 - 01

Title Probabilistic Leakage Assessment of Crystal River Unit 3 SG Tube End Cracks

PREPARED BY:		REVIEWED BY:	
Name	K.A.Colgan	Name	C.E.Martin
Signature	Date 8/10/2005	Signature	Date 8/10/2005

Technical Manager Statement: Initials

Reviewer is Independent.

Remarks:

This report documents a probabilistic methodology, developed for Crystal River Unit 3, to determine MSLB leakage rates for the OTSG tube end crack alternate repair criteria. This approach employs the same calculational methodology as that of the tube support plate alternate repair criteria (GL 95-05) incorporated in some PWR licenses. Regulator approval is expected to be required prior to implementation. The methodology is implemented in a MathCad spreadsheet entitled "LeakTEC" which is described and benchmarked herein.

Revision 1 of this document incorporates comments provided by the Nuclear Regulatory Commission in response to Progress Energy's LAR #290. This document serves as Addendum B to Crystal River Unit 3 Topical Report BAW-2346P, Revision 0.

*This document contains 38 pages including 13 in Appendix A (i.e., A1 through A13).

<u>**Record of Revisions**</u>

Section	Revision	Description of Change	Date
All	00	Original Release	12/2004
5.1	01	Removed reference to Section 7.0	8/2005
5.2, Step 6	01	Changed "Steps 1 through 6 ..." to read "Steps 1 through 5", clarified via footnote number 2 that the one-sided upper 95%/95% result is to be used.	8/2005
5.3	01	Added footnote regarding POD value to be used, removed reference to Section 7.0 pertaining to new TECs.	8/2005
6.0	01	Added description of extra benchmarking	
Tables 6-1 and 6-2	01	Modified Tables 6-1 and 6-2. Added additional benchmarking runs to Tables 6-1 and 6-2. Added footnotes 1 and 2 defining "known returned to service leakage" and "total returned to service leakage", respectively.	8/2005
Table 6-1	01	Changed LeakTEC result for SG A LTE as-found leakage from 0.00712 gpm to 0.00709 gpm to correct a typographical error	8/2005
Table 6-3	01	Added footnote 1 defining that the one-sided upper 95%/ 95% result is to be used for TEC leakage evaluation. Added footnote 2 defining the POD value to be used. Clarified definition for POD value of 1.0.	8/2005
7.1	01	Corrected the caution relating to voltage threshold, and clarified POD value to be used. Added clarification that the one-sided upper 95%/95% result is to be used for TEC leakage evaluation.	8/2005
7.2	01	Deleted	8/2005
7.3	01	Renumbered as 7.2	8/2005
9.0	01	Added Reference 7	8/2005

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Appendix A: LeakTEC Listing .... A1 through A13

1.0 Introduction

The NRC-approved bobbin voltage alternate repair criteria (ARC) described in Generic Letter 95-05 utilizes a probabilistic methodology to calculate total steam generator accident leakage at an upper 95% probability and 95% confidence level for axial ODSCC at tube support plates. This report documents an application of the same calculational approach to determine 95%/95% accident leakage rates for Crystal River Unit 3 tube end cracks (TEC). The probabilistic approach calculates bounding SG leakage at a high level of confidence, while reducing some of the conservatisms inherent in the current approach. The methodology is implemented in a MathCad spreadsheet entitled "LeakTEC" which is described and benchmarked within this report.

2.0 Background

Tube cracks have been identified within the roll expanded region near the primary tubesheet face in the Crystal River Unit 3 (CR-3) once through steam generators (OTSGs). An ARC which allows certain tubes containing TECs to remain inservice has been implemented at CR-3 for several years (Ref. 1). The determination of primary to secondary leakage under main steam line break (MSLB) conditions is an important aspect of the ARC, and is the subject of this evaluation.

MSLB leakage must be evaluated following each tube inspection and the calculated leakage must remain below the limit specified in the ARC. The leakage rates currently used to implement the ARC are based on the results of a laboratory test program (Ref. 1). The program applied simulated MSLB loads to a tube/tubesheet mockup and measured the resultant leakage though EDM notches within the tube under test. The testing demonstrated that expansion joint tightness is the key parameter which correlates with leakage rate. Joint tightness is quantified with a parameter called "delta dilation," a plant specific parameter which depends primarily upon axial tube load, tubesheet deformation, and primary pressure.

In the development of the ARC, the leakage test results were used with plant specific delta dilations to develop bounding leak rate estimates for various regions of the tubesheet. As currently implemented, these limiting leak rates are assigned to each identified TEC; a significant source of conservatism. Another significant source of conservatism lies in the use of delta dilation values which do not reflect the substantial difference between CR-3 axial tube loads and those employed in the leakage testing program. This is discussed in more detail in Section 3.0.

In recent years, the number of identified TECs has continued to increase and continued initiation is expected in both the hot and cold tube end regions. This, coupled with the conservatisms discussed above, may lead to significant increases in the number of tube repairs required. As a result, CR-3 initiated an effort to refine the method used to determine SG leakage associated with TECs. This report documents the results of that effort.

3.0 Crystal River Unit 3 MSLB Conditions

Specific CR-3 MSLB conditions which relate to this evaluation are discussed in this section. A more detailed discussion of MSLB conditions and assumptions is provided in Ref. 2.

During a CR-3 MSLB, the SG which is unaffected by the line break is rapidly isolated from the break, effectively preventing any leakage from that SG from significantly impacting offsite radiation dose rates. Therefore, the SG loads most appropriate for evaluating leakage to the environment are those associated with the SG whose steam line breaks (i.e., the "affected" SG).

The parameters most relevant to this evaluation are axial tube load and delta dilation. Table 3-1 summarizes CR-3 axial tube load and delta dilation values as a function of radial position within the tubesheet for the affected SG (Ref. 2). These values are based on the limiting assumption that 25% of the tubes are plugged when the MSLB occurs.

The unadjusted delta dilation values in Table 3-1 reflect tubesheet distortion, tube/tubesheet thermal deformation, and free (non-end capped) pressure tube dilation effects. However, they do not reflect the affect of axial load on tube dilation (Ref. 3). For the ARC as it is currently implemented, this approach is appropriate because leakage test results are applied in a similar manner. Specifically, even though a bounding axial load was imposed during the leak testing, the calculated delta dilations for the leak tests did not reflect that effect; therefore, the tested joint was actually looser (i.e., greater tube-to-tubesheet delta dilation) than indicated by the calculated delta dilation values. Because the CR-3 MSLB tube loads (663 lbf. max) are substantially lower than the tube load employed during the leak tests (3,060 lbf.), exclusion of this effect imposes an excessive level of conservatism on the estimated CR-3 MSLB leakage rate.

For this evaluation, CR-3 MSLB delta dilation values are adjusted to reflect the affect of axial tube load on joint tightness. This adjustment is discussed below. The leakage data, also adjusted for this effect, is discussed in Section 4.0.

Figure 3-1 illustrates that the axial tube load varies with tubesheet radius. Tubes located near the center of the tubesheet will experience compressive axial loads during an MSLB therefore no dilation adjustment is applied for these tubes. The tube diameter reduction resulting from an axial tensile load is calculated with the following equation:

$$\Delta Diameter = -\frac{PR_o v}{\pi R_{mid} Et}$$

where:

P = axial load from Table 3-1 (lbf)
R_o= outer radius within roll expansion (inch)
v = Poisson's ratio

R_{mid} = mid wall radius within roll expansion (inch)
E = modulus of elasticity at MSLB tube temperature (psi)
t = tube wall thickness within roll expansion (inch)

This calculation is documented in Ref. 4 and the resulting adjusted delta dilations are provided in Table 3-1. Figures 3-2 and 3-3 illustrate that because of the relatively low loads, the adjustment causes very little change in the delta dilation values.

Figure 3-1, CR-3 MSLB Axial Tube Load

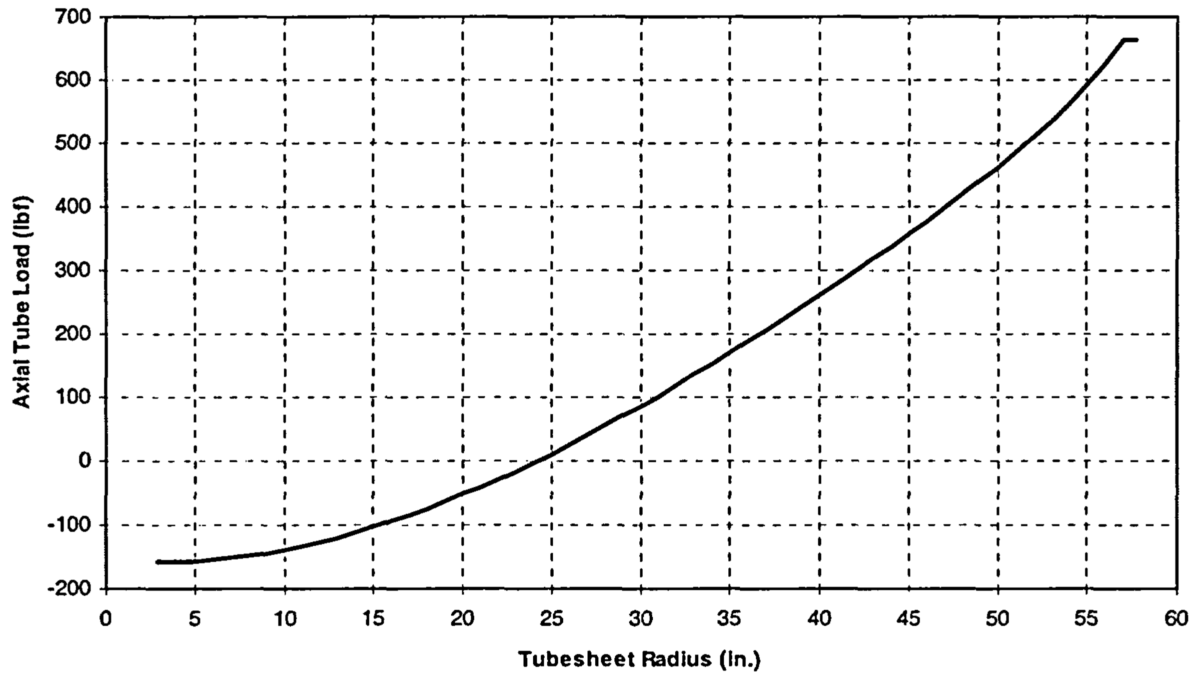


Figure 3-2, CR-3 Upper Tube End Delta Dilation

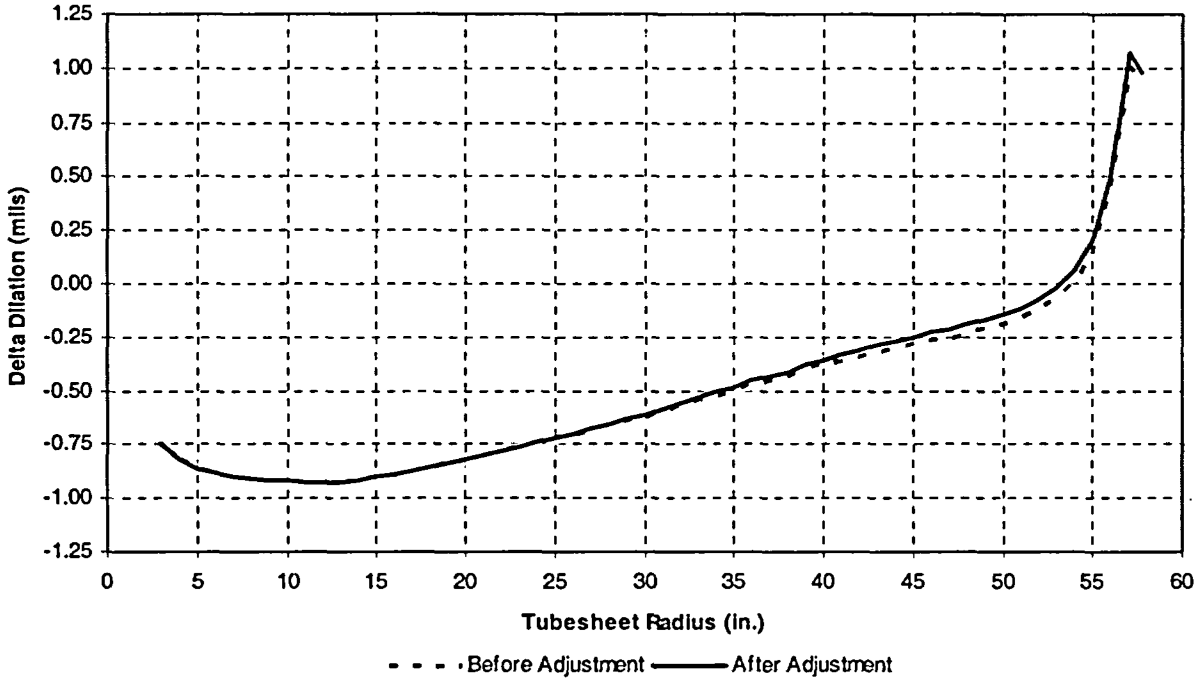


Figure 3-3, CR-3 Lower Tube End Delta Dilation

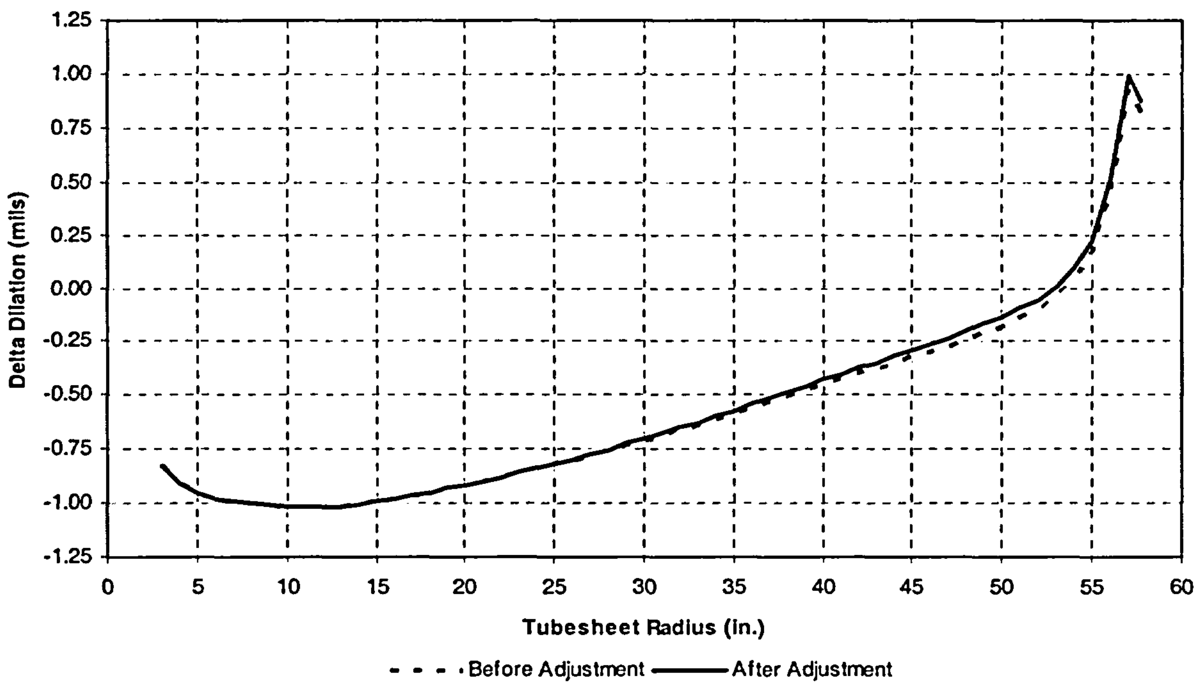


Table 3-1, CR-3 MSLB Delta Dilations and Tube Loads
(Affected SG, 25% tube plugging)

