March 8, 2000 Template NRR-058

Mr. J. A. Scalice
Chief Nuclear Officer and
Executive Vice President
Tennessee Valley Authority
6A Lookout Place
1101 Market Street
Chattanooga, TN 37402-2801

SUBJECT: SEQUOYAH NUCLEAR PLANT, UNITS 1 AND 2 - ISSUANCE OF LICENSE AMENDMENTS REGARDING STEAM GENERATOR TUBE ALTERNATE REPAIR CRITERIA (TAC NOS. MA6856 AND MA6857) (TS 99-12)

Dear Mr. Scalice:

The Commission has issued the enclosed Amendment No. 252 to Facility Operating License No. DPR-77 and Amendment No. 243 to Facility Operating License No. DPR-79 for the Sequoyah Nuclear Plant (SQN), Units 1 and 2, respectively. These amendments are in response to your application dated October 14, 1999, as supplemented on February 23, 2000, and March 2, 2000, which requested approval to revise Section 4.4 of the Technical Specification surveillance testing requirements and their associated Bases to incorporate an alternate repair criteria (ARC) for axial primary water stress corrosion cracking at dented tube support plate intersections. The basis document for your request is Westinghouse Topical Report WCAP-15128, Revision 2. The U.S. Nuclear Regulatory Commission (NRC) staff has completed its review of the subject amendment request and has found the request acceptable for the next two operating cycles of SQN Units 1 and 2. The enclosed amendments involve the first application of the subject ARC. Licensees wishing to implement similar repair criteria at their facilities must submit a license amendment request for NRC staff review and approval.

A copy of our Safety Evaluation is also enclosed. A Notice of Issuance will be included in the Commission's next biweekly Federal Register notice.

Sincerely,

/RA/

Ronald W. Hernan, Sr. Project Manager, Section 2
Project Directorate II
Division of Licensing Project Management
Office of Nuclear Reactor Regulation

Docket Nos. 50-327 and 50-328

Enclosures: 1. Amendment No. 252 to DPR-77
2. Amendment No. 243 to DRP-79
3. Safety Evaluation

cc w/enclosures: See next page

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UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D.C. 20555-0001

March 8, 2000

Mr. J. A. Scalice
Chief Nuclear Officer and
Executive Vice President
Tennessee Valley Authority
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SUBJECT: SEQUOYAH NUCLEAR PLANT, UNITS 1 AND 2 - ISSUANCE OF LICENSE AMENDMENTS REGARDING STEAM GENERATOR TUBE ALTERNATE REPAIR CRITERIA (TAC NOS. MA6856 AND MA6857) (TS 99-12)

Dear Mr. Scalice:

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A copy of our Safety Evaluation is also enclosed. A Notice of Issuance will be included in the Commission's next biweekly Federal Register notice.

Sincerely,

Ronald W. Hernan

Ronald W. Hernan, Sr. Project Manager, Section 2
Project Directorate II
Division of Licensing Project Management
Office of Nuclear Reactor Regulation

Docket Nos. 50-327 and 50-328

Enclosures: 1. Amendment No. 252 to DPR-77
2. Amendment No. 243 to DPR-79
3. Safety Evaluation

cc w/enclosures: See next page

UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D.C. 20555-0001

TENNESSEE VALLEY AUTHORITY

DOCKET NO. 50-327

SEQUOYAH NUCLEAR PLANT, UNIT 1

AMENDMENT TO FACILITY OPERATING LICENSE

Amendment No. 252
License No. DPR-77

1. The Nuclear Regulatory Commission (the Commission) has found that:

    A. The application for amendment by Tennessee Valley Authority (the licensee) dated October 14, 1999, as supplemented on February 23, 2000, and March 2, 2000, complies with the standards and requirements of the Atomic Energy Act of 1954, as amended (the Act), and the Commission's rules and regulations set forth in 10 CFR Chapter I;

    B. The facility will operate in conformity with the application, the provisions of the Act, and the rules and regulations of the Commission;

    C. There is reasonable assurance (i) that the activities authorized by this amendment can be conducted without endangering the health and safety of the public, and (ii) that such activities will be conducted in compliance with the Commission's regulations;

    D. The issuance of this amendment will not be inimical to the common defense and security or to the health and safety of the public; and

    E. The issuance of this amendment is in accordance with 10 CFR Part 51 of the Commission's regulations and all applicable requirements have been satisfied.

2. Accordingly, the license is amended by changes to the Technical Specifications as indicated in the attachment to this license amendment and paragraph 2.C.(2) of Facility Operating License No. DPR-77 is hereby amended to read as follows:

(2) Technical Specifications

The Technical Specifications contained in Appendices A and B, as revised through Amendment No. 252 , are hereby incorporated in the license. The licensee shall operate the facility in accordance with the Technical Specifications.

3. This license amendment is effective as of its date of issuance, to be implemented no later than 45 days after issuance.

FOR THE NUCLEAR REGULATORY COMMISSION

Richard P. Correia

Richard P. Correia, Chief, Section 2
Project Directorate II
Division of Licensing Project Management
Office of Nuclear Reactor Regulation

Attachment: Changes to the Technical Specifications

Date of Issuance: March 8, 2000

ATTACHMENT TO LICENSE AMENDMENT NO. 252

FACILITY OPERATING LICENSE NO. DPR-77

DOCKET NO. 50-327

Replace the following pages of the Appendix A Technical Specifications with the attached revised pages. The revised pages are identified by amendment number and contain marginal lines indicating the areas of change.

REMOVE	INSERT
3/4 4-7	3/4 4-7
3/4 4-9	3/4 4-9
3/4 4-9a	3/4 4-9a
3/4 4-9b	3/4 4-9b
3/4 4-10a	3/4 4-10a
B 3/4 4-4	B 3/4 4-4
B 3/4 4-4a	B 3/4 4-4a
B 3/4 4-4b	B 3/4 4-4b
B 3/4 4-4c	B 3/4 4-4c

3. A tube inspection (pursuant to Specification 4.4.5.4.a.8) shall be performed on each selected tube. If any selected tube does not permit the passage of the eddy current probe for a tube inspection, this shall be recorded and an adjacent tube shall be selected and subjected to a tube inspection.

4. Indications left in service as a result of application of the tube support plate voltage-based repair criteria shall be inspected by bobbin coil probe during all future refueling outages. R226

c. The tubes selected as the second and third samples (if required by Table 4.4-2) during each inservice inspection may be subjected to a partial tube inspection provided:

1. The tubes selected for these samples include the tubes from those areas of the tube sheet array where tubes with imperfections were previously found.

2. The inspections include those portions of the tubes where imperfections were previously found.

NOTE: Tube degradation identified in the portion of the tube that is not a reactor coolant pressure boundary (tube end up to the start of the tube-to-tubesheet weld) is excluded from the Result and Action Required in Table 4.4-2. R193

d. Implementation of the steam generator tube/tube support plate repair criteria requires a 100 percent bobbin coil inspection for hot-leg and cold-leg tube support plate intersections down to the lowest cold-leg tube support plate with known outside diameter stress corrosion cracking (ODSCC) indications. The determination of the lowest cold-leg tube support plate intersections having ODSCC indications shall be based on the performance of at least a 20 percent random sampling of tubes inspected over their full length. R226

e. Inspection of dented tube support plate intersections will be performed in accordance with WCAP 15128, Revision 2, dated February 2000 as supplemented by TVA's letter to NRC dated March 2, 2000. This alternate repair criteria is applicable to Cycle 11 and 12 operation.

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

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.
C-3	More than 10% of the total tubes inspected are degraded tubes or more than 1% of the inspected tubes are defective.

Note: In all inspections, previously degraded tubes must exhibit significant (greater than 10%) further wall penetrations to be included in the above percentage calculations.

R226

4.4.5.4 Acceptance Criteria

a. As used in this Specification:

1. Imperfection means an exception to the dimensions, finish or contour of a tube from that required by fabrication drawings or specifications. Eddy-current testing indications below 20% of the nominal tube wall thickness, if detectable, may be considered as imperfections.

2. Degradation means a service-induced cracking, wastage, wear or general corrosion occuring or either inside or outside of a tube.

3. Degraded Tube means a tube containing imperfections greater than or equal to 20% of the nominal wall thickness caused by degradation.

4. % Degradation means the percentage of the tube wall thickness affected or removed by degradation.

5. Defect means an imperfection of such severity that it exceeds the plugging limit. A tube containing a defect is defective.

6. Plugging Limit means the imperfection depth at or beyond which the tube shall be removed from service and is equal to 40% of the nominal tube wall thickness. Plugging limit does not apply to that portion of the tube that is not within the pressure boundary of the reactor coolant system (tube end up to the start of the tube-to-tubesheet weld). This definition does not apply to tube support plate intersections if the voltage-based repair criteria are being applied. Refer to 4.4.5.4.a.10 for the repair limit applicable to these intersections. For Cycle 11 and 12 operation, this definition does not apply for axial PWSCC indications, or portions thereof, which are located within the thickness of dented tube support plates which exhibit a maximum depth greater than or equal to 40 percent of the initial tube wall thickness. Refer to 4.4.5.4.a.11 for the repair limits applicable to these intersections. R193 R226

7. Unserviceable describes the condition of a tube if it leaks or contains a defect large enough to affect its structural integrity in the event of an Operating Basis Earthquake, a loss-of-coolant accident, or a steam line or feedwater line break as specified in 4.4.5.3.c, above.

8. Tube Inspection means an inspection of the steam generator tube from the point of entry (hot leg side) completely around the U-bend to the top support of the cold leg.

9. Preservice Inspection means a tube inspection of the full length of each tube in each steam generator performed by eddy current techniques prior to service establish a baseline condition of the tubing. This inspection shall be performed prior to initial POWER OPERATION using the equipment and techniques expected to be used during subsequent inservice inspections.

10. Tube Support Plate Plugging Limit is used for the disposition of an alloy 600 steam generator tube for continued service that is experiencing predominately axially oriented outside diameter stress corrosion cracking confined within the thickness of the tube support plates. At tube support plate intersections, the plugging (repair) limit is based on maintaining steam generator tube serviceability as described below:

    a. Steam generator tubes, whose degradation is attributed to outside diameter stress corrosion cracking within the bounds of the tube support plate with bobbin voltages less than or equal to the lower voltage repair limit (Note 1), will be allowed to remain in service.

    b. Steam generator tubes, whose degradation is attributed to outside diameter stress corrosion cracking within the bounds of the tube support plate with a bobbin voltage greater than the lower voltage repair limit (Note 1), will be repaired or plugged, except as noted in 4.4.5.4.a.10.c below.

    c. Steam generator tubes, with indications of potential degradation attributed to outside diameter stress corrosion-cracking within the bounds of the tube support plate with a bobbin voltage greater than the lower voltage repair limit (Note 1), but less than or equal to upper voltage repair limit (Note 2), may remain in service if a rotating pancake coil inspection does not detect degradation. Steam generator tubes, with indications of outside diameter stress corrosion-cracking degradation with a bobbin coil voltage greater than the upper voltage repair limit (Note 2) will be plugged or repaired. R226

    d. Not applicable to SQN.

    e. If an unscheduled mid-cycle inspection is performed, the following mid-cycle repair limits apply instead of the limits identified in 4.4.5.4.a.10.a, 4.4.5.4.a.10.b, and 4.4.5.4.a.10.c.

The mid-cycle repair limits are determined from the following equations:

$$V_{MURL} = \frac{V_{SL}}{1.0+NDE+Gr\frac{(CL-\Delta t)}{CL}}$$

$$V_{MLRL}=V_{MURL}-(V_{URL}-V_{LRL})\frac{(CL-\Delta t)}{CL}$$

where:

V_{URL}	=	upper voltage repair limit
V_{LRL}	=	lower voltage repair limit
V_{MURL}	=	mid-cycle upper voltage repair limit based on time into cycle
V_{MLRL}	=	mid-cycle lower voltage repair limit based on V_{MURL} and time into cycle
Δt	=	length of time since last scheduled inspection during which V_{URL} and V_{LRL} were implemented
CL	=	cycle length (the time between two scheduled steam generator inspections)
V_{SL}	=	structural limit voltage
Gr	=	average growth rate per cycle length
NDE	=	95-percent cumulative probability allowance for nondestructive examination uncertainty (i.e., a value of 20-percent has been approved by NRC)

R226

Implementation of these mid-cycle repair limits should follow the same approach as in TS 4.4.5.4.a.10.a, 4.4.5.4.a.10.b, and 4.4.5.4.a.10.c.