Tubesheet Radius (in.)	Axial Load (lbf)	Delta Dilation (mils)			
		Before Adjusting for Axial Load		After Adjusting for Axial Load	
		Upper Tube End	Lower Tube End	Upper Tube End	Lower Tube End
3	-159	-0.75	-0.83	-0.75	-0.83
4	-159	-0.82	-0.91	-0.82	-0.91
5	-157	-0.86	-0.95	-0.86	-0.95
6	-155	-0.88	-0.98	-0.88	-0.98
7	-152	-0.90	-0.99	-0.90	-0.99
8	-149	-0.91	-1.00	-0.91	-1.00
9	-144	-0.92	-1.01	-0.92	-1.01
10	-139	-0.92	-1.02	-0.92	-1.02
11	-134	-0.93	-1.02	-0.93	-1.02
12	-127	-0.93	-1.02	-0.93	-1.02
13	-120	-0.93	-1.02	-0.93	-1.02
14	-112	-0.92	-1.01	-0.92	-1.01
15	-104	-0.90	-0.99	-0.90	-0.99
16	-95	-0.89	-0.98	-0.89	-0.98
17	-85	-0.87	-0.96	-0.87	-0.96
18	-75	-0.85	-0.95	-0.85	-0.95
19	-65	-0.84	-0.93	-0.84	-0.93
20	-53	-0.82	-0.92	-0.82	-0.92
21	-42	-0.80	-0.90	-0.80	-0.90
22	-29	-0.78	-0.88	-0.78	-0.88
23	-17	-0.76	-0.86	-0.76	-0.86
24	-3	-0.74	-0.84	-0.74	-0.84
25	10	-0.72	-0.82	-0.72	-0.82
26	25	-0.70	-0.80	-0.70	-0.80
27	39	-0.68	-0.78	-0.68	-0.78
28	54	-0.66	-0.76	-0.66	-0.76
29	70	-0.64	-0.73	-0.63	-0.72
30	85	-0.62	-0.71	-0.61	-0.70
31	101	-0.59	-0.69	-0.58	-0.68
32	118	-0.57	-0.66	-0.56	-0.65
33	135	-0.54	-0.64	-0.53	-0.63
34	152	-0.52	-0.61	-0.51	-0.60
35	169	-0.50	-0.59	-0.48	-0.57
36	187	-0.47	-0.56	-0.45	-0.54
37	205	-0.45	-0.53	-0.43	-0.51
38	223	-0.43	-0.51	-0.41	-0.49
39	242	-0.40	-0.48	-0.38	-0.46
40	260	-0.38	-0.45	-0.36	-0.43
41	279	-0.36	-0.43	-0.33	-0.40
42	298	-0.34	-0.40	-0.31	-0.37
43	318	-0.32	-0.38	-0.29	-0.35
44	337	-0.30	-0.35	-0.27	-0.32
45	357	-0.28	-0.32	-0.25	-0.29
46	377	-0.26	-0.30	-0.23	-0.27
47	398	-0.25	-0.27	-0.21	-0.23
48	419	-0.23	-0.24	-0.19	-0.20
49	440	-0.21	-0.21	-0.17	-0.17
50	462	-0.19	-0.18	-0.15	-0.14
51	485	-0.16	-0.14	-0.12	-0.10
52	509	-0.12	-0.10	-0.07	-0.05
53	534	-0.07	-0.04	-0.02	0.01
54	561	0.01	0.04	0.06	0.09
55	591	0.14	0.17	0.19	0.22
56	624	0.44	0.44	0.50	0.50
57	663	1.01	0.93	1.07	0.99
57.72	663	0.92	0.81	0.98	0.87

4.0 Leakage Test Data

In a manner similar to that described above for the CR-3 delta dilations, the leakage test results documented in Ref. 1 were adjusted to account for tube dilation under the applied test conditions.

During the tests the tubesheet mockup was loaded bilaterally to vary the extent of bore hole dilation while the tube was internally pressurized and axially loaded in tension. Positive bore hole dilation and the axial tensile load work to reduce joint tightness (i.e., a more positive delta dilation) while the internal tube pressure works to increase joint tightness.

As discussed in Section 3.0, the ARC as it is currently applied is based upon leak test results which do not account for the affect of axial load on delta dilation. However, for this evaluation, axial loading is taken into account. Under the limiting MSLB conditions tested (axial load 3060 lbf; pressure 2640 psi), the net tube dilation was determined to be +0.13 mils (Ref. 4)[1]. This value was subtracted from the tubesheet mockup bore dilations to arrive at the appropriate delta dilation values. The mockup bore dilations and resulting delta dilations, along with measured leakage rates, are provided in Table 4-2.

One test point (X bore dilation: 0.2 mils; Y bore dilation 1.5 mils; log(leakage): -6.69) had an indicated leakage that was several orders of magnitude lower than all other tests with the same delta dilation value and was therefore omitted from the evaluation.

Figure 4-1 illustrates the linear relationship between delta dilation and the logarithm of leakage. Table 4-1 provides the sample estimates of regression parameters for this relationship:

Table 4-1, Leakage Regression Sample Parameters

Regression Line	
Number of Data Points (N)	119
Intercept (B)	-4.7493
Slope (M)	1.0063
Standard Error of Regression (S)	0.79382

Variance-Covariance Matrix	
Intercept	Slope
0.011564 (V_{11})	-0.0090940 (V_{12})
-0.0090940 (V_{21})	0.013193 (V_{22})

In order to employ the probabilistic techniques as described in this report, it is necessary to confirm that the variation of log(leakage) about the regression line is normally distributed, and that no systematic variation of residuals exists with respect to delta dilation. Figure 4-2 illustrates that the regression residuals closely follow a normal distribution. An examination of Figure 4-3 confirms that there is no significant systematic relationship between the magnitude of regression residual and delta dilation. This validates the underlying assumptions required to implement the probabilistic evaluation described in the next section.

[1]. The tube dilation associated with test pressure alone is +0.41mils, the value used to determine delta dilation in Reference 1.

Figure 4-1, OTSG Tube End Leakage vs Delta Dilation

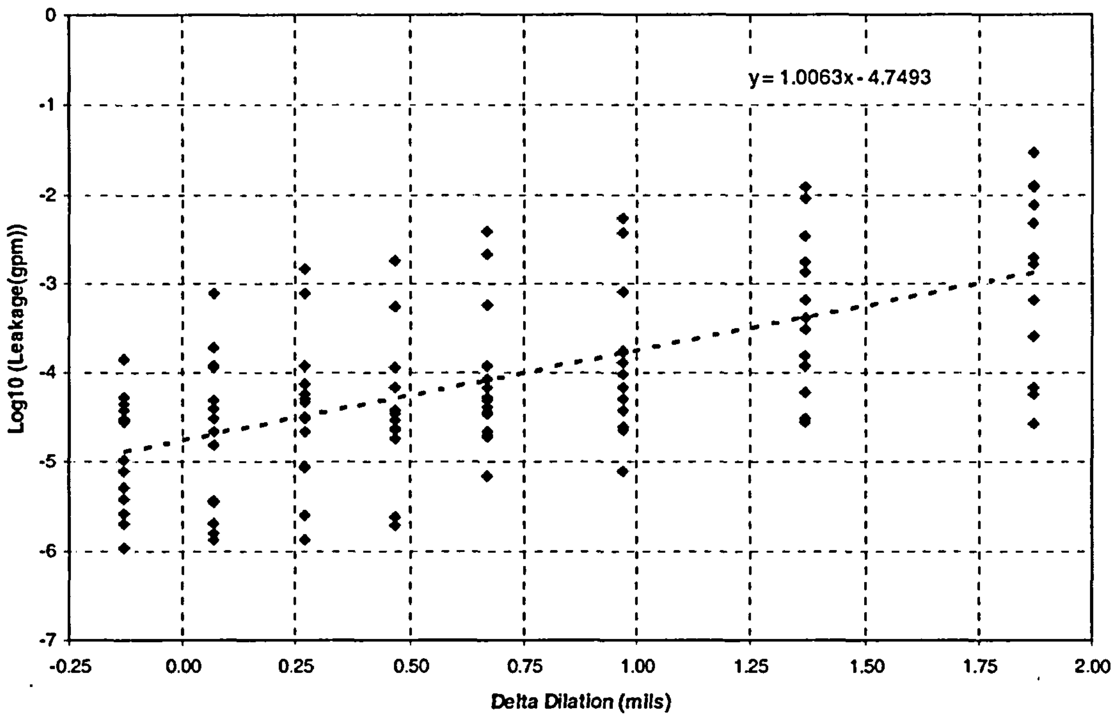


Figure 4-2, Residual Distribution

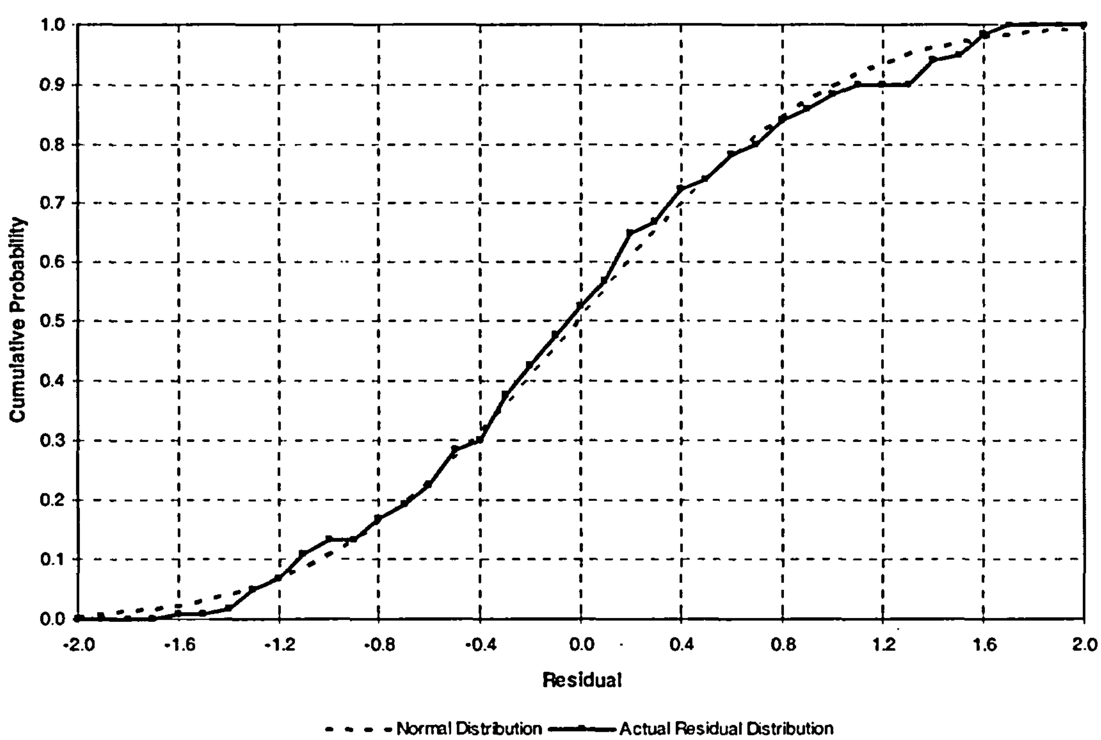


Figure 4-3, Regression Residuals

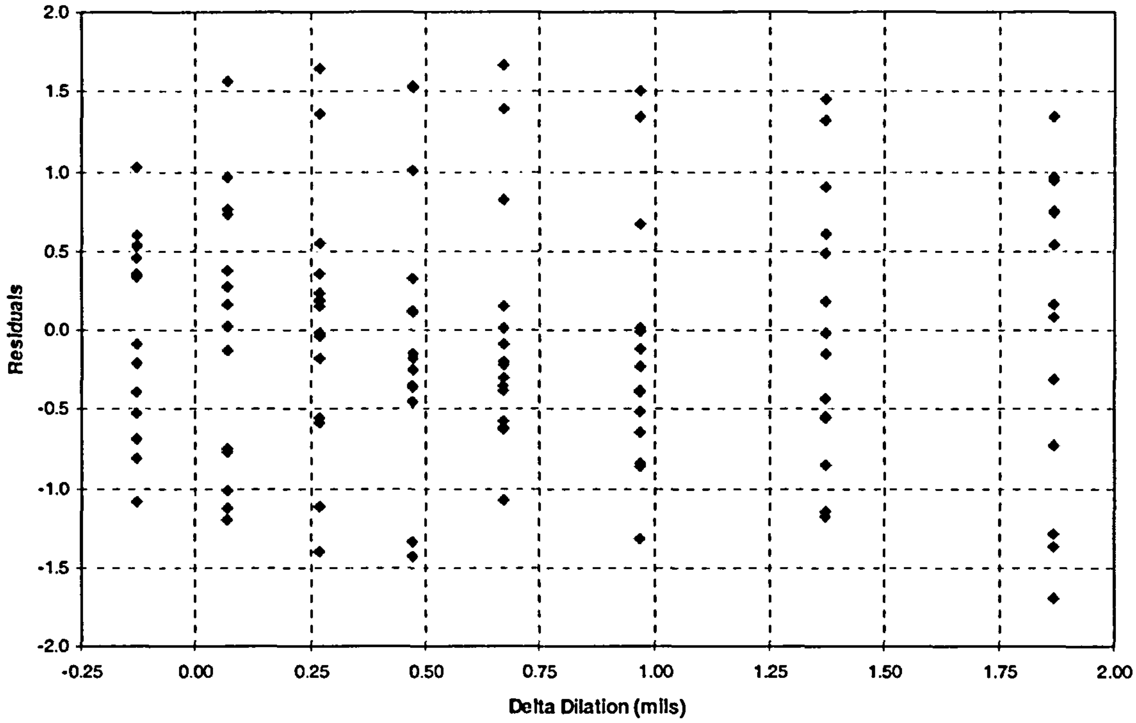


Table 4-2, Leakage Test Results
(Total axial load: 3,060 lbf; Pressure: 2,640 psi)