Note 1: The lower voltage repair limit is 1.0 volt for 3/4-inch diameter tubing or 2.0 volts for 7/8-inch diameter tubing.

Note 2: The upper voltage repair limit is calculated according to the methodology in GL 90-05 as supplemented. V_{URL} may differ at the TSPs and flow distribution baffle.

11. Primary Water Stress Corrosion Cracking (PWSCC) Tube Support Plate Plugging Limit is used for the disposition of an Alloy 600 steam generator tube for continued service that is experiencing predominantly axially oriented PWSCC at dented tube support plate intersections as described in WCAP 15128, Revision 2, dated February 2000 as supplemented by TVA's letter to NRC dated March 2, 2000. This alternate repair criteria is applicable to Cycle 11 and 12 operation.

e. For implementation of the depth-based repair criteria for axial PWSCC at dented TSPs, the results of the condition monitoring and operational assessments will be reported to the NRC within 120 days following completion of the inspection. The report will include tabulations of indications found in the inspection, tabulations of tubes repaired and left in service under the ARC, and growth rate distributions for indications found in the inspection as well as the growth distributions used to establish the tube repair limits. Any corrective actions found necessary in the event that condition monitoring requirements are not met will be identified in the report.

The mid-cycle equation of SR 4.4.5.4.a.10.e should only be used during unplanned inspection in which eddy current data is acquired for indications at the tube support plates.

SR 4.4.5.5 implements several reporting requirements recommended by GL 95-05 for situations which NRC wants to be notified prior to returning the S/Gs to service. For SR 4.4.5.5.d., Items 3 and 4, indications are applicable only where alternate plugging criteria is being applied. For the purposes of this reporting requirement, leakage and conditional burst probability can be calculated based on the as-found voltage distribution rather than the projected end-of-cycle voltage distribution (refer to GL 95-05 for more information) when it is not practical to complete these calculations using the projected EOC voltage distributions prior to returning the S/Gs to service. Note that if leakage and conditional burst probability were calculated using the measured EOC voltage distribution for the purposes of addressing GL Sections 6.a.1 and 6.a.3 reporting criteria, then the results of the projected EOC voltage distribution should be provided per GL Section 6.b(c) criteria. R226

Wastage-type defects are unlikely with proper chemistry treatment of the secondary coolant. However, even if a defect should develop in service, it will be found during scheduled inservice steam generator tube examinations. Plugging will be required for all tubes with imperfections exceeding the repair limit defined in Surveillance Requirement 4.4.5.4.a. The portion of the tube that the plugging limit does not apply to is the portion of the tube that is not within the RCS pressure boundary (tube end up to the start of the tube-to-tubesheet weld). The tube end to tube-to-tubesheet weld portion of the tube does not affect structural integrity of the steam generator tubes and therefore indications found in this portion of the tube will be excluded from the Result and Action Required for tube inspections. It is expected that any indications that extend from this region will be detected during the scheduled tube inspections. Steam generator tube inspections of operating plants have demonstrated the capability to reliably detect degradation that has penetrated 20% of the original tube wall thickness. R226 R193

Tubes experiencing outside diameter stress corrosion cracking within the thickness of the tube support plate are plugged or repaired by the criteria of 4.4.5.4.a.10. R226

The steam generator tube repair limits for primary water stress corrosion cracking (PWSCC) of SR 4.4.5 represents a steam generator tube alternate repair criteria for greater than or equal to 40 percent deep PWSCC indications which are located within the thickness of tube support plates. The repair bases for PWSCC are not applicable to other types of localized tube wall degradation located at the tube-to-tube support plate intersections.

The ARC includes completion of a condition monitoring assessment to determine the end-of-cycle (EOC) condition of the tube bundle. An operational assessment is completed to determine the need for tube repair on a forward-fit basis. The ARC is based on the use of crack depth profiles obtained from Plus Point analyses. Burst pressures and leak rates are calculated from depth profiles by searching the total crack length for the partial length that results in the lowest burst pressure and the longest length that would tear through-wall at steam-line break conditions. The repair bases for PWSCC at dented TSP intersections is obtained by projecting the crack profile to the end of the next operating cycle and determining if the projected profile meets the requirements of WCAP 15128, Revision 2, dated February 2000 as supplemented by TVA's letter to NRC dated March 2, 2000. The following provides the limits and bases for repair established in the WCAP analyses:

Freespan Indication Repair Limits

The tube will be repaired if the crack length outside the dented TSP is ≥40% maximum depth.

Crack Length Limit for ≥40% Maximum Depth

The crack length limit for ≥40% maximum depth indications is defined as 0.375 inch from the centerline of the TSP. This limit defines the edges of the TSP thickness of 0.75 inch for Model 51 S/Gs. It is acceptable for the crack to extend to both edges of the TSP as long as the maximum depth of the crack outside the TSP is <40% maximum depth and the requirements for EOC conditions are acceptable.

Operational Assessment Repair Bases

If the indication satisfies the above maximum depth and length requirements, the repair bases is then obtained by projecting the crack profile to the end of the next operating cycle and determining the burst pressure and leakage for the projected profile. The burst pressure and leakage is compared to the requirements in WCAP 15128, Revision 2, dated February 2000 as supplemented by TVA's letter to NRC dated March 2, 2000. Separate analyses are required for the total crack length and the length outside the TSP due to differences in requirements. If the projected EOC requirements are satisfied, the tube will be left in service.

The results of the condition monitoring and operational assessments will be reported to the NRC within 120 days following completion of the inspection.

Whenever the results of any steam generator tubing inservice inspection fall into Category C-3, these results will be promptly reported to the Commission pursuant to Specification 6.6.1 prior to resumption of plant operation. Such cases will be considered by the Commission on a case-by-case basis and may result in a requirement for analysis, laboratory examinations, tests, additional eddy-current inspection, and revision of the Technical Specifications, if necessary. R40

R226

3/4.4.7 CHEMISTRY

The limitations on Reactor Coolant System chemistry ensure that corrosion of the Reactor Coolant System is minimized and reduces the potential for Reactor Coolant System leakage or failure due to stress corrosion. Maintaining the chemistry within the Steady State Limits provides adequate corrosion protection to ensure the structural integrity of the Reactor Coolant System over the life of the plant. The associated effects of exceeding the oxygen, chloride and fluoride limits are time and temperature dependent. Corrosion studies show that operation may be continued with contaminant concentration levels in excess of the Steady State Limits, up to the Transient Limits, for the specified limited time intervals without having a significant effect on the structural integrity of the Reactor Coolant System. The time interval permitting continued operation within the restrictions of the Transient Limits provides time for taking corrective actions to restore the contaminant concentrations to within the Steady State Limits.

UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D.C. 20555-0001

TENNESSEE VALLEY AUTHORITY

DOCKET NO. 50-328

SEQUOYAH NUCLEAR PLANT, UNIT 2

AMENDMENT TO FACILITY OPERATING LICENSE

Amendment No. 243
License No. DPR-79

1. The Nuclear Regulatory Commission (the Commission) has found that:

   A. The application for amendment by Tennessee Valley Authority (the licensee) dated October 14, 1999, as supplemented on February 23, 2000, and March 2, 2000, complies with the standards and requirements of the Atomic Energy Act of 1954, as amended (the Act), and the Commission's rules and regulations set forth in 10 CFR Chapter I;

   B. The facility will operate in conformity with the application, the provisions of the Act, and the rules and regulations of the Commission;

   C. There is reasonable assurance (i) that the activities authorized by this amendment can be conducted without endangering the health and safety of the public, and (ii) that such activities will be conducted in compliance with the Commission's regulations;

   D. The issuance of this amendment will not be inimical to the common defense and security or to the health and safety of the public; and

   E. The issuance of this amendment is in accordance with 10 CFR Part 51 of the Commission's regulations and all applicable requirements have been satisfied.

2. Accordingly, the license is amended by changes to the Technical Specifications as indicated in the attachment to this license amendment and paragraph 2.C.(2) of Facility Operating License No. DPR-79 is hereby amended to read as follows:

   (2) Technical Specifications

   The Technical Specifications contained in Appendices A and B, as revised through Amendment No. 243 , are hereby incorporated in the license. The licensee shall operate the facility in accordance with the Technical Specifications.

3. This license amendment is effective as of its date of issuance, to be implemented no later than 45 days after issuance.

FOR THE NUCLEAR REGULATORY COMMISSION

Richard P. Correia

Richard P. Correia, Chief, Section 2
Project Directorate II
Division of Licensing Project Management
Office of Nuclear Reactor Regulation

Attachment: Changes to the Technical Specifications

Date of Issuance: March 8, 2000

3/4.4.6 REACTOR COOLANT SYSTEM LEAKAGE

3/4.4.6.1 LEAKAGE DETECTION SYSTEMS

The RCS leakage detection systems required by this specification are provided to monitor and detect leakage from the Reactor Coolant Pressure Boundary. These detection systems are consistent with the recommendations of Regulatory Guide 1.45, "Reactor Coolant Pressure Boundary Leakage Detection Systems," May 1973.

3/4.4.6.2 OPERATIONAL LEAKAGE

Industry experience has shown that while a limited amount of leakage is expected from the RCS, the unidentified portion of this leakage can be reduced to a threshold value of less than 1 GPM. This threshold value is sufficiently low to ensure early detection of additional leakage.

The surveillance requirements for RCS Pressure Isolation Valves provide added assurances of valve integrity thereby reducing the probability of gross valve failure and consequent intersystem LOCA. Leakage from the RCS isolation valves is IDENTIFIED LEAKAGE and will be considered as a portion of the allowed limit.

The 10 GPM IDENTIFIED LEAKAGE limitation provides allowance for a limited amount of leakage from known sources whose presence will not interfere with the detection of UNIDENTIFIED LEAKAGE by the leakage detection systems.

The CONTROLLED LEAKAGE limitation restricts operation when the total flow supplied to the reactor coolant pump seals exceeds 40 GPM with the modulating valve in the supply line fully open at a nominal RCS pressure of 2235 psig. This limitation ensures that in the event of a LOCA, the safety injection flow will not be less than assumed in the accident analyses.

The total steam generator tube leakage limit of 600 gallons per day for all steam generators and 150 gallons per day for any one steam generator will minimize the potential for a significant leakage event during steam line break. Based on the NDE uncertainties, bobbin coil voltage distribution and crack growth rate from the previous inspection, the expected leak rate following a steam line rupture is limited to below 8.21 gpm at atmospheric conditions and 70°F in the faulted loop, which will limit the calculated offsite doses to within 10 percent of the 10 CFR 100 guidelines. If the projected and cycle distribution of crack indications results in primary-to-secondary leakage greater than 8.21 gpm in the faulted loop during a postulated steam line break event, additional tubes must be removed from service in order to reduce the postulated primary-to-secondary steam line break leakage to below 8.21 gpm. R226 R241

The 150-gallons per day limit incorporated into SR 4.4.6 is more restrictive than the standard operating leakage limit and is intended to provide an additional margin to accommodate a crack which might grow at a greater than expected rate or unexpectedly extend outside the thickness of the tube support plate. Hence, the reduced leakage limit, when combined with an effective leak rate monitoring program, provides additional assurance that, should a significant leak be experienced, it will be detected, and the plant shut down in a timely manner.

PRESSURE BOUNDARY LEAKAGE of any magnitude is unacceptable since it may be indicative of an impending gross failure of the pressure boundary. Therefore, the presence of any PRESSURE BOUNDARY LEAKAGE requires the unit to be promptly placed in COLD SHUTDOWN.

R226

ATTACHMENT TO LICENSE AMENDMENT NO. 243

FACILITY OPERATING LICENSE NO. DPR-79

DOCKET NO. 50-328

Replace the following pages of the Appendix A Technical Specifications with the attached revised pages. The revised pages are identified by amendment number and contain marginal lines indicating the areas of change.