Diametral Dilation (mils)					Leakage (gpm) (Ref. 1, Table B-1)	
Tubesheet Mockup Bore Dilation		Bore / Tube Delta Dilation		Limiting Delta Dilation		
X	Y	X	Y		Measured	Log 10
0	0	-0.13	-0.13	-0.13	1.41E-04	-3.851
0	0	-0.13	-0.13	-0.13	5.24E-05	-4.281
0	0	-0.13	-0.13	-0.13	1.09E-06	-5.963
0	0	-0.13	-0.13	-0.13	3.87E-06	-5.412
0	0	-0.13	-0.13	-0.13	2.66E-06	-5.575
0	0.2	-0.13	0.07	0.07	1.91E-04	-3.719
0	0.2	-0.13	0.07	0.07	4.92E-05	-4.308
0	0.2	-0.13	0.07	0.07	1.33E-06	-5.876
0	0.2	-0.13	0.07	0.07	3.75E-06	-5.426
0	0.2	-0.13	0.07	0.07	3.51E-06	-5.455
0	0.4	-0.13	0.27	0.27	1.47E-03	-2.833
0	0.4	-0.13	0.27	0.27	4.78E-05	-4.321
0	0.4	-0.13	0.27	0.27	2.54E-06	-5.595
0	0.4	-0.13	0.27	0.27	8.60E-06	-5.066
0	0.4	-0.13	0.27	0.27	5.69E-05	-4.245
0	0.6	-0.13	0.47	0.47	1.82E-03	-2.740
0	0.6	-0.13	0.47	0.47	1.84E-05	-4.735
0	0.6	-0.13	0.47	0.47	2.42E-06	-5.616
0	0.6	-0.13	0.47	0.47	2.30E-05	-4.638
0	0.6	-0.13	0.47	0.47	3.74E-05	-4.427
0	0.8	-0.13	0.67	0.67	2.09E-03	-2.680
0	0.8	-0.13	0.67	0.67	1.96E-05	-4.708
0	0.8	-0.13	0.67	0.67	2.03E-05	-4.693
0	0.8	-0.13	0.67	0.67	6.76E-05	-4.170
0	0.8	-0.13	0.67	0.67	2.23E-05	-4.652
0	1.1	-0.13	0.97	0.97	3.70E-03	-2.432
0	1.1	-0.13	0.97	0.97	1.65E-04	-3.783
0	1.1	-0.13	0.97	0.97	7.99E-06	-5.097
0	1.1	-0.13	0.97	0.97	3.75E-05	-4.426
0	1.1	-0.13	0.97	0.97	6.73E-05	-4.172
0.2	1.5	0.07	1.37	1.37	1.20E-02	-1.921
0.2	1.5	0.07	1.37	1.37	1.20E-04	-3.921
0.2	1.5	0.07	1.37	1.37	2.80E-05	-4.553
0.2	1.5	0.07	1.37	1.37	1.57E-04	-3.804
0.2	1.5	0.07	1.37	1.37	3.03E-04	-3.519
0.3	2	0.17	1.87	1.87	1.19E-02	-1.924
0.3	2	0.17	1.87	1.87	6.50E-04	-3.187
0.3	2	0.17	1.87	1.87	2.71E-05	-4.567
0.3	2	0.17	1.87	1.87	1.95E-03	-2.710
0.3	2	0.17	1.87	1.87	7.48E-03	-2.126
0	0	-0.13	-0.13	-0.13	8.04E-06	-5.095
0	0	-0.13	-0.13	-0.13	4.50E-05	-4.347
0	0	-0.13	-0.13	-0.13	5.25E-06	-5.280
0	0	-0.13	-0.13	-0.13	1.08E-05	-4.967
0	0	-0.13	-0.13	-0.13	2.93E-05	-4.533

Table 4-2, Continued

Diametral Dilation (mils)					Leakage (gpm) (Ref. 1, Table B-1)	
Tubesheet Mockup Bore Dilation		Bore / Tube Delta Dilation		Limiting Delta Dilation		
X	Y	X	Y		Measured	Log 10
0	0.2	-0.13	0.07	0.07	4.98E-05	-4.303
0	0.2	-0.13	0.07	0.07	1.13E-04	-3.947
0	0.2	-0.13	0.07	0.07	1.56E-05	-4.807
0	0.2	-0.13	0.07	0.07	3.93E-05	-4.406
0	0.2	-0.13	0.07	0.07	1.20E-04	-3.921
0	0.4	-0.13	0.27	0.27	3.15E-05	-4.502
0	0.4	-0.13	0.27	0.27	1.17E-04	-3.932
0	0.4	-0.13	0.27	0.27	2.17E-05	-4.664
0	0.4	-0.13	0.27	0.27	5.14E-05	-4.289
0	0.4	-0.13	0.27	0.27	7.54E-05	-4.123
0	0.6	-0.13	0.47	0.47	2.98E-05	-4.526
0	0.6	-0.13	0.47	0.47	1.13E-04	-3.947
0	0.6	-0.13	0.47	0.47	2.96E-05	-4.529
0	0.6	-0.13	0.47	0.47	3.48E-05	-4.458
0	0.6	-0.13	0.47	0.47	5.41E-04	-3.267
0	0.8	-0.13	0.67	0.67	4.13E-05	-4.384
0	0.8	-0.13	0.67	0.67	1.20E-04	-3.921
0	0.8	-0.13	0.67	0.67	3.46E-05	-4.461
0	0.8	-0.13	0.67	0.67	3.71E-05	-4.431
0	0.8	-0.13	0.67	0.67	5.61E-04	-3.251
0	1.1	-0.13	0.97	0.97	6.88E-05	-4.162
0	1.1	-0.13	0.97	0.97	1.28E-04	-3.893
0	1.1	-0.13	0.97	0.97	2.44E-05	-4.613
0	1.1	-0.13	0.97	0.97	5.11E-05	-4.292
0	1.1	-0.13	0.97	0.97	7.96E-04	-3.099
0.2	1.5	0.07	1.37	1.37	1.19E-04	-3.924
0.2	1.5	0.07	1.37	1.37	4.03E-04	-3.395
0.2	1.5	0.07	1.37	1.37	1.72E-03	-2.764
0.2	1.5	0.07	1.37	1.37	3.38E-03	-2.471
0.3	2	0.17	1.87	1.87	1.95E-03	-2.710
0.3	2	0.17	1.87	1.87	1.64E-03	-2.785
0.3	2	0.17	1.87	1.87	6.95E-05	-4.158
0.3	2	0.17	1.87	1.87	4.69E-03	-2.329
0.3	2	0.17	1.87	1.87	7.53E-03	-2.123
0	0	-0.13	-0.13	-0.13	3.73E-05	-4.428
0	0	-0.13	-0.13	-0.13	2.84E-05	-4.547
0	0	-0.13	-0.13	-0.13	3.02E-05	-4.520
0	0	-0.13	-0.13	-0.13	2.04E-06	-5.690
0	0	-0.13	-0.13	-0.13	4.44E-05	-4.353
0	0.2	-0.13	0.07	0.07	3.07E-05	-4.513
0	0.2	-0.13	0.07	0.07	7.61E-04	-3.119
0	0.2	-0.13	0.07	0.07	2.17E-05	-4.664
0	0.2	-0.13	0.07	0.07	2.04E-06	-5.690
0	0.2	-0.13	0.07	0.07	1.57E-06	-5.804
0	0.4	-0.13	0.27	0.27	5.13E-05	-4.290

Table 4-2, Continued

Diametral Dilation (mils)					Leakage (gpm) (Ref. 1, Table B-1)	
Tubesheet Mockup Bore Dilation		Bore / Tube Delta Dilation		Limiting Delta Dilation		
X	Y	X	Y		Measured	Log 10
0	0.4	-0.13	0.27	0.27	7.66E-04	-3.116
0	0.4	-0.13	0.27	0.27	3.04E-05	-4.517
0	0.4	-0.13	0.27	0.27	9.13E-06	-5.040
0	0.4	-0.13	0.27	0.27	1.33E-06	-5.876
0	0.6	-0.13	0.47	0.47	6.99E-05	-4.156
0	0.6	-0.13	0.47	0.47	1.77E-03	-2.752
0	0.6	-0.13	0.47	0.47	6.88E-05	-4.162
0	0.6	-0.13	0.47	0.47	2.35E-05	-4.629
0	0.6	-0.13	0.47	0.47	1.94E-06	-5.712
0	0.8	-0.13	0.67	0.67	4.99E-05	-4.302
0	0.8	-0.13	0.67	0.67	3.91E-03	-2.408
0	0.8	-0.13	0.67	0.67	8.56E-05	-4.068
0	0.8	-0.13	0.67	0.67	5.30E-05	-4.276
0	0.8	-0.13	0.67	0.67	7.02E-06	-5.154
0	1.1	-0.13	0.97	0.97	9.74E-05	-4.011
0	1.1	-0.13	0.97	0.97	5.35E-03	-2.272
0	1.1	-0.13	0.97	0.97	1.71E-04	-3.767
0	1.1	-0.13	0.97	0.97	1.71E-04	-3.767
0	1.1	-0.13	0.97	0.97	2.30E-05	-4.638
0.2	1.5	0.07	1.37	1.37	1.32E-03	-2.879
0.2	1.5	0.07	1.37	1.37	8.98E-03	-2.047
0.2	1.5	0.07	1.37	1.37	6.47E-04	-3.189
0.2	1.5	0.07	1.37	1.37	3.01E-05	-4.521
0.2	1.5	0.07	1.37	1.37	5.96E-05	-4.225
0.3	2	0.17	1.87	1.87	2.99E-02	-1.524
0.3	2	0.17	1.87	1.87	1.24E-02	-1.907
0.3	2	0.17	1.87	1.87	7.57E-03	-2.121
0.3	2	0.17	1.87	1.87	2.55E-04	-3.593
0.3	2	0.17	1.87	1.87	5.72E-05	-4.243

5.0 Probabilistic Leakage Evaluation

The probabilistic calculation of CR-3 TEC leakage is implemented in MathCad spreadsheet "LeakTEC" (Appendix A). LeakTEC uses the delta dilation values from Section 3.0, the regression parameters developed in Section 4.0, and specific ECT inspection results to determine total SG leakage at various probability and confidence levels. This section describes the methodology employed within LeakTEC to accomplish this task. A complete validation of LeakTEC is documented in Ref. 4.

5.1 Overview

For each TEC identified during an inspection, a leakage value corresponding to the crack's delta dilation is obtained by sampling from the leakage regression. These probabilistic leakage values reflect the uncertainty that is inherent in the regression. The sum of the leakage samples from all identified cracks represents one probabilistic estimate – or one Monte Carlo trial – of total SG leakage. Repeated many times, this process generates a collection of probabilistic estimates of total SG leakage. This collection is the simulated distribution of total SG leakage from which values at a desired probability and confidence level can be directly obtained.

Leakage may be evaluated for either condition monitoring (CM) or operational assessment (OA) purposes. This is the only option required to be specified by the LeakTEC user. The CM evaluation estimates MSLB leakage for all cracks as found, while the OA evaluation accounts for the inspection technique's probability of detection (POD) and any tube repairs performed to address TECs. The leakage associated with new cracks which develop during the next operating interval must also be accounted for in the OA; however, this aspect of the evaluation is beyond the scope of this document. Progress Energy has developed an analytical means of accounting for this source of leakage.

LeakTEC accepts as an input, a list of tubes which contain TECs, identified by row and column. For each tube the following additional information must also be provided: the affected tube end, the number of cracks, maximum crack voltage, and an indicator as to whether the tube will be repaired. The spreadsheet determines each tube's radial position within the tubesheet matrix based on the row and column values. In turn, the CR-3 MSLB delta dilation is determined for each tube based on its radial position within the tubesheet.

5.2 Condition Monitoring Leakage Determination

At the heart of LeakTEC lies the Monte Carlo simulation which generates probabilistic leakage estimates for each crack and determines total leakage at desired probability and confidence levels. The approach employed is closely modeled on the process used in the TSP ODSCC ARC (Ref. 5). Probabilistic slope, intercept, and regression error values are generated for each Monte Carlo trial. For each crack, these values are used along with a random normal deviate applied to the regression error, to generate a probabilistic leak rate estimate. These estimates are summed to generate a probabilistic estimate of total SG leakage; a process that is repeated thousands of times. This process as applied to condition monitoring is described in more detail below.

Step 1: The χ^2 distribution is used to model the uncertainty which is inherent in the sample estimate of standard error of regression provided in Section 4.0. In the equations below a random χ^2 deviate for N-2, or 117 degrees of freedom is used to generate a probabilistic value of the standard error of regression:

$$f_v = \frac{(N-2)}{\chi^2_{(N-2),RANDOM}}$$

$$RnS = S\sqrt{f_v}$$

where:

N = number of data pairs used to calculate the regression coefficients
N = 119
S = sample estimate of the standard error of regression
S = 0.79382
RnS = probabilistic standard error of regression

Step 2: The same approach is used to generate probabilistic estimates of the variance-covariance values for slope and intercept:

$$RnV_{11} = f_v V_{11}$$
$$RnV_{12} = f_v V_{12}$$
$$RnV_{22} = f_v V_{22}$$

where:

V_{11} = sample estimate of the variance of the intercept
V_{12} = sample estimate of the covariance of intercept and slope
V_{22} = sample estimate of the variance of the slope
RnV_{xx} = probabilistic value

Step 3: A probabilistic intercept value is then generated as follows:

$$Rn\beta 3 = B + Z_1\sqrt{RnV_{11}}$$

where:

B = sample estimate of the intercept
B = -4.7493
Z_1 = a random normal deviate

$Rn\beta 3$ = probabilistic intercept

Step 4: A probabilistic value for slope must also be generated. While the slope and intercept are individually normally distributed, they are not independent of each other. Taken together they are bivariate normally distributed. The probabilistic value of slope is constrained by the probabilistic value of intercept developed in Step 3. This co-dependence is quantified by parameter V_{12}, the covariance of intercept and slope. The probabilistic slope value is calculated as follows:

$$Rn\beta 4 = M + Z_1 \frac{RnV_{12}}{\sqrt{RnV_{11}}} + Z_2 \sqrt{RnV_{22} - \frac{(RnV_{12})^2}{RnV_{11}}}$$

where:

M = sample estimate of the slope
M = 1.0063
Z_2 = a random normal deviate
$Rn\beta 4$ = probabilistic slope

Step 5: Using the probabilistic values of slope, intercept, and regression error a probabilistic estimate of leakage is obtained for each crack. The sum of the leakage for all cracks represents one probabilistic estimate of total SG leakage:

$$Leakage_i = InvLog_{10}(Rn\beta 3 + DD_i Rn\beta 4 + Z_3 RnS)$$

$$SGLeak_k = \sum_{i=1}^{NumCracks} Leakage_i$$

where:

DD_i = delta dilation for crack i
Z_3 = a random normal deviate
$Leakage_i$ = leakage rate for crack i
$SGLeak_k$ = total SG leakage rate for trial k

Step 6: Steps 1 through 5 are repeated, generating thousands of $SGLeak_k$ values. Together these values represent the simulated distribution of expected total SG leakage. Once ordered from smallest to largest, leakage values at desired probability and confidence levels can be taken directly from the distribution using an appropriate index value. For example, the one-sided upper 95% probability / 95% confidence[2] value of leakage in an ordered distribution of 10,000 values would be the 9,537th value. This index is the smallest value of n for which the following relationship is true (Ref. 5):

[2] The statistical figure of merit to be used to evaluate TEC leakage against the accident leakage performance criteria is the one-sided upper 95% probability / 95% confidence value.

$$\frac{1}{1+\frac{N-n+1}{n}F_{1-\alpha,2(N-n+1),2n}} \geq P$$

where:

P = probability (fractional)
$1\text{-}\alpha$ = confidence (fractional)
N = number of trials
F = critical value from the F-distribution
n = the index corresponding to the specified probability and confidence

5.3 Operational Assessment Leakage Determination

The OA calculation is identical to the process described above except for one additional step. That step adjusts the number of cracks in each tube to reflect the inspection POD and to reflect any tube repairs to be performed prior to returning the SG to service. Within LeakTEC this step is performed for all imported tubes prior to each Monte Carlo trial. It is applied probabilistically such that "fractional cracks" are appropriately represented in the results.

As illustrated by the following equation, a POD value of less than one increases the number of inservice cracks expected during the next operating cycle, while tube repairs reduce the number of inservice cracks:

$$NumCracks_{(n+1)} = \frac{NumCracks_n}{POD} - NumRepaired_n$$

where:

$NumCracks_n$ = the number of TECs identified in a particular tube during the current outage
$NumRepaired_n$ = of the TECs above, the number removed from service during the current outage
$NumCracks_{(n+1)}$ = the number of TECs expected at the next outage in a tube having the same delta dilation value

For example if POD is 0.84[3], a tube with two cracks identified and repaired during the current outage would yield 0.381 cracks for OA evaluation purposes. To account for the fractional crack, prior to each Monte Carlo trial the fraction is compared with a random number between zero and one. If the random number is greater than the fraction, the number of cracks is rounded down to the nearest integer. Otherwise it is rounded up to the nearest integer. For this example, in a large number of trials the number of cracks

[3] The NRC approved value of POD for estimating the quantity of undetected TEC leakage is 0.84.

evaluated for this tube will equal one in 38.1% of the trials (i.e., 0.381 x 100%) and will equal zero in 61.9% of the trials.

6.0 Benchmarking

It is desirable to benchmark the probabilistic approach described in this report against the deterministic approach described in Ref. 1. To accomplish this, October 2003 (EOC13) CR-3 inspection results were evaluated using LeakTEC and the results were compared with those documented in the post-inspection CMOA (Ref. 6).

Additional deterministic estimates for EOC13 were also developed (Ref. 7) for benchmarking purposes in response to comments received from the NRC. These estimates are based on a methodology similar to that of Ref. 6; however, a continuous leakage vs. delta dilation relationship was used in lieu of tubesheet zones. Estimates were generated with and without consideration for the affect of tube load on delta dilation values from the leakage test program (i.e., Poisson Effect). Note that these additional deterministic estimates are provided for benchmarking purposes only.

Tables 6-1 and 6-2 summarize the leakage values determined using the various approaches, while detailed LeakTEC results are provided in Table 6-3. As expected, the probabilistic approach yields lower leakage estimates than the Ref. 6 deterministic approach. Tables 6-1 and 6-2 illustrate that LeakTEC reduces the estimated MSLB leakage by a factor of up to 3.3.

The elimination of tubesheet zones in the deterministic evaluation produced a 12% to 15% reduction in the estimates of total SG leakage returned to service as compared with the Ref. 6 approach. Accounting for the Poisson Effect further reduced the estimates by an additional 45%. In a number of cases, these deterministic estimates fall below the probabilistic values.

Table 6-1, SG A EOC13 MSLB Leakage Comparison

		Leak Rate Estimates (GPM)		
		As-Found	*Known Returned to Service[1]*	*Total Returned to Service[2]*
SG A Upper TECs (1467 TECs Detected)	*CMOA*	0.932	0.266	--
	Deterministic, No Zones, w/o Poisson Effect	0.783	0.239	0.388
	Deterministic, No Zones, With Poisson Effect	0.370	0.113	0.183
	LeakTEC (95/95)	0.296	0.127	0.186
SG A LowerTECs (7 TECs Detected)	*CMOA*	0.0130	0.0130	--
	Deterministic, No Zones, w/o Poisson Effect	0.0114	0.0114	0.0136
	Deterministic, No Zones, With Poisson Effect	0.00541	0.00541	0.00644
	LeakTEC (95/95)	0.00709	0.00726	0.00848
SG A Combined (1474 TECs Detected)	*CMOA*	0.945	0.279	0.459
	Deterministic, No Zones, w/o Poisson Effect	0.794	0.250	0.402
	Deterministic, No Zones, With Poisson Effect	0.375	0.118	0.189
	LeakTEC (95/95)	0.298	0.132	0.188

1. 'Known Returned to Service' is the leakage from NDE-identified TECs that were not repaired during the outage.
2. 'Total Returned to Service' includes leakage 'Known Returned to Service' plus leakage from TECs not identified by NDE but expected to be present based on a POD of 0.84.

Table 6-2, SG B EOC13 MSLB Leakage Comparison

		Leak Rate Estimates (GPM)		
		As-Found	*Known Returned to Service*[1]	*Total Returned to Service*[2]
SG B Upper TECs (1173 TECs Detected)	*CMOA*	1.102	0.278	--
	Deterministic, No Zones, w/o Poisson Effect	0.985	0.242	0.430
	Deterministic, No Zones, With Poisson Effect	0.466	0.115	0.203
	LeakTEC (95/95)	0.344	0.123	0.191
SG B LowerTECs (115 TECs Detected)	*CMOA*	0.124	0.107	--
	Deterministic, No Zones, w/o Poisson Effect	0.0884	0.0796	0.0964
	Deterministic, No Zones, With Poisson Effect	0.0418	0.0376	0.0456
	LeakTEC (95/95)	0.0418	0.0388	0.0455
SG B Combined (1288 TECs Detected)	*CMOA*	1.226	0.385	0.619
	Deterministic, No Zones, w/o Poisson Effect	1.073	0.322	0.526
	Deterministic, No Zones, With Poisson Effect	0.508	0.153	0.249
	LeakTEC (95/95)	0.376	0.156	0.228

1. 'Known Returned to Service' is the leakage from NDE-identified TECs that were not repaired during the outage.
2. 'Total Returned to Service' includes leakage 'Known Returned to Service' plus leakage from TECs not identified by NDE but expected to be present based on a POD of 0.84.

Table 6-3, LeakTEC Results based on EOC13 Inspection Data

	Type	POD	Leakage (gpm) @ 50/50	Leakage (gpm) @ 95/50	Leakage (gpm) @ 95/95	Computation Time (min.)*
SG A Upper						
1467 UTECs, 246 Repaired, 1221 RTS	CM	--	0.151	0.293	0.296	7.0
	OA	0.84	0.0909	0.184	0.186	9.5
	OA	1.00	0.0625	0.126	0.127	8.0
SG A Lower						
7 LTECs, 0 Repaired, 7 RTS	CM	--	0.000863	0.00686	0.00709	0.05
	OA	0.84	0.00110	0.00815	0.00848	0.07
	OA	1.00	0.000832	0.00702	0.00726	0.07
SG A Combined						
1467 UTECs, 7 LTECs, 246 Repaired, 1228 RTS	CM	--	0.153	0.294	0.298	7.0
	OA	0.84	0.0932	0.185	0.188	10.0
	OA	1.00	0.0641	0.130	0.132	8.5
SG B Upper						
1173 UTECs, 214 Repaired, 959 RTS	CM	--	0.175	0.340	0.344	5.75
	OA	0.84	0.0949	0.189	0.191	8.5
	OA	1.00	0.0609	0.122	0.123	6.5
SG B Lower						
115 LTECs, 3 Repaired, 112 RTS	CM	--	0.0156	0.0410	0.0418	0.5
	OA	0.84	0.0175	0.0446	0.0455	1.0
	OA	1.00	0.0142	0.0381	0.0388	0.75
SG B Combined						
1173 UTECs, 115 LTECs, 217 Repaired, 1071 RTS	CM	--	0.193	0.372	0.376	6.25
	OA	0.84	0.114	0.225	0.228	8.75
	OA	1.00	0.0772	0.154	0.156	7.5

RTS = Returned to service
UTEC = Upper Tube End Cracks
LTEC = Lower Tube End Cracks
Number of Trials = 20,000 in all cases
*With a 2.16 GHz Pentium 4 CPU

1. The statistical figure of merit to be used to evaluate TEC leakage against the accident leakage performance criteria is the one-sided upper 95% probability / 95% confidence value.

2. The NRC approved value of POD for estimating the quantity of undetected TEC leakage is 0.84. The POD value of "1.0" is only a mathematical means of calculating the "known return to service" part of the total return to service leakage.

7.0 Field Implementation

7.1 User Instructions

A typical implementation of LeakTEC involves the following steps:

1) Confirm that the spreadsheet to be used is the validated version by running it with input data from a documented case such as those discussed in Section 6.0. Confirm that the same results are generated. Note that due to the probabilistic nature of this calculation, the repeatability of results is dependent upon the number of trials used. If the number of trials specified is too low, the results will vary significantly from one run to another.

2) Within the "Options and Inputs" section of LeakTEC, perform the following:

   a) Choose the type of leakage assessment to be performed (CM or OA).

   b) If "Operational Assessment" was selected, specify the POD value. The NRC approved POD value for estimating the leakage from undetected TECs is 0.84. To determine the known leakage returned to service - that is, leakage from TECs identified by NDE and not repaired - execute the "Operational Assessment" option with a POD value of 1.0.

   c) Specify an appropriate voltage screening threshold. If no screening is to be applied, VThresh should equal zero.

CAUTION
A non-zero value for voltage threshold may only be used if approved by the NRC.

   d) Specify the Excel file which contains crack data to be imported. Do this by modifying the filename and data range within the properties of the "InCrkDat" source file. The following example illustrates the required Excel file format:

Row	Column	Tube End	Number of Cracks	Repair Flag	Maximum Voltage
113	115	UTE	2	N	0.2

N = not to be repaired
R = to be repaired

3) Occasionally it may be desirable to modify the number of Monte Carlo trials to be used. This parameter "NumTrials," is defined within the "Constants" section of LeakTEC. This parameter must be a positive integer and is constrained to be ≥100

within the spreadsheet. However, in practice the value should be set to at least 10,000.

4) Press CTRL+F9 to recalculate the entire spreadsheet.

5) Once the evaluation is complete, calculated leakage rates are available in the "Results" section. The one-sided, upper 95% probability / 95% confidence leakage value is to be used to evaluate TEC leakage against the accident leakage performance criteria.

7.2 <u>LeakTEC Usage Notes</u>

1) MathCad's automatic calculation feature should be disabled (Tools|Calculate). This will prevent the spreadsheet from recalculating before all desired input changes have been made.

2) Two files which contain information imported within the "Constants" section must reside within the same file directory as the spreadsheet. The files are: "DeltaDilation w Axial Load.xls" and "TRvTID.xls." If it should become necessary to re-link these files within LeakTEC, the appropriate data ranges are as follows:

Filename	Data Range
DeltaDilation w Axial Load.xls	CR3-Specific!k3:m58
TRvTID.xls	Sheet1!a2:c15532

3) A read-only master copy and backup of the spreadsheet and above files should be maintained.

4) For CM simulations, the following equation provides an order of magnitude estimate of computation time:

$$t = \frac{(NumTrials)(NumCracks)}{(1.92E06)(P)}$$

where:

t = computation time (minutes)
$NumTrials$ = number of Monte Carlo trials
$NumCracks$ = number of cracks evaluated
P = CPU clock speed (GHz)

5) The OA computation takes longer than the CM computation. The time depends upon the POD value and the number of cracks to be repaired, in addition to the number of cracks imported.