REMOVE	INSERT
3/4 4-11	3/4 4-11
3/4 4-13	3/4 4-13
3/4 4-14	3/4 4-14
3/4 4-14a	3/4 4-14a
3/4 4-14b	3/4 4-14b
3/4 4-10c	3/4 4-14c
B 3/4 4-3a	B 3/4 4-3a
B 3/4 4-3b	B 3/4 4-3b

1. All nonplugged tubes that previously had detectable wall penetrations (greater than 20%).

2. Tubes in those areas where experience has indicated potential problems.

3. A tube inspection (pursuant to Specification 4.4.5.4.a.8) shall be performed on each selected tube. If any selected tube does not permit the passage of the eddy current probe for a tube inspection, this shall be recorded and an adjacent tube shall be selected and subjected to a tube inspection.

4. Indications left in service as a result of application of the tube support plate voltage-based repair criteria shall be inspected by bobbin coil probe during all future refueling outages. R213

c. The tubes selected as the second and third samples (if required by Table 4.4-2) during each inservice inspection may be subjected to a partial tube inspection provided:

1. The tubes selected for these samples include the tubes from those areas of the tube sheet array where tubes with imperfections were previously found.

2. The inspections include those portions of the tubes where imperfections were previously found.

Note: Tube degradation identified in the portion of the tube that is not a reactor coolant pressure boundary (tube end up to the start of the tube-to-tubesheet weld) is excluded from the Result and Action Required in Table 4.4-2. R181

d. Implementation of the steam generator tube/tube support plate repair criteria requires a 100 percent bobbin coil inspection for hot-leg and cold-leg tube support plate intersections down to the lowest cold-leg tube support plate with known outside diameter stress corrosion cracking (ODSCC) indications. The determination of the lowest cold-leg tube support plate intersections having ODSCC indications shall be based on the performance of at least a 20 percent random sampling of tubes inspected over their full length. R213

e. Inspection of dented tube support plate intersections will be performed in accordance with WCAP 15128, Revision 2, dated February 2000 as supplemented by TVA's letter to NRC dated March 2, 2000. This alternate repair criteria is applicable to Cycle 11 and 12 operation.

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

Category	Inspection Results
C-1	Less than 5% of the total tubes inspected are degraded tubes and none of the inspected tubes are defective.

R213

4.4.5.4 Acceptance Criteria

a. As used in this Specification:

1. Imperfection means an exception to the dimensions, finish or contour of a tube from that required by fabrication drawings or specifications. Eddy-current testing indications below 20% of the nominal tube wall thickness, if detectable, may be considered as imperfections.

2. Degradation means a service-induced cracking, wastage, wear or general corrosion occurring on either inside or outside of a tube.

3. Degraded Tube means a tube containing imperfections greater than or equal to 20% of the nominal wall thickness caused by degradation.

4. % Degradation means the percentage of the tube wall thickness affected or removed by degradation.

5. Defect means an imperfection of such severity that it exceeds the plugging limit. A tube containing a defect is defective.

6. Plugging Limit means the imperfection depth at or beyond which the tube shall be removed from service and is equal to 40% of the nominal tube wall thickness. Plugging limit does not apply to that portion of the tube that is not within the pressure boundary of the reactor coolant system (tube end up to the start of the tube-to-tubesheet weld). This definition does not apply to tube support plate intersections if the voltage-based repair criteria are being applied. Refer to 4.4.5.4.a.10 for the repair limit applicable to these intersections. For Cycle 11 and 12 operation, this definition does not apply for axial PWSCC indications, or portions thereof, which are located within the thickness of dented tube support plates which exhibit a maximum depth greater than or equal to 40 percent of the initial tube wall thickness. Refer to 4.4.5.4.a.11 for the repair limits applicable to these intersections. R181 R213

7. Unserviceable describes the condition of a tube if it leaks or contains a defect large enough to affect its structural integrity in the event of an Operating Basis Earthquake, a loss-of-coolant accident, or a steam line or feedwater line break as specified in 4.4.5.3.c, above.

8. Tube Inspection means an inspection of the steam generator tube from the point of entry (hot leg side) completely around the U-bend to the top support of the cold leg.

9. Preservice Inspection means an inspection of the full length of each tube in each steam generator performed by eddy current techniques prior to service to establish a baseline condition of the tubing. This inspection shall be performed prior to initial POWER OPERATION using the equipment and techniques expected to be used during subsequent inservice inspections.

10. Tube Support Plate Plugging Limit is used for the disposition of an alloy 600 steam generator tube for continued service that is experiencing predominately axially oriented outside diameter stress corrosion cracking confined within the thickness of the tube support plates. At tube support plate intersections, the plugging (repair) limit is based on maintaining steam generator tube serviceability as described below:

    a. Steam generator tubes, whose degradation is attributed to outside diameter stress corrosion cracking within the bounds of the tube support plate with bobbin voltages less than or equal to the lower voltage repair limit (Note 1), will be allowed to remain in service.

    b. Steam generator tubes, whose degradation is attributed to outside diameter stress corrosion cracking within the bounds of the tube support plate with a bobbin voltage greater than the lower voltage repair limit (Note 1), will be repaired or plugged, except as noted in 4.4.5.4.a.10.c below. R213

    c. Steam generator tubes, with indications of potential degradation attributed to outside diameter stress corrosion-cracking within the bounds of the tube support plate with a bobbin voltage greater than the lower voltage repair limit (Note 1), but less than or equal to upper voltage repair limit (Note 2), may remain in service if a rotating pancake coil inspection does not detect degradation. Steam generator tubes, with indications of outside diameter stress corrosion-cracking degradation with a bobbin coil voltage greater than the upper voltage repair limit (Note 2) will be plugged or repaired.

    d. Not applicable to SQN.

    e. If an unscheduled mid-cycle inspection is performed, the following mid-cycle repair limits apply instead of the limits identified in 4.4.5.4.a.10.a, 4.4.5.4.a.10.b, and 4.4.5.4.a.10.c.

The mid-cycle repair limits are determined from the following equations:

$$V_{MURL} = \frac{V_{SL}}{1.0 + NDE + Gr\frac{(CL-\Delta t)}{CL}}$$

$$V_{MLRL} = V_{MURL} - (V_{URL} - V_{LRL})\frac{(CL - \Delta t)}{CL}$$

where:

V_{URL}	=	upper voltage repair limit
V_{LRL}	=	lower voltage repair limit
V_{MURL}	=	mid-cycle upper voltage repair limit based on time into cycle
V_{MLRL}	=	mid-cycle lower voltage repair limit based on V_{MURL} and time into cycle
Δt	=	length of time since last scheduled inspection during which V_{URL} and V_{LRL} were implemented
CL	=	cycle length (the time between two scheduled steam generator inspections)
V_{SL}	=	structural limit voltage
Gr	=	average growth rate per cycle length
NDE	=	95-percent cumulative probability allowance for nondestructive examination uncertainty (i.e., a value of 20-percent has been approved by NRC)

R213

Implementation of these mid-cycle repair limits should follow the same approach as in TS 4.4.5.4.a.10.a, 4.4.5.4.a.10.b, and 4.4.5.4.a.10.c.

Note 1: The lower voltage repair limit is 1.0 volt for 3/4-inch diameter tubing or 2.0 volts for 7/8-inch diameter tubing.

Note 2: The upper voltage repair limit is calculated according to the methodology in GL 90-05 as supplemented. V_{URL} may differ at the TSPs and flow distribution baffle.

11. <u>Primary Water Stress Corrosion Cracking (PWSCC) Tube Support Plate Plugging Limit</u> is used for the disposition of an Alloy 600 steam generator tube for continued service that is experiencing predominantly axially oriented PWSCC at dented tube support plate intersections as described in WCAP 15128, Revision 2, dated February 2000 as supplemented by TVA's letter to NRC dated March 2, 2000. This alternate repair criteria is applicable to Cycle 11 and 12 operation.

b. The steam generator shall be determined OPERABLE after completing the corresponding actions (plug all tubes exceeding the plugging limit and all tubes containing through-wall cracks) required by Table 4.4-2.

4.4.5.5 Reports

a. Following each inservice inspection of steam generator tubes, the number of tubes plugged in each steam generator shall be reported to the Commission within 15 days.

b. The complete results of the steam generator tube inservice inspection shall be submitted to the Commission in a Special Report pursuant to Specification 6.9.2 within 12 months following the completion of the inspection. This Special Report shall include:

1. Number and extent of tubes inspected. R213

2. Location and percent of wall-thickness penetration for each indication of an imperfection.

3. Identification of tubes plugged.

c. Results of steam generator tube inspections which fall into Category C-3 shall be reported pursuant to Specification 6.6.1 prior to resumption of plant operation. The written followup of this report shall provide a description of investigations conducted to determine cause of the tube degradation and corrective measures taken to prevent recurrence. R28

d. For implementation of the voltage-based repair criteria to tube support plate intersections, notify the staff prior to returning the steam generators to service should any of the following conditions arise:

1. If estimated leakage based on the projected end-of-cycle (or if not practical using the actual measured end-of-cycle) voltage distribution exceeds the leak limit (determined from the licensing basis dose calculation for the postulated main steam line break) for the next operating cycle. R213

2. If circumferential crack-like indications are detected at the tube support plate intersections.

3. If indications are identified that extend beyond the confines of the tube support plate.

4. If indications are identified at the tube support plate elevations that are attributable to primary water stress corrosion cracking.

5. If the calculated conditional burst probability based on the projected end-of-cycle (or if not practical, using the actual measured end-of-cycle) voltage distribution exceeds 1×10^{-2}, notify the NRC and provide an assessment of the safety significance of the occurrence.

R213

e. For implementation of the depth-based repair criteria for axial PWSCC at dented TSPs, the results of the condition monitoring and operational assessments will be reported to the NRC within 120 days following completion of the inspection. The report will include tabulations of indications found in the inspection, tabulations of tubes repaired and left in service under the ARC, and growth rate distributions for indications found in the inspection as well as the growth distributions used to establish the tube repair limits. Any corrective actions found necessary in the event that condition monitoring requirements are not met will be identified in the report.

where V_{GR} represents the allowance for flaw growth between inspections and V_{NDE} represents the allowance for potential sources of error in the measurement of the bobbin coil voltage. Further discussion of the assumptions necessary to determine the voltage repair limit are discussed in GL 95-05.

The mid-cycle equation of SR 4.4.5.4.a.10.e should only be used during unplanned inspection in which eddy current data is acquired for indications at the tube support plates. R213

SR 4.4.5.5 implements several reporting requirements recommended by GL 95-05 for situations which NRC wants to be notified prior to returning the S/Gs to service. For SR 4.4.5.5.d., Items 3 and 4, indications are applicable only where alternate plugging criteria is being applied. For the purposes of this reporting requirement, leakage and conditional burst probability can be calculated based on the as-found voltage distribution rather than the projected end-of-cycle voltage distribution (refer to GL 95-05 for more information) when it is not practical to complete these calculations using the projected EOC voltage distributions prior to returning the S/Gs to service. Note that if leakage and conditional burst probability were calculated using the measured EOC voltage distribution for the purposes of addressing GL Sections 6.a.1 and 6.a.3 reporting criteria, then the results of the projected EOC voltage distribution should be provided per GL Section 6.b(c) criteria.

Wastage-type defects are unlikely with proper chemistry treatment of the secondary coolant. However, even if a defect should develop in service, it will be found during scheduled inservice steam generator tube examinations. Plugging will be required for all tubes with imperfections exceeding the repair limit defined in Surveillance Requirement 4.4.5.4.a. R213 The portion of the tube that the plugging limit does not apply to is the portion of the tube that is not within the RCS pressure boundary (tube end up to the start of the tube-to-tubesheet weld). R181 The tube end to tube-to-tubesheet weld portion of the tube does not affect structural integrity of the steam generator tubes and therefore indications found in this portion of the tube will be excluded from the Result and Action Required for tube inspections. It is expected that any indications that extend from this region will be detected during the scheduled tube inspections. Steam generator tube inspections of operating plants have demonstrated the capability to reliably detect degradation that has penetrated 20% of the original tube wall thickness.