8.0 Summary and Conclusions

A refinement of the MSLB leakage calculation methodology which is applicable to the CR-3 ARC for SG tube end cracking has been described in this report. This methodology employs Monte Carlo techniques and is implemented in MathCad spreadsheet "LeakTEC." Several benchmarking cases have demonstrated that, as expected, this approach yields lower leakage estimates than the deterministic approach currently in use. Instructions for field implementation of the spreadsheet have also been provided.

9.0 References

1) FANP, "ARC for Tube End Cracking in the Tube-to-Tubesheet Roll Joint of OTSGs," BAW-2346P, April 1999

2) FANP Calculation 32-5003879-03, "OTSG Tube End Crack Leak Rate vs. Tubesheet Radius," November 11, 1999

3) FANP Calculation 32-5002623-02, "OTSG Transient Analysis," May 1999

4) FANP Calculation 32-5053981-00, "Probabilistic Implementation of CR-3 TEC ARC - Supporting Calculations"

5) WCAP-14277, "SLB Leak Rate and Tube Burst Probability Analysis Methods for ODSCC at TSP Intersections," Revision 1, December 1996

6) FANP Calculation 32-5035732-00, "CR3 RFO-13 TEC ARC Leakage Calculation," January 16, 2004

7) FANP Calculation 32-5070303-00, "Deterministic Leakage Assessment of Crystal River Unit 3 Steam Generator Tube End Cracks," August 2005

Appendix A – LeakTEC Listing

INTRODUCTION

This spreadsheet calculates the total primary to secondary steam generator leak rate from tube end cracks (TEC) for Crystal River Unit 3 under limiting MSLB conditions. The spreadsheet employs Monte Carlo simulation techniques to generate leak rates at 50%/50%, 95%/50%, and 95%/95% probability/confidence levels, and may be used for both Condition Monitoring and Operational Assessment purposes. The probabilistic aspects of this evaluation are similar to that of the tube support plate ODSCC alternate repair criteria currently employed by several PWRs.

Required inputs are identified in the "OPTIONS AND INPUT DATA" section below. Calculated leak rates are obtained from the "RESULTS" section further on in the spreadsheet.

The master version of this spreadsheet is entitled "LeakTEC.mcd."

INTRODUCTION

OPTIONS AND INPUT DATA

Choose Leakage Assessment Type:

(•) Condition Monitoring

( ) Operational Assessment

Specify Probability of Detection (for OA):

POD ≡ 1.0 *This value has no affect on CM results*

Specify Crack Voltage Threshold:

VThresh ≡ 0 *Cracks with voltage below this value will be excluded from the evaluation.* **CAUTION: A non-zero value for voltage threshold may only be used if approved by the NRC.**

Specify Filename to Import Crack Locations, Quantities, and Repair Plans:

InCrkDat :=

NC := CntCrks(InCrkDat) *Simulation will not run if the number of cracks to evaluate is zero.*

NC =

	0	1
0	"Number of lines in the data file:"	1115
1	"Number of UTE cracks imported:"	1467
2	"Number of LTE cracks imported:"	0
3	"Number of cracks flagged for repair:"	246
4	"Number of cracks not flagged for repair:"	1221
5	"Total cracks imported:"	1467
6	"Number of cracks to evaluate:"	1467

InCrkDat =

	0	1	2	3	4	5
0	1	7	"UTE"	2	"R"	100
1	1	8	"UTE"	3	"R"	100
2	1	9	"UTE"	1	"R"	100
3	2	10	"UTE"	1	"R"	100
4	2	11	"UTE"	1	"R"	100
5	3	14	"UTE"	1	"R"	100
6	3	21	"UTE"	1	"R"	100
7	3	31	"UTE"	1	"R"	100
8	4	17	"UTE"	2	"R"	100
9	4	26	"UTE"	2	"R"	100
10	4	37	"UTE"	1	"R"	100
11	5	1	"UTE"	2	"R"	100
12	5	3	"UTE"	1	"R"	100
13	5	20	"UTE"	2	"R"	100
14	5	21	"UTE"	1	"N"	100
15	5	23	"UTE"	1	"N"	100

Row, column, tube end, number of cracks, repair flag, max crack voltage (truncated listing if more than 16 lines)

OPTIONS AND INPUT DATA

CONSTANTS

Number of Monte Carlo Trials:

NumTrials ≡ 20000

The number of Monte Carlo trials should should be as large as necessary to achieve repeatable run-to-run results.

Mode := if(NumTrials < 100, −2, Mode)

Mode = 1

Log(Leak) v Delta Dilation Regression Parameters:

N ≡ 119 *Number of points*

S ≡ 0.79382 *Standard error of regression*

$RgV \equiv S^2$ *Regression error variance* RgV = 0.63

M ≡ 1.0063 *Slope*

B ≡ −4.7493 *Intercept*

$V_{11} \equiv 0.011564$ $V_{12} \equiv -0.009094C$ *Variance matrix*

$V_{21} \equiv -0.009094C$ $V_{22} \equiv 0.013193$ *Variance matrix*

Delta Dilation v Tubesheet Radius:

DDilation := *Import accident delta dilation values*

rows(DDilation) = 56 *Number of data lines imported*

DDilation =

	0	1	2
0	3	-0.75	-0.83
1	4	-0.82	-0.91
2	5	-0.86	-0.95
3	6	-0.88	-0.98
4	7	-0.9	-0.99
5	8	-0.91	-1
6	9	-0.92	-1.01
7	10	-0.92	-1.02
8	11	-0.93	-1.02
9	12	-0.93	-1.02
10	13	-0.93	-1.02
11	14	-0.92	-1.01
12	15	-0.9	-0.99
13	16	-0.89	-0.98
14	17	-0.87	-0.96
15	18	-0.85	-0.95

Tubesheet radius (in.), upper TS delta dilation (mils), lower TS delta dilation (mils) (truncated listing)

Tubesheet Radius v Tube Number:

TRvTID := *Import tubesheet radius vs tube number*

rows(TRvTID) = 15531 *Number of data lines imported*

TRvTID =

	0	1	2
0	1	1	57.21
1	1	2	57.12
2	1	3	57.04
3	1	4	56.97
4	1	5	56.92
5	1	6	56.88
6	1	7	56.85
7	1	8	56.84
8	1	9	56.84
9	1	10	56.85
10	1	11	56.88
11	1	12	56.92
12	1	13	56.97
13	1	14	57.04
14	1	15	57.12
15	1	16	57.21

Tubesheet radius vs tube number (truncated listing)

ORIGIN ≡ 0

CONSTANTS

PREPROCESSING

<u>Check the Crack Input File for Problems</u>:

$\mathrm{Mode} := \mathrm{if}\left[\left(NC_{1,1} + NC_{2,1} \neq NC_{5,1}\right), -1, \mathrm{Mode}\right]$

$\mathrm{Mode} := \mathrm{if}\left[\left(NC_{3,1} + NC_{4,1} \neq NC_{5,1}\right), -1, \mathrm{Mode}\right]$

Mode = 1

If mode is not 1 or 2, simulation will not run.

$\mathrm{TCrks} := NC_{5,1}$

<u>Eliminate Cracks Not > or = to the Voltage Threshold</u>:

CrkDat := ElimLoVolts(InCrkDat)

<u>Add the Radius Value to the Crack Data Matrix</u>:

$i := 0 .. \mathrm{rows}(\mathrm{CrkDat}) - 1$

$\mathrm{CrkDat}_{(i,5)} := \mathrm{RadLookup}\left[\mathrm{CrkDat}_{(i,0)}, \mathrm{CrkDat}_{(i,1)}, \mathrm{TRvTID}\right]$

Add the Delta Dilation Value to the Crack Data Matrix:

$CrkDat_{(i,6)} := DDLookup\left[CrkDat_{(i,5)}, CrkDat_{(i,2)}, DDilation\right]$

This array contains: Row, Col, Leg, #Cracks, TS Radius, Delta Dilation. If simulation does not run, check this array for "Error" entry caused by invalid tube row or column.

CrkDat =

	0	1	2	3	4	5	6
0	1	7	"UTE"	2	"R"	56.85	0.9841
1	1	8	"UTE"	3	"R"	56.84	0.9783
2	1	9	"UTE"	1	"R"	56.84	0.9783
3	2	10	"UTE"	1	"R"	56.19	0.6055
4	2	11	"UTE"	1	"R"	56.14	0.5769
5	3	14	"UTE"	1	"R"	55.4	0.3148
6	3	21	"UTE"	1	"R"	55.4	0.3148
7	3	31	"UTE"	1	"R"	56.57	0.8235
8	4	17	"UTE"	2	"R"	54.67	0.1498
9	4	26	"UTE"	2	"R"	54.74	0.1591
10	4	37	"UTE"	1	"R"	56.33	0.6858
11	5	1	"UTE"	2	"R"	57.29	1.0339
12	5	3	"UTE"	1	"R"	56.72	0.9095
13	5	20	"UTE"	2	"R"	53.89	0.0518
14	5	21	"UTE"	1	"N"	53.85	0.0485
15	5	23	"UTE"	1	"N"	53.81	0.0452

Calculate Index Values for 50/50, 95/50, and 95/95 Leakage:

$Indx5050 \equiv round[(NumTrials \cdot 0.5) - 1]$ $\quad$ $Indx5050 = 9999$

$Indx9550 \equiv round[(NumTrials \cdot 0.95) - 1]$ $\quad$ $Indx9550 = 18999$

$$Indx9595 \equiv \left| \begin{array}{l} P \leftarrow 0.95 \\ n_o \leftarrow trunc(0.95 \cdot NumTrials) \\ \text{for } \; n \in n_o .. NumTrials \\ \quad \left| \begin{array}{l} Crit \leftarrow \dfrac{1}{1 + \dfrac{NumTrials - n + 1}{n} \cdot qF[0.95, [2 \cdot (NumTrials - n + 1)], 2 \cdot n]} \\ \text{return } \; n - 1 \; \text{ if } \; Crit \ge P \end{array} \right. \\ n \leftarrow \text{"error"} \end{array} \right.$$

$Indx9595 = 19050$

PREPROCESSING

RESULTS

Press CTRL + F9 to calculate.

Leak(CrkDat, Mode) =

	0	1
0	"50/50 CM Accident Leakage"	0.1512575
1	"95/50 CM Accident Leakage"	0.2931619
2	"95/95 CM Accident Leakage"	0.2958761

GPM

RESULTS

FUNCTIONS

Given a Matrix of Crack Data, Keep only Those Exceeding the Voltage Threshold:

```
ElimLoVolts(InCrkDat) ≡ | j ← -1
                        | for i ∈ 0.. rows(InCrkDat) - 1
                        |   if InCrkDat(i,5) ≥ VThresh
                        |      | j ← j + 1
                        |      | CrkDat(j,0) ← InCrkDat(i,0)
                        |      | CrkDat(j,1) ← InCrkDat(i,1)
                        |      | CrkDat(j,2) ← InCrkDat(i,2)
                        |      | CrkDat(j,3) ← InCrkDat(i,3)
                        |      | CrkDat(j,4) ← InCrkDat(i,4)
                        | CrkDat
```

Given a Row and Col, Return the TS Radius:

```
RadLookup(Ro, Co, Tr) ≡ | Radius ← "Error"
                        | rows ← rows(Tr) - 1
                        | for r ∈ 0.. rows
                        |   if [Tr(r,0) = Ro] ∧ [Tr(r,1) = Co]
                        |      | Radius ← Tr(r,2)
                        |      | break
                        | return Radius
```

Given a Radius, Return the Appropriate Delta Dilation Value:

This function interpolates to obtain the delta dilation value.

$$
\mathrm{DDLookup}(\mathrm{Rad}, \mathrm{Leg}, \mathrm{DDilation}) \equiv
\left|
\begin{array}{l}
\text{return "Error" if Rad = "Error"} \\
j \leftarrow 1 \\
j \leftarrow 2 \ \text{ if } \ \mathrm{Leg} = \text{"LTE"} \\
\mathrm{Rad} \leftarrow 3 \ \text{ if } \ \mathrm{Rad} < 3 \\
\mathrm{RadFloor} \leftarrow \mathrm{floor}(\mathrm{Rad}) \\
\mathrm{RadCeil} \leftarrow \mathrm{ceil}(\mathrm{Rad}) \\
\mathrm{RadCeil} \leftarrow 57.72 \ \text{ if } \ \mathrm{RadCeil} > 57.72 \\
\mathrm{RadDel} \leftarrow \mathrm{RadCeil} - \mathrm{RadFloor} \\
\mathrm{RadInc} \leftarrow \mathrm{Rad} - \mathrm{RadFloor} \\
\mathrm{DDFloor} \leftarrow \mathrm{DDFloor} \leftarrow \mathrm{DDilation}_{(\mathrm{RadFloor}-3,\, j)} \\
\mathrm{DDCeil} \leftarrow \mathrm{DDCeil} \leftarrow \mathrm{DDilation}_{(\mathrm{RadFloor}-2,\, j)} \\
\mathrm{DDDel} \leftarrow \mathrm{DDCeil} - \mathrm{DDFloor} \\
\mathrm{DeltaD} \leftarrow \mathrm{DDFloor} + \dfrac{\mathrm{RadInc} \cdot \mathrm{DDDel}}{\mathrm{RadDel}} \\
\mathrm{DeltaD}
\end{array}
\right.
$$

Count Various Crack Classifiers:

```
CntCrks(CrkDat) ≡ | UCrks ← 0
                  | LCrks ← 0
                  | RCrks ← 0
                  | NCrks ← 0
                  | TCrks ← 0
                  | ECrks ← 0
                  | Lines ← rows(CrkDat)
                  | for  i ∈ 0.. Lines − 1
                  |     | UCrks ← UCrks + CrkDat(i,3)  if  CrkDat(i,2) = "UTE"
                  |     | LCrks ← LCrks + CrkDat(i,3)  if  CrkDat(i,2) = "LTE"
                  |     | RCrks ← RCrks + CrkDat(i,3)  if  CrkDat(i,4) = "R"
                  |     | NCrks ← NCrks + CrkDat(i,3)  if  CrkDat(i,4) = "N"
                  |     | TCrks ← TCrks + CrkDat(i,3)
                  |     | ECrks ← ECrks + CrkDat(i,3)  if  CrkDat(i,5) ≥ VThresh
                  |        ( "Number of lines in the data file:"          Lines )
                  |        ( "Number of UTE cracks imported:"             UCrks )
                  |        ( "Number of LTE cracks imported:"             LCrks )
                  | Out ←  ( "Number of cracks flagged for repair:"       RCrks )
                  |        ( "Number of cracks not flagged for repair:"   NCrks )
                  |        ( "Total cracks imported:"                     TCrks )
                  |        ( "Number of cracks to evaluate:"              ECrks )
```

CM Leakage Calculation: Total SG Leakage at 50/50, 95/50, and 95/95 Prob./Conf. Levels:

'CMLeaks' calculates accident leakage values for condition monitoring purposes (i.e., calculates total SG leakage for cracks as-found). Within the function, a vector containing "NumTrials" leakage values is generated. Each value is a probabilistic estimate of total SG leakage. The 50/50, 95/50, and 95/95 leakage values are taken directly from this (sorted) vector.

```
CMLeaks(CrkDat) ≡ | NDatLim ← rows(CrkDat) − 1
                  | for t ∈ 0.. NumTrials − 1
                  |   | CumuL ← 0
                  |   | fv ← (N − 2) / rchisq(1, N − 2)_0
                  |   | RnS ← √(fv·RgV)
                  |   | RnV11 ← fv·V_11
                  |   | RnV22 ← fv·V_22
                  |   | RnV12 ← fv·V_12
                  |   | Z1 ← rnorm(1,0,1)_0  on error  Z1 ← rnorm(1,0,1)_0
                  |   | Z2 ← rnorm(1,0,1)_0  on error  Z2 ← rnorm(1,0,1)_0
                  |   | Rnβ3 ← B + Z1·√RnV11
                  |   | Rnβ4 ← M + Z1·RnV12/√RnV11 + Z2·√(RnV22 − (RnV12)^2/RnV11)
                  |   | for r ∈ 0.. NDatLim
                  |   |   | continue  if  CrkDat_(r,3) = 0
                  |   |   | for c ∈ 1.. CrkDat_(r,3)
                  |   |   |   | DD ← CrkDat_(r,6)
                  |   |   |   | Z3 ← rnorm(1,0,1)_0  on error  Z3 ← rnorm(1,0,1)_0
                  |   |   |   | LogL ← Rnβ3 + DD·Rnβ4 + Z3·RnS
                  |   |   |   | CumuL ← (CumuL + 10^LogL)
                  |   | TotLeakTrials_t ← CumuL
                  | Leak_Sorted ← sort(TotLeakTrials)
                  | L_5050 ← Leak_Sorted_Indx5050
                  | L_9550 ← Leak_Sorted_Indx9550
                  | L_9595 ← Leak_Sorted_Indx9595
                  |        ( "50/50 CM Accident Leakage"  L_5050 )
                  | Out ←  ( "95/50 CM Accident Leakage"  L_9550 )
                  |        ( "95/95 CM Accident Leakage"  L_9595 )
```

Alter the Number of Cracks to Account for Repairs and POD:

$$
\mathrm{ApplyPODtoCrackData(CDat)} \equiv \left|
\begin{array}{l}
\mathrm{NDatLim} \leftarrow \mathrm{rows(CDat)} - 1 \\
\text{for } \; r \in 0 .. \mathrm{NDatLim} \\
\quad \left|
\begin{array}{l}
\mathrm{NCrks} \leftarrow \mathrm{CDat}_{(r,3)} \\
\mathrm{PODCrks} \leftarrow \dfrac{\mathrm{NCrks}}{\mathrm{POD}} \\
\mathrm{PODCrks} \leftarrow \mathrm{PODCrks} - \mathrm{NCrks} \;\; \text{if} \;\; \mathrm{CDat}_{(r,4)} = \text{"R"} \\
\mathrm{Lo} \leftarrow \mathrm{floor(PODCrks)} \\
\mathrm{Hi} \leftarrow \mathrm{ceil(PODCrks)} \\
\mathrm{Frac} \leftarrow \mathrm{PODCrks} - \mathrm{Lo} \\
\mathrm{PODCrks} \leftarrow \mathrm{Lo} \\
\mathrm{Rndm} \leftarrow \mathrm{rnd}(1) \\
\mathrm{PODCrks} \leftarrow \mathrm{Hi} \;\; \text{if} \;\; \mathrm{Rndm} < \mathrm{Frac} \\
\mathrm{CDat}_{(r,3)} \leftarrow \mathrm{PODCrks}
\end{array}
\right. \\
\text{return } \; \mathrm{CDat}
\end{array}
\right.
$$

OA Leakage Calculation: Total SG Leakage at 50/50, 95/50, and 95/95 Prob./Conf. Levels:

'OALeaks' calculates accident leakage values for operational assessment purposes (i.e., calculates total SG leakage for cracks projected at the next EOC). The function is very similar to 'CMLeaks'; however, prior to each Monte Carlo trial, the number of cracks at each location is adjusted to account for those repaired, and to reflect the affect of POD.

$$
\begin{aligned}
\mathrm{OALeaks}(\mathrm{CrkDat}) \equiv\ & \mathrm{NDatLim} \leftarrow \mathrm{rows}(\mathrm{CrkDat}) - 1\\
& \text{for } t \in 0 .. \mathrm{NumTrials} - 1\\
& \quad \mathrm{AdCrkDat} \leftarrow \mathrm{ApplyPODtoCrackData}(\mathrm{CrkDat})\\
& \quad \mathrm{CumuL} \leftarrow 0\\
& \quad \mathrm{fv} \leftarrow \frac{(N-2)}{\mathrm{rchisq}(1, N-2)_0}\\
& \quad \mathrm{RnS} \leftarrow \sqrt{\mathrm{fv}\cdot \mathrm{RgV}}\\
& \quad \mathrm{RnV11} \leftarrow \mathrm{fv}\cdot V_{11}\\
& \quad \mathrm{RnV22} \leftarrow \mathrm{fv}\cdot V_{22}\\
& \quad \mathrm{RnV12} \leftarrow \mathrm{fv}\cdot V_{12}\\
& \quad Z1 \leftarrow \mathrm{rnorm}(1,0,1)_0 \ \text{ on error } \ Z1 \leftarrow \mathrm{rnorm}(1,0,1)_0\\
& \quad Z2 \leftarrow \mathrm{rnorm}(1,0,1)_0 \ \text{ on error } \ Z2 \leftarrow \mathrm{rnorm}(1,0,1)_0\\
& \quad \mathrm{Rn}\beta 3 \leftarrow B + Z1\cdot\sqrt{\mathrm{RnV11}}\\
& \quad \mathrm{Rn}\beta 4 \leftarrow M + Z1\cdot\frac{\mathrm{RnV12}}{\sqrt{\mathrm{RnV11}}} + Z2\cdot\sqrt{\mathrm{RnV22} - \frac{(\mathrm{RnV12})^2}{\mathrm{RnV11}}}\\
& \quad \text{for } r \in 0 .. \mathrm{NDatLim}\\
& \quad\quad \text{continue } \ \text{if } \ \mathrm{AdCrkDat}_{(r,3)} = 0\\
& \quad\quad \text{for } c \in 1 .. \mathrm{AdCrkDat}_{(r,3)}\\
& \quad\quad\quad \mathrm{DD} \leftarrow \mathrm{AdCrkDat}_{(r,6)}\\
& \quad\quad\quad Z3 \leftarrow \mathrm{rnorm}(1,0,1)_0 \ \text{ on error } \ Z3 \leftarrow \mathrm{rnorm}(1,0,1)_0\\
& \quad\quad\quad \mathrm{LogL} \leftarrow \mathrm{Rn}\beta 3 + \mathrm{DD}\cdot\mathrm{Rn}\beta 4 + Z3\cdot\mathrm{RnS}\\
& \quad\quad\quad \mathrm{CumuL} \leftarrow \left(\mathrm{CumuL} + 10^{\mathrm{LogL}}\right)\\
& \quad \mathrm{TotLeakTrials}_t \leftarrow \mathrm{CumuL}\\
& \mathrm{Leak\_Sorted} \leftarrow \mathrm{sort}(\mathrm{TotLeakTrials})\\
& \mathrm{L\_5050} \leftarrow \mathrm{Leak\_Sorted}_{\mathrm{Indx5050}}\\
& \mathrm{L\_9550} \leftarrow \mathrm{Leak\_Sorted}_{\mathrm{Indx9550}}\\
& \mathrm{L\_9595} \leftarrow \mathrm{Leak\_Sorted}_{\mathrm{Indx9595}}\\
& \mathrm{Out} \leftarrow \begin{pmatrix} \text{"50/50 OA Accident Leakage"} & \mathrm{L\_5050}\\ \text{"95/50 OA Accident Leakage"} & \mathrm{L\_9550}\\ \text{"95/95 OA Accident Leakage"} & \mathrm{L\_9595} \end{pmatrix}
\end{aligned}
$$

Process Errors and Execute Correct Function based on User Selection:

```
Leak(CrkDat, Mode) ≡ | return "'NumTrials' is too small"  if  Mode = -2
                     | return "Crack file contains improper characters"  if  Mode = -1
                     | return "Must specify CM or OA"  if  Mode = 0
                     | return CMLeaks(CrkDat)  if  Mode = 1
                     | return OALeaks(CrkDat)  if  Mode = 2
                     | "Error"
```

FUNCTIONS

PROGRESS ENERGY FLORIDA, INC.

CRYSTAL RIVER UNIT 3

DOCKET NUMBER 50-302/LICENSE NUMBER DPR-72

ATTACHMENT F

LICENSE AMENDMENT REQUEST #290, REVISION 1

Addendum C Dated August 12, 2005 to Topical Report 2346P, Revision 0

Crystal Unit 3

LAR # 290

Addendum C to Topical Report BAW-2346P Rev 0

EC 61937 Rev 0 Dated 8/12/05

<u>CR3 OTSG Tube End Crack (TEC) Leakage Projections</u>

This document provides the basis for future projection method for axial Tube End Crack (TEC) indication MSLB accident induced leakage at Crystal River Unit 3. These projections will be used to determine the projected TEC leakage for the next OTSG inspection in conjunction with NRC approved LAR # 290 or existing leak rates to determine the required tube repairs (plugging or re-rolling) to be performed during an outage to address the TEC Alternate Repair Criteria (ARC). The projections will also provide input to the Operational Assessment (OA) upon conclusion of an outage. This method will demonstrate a conservative approach to TEC leakage predictions based on the current CR3 TEC trends.

<u>Inputs/Assumptions</u>:

a. The described method satisfies the minimum requirements for calculating the projected TEC leakage contained in BAW-2346P Rev 0 as required by ITS 5.6.2.10.2.f.

b. TEC leakage rates based on the methodology in Framatome calculation 51-5053331-01 (Ref 3) and 32-5053981-00 (Ref 4) may be used <u>IF</u> the NRC has approved Licensing Amendment Request (LAR) # 290. These leak rates are based on a probabilistic calculation approach. The LAR method provides an alternate method of determining TEC leak rates vs. tubesheet radius that is expected to result in more realistic, but still conservative, TEC leak rates. These leak rates are determined by a Framatome developed software program called LeakTEC using a 95/95 Monte Carlo statistical method.

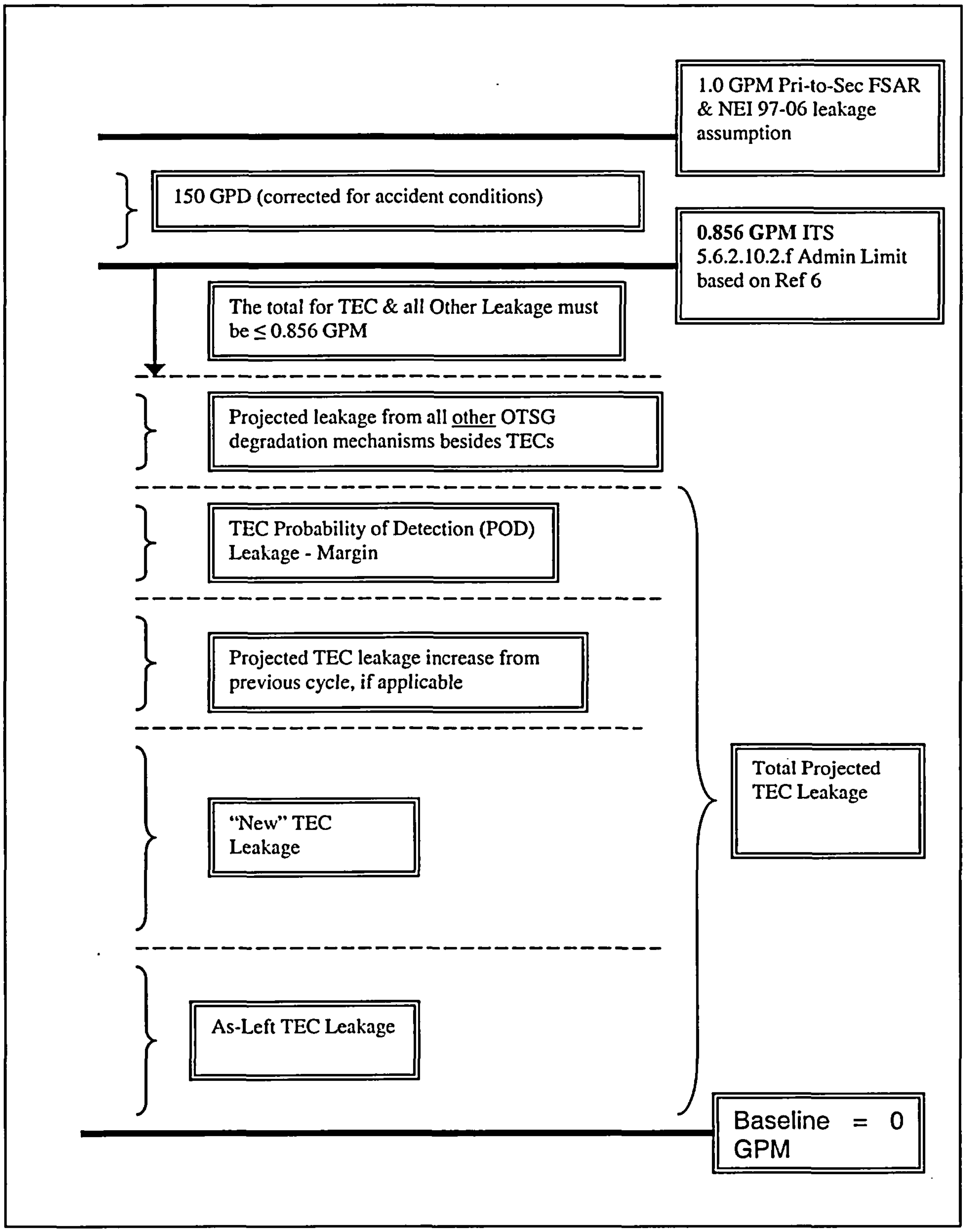
c. This method meets the intent of the EPRI Steam Generator Integrity Assessment Guideline (Ref 5) and NEI 97-06 (Ref 7) for determining the projected (OA) TEC leakage for the limiting OTSG accident conditions.

d. TEC leakage instead of numbers of indications is used for this projection method. Leakage is used since it is identified as a maximum postulated leak rate and is the ITS 5.6.2.10.2.f administrative limit for TEC's. There is no limitation on the number of TEC indications as long as the postulated leakage limits in ITS 5.6.2.10.2.f are satisfied.

e. Examples of leak rate numbers in this evaluation use typical leakage rates from Ref 1. The corresponding leakage using the LAR # 290 method will be significantly lower.