Tubes experiencing outside diameter stress corrosion cracking within the thickness of the tube support plate are plugged or repaired by the criteria of 4.4.5.4.a.10. R213

The steam generator tube repair limits for primary water stress corrosion cracking (PWSCC) of SR 4.4.5 represents a steam generator tube alternate repair criteria for greater than or equal to 40 percent deep PWSCC indications which are located within the thickness of tube support plates. The repair bases for PWSCC are not applicable to other types of localized tube wall degradation located at the tube-to-tube support plate intersections.

The ARC includes completion of a condition monitoring assessment to determine the end-of-cycle (EOC) condition of the tube bundle. An operational assessment is completed to determine the need for tube repair on a forward-fit basis. The ARC is based on the use of crack depth profiles obtained from Plus Point analyses. Burst pressures and leak rates are calculated from depth profiles by searching the total crack length for the partial length that results in the lowest burst pressure and the longest length that would tear through-wall at steam-line break conditions. The repair bases for PWSCC at dented TSP intersections is obtained by projecting the crack profile to the end of the next operating cycle and determining if the projected profile meets the requirements of WCAP 15128, Revision 2, dated February 2000 as supplemented by TVA's letter to NRC dated March 2, 2000. The following provides the limits and bases for repair established in the WCAP analyses:

Freespan Indication Repair Limits

The tube will be repaired if the crack length outside the dented TSP is ≥40% maximum depth.

Crack Length Limit for ≥40% Maximum Depth

The crack length limit for ≥40% maximum depth indications is defined as 0.375 inch from the centerline of the TSP. This limit defines the edges of the TSP thickness of 0.75 inch for Model 51 S/Gs. It is acceptable for the crack to extend to both edges of the TSP as long as the maximum depth of the crack outside the TSP is <40% maximum depth and the requirements for EOC conditions are acceptable.

Operational Assessment Repair Bases

If the indication satisfies the above maximum depth and length requirements, the repair bases is then obtained by projecting the crack profile to the end of the next operating cycle and determining the burst pressure and leakage for the projected profile. The burst pressure and leakage is compared to the requirements in WCAP 15128, Revision 2, dated February 2000 as supplemented by TVA's letter to NRC dated March 2, 2000. Separate analyses are required for the total crack length and the length outside the TSP due to differences in requirements. If the projected EOC requirements are satisfied, the tube will be left in service.

The results of the condition monitoring and operational assessments will be reported to the NRC within 120 days following completion of the inspection.

Whenever the results of any steam generator tubing inservice inspection fall into Category C-3, these results will be promptly reported to the Commission pursuant to Specification 6.6.1 prior to resumption of plant operation. Such cases will be considered by the Commission on a case-by-case basis and may result in a requirement for analysis, laboratory examinations, tests, additional eddy-current inspection, and revision of the Technical Specifications, if necessary.

R213

UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D.C. 20555-0001

SAFETY EVALUATION BY THE OFFICE OF NUCLEAR REACTOR REGULATION

RELATED TO AMENDMENT NO. *252* TO FACILITY OPERATING LICENSE NO. DPR-77

AND AMENDMENT NO. *243* TO FACILITY OPERATING LICENSE NO. DPR-79

TENNESSEE VALLEY AUTHORITY

SEQUOYAH NUCLEAR PLANT, UNITS 1 AND 2

DOCKET NOS. 50-327 AND 50-328

1.0 INTRODUCTION

By letter dated October 14, 1999, as supplemented by letters dated February 23, 2000, and March 2, 2000, the Tennessee Valley Authority (TVA, the licensee) submitted a technical specification (TS) amendment request (application) for the Sequoyah Nuclear Plant (SQN), Units 1 and 2, to incorporate new alternate repair criteria (ARC) for steam generator (SG) tubes with primary water stress corrosion cracking (PWSCC) at dented tube support plate (TSP) intersections. This amendment request would apply only to Operating Cycles 11 and 12 at both units. The supplemental letters did not expand the scope of the initial amendment request or change the U.S. Nuclear Regulatory Commission (NRC) staff's initial proposed no significant hazards consideration determination.

Currently, the applicable tube repair criteria for this type of flaw indication are the standard depth-based criteria; namely, tubes with indicated maximum flaw depths greater than or equal to 40% of the initial tube wall thickness must be plugged. The proposed ARC consists of an integrated approach to managing PWSCC at dented TSP intersections to ensure that tube structural and leakage integrity are maintained. This integrated approach includes an inspection program for detection and sizing of PWSCC flaws and methodologies for assessing tube structural and leakage integrity. The ARC itself is not a fixed value; rather, tubes with PWSCC indications are accepted for continued service when it can be demonstrated by the assessment methodologies that structural and leakage integrity will be maintained until the next scheduled inspection outage.

2.0 BACKGROUND

Sequoyah Units 1 and 2 are 4-loop Westinghouse plants with Model 51 SGs. Each SG contains about 3300 tubes. The SG tubes are mill annealed Alloy 600 with an outer diameter of 0.875 inches and a wall thickness of 0.050 inches. Each SG contains seven TSPs to provide lateral support to the tubes. The TSPs are carbon steel, 3/4-inch thick, with drilled holes through which the tubes are inserted. There is nominally a 0.013 to 0.018-inch diametral clearance between the tube and TSP at each TSP intersection. At Sequoyah Unit 1, however, corrosion of the carbon steel TSPs has led to the buildup of hard corrosion product (primarily magnetite) in the annulus between the tube and tubeheet. This magnetite buildup ultimately leads to radial deformation of the tubes at the vicinity of the intersection. This radial deformation of the tube is referred to as denting. The strain in the tubes at dent locations renders the tubes susceptible to PWSCC. Both denting and PWSCC can be detected using the eddy current test method during inservice inspection. The vast majority of TSP intersections in the Unit 1 SGs are dented. PWSCC indications detected to date number in the hundreds. The Unit 1 SGs are scheduled for replacement at the conclusion of Cycle 12 of operation. This is two fuel cycles beyond the March 2000 refueling outage, when the proposed ARC would be first implemented.

At Sequoyah Unit 2, relatively few TSP intersections have been found to be dented. No PWSCC indications have been detected to date.

3.0 PROPOSED TECHNICAL SPECIFICATION AMENDMENT

TVA proposes to revise the TS for Sequoyah Units 1 and 2 to establish an ARC for PWSCC at dented TSP intersections as follows:

- Add a new TS surveillance requirement (SR) (4.4.5.2.e) to require inspection of dented tube support plate intersections to be performed in accordance with Westinghouse Topical Report WCAP-15128, "Depth-Based SG Tube Repair Criteria for Axial PWSCC at Dented TSP Intersections," Revision 2, dated February 2000. This ARC is applicable to Cycles 11 and 12 of operation at Units 1 and 2.

- Revise the definition of "plugging limit" in SR 4.4.5.4.a.6 to state that, for Cycle 11 and 12 operation, the 40% depth-based limit does not apply to axial PWSCC indications, or portions thereof, which are located within the thickness of dented TSPs. The revised definition states that the repair limits applicable to these intersections are given in SR 4.4.5.4.a.11.

- Add new specification SR 4.4.5.4.a.11 which states that the PWSCC TSP plugging limit is used for the disposition of an Alloy 600 SG tube for continued service that is experiencing predominantly axially oriented PWSCC at dented TSP intersections. This plugging limit is described in WCAP-15128, Revision 2, dated February 2000. This ARC is applicable to Cycle 11 and 12 of operation.

- Add new reporting requirement (SR 4.4.5.5.e) that states that for implementation of the PWSCC TSP plugging limit, the results of the condition monitoring and operational assessments will be reported to the NRC within 120 days following completion of the inspection. The report will include tabulations of indications found by inspection, tabulations of both tubes repaired and those left in service under the ARC, and growth rate distributions indicated by the inspection results. Any corrective actions found necessary in the event that condition monitoring requirements defined in WCAP-15128, Revision 2, are not met will be identified in the report.

The proposed TS amendment includes an addition to the TS Bases summarizing the ARC methodology (for PWSCC at dented TSPs) as described in detail in WCAP-15128, Revision 2.

4.0 WCAP-15128, REVISION 2, METHODOLOGY OVERVIEW

The scope of the WCAP-15128 methodology includes an inspection program to identify and size PWSCC indications at dented TSP intersections; models for assessing inspection flaw detection and sizing performance, crack growth rate, burst pressure, and accident-induced leakage; and an operational assessment and a condition monitoring methodology. Each PWSCC indication found by inspection is dispositioned as acceptable or unacceptable for continued service based on its measured crack profile and the results of an operational assessment. The operational assessment projects the potential growth of the indication to the next scheduled inspection, allowing for potential error in the measured crack size, and determines the associated burst pressure capability and potential leak rate under postulated accident conditions. The success criteria for burst pressure capability and accident induced leak rate are consistent with those in NRC Regulatory Guide 1.121 (Reference 1) and Nuclear Energy Institute publication NEI 97-06, Revision 1b, "Steam Generator Program Guidelines" (Reference 2). Tubes with PWSCC indications not satisfying the applicable burst pressure and accident leak rate success criteria (see Section 5.4 of this safety evaluation (SE)) are removed from service by plugging. Tubes with PWSCC indications satisfying these criteria may be left in service without plugging. Finally, a condition monitoring assessment is performed on the PWSCC indications found at each inspection to confirm that the burst pressure and accident leakage acceptance criteria were in fact met during the preceding inspection interval.

5.0 EVALUATION

5.1 SG Eddy Current Inspection Program

As part of this ARC, TVA will apply two SG tube eddy current inspection techniques. The first technique uses a bobbin coil probe, and the second technique uses a +Point probe. At TSP intersections where the dents are less than or equal to 2 volts in size, TVA relies on the bobbin coil technique to quantify the dent size and to detect the presence of PWSCC. If the bobbin inspection detects a flaw-like eddy current signal, TVA reinspects the intersections using the +Point technique to confirm and size the indication. At TSP intersections where the dents are larger than 2 volts in size, TVA relies on the +Point technique to both detect and size PWSCC indications.

Westinghouse tested and evaluated the eddy current inspection techniques to be applied as part of this ARC following guidance in the Electric Power Research Institute's (EPRI's) "PWR Steam Generator Examination Guidelines," specifically Appendix H (Reference 3) and the NRC staff's Draft Regulatory Guide DG-1074, "Steam Generator Tube Integrity" (Reference 4). From this testing and evaluation, they developed the probabilities of detection (PODs), nondestructive examination (NDE) sizing uncertainties, and a PWSCC indication growth rate methodology to be applied in the operational assessment and condition monitoring. Although the staff reviewed all aspects of the NDE technique development and evaluation, we focused our attention on the data set upon which the technique was developed, the results of the POD and NDE sizing uncertainty evaluations, the growth rate methodology, and the steam generator inspection plan. Each of these areas is discussed in more detail below.

5.1.1 PWSCC Data Set

The first step in the development of a qualified NDE technique is to assemble a relevant data set. The staff reviewed the data set used by Westinghouse to qualify and validate the two NDE techniques to be applied as part of this ARC. The data set includes five PWSCC flaws obtained from service-degraded tube specimens, one from Sequoyah and four from Diablo Canyon. The characteristics of these tubes (i.e., location in the SG, size of the dents, and size of the defects) appear fairly typical and representative of the types of indications to which this ARC is to be applied. Westinghouse supplemented the data set with over 50 additional PWSCC flaws obtained by mechanically denting and chemically attacking 7/8-inch diameter mill annealed Alloy 600 tubing. These flaws varied in length and depth to encompass both very short and very long flaws, very shallow and very deep flaws (lengths of 0.12 inches to 2.6 inches, average depths of 7% to 96% through-wall, maximum depths of 16% to 100% through-wall). The flaws were axially oriented PWSCC that initiated within the dented portion of the tube in the minor axis of the dent, consistent with field operating experience. The crack morphology of the laboratory specimens also appears consistent with the pulled tubes. The specimens developed one or two cracks per TSP intersection. The cracks were well aligned axially, some with uncorroded ligaments. The staff visited the Westinghouse test facility for part of the NDE performance testing and found that there was no discernable difference in the eddy current signals obtained from service-induced cracks and laboratory-supplied cracks (Reference 5).

Westinghouse used standard field equipment in the eddy current data acquisition phase. Prior to obtaining the NDE data, they placed carbon steel collars around the specimens to simulate the TSPs and also packed the crevices between the lab specimens and the TSP simulant collars with a magnetite mixture. In this way the NDE examination of the laboratory specimens included signals from both the TSP and the crevice deposits, as tubes do in the field.

Westinghouse compared the dent morphology and eddy current signals obtained from the laboratory specimens with those typically seen in the field. In general, the laboratory specimens' dent size was typical of that seen in the field, but the dent morphology was not typical. The laboratory specimens had more localized deformation of the tubes than generally seen in the field. Although not prototypical, Westinghouse characterized the laboratory dents as being more difficult to analyze because of the localized distortion and the location of the flaw in relation to that distortion.

The NRC staff finds that the PWSCC data set described in the WCAP meets the industry guidelines for NDE technique qualification as discussed in the EPRI guidelines as well as draft staff guidelines in DG-1074. The data set includes pulled tube specimens supplemented by laboratory specimens that appear representative of field conditions with respect to crack size, crack morphology and the inclusion of denting, TSPs, and TSP crevice deposits. The number of specimens included in the data set is adequate and includes a diverse representation of lengths and depths. The laboratory specimens were fabricated from 7/8-inch mill annealed Alloy 600 tubing, representative of the tubing in the Sequoyah and Diablo Canyon plants. The staff found that PWSCC associated with very large dent voltages (i.e., greater than 5 volts) was not represented by the PWSCC data set. Because the +Point probe is a surface riding coil that nominally does not respond to dents, the staff believes the lack of large dents in the PWSCC data set can, in general, be considered acceptable. In addition, TVA committed to enhancing their analyst guidelines to ensure correct probe positioning and movement (i.e., through the use of axial encoders and observation of the trigger pulse).

5.1.2 POD (Probability of Detection)

As discussed above, Sequoyah will apply two eddy current test techniques during its steam generator tube inspection. They will use the bobbin coil technique to detect the presence of PWSCC at TSP intersections where the dents are less than or equal to 2.0 volts in size. At TSP intersections where the dents are larger than 2.0 volts in size, Sequoyah will use the +Point technique to both detect and size PWSCC indications. Westinghouse qualified these two eddy current test techniques for this specific ARC application following the EPRI guidelines. The Appendix H guidelines place a minimum acceptance criterion on the POD of greater than or equal to 80% at the 90% confidence level. Westinghouse documented a POD of 0.86 at 90% confidence for maximum depths greater than 34% through-wall for the bobbin coil technique and 0.92 at 90% confidence for maximum depths greater than 34% through-wall for the +Point technique. These results are documented in ETSS # 96012 for the bobbin coil technique and ETSS # 96703 for the +Point technique. These PODs meet the Appendix H guidelines and therefore, the techniques may be considered qualified for detection of PWSCC at dented TSP intersections.

Westinghouse also validated these NDE techniques following the staff's draft guide DG-1074. The NRC staff focused its attention on the results of this validation effort because this effort provides the most representative assessment of the ability of these NDE techniques. This phase of the NDE technique testing consisted of two or three independent teams performing blind analysis of the PWSCC data set described earlier. From this testing, Westinghouse reassessed the POD performance, quantified the NDE sizing uncertainties, and quantified the more recent growth rates at Sequoyah.

With respect to the POD, Westinghouse obtained results similar to those obtained for the Appendix H qualification discussed above. The staff agrees that the performance of the +Point coil demonstrated the effectiveness of this specific NDE technique. The POD values easily met the guidelines of Appendix H and the false call rates were very low. However, the POD determined for the bobbin coil technique, although it met Appendix H, also had very high false call rates associated with achieving this POD. The staff is concerned with the high false call rate for the bobbin coil test because it may be masking the true performance of the bobbin coil technique. This in itself is not a concern if analysts continue to overcall in the field. This would be a conservative practice because all bobbin indications receive a reinspection with the +Point probe. However, if the high overcall rate is masking a poor POD, and the analysts relax their standards and do not call as conservatively in the field, this may result in missed PWSCC indications. One way of helping to ensure that analysts continue to call conservatively in the field is to track the +Point confirmation rates. If TVA continues to have a low +Point confirmation rate (i.e., less than 10%), this indicates that analysts are calling the bobbin coil inspection results conservatively. TVA committed to providing this information in its 120-day reports.

Missed PWSCC indications may become a structural or leakage integrity concern in two ways. The first way is if the NDE technique is incapable of detecting structurally or leakage significant indications. Westinghouse provided a discussion of the undetected indications in the WCAP and found that largest indications not detected by either the bobbin coil or +Point probe were neither structurally nor leakage significant. This corroborates the staff's experience to date. The second more likely way missed PWSCC indications can become a problem is due to high growth rates. With high growth rates a more sensitive NDE technique is required to detect very small indications or a shortened operating cycle is required so that the large growth rates will not impair tube integrity. Based on Sequoyah's growth rate assessment over the past two Cycles, the sensitivity of the NDE techniques to be applied at the upcoming outage are sufficient to provide reasonable assurance that significant PWSCC flaws will be detected and evaluated before such indications become a challenge to structural and/or leakage integrity. The condition monitoring results over the next two Cycles will assist the staff in further assessing this aspect of the ARC for any approval of use of the ARC beyond the two operating cycles authorized by these amendments for SQN.

TVA uses POD explicitly in its operational assessment of steam generator tube leakage. Because of the concerns discussed above with the validity of the assumed bobbin coil POD, TVA agreed to use a constant POD value of 0.6. The staff finds this acceptable because operating experience to date using this POD value for the ARC for outer diameter stress corrosion cracking (ODSCC) at the TSPs (i.e., Generic Letter (GL) 95-05) indicates its use results in conservative projections of the end of Cycle conditions. The use of this same value for PWSCC at the TSPs should provide comparable results because PWSCC is, in general, more easily detected by the bobbin coil compared to ODSCC, as long as the dents are small (i.e., less than 2 volts in size).

5.1.3 NDE Sizing Uncertainties

As part of the validation testing, Westinghouse determined the NDE sizing uncertainties to be applied as part of this ARC by comparing NDE data obtained from three independent analyses with destructive examination data for the tube specimens. NDE sizing uncertainties were determined for length, average depth and maximum depth. Westinghouse used the method of least squares regression analysis in examining the relationship between the NDE data and the destructive examination data. The staff found the use of a linear regression acceptable for this application. Westinghouse evaluated the results of various statistical tests (e.g., correlation coefficient, p-value, residual analysis), and these results support the use of this model. Sequoyah will apply these NDE sizing uncertainties to the crack profiles obtained from the inspection when performing the operational assessment and condition monitoring.

5.1.4 Growth Rates

Westinghouse determined three separate growth rate distributions for indication length, maximum depth, and average depth. These growth rates are based on data from the last two inspections at Sequoyah (Cycles 8 and 9) and will be applied at Sequoyah's upcoming outage. In determining the growth rate distributions, Westinghouse set negative growth rates to zero and only used data for which the indication could be sized for both Cycles. Westinghouse found that when the later Cycle indication was large, the prior Cycle data could be sized. Therefore, they believe that omitting data with no prior Cycle indication would not affect the large growth rate tail of the growth distributions. The staff finds this approach reasonable. If TVA finds large, structural and leak significant PWSCC indications that did not have any prior Cycle information, this will be evident in the condition monitoring and will be factored into Sequoyah's operational assessment.

of WCAP-15128, Revision 2. The NRC staff's evaluation of this methodology focused on the development of the regression models for performing the burst pressure analysis.

The process up to the establishment of an "adjusted" crack profile from the NDE inspection results is addressed in Section 5.4 of this SE. After the "adjusted" crack profile is established for the first iteration, a crack front search routine is entered which samples every continuous combination of flaw subregions to determine the subregion which exhibits the lowest burst pressure, the so-called "weakest link." The "weakest link" theory used by TVA assumes that for a given crack profile, some part of that crack profile will, based on its length and average depth, control the burst behavior of the flaw. This theory also assumes that the flawed region adjacent to, but outside of, the "weakest link" zone, which is effectively assumed to be unflawed for modeling purposes, does not provide a first-order effect with respect to the burst behavior. However, not accounting for these adjacent flawed regions may contribute to the observed scatter of the available test data around the regression model.

The original burst test data base which was used for developing the regression models for this ARC is given in Table 5-1 of WCAP-15128, Revision 2. However, a more complete 119 point data base (which reconciles any apparent differences in the information presented in Section 3.0 and Section 5.0 of Revision 2 of the WCAP Report) is referenced in TVA letter dated March 2, 2000. It is this 119 point data base that was used to develop the final regression model.

The data base consisted of both pulled tube data and laboratory test specimen data having either PWSCC or ODSCC flaws. Since the burst behavior is governed by ductile tearing and no substantial though-wall stress gradients (which would affect inside diameter and outside diameter flaws differently) are expected, the use of a mixed PWSCC and ODSCC data base was considered by the NRC staff to be acceptable. Furthermore, when comparing the observed burst pressure to the model predicted burst pressure, a correction factor was applied to the model prediction for the ODSCC data points and those PWSCC data points which came from lined tubes to correct for the absence of pressurization on the crack flanks. The characterization of each flaw's "weakest link" zone in terms of its effective length (L_{eff}) and average depth (D_{avg}) was made from post-burst testing metallographic examination.

TVA's modeling approach began with establishing lower-bound, mechanistic models which would then be regressed to the burst test data base. Since TVA's approach characterizes the "weakest link" zone by L_{eff} and D_{avg}, TVA noted that the burst pressure of the flaw must be between the burst pressure of the unflawed tube and the burst pressure of a through-wall flaw of length L_{eff}. TVA proposed that two lower bound models should therefore be considered: the first, a part-through-wall flaw model (PTW model) based on the work of Cochet (References 6 and 7) for outside diameter cracks; and the second, a through-wall flaw model (TW model) from work performed to support limits contained in the American Society of Mechanical Engineers (ASME) Code (Reference 8). The models are given in equations 1 and 2 below. To obtain the model predicted burst pressure for a given flaw, the burst pressure would be calculated using each model and the larger of the two predictions would be assigned as the model predicted burst pressure. The larger of the two values is used because if the PTW model result is less than the TW model result, the PTW model is providing a non-physical answer which is possible for deep flaws with small remaining ligaments. Likewise, if the PTW model result is greater than the TW model result, then it is physically acceptable.

(1) PTW Model $P_{Bo} = 0.58*(S_Y + S_U)*(t/R_i)*\{1 - h*[L_{eff} / (L_{eff} + 2*t)]\}$

(2) TW Model $P_{B(TW)} = 1.15*(S_Y + S_U)*(t/R_o)*\{4 + 1.61*[L_{eff} / (R_m*t)]\}^{-1/2}$

where: P_{Bo} = the predicted burst pressure for an outside diameter PTW flaw
$P_{B(TW)}$ = the predicted burst pressure for a TW flaw
S_Y = the yield strength of the tube
S_U = the ultimate strength of the tube
t = the thickness of the tube
R_i = the inside radius of the tube
R_o = the outside radius of the tube
R_m = the mean radius of the tube
L_{eff} = the effective length of the "weakest link" zone
h = the ratio of the average depth of the "weakest link" zone to the thickness of the tube

As noted previously, since the burst test data base also contains data from the testing of unlined, PTW, PWSCC flaws, a correction factor to account for pressurization of the crack flanks was developed and applied to the base PTW model in equation 1 when making predictions for these samples. The correction factor was:

(3) $$P_{Bi} = P_{Bo} / \{1 + (t/R_i)*[L_{eff} / (L_{eff} + 2*t)]\}$$

where: P_{Bi} = the predicted burst pressure for an unlined, inside diameter PTW flaw

and the other variables are as defined above.

Next, TVA developed a best-estimate model by linear regression of the model predicted burst pressures versus the actual test burst pressures. It is important to note that the acceptability of this modeling methodology relies on this reconciliation of the initial, mechanistic models to available test data through the regression analysis. The linear regression was performed by first normalizing the model predicted and actual test burst pressures by twice the flow stress of the tube material, equal to $(S_U + S_Y)$. The normalized values, G_M for the normalized model predicted burst pressure and G_A for the normalized actual test burst pressure, were then plotted by taking the natural logarithm of each value. The linear regression analysis was then performed as:

(4) $$\ln G_A = m*(\ln G_M) + b$$

The standard error of the regression model is then determined from the standard deviation of the regression errors from the data points in the data base. It should be noted that TVA also considered plotting the data in linear form for purposes of performing the regression analysis, but observed superior results from the use of the log-log mapping.