CR3 OTSG ACCIDENT-INDUCED (MSLB) PRIMARY-TO-SECONDARY LEAKAGE LIMITS SIMPLIFIED DIAGRAM (PER OTSG)

Figure 1



CR3 TEC Leakage Projection Model

$$P_L = AL_{TEC\ Leakage} + POD_{Leakage} + N_{Leakage} + Add_{Leakage}$$

P_L= Total Projected Leakage
$AL_{TEC\ Leakage}$ = As-Left TEC Leakage from the current inspection (Note 1)
$POD_{Leakage}$ = The current inspection As-Found Leakage divided by 0.84 minus the current inspection As-found leakage (i.e., (0.7/0.84) – 0.7) (Note 2)
$N_{Leakage}$= New Leakage - Current As-Found TEC Leakage minus the Previous As-Left TEC Leakage (Note 3)
$Add_{Leakage}$ = Additional leakage based on trending (Note 4).

Note 1 – As-Left TEC Leakage includes the total of all radial zone tubes including both upper and lower tube end indications. This includes all tubes with TEC indications identified during an inspection that are not repaired prior to closing out the OTSG.

Note 2 - Use equation for POD from BAW-2346P Rev 0. This can be calculated by the following equation example: [As-found total TEC leakage/0.84* – As-found total TEC leakage]; [(0.7/0.84) – 0.7] = 0.133 gpm.

Note 3 – New TEC Leakage is the amount of total TEC leakage detected (as-found) above the amount left in service from the previous inspection. For example: $14R_{As\text{-}Found\ TEC\ Leakage} - 13R_{As\text{-}Left\ TEC\ Leakage}$) equals the "New" TEC Leakage for one operating cycle. This is done for both upper and lower tube ends. This amount includes the TEC indications/leakage that were either not detected in previous outages or developed during the previous operating cycle. The assumption is that the new TECs that were identified in the previous operating cycle represent a similar trend of what future cycle "new" TEC leakage will be.

Note 4 – To account for a TEC increasing leakage trend, an additional amount of TEC leakage needs to be added above the previous cycle "new" TEC leakage IF there is any recent increasing new leakage trend. The use of a linear extrapolation method using the changes in New TEC leakage was selected as the way to project potential increases in the TEC leak rates. See Enclosure 1 for a description of why this method was chosen. Linear extrapolation involves comparing the "new" TEC leakage from the previous two operating cycles. For example, determine the $14R_{\ As\text{-}found\ TEC\ leakage} - 13R_{\ As\text{-}left\ TEC\ Leakage}$ new TEC leakage and compare to the $13R_{\ As\text{-}found\ TEC\ leakage} - 12R_{\ As\text{-}left\ TEC\ Leakage}$) new TEC leakage. If the most recent operating cycle "new" TEC leakage is less than the previous "new" TEC leakage, then there is no apparent increase and this amount is 0.0 gpm. This means that a decreasing trend cannot be used to provide a leakage credit.

However, if the most recent operating cycle "new" TEC leakage is greater than the previous "new" TEC leakage, than the leakage difference between the two operating cycles should be added to the projection. As examples, if the 13R new leakage was 0.45 gpm and the 14R new leakage is 0.45 gpm than no increasing leakage trend is apparent and no additional leakage amount is applied to this parameter. Conversely, if the 13R new leakage was 0.40 gpm and the 14R new leakage is 0.45 gpm than an increasing trend may be developing. In this case, an additional leakage amount of 0.05 gpm (0.45 – 0.40) should be added to the projected leakage. The equation for this process is ($14R_{new\ leakage} - 13R_{\ new\ leakage}$) = Increase Leakage Amount. To account for the possibility of a continuously increasing trend that deviates from the expected steady or decreasing growth rates observed in Figure 2, also compare the new leakage values for the 12R new and 13R new leakages. If the new leakage from 13R was greater than the new leakage from 12R, then determine that difference. If the 13R-14R increase is larger than the 12R-13R increase, then an increasing rate trend may be occurring. In this case, an additional amount will be added to the 13R-14R extrapolated amount. This overall process can be summarized by:

1. If there is no increasing trend between the $12R_{new}$ to $13R_{new}$ to $14R_{new}$, then there is no increasing trend and the Increasing Leakage is 0.0 GPM.
2. If there is an increasing trend only from $12R_{new}$ to $13R_{new}$, but not for $13R_{new}$ to $14R_{new}$, then there is no increasing trend and the Increasing Leakage is 0.0 GPM.
3. If there is an increasing trend only from $13R_{new}$ to $14R_{new}$, then the Increase Leakage is determined by: Increasing Leakage = $(14R_{new} - 13R_{new})$.
4. If the last two cycles show an increase in new leakage and the most recent increase is less than the previous increase, then Increase Leakage is determined by: Increasing Leakage = $(14R_{new} - 13R_{new})$.
5. If the last two cycles show an increase in new leakage and the most recent increase is greater than the previous increase, then Increasing Leakage is determined by: $(14R_{new} - 13R_{new}) + [(14R_{new} - 13R_{new}) - (13R_{new} - 12R_{new})]$ = Increasing Leakage.

Overall Acceptance Criteria:

Total Projected TEC Leakage + All Other Degradation Leakage (Roll Transitions, Non-tube end degradation, etc) must be ≤1 GPM-150 GPD (0.856 GPM) Prior to OTSG Closeout

Or Reroll/Plug (Repair) as necessary in the current outage to get the total projected TEC leakage & other degradation for next outage below 0.856 GPM

EXAMPLE (Note – These are example numbers only)

As an example of how the overall calculation is performed, see the following:

- As-Left TEC Leakage from 13R = 0.325 gpm
- 11R to 12R New TEC Leakage = 0.360 gpm
- 12R to 13R New TEC Leakage = 0.350 gpm
- As-Found TEC Leakage for 14R = 0.7 gpm
- POD Leakage for 14R = [(0.7/0.84) – 0.7] = 0.133 gpm
- New Leakage for previous Cycle = (0.7 – 0.325) = 0.375 gpm
- Additional Leakage Trend [(13R to 14R new) – (12R to 13R new)] = [(0.375 gpm) – (0.350 gpm)] = 0.025 gpm
- Total of "Other" OTSG Leakage = 0.06 gpm from the Operational Assessment

If no repairs are initially performed, the as-left TEC leakage will be the same as the as-found TEC leakage. Therefore, projected TEC leakage =

As-Left 14R TEC Leakage = 0.7 gpm
+
Change (New) 14R TEC Leakage = 0.375 gpm
+
Undetected Indication POD Leakage = 0.133 gpm
+
Increasing Trend TEC Leakage (applicable in this case) = 0.025 gpm

= Projected TEC Leakage = 1.233 gpm

Combined with 0.06 gpm for the "Other" OTSG degradation the total projected leakage = 1.293gpm

Since the 1.293 gpm total is greater than the 0.856 administrative ITS limit, some the as-found TEC indications/leakage must be removed from service before returning the OTSG to service. Therefore, the as-found TEC leakage must be reduced by at least (1.293 gpm – 0.856 gpm) 0.437 gpm. The as-left TEC leakage must be reduced to at least 0.7 gpm – 0.437 gpm = 0.263 gpm. This means that repairs must be completed on the existing as-found TEC indications to result in an as-left TEC total of ≤ 0.263 gpm.

References:

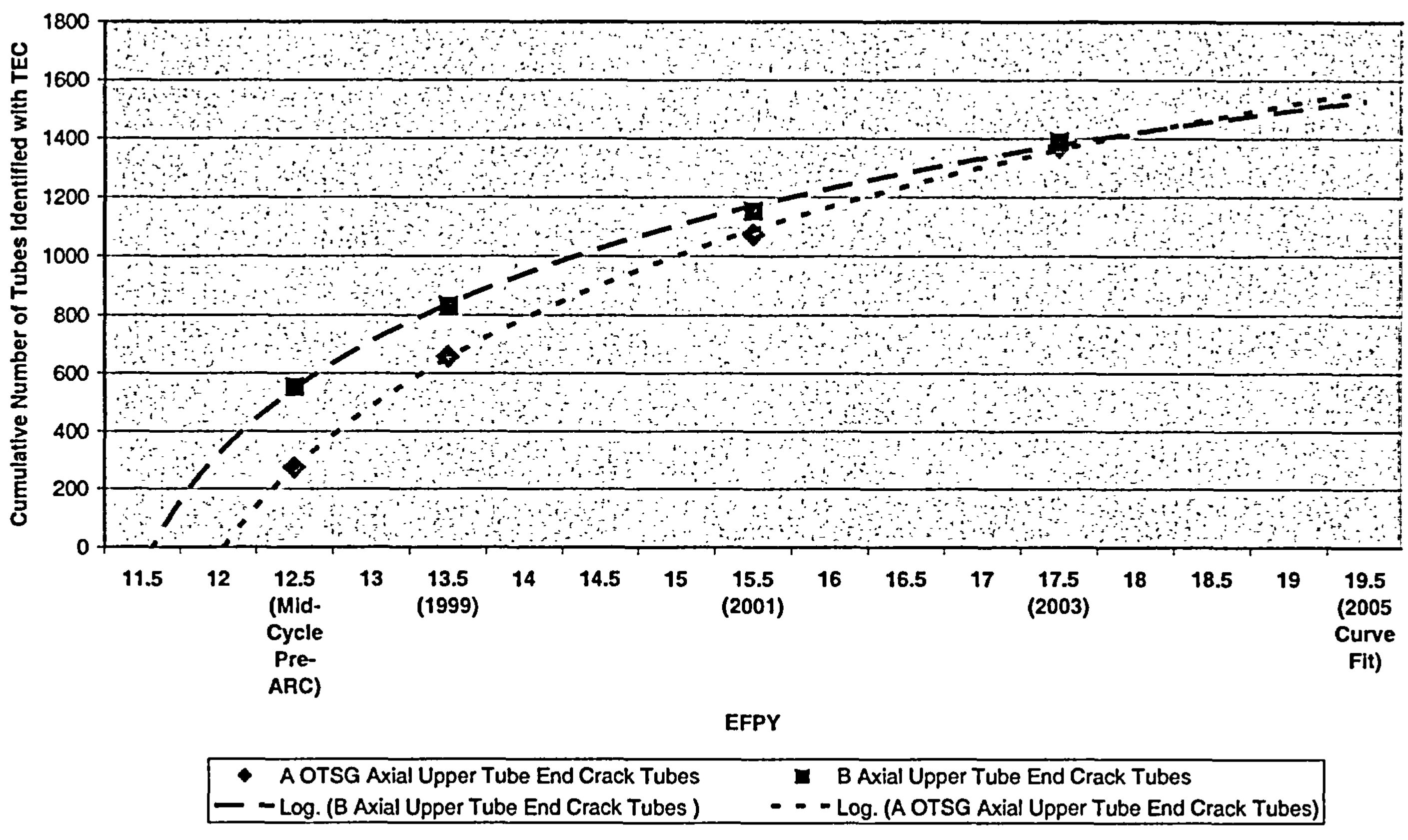
1. BAW-2346P Rev 0, Dated 04/99, Alternate Repair Criteria for Tube End Cracking in the Tube-to-Tubesheet Roll Joint of Once Through Steam Generators
2. Framatome Calculation 32-5003879-03, Rev 3, Dated 11/1999, OTSG Tube End Crack Leak Rate
3. Framatome Calculation 51-5053331-01, Rev 1, Dated 8/10/05, Probabilistic Leakage Assessment of Crystal River Unit 3 SG Tube End Cracks
4. Framatome Calculation 32-5053981-00, Rev 0, Dated 12/2004, Probabilistic Implementation of CR-3 TEC ARC-Supporting Calculations
5. EPRI Report TR-107621-R1, Dated 03/00, Steam Generator Integrity Assessment Guidelines
6. Framatome Calculation 32-5035732-00, Rev 0, Dated 01/04, CR3 RFO-13 TEC ARC Leakage Calculation
7. NEI 97-06 Rev 1, Steam Generator Program Guidelines, Dated 12/1999

Enclosure 1

The method for projecting future TEC leakage to account for possible increasing rates was based on having a limited number of historical data points available while still providing conservative projections. To date (thru 13R), there are only two data points (11R - 12R & 12R - 13R) for new TEC leakage because the TEC ARC has only been in effect since the 1999 (11R) outage. We have the new leakage that developed from 11R to 12R and the new leakage that developed from 12R to 13R. If the overall leakage is increasing, a linear projection assumes that it will continue to increase at the same rate. CR3 plant data in Figure 2 shows that the increase in cumulative number of tubes with TEC upper indications is actually slowing down. (i.e. The cumulative number of indications continues to go up over time, but at a slower rate). Note - Lower TEC tubes are not included in the graph because there is only one data point in 13R. Some of the decrease may be due to the fact that as tube ends are rerolled or plugged, the total population of available tubes is decreasing. This would indicate that the change in total leakage rate should also be steady or decreasing. This is supported by the most recent data from 13R where 11 out of the 12 radial zones showed either no change or a decrease in percent of tubes with new TECs (Reference Letter 3F0505-12 Attachment D Response b.vii.to NRC) from 12R to 13R.