The staff has concluded that the variables contained in the models for predicting the burst pressure of a given flaw were reasonable and would be expected to result in a physically accurate model. The staff has also been able to reproduce the regression analysis proposed by TVA from the normalized model predicted and actual test burst pressures. Therefore, the

TVA plans to apply its growth rate data from Cycles 8 and 9 in its operational assessment for Cycle 11. The staff requested Sequoyah to consider the Cycle 10 growth rate to ensure that a significant increase in growth rate has not occurred during the past operating cycle. Because of the significant time and cost penalty associated with updating the growth rate data to include all the Cycle 10 data, TVA proposed a modified growth rate update. Sequoyah will determine the Cycle 10 growth rates for all tubes already in service with PWSCC indications (approximately 54 indications). These tubes were left in service during the last inspection because the maximum depth was less than 40% through-wall. Sequoyah will then combine the additional Cycle 10 growth data from these indications with the Cycles 8 and 9 growth rate data. In addition, when new indications are found and sized during the upcoming inspection, TVA will compare the new indications' depths and lengths to the sizes of indications found at the last inspection. If the new indications have average or maximum depths comparable to the largest indications found at the last inspection and left in service, growth rates will be obtained for these new indications by reevaluating and sizing the Cycle 9 data. Upon obtaining these growth rates, the data will also be added to the existing growth distribution. TVA will compare the growth rate cumulative distribution function (CDF) obtained from this new growth rate data with the CDF obtained from the original Cycles 8 and 9 growth rate data. For determining tube repair limits, Sequoyah will apply the growth rate distribution that has the larger growth rate above the 90% cumulative probability. In its 120-day report, TVA will provide the staff its evaluation of all the Cycle 10 growth rate data and provide an updated operational assessment, as appropriate. The staff finds this approach acceptable because TVA is appropriately considering Cycle 10 growth rates in its repair decisions. Because it is impracticable at this time for Sequoyah to consider all Cycle 10 growth rates, the number of inservice tubes that TVA will be able to consider in an updated distribution is likely to provide an acceptable summation of how growth rates are changing. For a permanent license amendment to implement this ARC, the staff may require a complete assessment of the prior Cycle growth rates. The staff will be monitoring how this more limited approach works in its review of the 120-day reports.

5.1.5 Inspection Scope

TVA will perform a 100% bobbin coil inspection of all TSP intersections. The bobbin coil inspection quantifies the voltage response of dents at each TSP intersection and is the NDE technique relied upon to detect PWSCC at TSP intersections with dents not exceeding 2 volts. TVA will use the +Point coil to confirm all bobbin coil indications and to inspect all prior PWSCC indications left in service. Sequoyah will also use the +Point probe to inspect all TSP intersections with greater than 2 volt dents up to the highest TSP in each steam generator for which PWSCC has been detected in the current and previous inspections and 20% of such intersections in the next higher TSP. The staff finds the bobbin coil and +Point inspection scope to be comprehensive, appropriately sensitive to inspection findings, and consistent with industry practice.

5.2 Burst Pressure Analyses

TVA documented their approach to performing the burst pressure operational assessment and condition monitoring analyses (for tubes taken out of service) for PWSCC indications at dented TSPs in Section 5.0 of WCAP-15128, Revision 2. These operational assessments are based on the use of a Monte Carlo simulation approach to evaluate individual crack indications identified by the eddy current inspections. Note that, for clarity, the variables used to represent specific quantities in the following discussion may not be identical to those used in Section 5.0

staff has concluded that TVA's burst pressure analysis methodology is acceptable for the operational assessment of PTW PWSCC at dented TSP intersections in this ARC.

5.3 Accident Leakage Analysis

TVA documented their approach to performing the accident-induced leakage analyses for the purposes of operational assessment and condition monitoring for PWSCC indications at dented TSPs in Section 6.0 of WCAP-15128, Revision 2 and clarified or amended portions of the approach by letter dated March 2, 2000. The leakage evaluations would be based on the use of a leakage rate regression model via a Monte Carlo simulation approach to evaluate the entire SG. This section will discuss the overall evaluation methodology and the development of the leak rate regression model in detail. Note that, for clarity, the variables used to represent specific quantities in the following discussion may not be identical to those used in Section 6.0 of WCAP-15128, Revision 2.

The process up to the establishment of an "adjusted" crack profile from the NDE inspection results is addressed in Section 5.4 of this SE. After the "adjusted" crack profile is established for the first flaw, a crack front search routine is entered which samples every continuous combination of flaw subregions to determine the ligament tearing pressure, P_T, for each subregion. This determination of P_T for each subregion is done using the Argonne National Laboratory (ANL) model (Reference 9). The ANL model is constructed around the burst pressure of the undegraded tube, P_0, and a reduction factor, m_p, dependant on the geometry of the tube and the length and depth of the subregion being evaluated. One modification to the model given in Reference 9 was incorporated into the ANL model for use with this ARC. The formulas cited in Reference 9 for calculating the reduction factor, m_p, are based on the use of an alpha (α) fit parameter. The α parameter was changed from 0.9 to 0.85 when subsequent examination of the original calculation revealed that some minor changes in the computation were required to account for temperature effects on the material properties (the tensile tests were performed at room temperature and the burst tests at 600 °F) and the number of data for which ANL depth measurements were available. The NRC staff concludes that the licensee considered appropriate factors when reevaluating the α parameter and therefore the use of a value of 0.85 for α is acceptable.

Next, the critical pressure is established. The critical pressure, P_{crit}, is the postulated steam line break (SLB) event pressure modified by the uncertainty in the ANL model. Uncertainty in the ANL model for the first flaw is determined by Monte Carlo selection from a histogram of model errors provided in Table 6-6 of the WCAP. The ligament tearing pressure for each subregion is then compared to the critical pressure. All continuous subregions for which P_T is less than P_{crit} are identified. If there are no such subregions, the Monte Carlo result is that the flaw will not "pop-through" and leak under SLB conditions and the evaluation moves on to the next identified flaw. If more than one subregion exhibits a P_T less than P_{crit}, then the longest such subregion is selected as the principal "pop-through" region, R_1, for the leakage calculation. Finally, the results of the P_{crit} versus P_T comparison are searched again and the next two longest, distinct, subregions that are predicted to "pop-through" (one to either side of the principal breakthrough region) are identified (if any exist). These subregions are also noted, R_2 and R_3, and the leakage regression model, described below, is used to tally the overall leakage from the flaw as the sum of the leakage from R_1, R_2, and R_3 for comparison to total leakage limits. In addition, accident leakage associated with each free span portion of the flaw is summed separately for comparison to other leakage limits.

TVA's leakage rate analysis methodology development began with the use of the CRACKFLO code. The CRACKFLO code was developed by Westinghouse and has previously been used

to calculate the leakage rates for free span cracks. The CRACKFLO code is a one-dimensional fluid flow model based on the use of Henry's non-equilibrium equation (References 10 and 11)

to account for the effects of finite flashing rates. The governing one-dimensional momentum equation for a homogenous two-phase fluid is given as:

(5) $$(dP/dy) = (1/A_c) * d[G^{2*}A_c/\rho]/dy + (f^*G^2)/(2^*D^*\rho)$$

where: P = the static pressure
y = the flow coordinate
A_c = the crack opening area
G = the mass flux
ρ = the fluid density
D = the flow path hydraulic diameter
f = the friction factor

TVA then applied the CRACKFLO model to the prediction of leakage rates from three PWSCC test samples, two ODSCC test samples, and one fatigue test sample. The sample data base is described in Table 6-1 of Section 6.0 of WCAP-15128, Revision 2, and included six sets of data from laboratory samples and pulled tubes. The laboratory fatigue crack sample was the only one not tested at steam line break conditions and the data from it were not used in developing the correlations in WCAP-15128, Revision 2. Material properties, principally the material flow stress which is necessary for calculating the crack opening area, were available for some specimens. In the absence of tube-specific property data, mean material properties were used. TVA concluded that this would be acceptable since the model predicted leakage rates show only a modest sensitivity to materials property parameters. Lack of knowledge of the tube-specific material properties parameters was also expected to be captured by the scatter of the data around the model regression analysis and thus the uncertainty associated with the use of the model in the Monte Carlo analysis. It was however noted by TVA that inherent differences in crack morphology (the surface roughness and tortuosity) needed to be accounted for when comparing the leak rate data base to the leakage values predicted by the model. This was a point of concern in the NRC staff's review of the ARC and is addressed further below.

TVA chose to develop their leak rate model using the through-wall crack length associated with each flaw in the leakage data base and estimates of the surface roughness and tortuosity consistent with the type of flaw (PWSCC, ODSCC). TVA noted that the choice of through-wall crack length instead of mean crack length was an arbitrary choice. However, as long as the selected choice is used consistently to characterize both the data in the leak rate data base (and thus used in the final regression analysis of the model versus the available data) and the indications found in-service (although TVA's position has been that the application of the ANL breakthrough model will overestimate the predicted through-wall crack length for flaws found in-service), the choice should not have an effect on validity of the overall model. Likewise the precise choice of surface roughness and tortuosity values for each type of flaw should not have an overall effect on the validity of the model provided that the relative differences in roughness and tortuosity (with ODSCC being characterized as rougher and more tortuous) are addressed. Any non-systematic mischaracterization would again be expected to contribute to the scatter of the data around the regression line and the uncertainty in the model predictions.

The NRC staff arrived at the following observations about the leakage model data base and its characterization. The staff was concerned that one data point, identified as specimen 11-3, crack 1, was not included in the data base. This sample leaked at a rate of 2.14 gallons per minute from a 1.072 inch long flaw. TVA explained in their letter of March 2, 2000, that this point was not included because the data from the Tube 11-3, crack-1 specimen was not available when the model was being developed. The staff has concluded that, given the robustness of the leak rate data base, the omission of specimen 11-3, crack 1 data point does not compromise the overall methodology.

However, as noted in Item (4) of Section 5.10 of this SE to support a permanent amendment, the staff requests that refinements to the leakage regression modeling be made in the future to account for the use of the ANL model for breakthrough. It is expected that the crack profiles, prior to SLB testing, would be determined from post-test destructive evaluations. These crack profiles would then be input into the ANL model to determine predicted length of the "pop-through" region. These predicted lengths would then be used with the CRACKFLO model to determine predicted leakage rates.

Finally, the predicted leakage rates would be regressed to the available leak rate data. When these refinements are done, the staff also requests that the specimen 11-3, crack 1 data point be included in the modeling effort.

For the regression analysis, the leak rate test data and CRACKFLO prediction were converted into log-log space. Hence, the final form of the linear regression analysis produced a model described by:

(6) $$\log (Q_{actual}) = m * \log (Q_{CRACKFLO}) - b$$

where: Q_{actual} = the measured leakage from a specified test in the leak rate data base
$Q_{CRACKFLO}$ = the predicted leakage for the flaw based on the CRACKFLO model

and m and b are the fit parameters of the regression analysis. This regression analysis model and the modeling of its associated uncertainty distributions for scatter of the leakage data about the regression line, the regression slope parameter, the regression intercept parameter, and material flow stress are then used with the Monte Carlo simulation to establish the leakage from each flaw in the SG.

The NRC staff has concluded that TVA's approach to developing the leak rate regression model is acceptable. Although the leakage model is shown to be dependant on many more parameters than the corresponding burst model, and some of these parameters require the use of "nominal" values absent tube-specific or flaw-specific data, the final regression to established data is expected to compensate for random errors in characterization of the test sample cases. The use of the regression model and its associated uncertainty in the Monte Carlo analysis explicitly addresses these concerns. However, if during inservice applications of this methodology, the "nominal" settings of some parameters were changed without re-calibrating the results to the data, the model would no longer be valid. NRC staff approval would be required prior to the use of any change to these "nominal" parameter values for inservice evaluations.

5.4 ARC Implementation

The proposed PWSCC ARC is applicable to axial PWSCC indications, or portions thereof, that are located within the thickness of dented TSP intersections. In general, PWSCC may extend outside the thickness of the TSP into the free span region. The proposed PWSCC ARC is not applicable to the portions of PWSCC extending into the free span region. These portions of PWSCC cracks will continue to be evaluated against the current 40% depth-based limit.

The PWSCC ARC is not a fixed criteria in terms of allowable PWSCC depth or length. Rather, PWSCC indications found by inspection are dispositioned as acceptable or unacceptable for continued service based on their measured size and the results of an operational assessment relative to the applicable acceptance criteria (discussed below) for burst and accident leakage integrity. The operational assessment projects the potential growth of the indication to the next scheduled inspection, allowing for potential error in the measured crack size, and determines the associated burst pressure capability and potential leak rate under postulated accident conditions.

The applicable acceptance criteria for burst pressure are taken from the guidelines of NRC Regulatory Guide 1.121 (Reference 1), NRC draft guide DG-1074 (Reference 4), and NEI 97-06, Revision 1 (Reference 2), and are acceptable to the staff. The criteria include maintaining a factor of at least three against burst under normal operating differential pressure and a factor at least 1.4 against burst during postulated design basis accidents such as a main steam line break (MSLB). The ARC methodology assumes that the portion of the PWSCC crack within the thickness of the dented TSP is constrained against burst and, therefore, the factor of three criterion is always satisfied for this portion of the crack. Thus, only the free span portions of a given PWSCC crack, if any, are evaluated against the factor of three criterion. For MSLB, no credit is taken for the constraining effect of the TSP because the TSP is assumed to displace axially as a result of secondary side blowdown effects, potentially exposing the entire PWSCC crack to an unconstrained condition. Thus, the total PWSCC crack (including the portions initially inside and outside the thickness of the TSP) is treated as a free span crack for purposes of evaluation against the 1.4 factor against burst criterion for postulated accidents.

The staff agrees with this assumption provided that the TSP ligaments between tube holes are free of cracks. This is likely given that the level of denting at Sequoyah is believed by the staff to be "minor" as defined in NUREG-0523 (Reference 14). However, as required by these amendments, TVA will examine the eddy current data for evidence of support plate cracking and exclude affected TSP intersections from application of the ARC.

Input parameters for the operational assessment for burst are as follows:

- the depth profile and length of each PWSCC indication and its location relative to the centerline of the TSP as measured by the +Point coil,

- +Point sizing error distributions for flaw maximum depth, average depth and length (see Section 5.1.3),

- growth rate distributions, adjusted for Cycle length and T_{hot}, in terms of maximum depth, average depth, and length (see Section 5.1.4), and

- flow stress distribution

Monte Carlo simulations are performed to account for the uncertainties/errors in the input parameters and in the predictive model for burst. During a given simulation, the as-measured crack depth profile and length are adjusted by random samples of the sizing error distributions. For burst evaluations, the depth adjustment is taken from the error distribution for average depth. The staff considers this appropriate because burst tends to be a function of average depth over a significant length rather than a localized maximum depth. For accident leakage evaluations, the depth adjustment is taken from the error distribution for maximum depth. Depth adjustments are applied to every point along the depth profile. The resulting depth profile and length is then adjusted further by randomly sampling the appropriate growth rate distribution resulting in a projected end-of-Cycle (EOC) crack depth profile and length. The projected EOC crack is applied to the burst pressure model described in Section 5.2. The deterministic burst model is applied using the weak link methodology to determine a nominal burst pressure. The nominal burst pressure is adjusted to reflect the burst data regression calibration. Additional adjustments are applied to this burst pressure calculation to reflect a random sample of the burst pressure uncertainty about the regression calibration and to reflect a random sample of material flow stress variability. This results in the final estimate of the burst pressure capability of the subject indication for a given simulation. Thousands of simulations are performed for each indication resulting in a distribution of burst pressures for each indication. The predicted burst pressure capability for a given indication is the lower 95% quantile value of the distribution evaluated at 95% confidence. Use of a 95/95 lower bound estimate is consistent with NRC draft guidelines in Reference 4 and is acceptable to the NRC staff. Predicted burst pressure capabilities determined in this fashion conservatively take no credit for the constraint against burst which may be provided by the TSP.

Although the PWSCC ARC applies only to that portion of the crack inside the thickness of the TSP, the above operational assessment methodology is applied to the total length of each PWSCC indication, even where the indication extends outside the thickness of the TSP into the free span. The applicable acceptance criterion for burst pressure for the total PWSCC crack is the 1.4 criterion as discussed above. The above operational assessment methodology is also conducted for each free span portion of the PWSCC crack. The applicable acceptance criterion for burst pressure for the free span portion is the factor of three criterion. Tubes with PWSCC indications not satisfying the applicable burst pressure success criteria are removed from service by plugging. Tubes with PWSCC indications satisfying these criteria may be left in service without plugging provided the projected accident leakage for the subject indication combined with the leakage contributions for all other indications projected to exist at the time of the next inspection satisfy the applicable acceptance limits as discussed below. In addition, the free span portions of the PWSCC indications must satisfy the 40% depth-based limit based on the maximum free span depth measured by the +Point coil.

For accident induced leak rate, two acceptance limits are applicable. First, the total SG leak rate must be less than or equal to the assumed leak rate in the NRC approved licensing basis accident analyses. In addition, total SG leak rate from unconfined or free span indications must be equal to or less than 1 gallon per minute (gpm). Therefore, accident leakage associated with each "total" PWSCC indication is summed with all other sources of accident leakage and evaluated relative to the assumed leak rate in the NRC approved licensing basis accident analyses. In addition, accident leakage associated with each free span portion is summed with all other sources of free span accident leakage and evaluated relative to the applicable 1 gpm limit. These criteria are consistent with criteria in NEI 97-06, Revision 1 (Reference 2), and are acceptable. If the applicable accident leakage success criteria are not met, tubes with the largest calculated leakage will be removed from service until the revised cumulative leakage for the SG meets the success criteria. Tubes with PWSCC indications satisfying these criteria may be left in service without plugging provided the burst pressures projected to exist at the time of the next inspection satisfy the applicable acceptance limits as discussed above.

Input parameters for the operational assessment for accident leakage are similar to those for the burst evaluation with the exception that the depth parameter of interest in the sizing error and growth rate distributions is maximum depth rather than average depth. Similarly, Monte Carlo simulations are performed to account for the uncertainties/errors in the input parameters and in the predictive model accident leak rate. For a given PWSCC indication, the depth profile and length measured by +Point in the field are adjusted by random samplings on the applicable sizing error and growth rate distributions leading to a projected EOC depth profile and length. The projected EOC crack is applied to the accident leakage model discussed in Section 5.3. This projected crack is evaluated by an iterative application of the ANL equation to identify the maximum length of through-wall penetrations under the pressure loading associated with the most limiting postulated accident. These through-wall penetrations are applied to the deterministic CRACKFLO model to obtain a nominal leak rate. The nominal leak rate is adjusted to reflect the leak rate data regression calibration. Additional adjustments are applied to this calculated leak rate to reflect a random sample of the uncertainty distributions for scatter of the leakage data about the regression line, the regression slope parameter, the regression intercept parameter, and material flow stress. This results in the final estimate of the projected EOC accident leak rate for the subject indication for a given simulation. In a similar fashion, projected EOC leak rates are calculated for each PWSCC indication. Summation of the calculated projected EOC leak rates for each PWSCC indication leads to an estimate of total leak rate for a given simulation. Thousands of simulations are performed for the population of PWSCC indications leading to a distribution of potential total accident leak rates. For operational assessments, the predicted total accident leak rate is the upper 95% quantile value of the distribution evaluated at the 95% confidence level. Use of a 95/95 upper bound estimate is consistent with NRC draft guidelines in Reference 4 and is acceptable to the NRC staff. Predicted leak rates determined in this fashion conservatively take no credit for the constraint against leakage which may be provided by the TSP.

5.5 Operational Assessments and POD

In accordance with NRC GL 95-05 (Reference 12), plants with approved voltage-based ARCs for ODSCC at TSPs make a POD adjustment to the conditional probability of burst evaluations and accident leakage evaluations performed as part of the operational assessment. The purpose of this adjustment is to account for flaws which may not be detected during a given inspection in terms of their potential contribution to the total conditional probability of burst and total accident leak rate at the next EOC. The currently approved POD assumption for this purpose is 0.6. The POD adjustment involves taking the as-found distribution of indications as a function of the flaw size parameter (in this case voltage) and factoring up the number of indications for each flaw size by the ratio of 1/POD. There is general agreement between the staff and industry that this is a very conservative estimate of actual POD performance in the field for larger flaws which would likely be dominant contributors to the total conditional burst probability and total leak rate.

Given the staff concerns regarding the conservatism of the POD estimates discussed in Section 5.1.2, TVA agreed to revise the WCAP to include a similar POD adjustment (i.e., POD = 0.6) for the PWSCC ARC accident leakage evaluation pending resolution of these concerns. The PWSCC ARC methodology does not include a conditional burst probability evaluation as part of the operational assessment. The staff believes this to be a very conservative assumption for this application.

No POD adjustment will be applied for the PWSCC ARC burst assessment. The burst assessment for this ARC is intended to demonstrate that the most limiting indication in the SGs will satisfy the applicable burst criteria. It is implicitly assumed in the burst pressure evaluation that the most limiting indication at next EOC from a burst pressure perspective will come from the population of detected indications which were left in service at the last inspection. This is the appropriate assumption in terms of evaluating whether a given tube with a given indication should or should not be left in service without plugging. However, operational assessments are performed not simply to support implementation of ARCs. Operational assessments are necessary even when implementing the standard 40% depth-based limit to ensure that tube integrity will be maintained for the planned inspection Cycle. This is consistent with the industry's formal position in NEI 97-06, Revision 1 (Reference 2).

Looking at operational assessments from this broader perspective, TVA should monitor the appearance of new indications and their measured size as compared to the size of flaws which were accepted for continued service in previous inspections to ensure that an explicit accounting for such indications when comparing to the factor of three and 1.4 criteria is not necessary. The staff requests that TVA assess the early experience with "old" versus "new" PWSCC indications and the need for accounting for the appearance of such new indications when submitting their request for a permanent PWSCC ARC amendment.

5.6 Condition Monitoring Assessment

Condition monitoring refers to assessing the "as-found" condition of the SG tubes during an inservice inspection relative to the applicable acceptance limits for burst and accident leakage integrity. Satisfaction of these criteria demonstrates that adequate structural and leakage integrity was maintained throughout the most recent operating Cycle.

The scope of the condition monitoring assessment for PWSCC at the TSPs includes all indications with greater than or equal to 40% maximum depth outside the TSP, indications requiring repair due to not satisfying the burst pressure acceptance criteria under projected EOC conditions, and indications projected by the operational assessment to contribute leakage under accident conditions at the next EOC. The staff finds this scope acceptable. This scope excludes only indications projected by operational assessment to satisfy the applicable burst criteria and to be leak tight under accident conditions at the next EOC. Such indications, therefore, can be assumed to satisfy the applicable burst criteria and to be leak tight under beginning of Cycle (BOC) conditions.

Condition monitoring assessments of PWSCC indications are performed using Monte Carlo simulations in a manner similar to that described for operational assessment with the following differences:

- Condition monitoring is an assessment of the "as-found" condition of the tubing. Therefore, the PWSCC depth profiles and length are not adjusted for growth.

- Condition monitoring assessments do not include a POD adjustment. This is based on the premise that flaws resulting in unacceptable burst margins or which may leak would be expected to be detected by bobbin and +Point at that point in time. This premise is consistent with the approach in NRC GL 95-05 (Reference 12) for voltage-based repair limits and with the draft guidelines in DG-1074 (Reference 4) and is acceptable to the staff.

- Predicted burst pressures for condition monitoring will be the lower 95% quantile value of the burst pressure distribution evaluated at a 50% confidence level rather than a 95% confidence value as is the case for operational assessment. Similarly, predicted accident leak rates will be the upper 95% quantile value of the leak rate distribution evaluated at 50% confidence. This is consistent with the draft guidelines DG-1074 (Reference 4) and is acceptable to the staff.