Various curve fit projections were evaluated for predicting increasing TEC leakage rates. The low number of data points restricts the use of many of the typically used methods. By extrapolating the increase between the two previous cycles to 15R, the linear extrapolation method (not to be less than the 14R new leakage) was the most conservative. Therefore, the linear extrapolation method will be used based on the readings for new leakage.

CR3 Number of Upper Tube Ends with TEC
Figure 2



PROGRESS ENERGY FLORIDA, INC.

CRYSTAL RIVER UNIT 3

DOCKET NUMBER 50-302/LICENSE NUMBER DPR-72

ATTACHMENT G

LICENSE AMENDMENT REQUEST #290, REVISION 1

Response to NRC Request for Additional Information (RAI) Regarding License Amendment Request #290, Revision 0

NRC Question

1. **In your January 27, 2005, submittal, you proposed to modify the portion of the accident induced leakage methodology associated with implementation of the tube end cracking (TEC) alternate repair criteria. The TEC accident induced leakage methodology involves two parts: (1) projecting the number of TEC indications and (2) assigning a leakage value to each TEC indication. Your January 27, 2005 proposal involves changing the portion of the methodology for assigning a leakage value to each TEC indication to make it less conservative.**

   As discussed in Licensee Event Report 50-302/2004-004-00 dated November 22, 2004 (ML043340228), you exceeded your accident induced leakage limit during your 2003 refueling outage (designated 13R). One of the primary reasons for this occurrence was that you did not conservatively project the number of TEC indications Furthermore, in your letter dated May 20, 2005, you indicated that part of your corrective action to ensure the leakage limit would not be exceeded included your January 27, 2005 license amendment request.

   Although your license amendment request may result in lower amounts of accident induced leakage, it does not address the fundamental cause of exceeding the accident induced leakage limit during several of your previous outages (i.e., the under prediction in the number of indications detected during the outage). As a result, please provide the method to be used to ensure that the number of TEC indications will be conservatively projected in all future outages for NRC review and approval. We suggest that this methodology and its technical justification be submitted as Addendum C to BAW-2346. (Section 7.2 of the submittal appears to discuss three new potential approaches for accounting for new indications which may occur during the operating cycle. However, Section 7.2 does not specifically commit to performing any of these three approaches. In addition, the description of each of these approaches would need to be amplified such as to provide a complete description of the approach. Finally, Section 7.2 lacks a technical rationale for why any of these approaches will yield a conservative estimate of the number of TEC indications which will exist at the end of the next cycle. For example, had these approaches been implemented in past cycles, how would the projected number of indications at the next end of cycle have compared to what was actually found?)

Response

Framatome-ANP document 51-5053331-00 (Probabilistic Leakage Methodology of Crystal River Unit 3 SG Tube End Cracks) provided as Addendum B (Attachment E of this submittal) has been revised to exclude Section 7.2 as well as any references to those potential approaches for accounting for new TEC indications. The Framatome-ANP document no longer identifies any method to projecting TEC indications or leakage.

Crystal River Unit 3 (CR-3) has instead developed a method to account for future TEC leakage that uses plant specific historical leakage rates using data from the refueling 11R (1999), 12R (2001), and 13R (2003) outage inspections. This method is described in Addendum C to BAW-2346P Rev 0 which is being submitted in this letter (Attachment F). Existing leakage trends show that the number of new as-found tubes with TEC indications has not changed significantly in the previous two cycles and therefore the use of historical data is used to help predict future leakage. Predicted TEC leakage includes separate components for determining the as-left leakage, new leakage, POD leakage, and an increased leak rate amount if increasing trends are detected. These leakage components are combined to produce the predicted TEC leakage per steam generator. This method was selected because it can be shown to provide realistic, but still conservative leakage projections. This method will continue to meet the Topical Report BAW-2346P Revision 0, assumptions for the Alternate Repair Criteria (ARC).

A prediction methodology used by the Diablo Canyon plant called POPCD (Probability of Prior Cycle Detection) was also reviewed as a possible prediction method for CR-3. At other plants, POPCD is used along with bobbin probe examinations to adjust the bobbin POD instead of using a more accurate rotating coil probe. CR-3 already uses a rotating coil probe to examine the tube ends. Our OTSG eddy-current and engineering evaluation vendor Framatome-ANP also determined that the POPCD method was not a good fit for the TEC degradation mechanism at CR-3. The lack of OTSG industry plant data on TECs also made it difficult to provide an adequate basis for using POPCD or any other method.

The CR-3 proposed method was used to benchmark against a previous cycle of known TEC leak data. The data below represents the use of this method if it had been used in the 12R (2001) refueling outage to predict the 13R (2003) TEC leakage. The data from 12R shown below contains data that has no "Increase" leakage value because there was insufficient data from prior outages to have a trend. In all future outages, the increase leakage component will be no less than zero and will be greater if the trend is upward. This means that when this method is used in the 14R, and beyond, the predicted leakage will be at least if not more conservative than the 13R predicted values presented here.

A OTSG Predicted TEC Leakage for 13R		**B OTSG Predicted TEC Leakage for 13R**	
As-Left for 12R	0.625 GPM	As-Left for 12R	0.625 GPM
New (12R – 11R)	0.336 GPM	New (12R – 11R)	0.442 GPM
POD	0.120 GPM	POD	0.169 GPM
Increase Trend	N/A – No prior cycle data	Increase Trend	N/A – No prior cycle data
Total =	**1.081 GPM**	**Total =**	**1.236 GPM**
A OTSG Actual TEC Leakage for 13R		**B OTSG Actual TEC Leakage for 13R**	
As-Found 13R Upper	0.932 GPM	As-Found 13R Upper	1.102 GPM
As-Found 13R Lower	0.013 GPM	As-Found 13R Lower	0.124 GPM
Actual 13R Total =	**0.945 GPM**	**Actual 13R Total =**	**1.226 GPM**

Conclusion: The predicted TEC leakage for both steam generators over-predicted the actual A-OTSG upper TEC leakage by ~ 16% and ~ 12% in B-OTSG. The first of-a-kind lower TECs were not expected in 13R, but there was still sufficient margin to address that increase.

NRC Question

2. **The assumed axial loading for main steam line break (MSLB) is 663 lbs max. Does this load correspond to the specific MSLB considered in the FSAR accident analyses? Are descriptions of the supporting thermal-hydraulic and structural analyses for this load on the docket and, if so, where? Has the thermal-hydraulic analysis been reviewed and approved by the staff?**

Response

The 663 lb tube load is based on CR-3 specific analyses documented in proprietary Topical Report BAW-10164P, "RELAP5/MOD2-B&W-An Advanced Computer Program for Light Water Reactor LOCA and Non-LOCA Transient Analysis," Revision V, November 1998 [Referenced in Chapter 14 of the CR-3 FSAR (Submitted to the NRC by Babcock and Wilcox Co. on November 11, 1980, Accession Number 8011180258] and Framatome ANP proprietary document "OTSG Transient Analysis", Appendix M (CR-3 Plant Specific MSLB), Revision 5, October 1999. The descriptions of the thermal-hydraulic and structural analyses for this load are not in the CR-3 docket, but the results were previously reviewed and accepted as part of License Amendment No. 188 (Table 2 of License Amendment Request #249, Revision 0, Once Through Steam Generator Tube Surveillance Program (TAC No. MA5395), Addendum to Babcock & Wilcox Owners Group Topical Report BAW-2346P dated May 28, 1999).

The Chapter 14 MSLB scenario provided the boundary conditions for the calculation of the tube loads. Note that CR-3 tube loads are smaller than the generic tube loads calculated in the past (BAW-10146P, Determination of Minimum Tube wall Thickness for 177 FA Once Through Steam Generators dated October 1980, Referenced in Chapter 14 of the CR-3 FSAR). This is attributable to differences in system hardware, their response to transient conditions and more advanced analytical methods (i.e. ANSYS, RELAP).

NRC Question

3. **Tables 6-1 and 6-2 in Attachment A of the licensee's January 27, 2005 submittal purport to benchmark the probabilistic approach (LeakTEC) with the deterministic approach for performing condition monitoring and operational assessment. These Tables suggest the probabilistic approach reduces the leakage estimates by roughly 2/3 compared to the reference deterministic approach. However, whereas the leakage versus delta dilation (or tubesheet radius) data used in the probabilistic analysis had been adjusted to reflect the change in tube diameter associated with the Crystal River 663 lb (max.) axial load, the deterministic approach utilized leakage data reflecting a change in tube diameter associated with a 3060 lb (max.) axial load. In addition, the deterministic method considered conservative step functions for the leak rate versus delta dilation and tubesheet radius relationships rather than more realistic smooth relationships. What is the effect on the deterministic results in Tables 6-1 and 6-2 if the leakage data upon which they are based are revised to reflect the tube diameter change associated with the Crystal River 663 lb (max.) axial load and if the leakage versus delta dilation and tubesheet radius relationships utilized were based on continuous curves (developed by interpolation) rather than conservative step functions?**

Response

Additional deterministic leakage estimates have been developed to reflect the effects discussed in RAI #3 and Addendum B (Attachment E) has been revised to include the information in Tables 6-1 and 6-2. The results of this work reveal that the elimination of tubesheet zones in favor of a continuous approach reduced the End of Cycle 13 (EOC13) estimate of total leakage returned to service by 12% to 15% as compared with deterministic estimates documented in the Condition Monitoring/Operational Assessment (CMOA). Accounting for the affect of axial load on delta dilation in the leak test data further reduced this estimate by an additional 45%. Removal of both of these sources of conservatism from the deterministic leakage calculation methodology yields results which, in a number of cases, fall below the probabilistic estimates. All estimates except for those documented in the CMOA are based upon CR-3 delta dilation values which include the effect of axial load on tube dilation. However, as illustrated in Addendum B, Figures 3-2 and 3-3 this has a negligible affect on the delta dilation values due to the relatively low axial loads present during the MSLB.

NRC Question

4. **The second sentence of the fourth paragraph of page 15 of 24 includes "maximum crack voltage" as an input parameter to LeakTEC. How is this parameter used in the analyses? Also, in item 2c on page 21 of 24 states that a non-zero value for voltage threshold may only be used if approved by the utility and/or NRC. The staff believes this statement is incorrect and that NRC approval is required in order to use a non-zero voltage threshold value. Item 2c should be clarified accordingly.**

Response

The voltage threshold parameter is not used in the analyses methodology submitted for approval in LAR #290. It was provided in the LeakTEC spreadsheet as a feature for possible future application but would only be used with specific NRC approval. Approval is not being sought for the use of this feature in LAR #290. Addendum B (Attachment E) has been revised to affirm that this feature is not to be used without NRC approval.

NRC Question

5. **The first sentence of the last paragraph on page 18 of 24 states, "For example, if POD is 0.84, a tube ..." Item 2b on page 21of 24 states, "If "Operational Assessment" was selected, specify the POD value." Table 6-3 on page 20 of 24 reports LeakTEC results for cases where POD is assumed to be 0.84 and 1.0, respectively. These sentences and any similar sentences in the report should be clarified to indicate that 0.84 is the NRC approved value for operational assessments.**

Response

Addendum B (Attachment E) has been revised to affirm that the NRC approved value of POD for estimating the quantity of undetected TEC leakage is 0.84. A POD value of 1.0 is used in conjunction with the LeakTEC "Operational Assessment" only when an estimate of the known return to service leakage is needed (i.e., leakage from TECs that are not repaired). The POD value of "1.0" is only a mathematical means of calculating the "known return to service" part of the total return to service leakage. Specifically, LeakTEC calculates the total return to service leakage as the sum of the undetected leakage plus the known return to service leakage, (TotalRTS = Undetected + KnownRTS). The "Undetected" part of the leakage equals the "AsFound/POD – AsFound". When using a POD value of 0.84, the "Undetected" leakage equals AsFound*(1/0.84 – 1) or ~0.19*AsFound. When using a POD value of 1.0 however, the "Undetected" part of the leakage equals AsFound*(1/1 – 1) or zero thus yielding only the "KnownRTS part of the leakage". The "KnownRTS" leakage is the "AsFound leakage minus the Repaired leakage" This concept has also been clarified within Ref. 1, Table 6-3.

NRC Question

6. Step 6 on page 17 of 24 should be corrected to state, "Steps 1 through 5 are repeated ..."

Response

Addendum B (Attachment E) has been revised to correct this error.

NRC Question

7. Section 1, "Introduction," (page 4 of 24) states that the report documents an ... approach to determine 95%/95% accident leakage rates for Crystal River Unit 3 tube end cracks. However, Step 6 on page 17 of 24 cites the one sided upper 95% probability/95% confidence value of leakage as "an example" of a desired probability and confidence value. Table 6-3 on page 20 of 24 adds further confusion on the desired probability and confidence value by showing LeakTEC results @ 50/50, 95/50, and 95/95. Please clarify Step 6 on page 17 of 24 and Table 6-3 on page 20 of 24 that the desired probability and confidence value for evaluating leakage against the accident leakage performance criteria (i.e., acceptance limit) is the one sided upper 95% probability/95% confidence value.

Response

Addendum B (Attachment E) has been revised to correct this error.

NRC Question

8. The Crystal River technical specifications references BAW-2346P, Rev 0, as providing the methodology for leaving tubes with TEC in service. BAW-2346P, Rev 0, as reviewed and approved by the NRC, does not include Addendum B which is the subject of the licensee's January 27, 2005, LAR #290, Rev. 0, nor does it include an Addendum C which the staff recommended be submitted in item 1 above. Addendums B and C would effectively change the methodology in BAW-2346P, Rev 0. Accordingly, the licensee should submit a technical specification amendment to reference BAW-2346P, Revision 1, rather than Revision 0. The licensee should state in the amendment request that Revision 1 incorporates Addenda B and C.

Response

LAR #290, Revision 1 provided in this submittal proposes to incorporate CR-3 specific Addenda B and C to BAW-2346P, Revision 0 into CR-3 Improved Technical Specification (ITS) 5.6.2.10.2.f. CR-3 has discussed with the NRC staff the proposed addition of these new requirements (Addenda B and C) without a Revision to BAW-2346P.