- The Monte Carlo accident leakage simulations may initially be performed for individual indications rather than a population of indications as is done for operational assessment. The calculated leakage rate for each indication will be the upper 95% quantile, 50% confidence value. The 95/50 values for each indication are summed to yield the total SG leakage rate. This "single tube" approach is more conservative than the "population" approach and is therefore acceptable to the staff. However, the "population" approach may be performed as an alternative when evaluating "total crack" leakage consistent with the operational assessment approach. This is also acceptable to the staff.

- The burst pressure and accident leakage acceptance limits for condition monitoring are the same as those for operational assessment (see Section 5.4) except as noted in the next bullet for burst pressure. If the acceptance limits for condition monitoring are not met, the results must be reported to the NRC as part of the 120-day report. A corrective action program must be initiated to identify the causative factors. These corrective actions must also be described in the 120-day report.

- As an alternative to demonstrating that the factor of 1.4 against burst criterion is satisfied for each indication at the applicable confidence limits, TVA may calculate the conditional probability that one or more tubes may burst under postulated MSLB conditions. The applicable acceptance limit for this calculated conditional probability is $1.0x10^{-2}$. The staff notes that a conditional probability of burst calculation is also performed for plants with voltage-based ARCs for ODSCC at TSPs in accordance with NRC GL 95-05. These calculations are also performed relative to a $1.0x10^{-2}$ criterion. (This criterion in the context of the voltage-based ARC is actually a reporting threshold rather than an acceptance limit.) Free span portions of PWSCC indications must still be demonstrated to satisfy the deterministic factors of three and 1.4 criteria for burst. This ensures that there are no risk implications associated with the use of the $1.0x10^{-2}$

criterion as discussed further in Section 5.8 of this SE. The 1.0×10^{-2} criteria is, therefore, consistent with draft guidelines for its use as given in DG-1074 (Reference 4). Further, the sum of the criteria for ODSCC and PWSCC (i.e., 2.0×10^{-2}) satisfies the draft guideline criterion in DG-1074 of 2.5×10^{-2} for the total conditional probability of burst associated with known mechanisms. Thus, the staff finds the proposed acceptance criterion for conditional probability of burst to be acceptable. The conditional probability of burst is evaluated using Monte Carlo simulations in a manner similar to that used to calculate the burst pressure of individual tubes. The essential difference is that each Monte Carlo simulation addresses the population of PWSCC indications rather than a single indication. The conditional probability is the number of simulations resulting in one or more tubes with burst pressures less than MSLB pressure divided by the total number of simulations performed and is evaluated at a 95% confidence level which is acceptable to the staff.

- If *in situ* pressure testing is performed for free span indications, the results of the burst pressure and accident leak rate tests are used in lieu of the analytical predictions for that indication. *In situ* pressure testing will be performed for any free span portion of a PWSCC indication which cannot be demonstrated analytically to satisfy the applicable 3 times normal operating pressure criterion or which is predicted to leak under accident conditions. The staff agrees that use of *in situ* pressure test results constitutes an acceptable alternative to the use of analytical predictions.

5.7 Operational Leak Rate Limits

The staff has generally requested that licensees submitting requests for ARC and sleeving amendments also change their TS LCO operational leakage limits to incorporate a 150 gallon per day (gpd) limit. This is a more restrictive limit than the standard technical specification limit of 500 gpd that was in place when the plants were originally licensed. This limit provides added assurance that should leakage develop in service, the plant will be shutdown for corrective action before rupture occurs. The Sequoyah TS already include 150 gpd operational leakage LCO limit. The staff finds this limit acceptable for purposes of supporting this PWSCC ARC amendment request.

5.8 Risk Considerations

Subsequent to TVA's initial ARC proposal in its letter dated October 14, 1999, TVA modified its proposal in its February 23, 2000, letter in response to the staff's request to limit application of the ARC to that portion of PWSCC indications located within the thickness of the TSP intersections. The current licensing basis in terms of structural margins, allowable leakage during design basis accidents, and tube repair criteria remains unchanged for free span portions of PWSCC indications. The staff believes that any changes to the current licensing basis for cracks in the free span need to be accompanied by a careful assessment of the risk implications of such changes. Available risk analyses (Reference13) suggest that free span portions of tubing would be substantially challenged during some types of severe accidents.

The confined portions of the PWSCC indications to which the ARC is applicable are not expected to be able to burst or leak substantially since, by virtue of the corrosion product buildup in the annulus between the dented tube and TSP, the TSPs are effectively locked in place and constrain the tubes against radial expansion. Thus, the confined portions of PWSCC indications would not be expected to be severely challenged during severe accidents. The only significant challenge which could potentially be applied to the confined region of the tubes would be a postulated design basis MSLB. The design basis MSLB is accompanied by blowdown of the secondary side resulting in transient pressure differentials across the TSPs. Taking no credit for the TSPs being locked to the tubes, these pressure loads may cause the TSPs to displace axially thus exposing the initially confined indications or a portion of these indications to free span conditions. Catastrophic MSLB accidents resulting in high blowdown loadings of the TSPs are estimated to be extremely infrequent and, thus, this design basis scenario is not believed to be a significant contributor to the realistic estimations of risk attempted by probabilistic risk analyses.

5.9 Future Tube Pulls

WCAP-15128, Revision 2, calls for removing a tube specimen from the SGs (i.e., a tube pull) prior to or subsequent to implementing the PWSCC ARC to support +Point sizing and to confirm the crack morphology consistent with the PWSCC data base. The WCAP states that the tube specimen should be selected so as to have a high probability of leaking such as to contribute to the leak rate data base. This criteria is satisfied if the indication leaks during *in situ* pressure testing or if the condition monitoring leakage assessment indicates a 50% probability that the indication will leak at the rate of 0.01 gpm under MSLB conditions. The tube pull may be performed in the Cycle following ARC implementation or later as necessary to satisfy the criteria for obtaining a likely leaker. The staff notes that tube pulling operations are expensive and can impact the outage schedule. The staff believes that the proposed criteria are appropriate for ensuring that pulled tubes will yield useful information relevant to all aspects of the ARC including flaw morphology and NDE verification and burst and leakage data. Thus, the staff concludes that the proposed tube pulling criteria are acceptable.

5.10 Needed Information to Support Permanent TS Change

The staff believes that TVA may request a permanent change to the SQN TS incorporating this ARC at a later date. A subsequent amendment request should provide the additional information listed below, as appropriate, to support a permanent TS change:

1. WCAP-15128, Revision 2, should be revised to incorporate the clarifications and commitments made in TVA's letter dated March 2, 2000.

2. Consider incorporating refinements into the operational assessment methodology to permit consideration of a more complete amount of the growth rate data from the most recent operating Cycle.

3. Assess the performance of the operational assessment methodologies for predicting EOC flaw distributions as function of flaw size. Assess differences between predicted and actual flaw size distributions in terms of their impact on predicted burst pressures for the most limiting tube and total SG accident leak rate.

4. Assess the early experience with the number and size of indications previously detected and left in service versus the number and size of indications of PWSCC indications not previously detected and the need for accounting for the appearance of such new indications in the operational assessment burst evaluation.

5. Consider developing refinements into the overall accident leakage model such that the leak test regression calibration of the deterministic model includes a calibration of the model to predict "pop-through" of crack ligaments. In addition, refinements to the breakthrough model should be incorporated to ensure that all potential "pop-through" ligaments are identified (within the limits of reasonable refinement of the model) and that all significant ligaments are included in the leakage assessment.

The staff expects that TVA will wish to propose a revision to the POD factor of 0.6 which is now applied to the operational assessment accident leak rate analyses. This is in view of the substantial conservatism associated with its use. An alternative POD proposal should address staff concerns that Westinghouse's current POD estimates are driven by a high false call rate during performance testing which may not be representative of what can be expected in the field. In addition, Westinghouse's POD estimates are based on a finite amount of data, so confidence levels attached to these estimates need to be defined and considered in the leakage analysis. The staff also acknowledges that there may be alternative approaches to using POD to account for the potential contribution of previously undetected cracks to EOC leakage.

The NRC staff notes that licensees wishing to implement similar repair criteria at their facilities must submit a license amendment request for NRC review and approval.

Overall Summary

The staff has completed its review of the proposed two Cycle technical specification amendment to incorporate a new ARC applicable to PWSCC located within the thickness of dented TSP intersections. The staff finds that the proposed PWSCC ARC amendment provides adequate assurance that tube structural and leakage integrity will be maintained without undue risk of public health and safety.

The staff has identified certain informational needs, as summarized in Section 5.10, which are necessary to support a permanent change to the technical specifications incorporating this ARC. In addition, resolution has not been reached on the most appropriate way to account for the appearance of new indications for purposes of projecting EOC leakage rates (i.e., the so-called "POD issue") during operational assessments and other relatively minor issues identified herein. This interim amendment includes a very conservative POD adjustment which should ensure a very conservative accident leakage assessment pending final resolution of the POD issue. Finally, any alternative POD proposal should address the staff's concerns identified herein.

6.0 STATE CONSULTATION

In accordance with the Commission's regulations, the Tennessee State official was notified of the proposed issuance of the amendment. The State official had no comments.

7.0 ENVIRONMENTAL CONSIDERATION

The amendment changes surveillance requirements. The NRC staff has determined that the amendment involves no significant increase in the amounts, and no significant change in the types, of any effluents that may be released offsite, and that there is no significant increase in individual or cumulative occupational radiation exposure. The Commission has previously issued a proposed finding that the amendment involves no significant hazards consideration, and there has been no public comment on such finding (64 FR 73100 dated December 29, 1999). Accordingly, the amendment meets the eligibility criteria for categorical exclusion set forth in 10 CFR 51.22(c)(9). Pursuant to 10 CFR 51.22(b) no environmental impact statement or environmental assessment need be prepared in connection with the issuance of the amendment.

8.0 CONCLUSION

The Commission has concluded, based on the considerations discussed above, that: (1) there is reasonable assurance that the health and safety of the public will not be endangered by operation in the proposed manner, (2) such activities will be conducted in compliance with the Commission's regulations, and (3) the issuance of the amendment will not be inimical to the common defense and security or to the health and safety of the public.

Principal Contributors: Emmett L. Murphy
Stephanie M. Coffin
Matthew A. Mitchell

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cc:
Mr. Karl W. Singer, Senior Vice President
Nuclear Operations
Tennessee Valley Authority
6A Lookout Place
1101 Market Street
Chattanooga, TN 37402-2801

Mr. Jack A. Bailey
Vice President
Engineering & Technical Services
Tennessee Valley Authority
6A Lookout Place
1101 Market Street
Chattanooga, TN 37402-2801

Mr. Masoud Bajestani
Site Vice President
Sequoyah Nuclear Plant
Tennessee Valley Authority
P.O. Box 2000
Soddy Daisy, TN 37379
General Counsel
Tennessee Valley Authority
ET 10H
400 West Summit Hill Drive
Knoxville, TN 37902

Mr. N. C. Kazanas, General Manager
Nuclear Assurance
Tennessee Valley Authority
5M Lookout Place
1101 Market Street
Chattanooga, TN 37402-2801

Mr. Mark J. Burzynski, Manager
Nuclear Licensing
Tennessee Valley Authority
4X Blue Ridge
1101 Market Street
Chattanooga, TN 37402-2801

Mr. Pedro Salas, Manager
Licensing and Industry Affairs
Sequoyah Nuclear Plant
Tennessee Valley Authority
P.O. Box 2000
Soddy Daisy, TN 37379

Mr. D. L. Koehl, Plant Manager
Sequoyah Nuclear Plant
Tennessee Valley Authority
P.O. Box 2000
Soddy Daisy, TN 37379

Mr. Russell A. Gibbs
Senior Resident Inspector
Sequoyah Nuclear Plant
U.S. Nuclear Regulatory Commission
2600 Igou Ferry Road
Soddy Daisy, TN 37379

Mr. Michael H. Mobley, Director
TN Dept. of Environment & Conservation
Division of Radiological Health
3rd Floor, L and C Annex
401 Church Street
Nashville, TN 37243-1532

County Executive
Hamilton County Courthouse
Chattanooga, TN 37402-2801