UNITED STATES
NUCLEAR REGULATORY COMMISSION
OFFICE OF NUCLEAR REACTOR REGULATION
WASHINGTON, D.C. 20555-0001

August 3, 1995

NRC GENERIC LETTER 95-05: VOLTAGE-BASED REPAIR CRITERIA FOR WESTINGHOUSE STEAM GENERATOR TUBES AFFECTED BY OUTSIDE DIAMETER STRESS CORROSION CRACKING

Addressees

All holders of operating licenses or construction permits for pressurized-water reactors (PWRs).

Purpose

The U.S. Nuclear Regulatory Commission (NRC) is issuing this generic letter to give guidance to licensees who may wish to request a license amendment to the plant technical specifications to implement alternate steam generator tube repair criteria applicable specifically to outside diameter stress corrosion cracking (ODSCC) at the tube-to-tube support plate intersections in Westinghouse-designed steam generators having drilled-hole tube support plates (TSPs) and alloy 600 steam generator tubing. In the past, the NRC has allowed some licensees to implement alternate steam generator repair criteria for this particular degradation mechanism on an operating cycle-specific basis. This generic letter does not restrict the approval of such repair criteria to a cycle specific basis. It is expected that recipients will review this information for applicability to their facilities and consider actions, as appropriate, to implement the alternate criteria. However, suggestions contained in this generic letter are not NRC requirements; therefore, no specific action or written response is required.

Background

The tubing of the steam generator constitutes more than half of the reactor coolant pressure boundary (RCPB). Design of the RCPB for purposes of structural and leakage integrity is a requirement under Title 10 of the *Code of Federal Regulations* Part 50 (10 CFR Part 50), Appendix A. Specific requirements governing the maintenance of steam generator tube integrity are in plant technical specifications and in Section XI of the American Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel Code (ASME Code). These include requirements for periodic inservice inspection of the tubing, flaw acceptance criteria (i.e., repair limits for plugging or sleeving), and primary-to-secondary leakage limits. These requirements, coupled with the broad scope of plant operational and maintenance programs, have formed the basis for ensuring adequate steam generator tube integrity.

Flaw acceptance criteria, termed "plugging" or "repair limits," are specified in the plant technical specifications. Current plant technical specifications require that flawed tubes be removed from service by plugging or be repaired by sleeving, if the depths of the flaws exceed the repair limit, typically 40 percent through-wall. The technical specification repair limits ensure that tubes accepted for continued service will retain adequate structural and leakage integrity during normal operating, transient, and postulated accident conditions, consistent with General Design Criteria (GDCs) 14, 15, 30, 31, and 32 of 10 CFR Part 50, Appendix A. Structural integrity refers to maintaining adequate margins against gross failure, rupture, and collapse of the steam generator tubing. Leakage integrity refers to limiting primary-to-secondary leakage to within acceptable limits.

The traditional strategy for achieving the objectives of the GDCs related to steam generator tube integrity has been to establish a minimum wall thickness requirement in accordance with the structural criteria of Regulatory Guide (RG) 1.121, "Bases for Plugging Degraded PWR Steam Generator Tubes." Development of minimum wall thickness requirements to satisfy RG 1.121 was governed by analyses for uniform thinning of the tube wall in the axial and circumferential directions. The assumption of uniform thinning results in development of a repair limit that is conservative for all flaw types occurring in the field. The resultant 40-percent depth-based repair limit typically incorporated into the technical specifications is conservative for highly localized flaws such as pits, short cracks, and in particular ODSCC that occurs at TSPs.

This generic letter offers guidance on the implementation of an alternate repair criterion to be applied to predominantly axially oriented ODSCC at TSP locations. This criterion does not set limits on the depth of ODSCC indications to ensure tube integrity margins; instead, it relies on correlating the eddy current voltage amplitude from a bobbin coil probe with the more specific measurement of burst pressure and leak rate. The staff recognizes that although total margin may be reduced following application of the voltage-based repair guidance of this generic letter, this guidance does ensure that structural and leakage integrity continues to be maintained with an acceptable level of margin consistent with the applicable GDCs of 10 CFR Part 50, Appendix A and the limits of 10 CFR Part 100. Since the voltage-based repair criteria do not incorporate minimum wall thickness requirements, there is a possibility that tubes with up to 100-percent through-wall cracks can remain in service. Because of the increased likelihood of through-wall cracks, the staff has included provisions for augmented steam generator tube inspections and more restrictive operational leakage limits in this generic letter guidance.

In taking the action described in this letter, the NRC staff is approving the use of the specific voltage-based repair criteria described herein as an acceptable measure for dealing with ODSCC tube degradation. This action should not be construed to discourage licensees from using better or further refined data acquisition techniques, eddy current technology, and eddy current data analysis techniques as they become available. The staff strongly encourages the industry to continue its efforts to improve the nondestructive examination (NDE) of steam generator tubes and continues to believe that inspection methods and repair criteria based on physical dimensions (e.g., length and depth) of defects are the most desirable when they can be achieved.

This generic letter is intended to provide relief while maintaining an acceptable level of safety for licensees having steam generators experiencing this particular degradation mechanism while the staff pursues a longer term resolution to the issue of steam generator degradation through the development of a steam generator rule. The staff recognizes that licensees may wish to pursue various alternatives to the guidance of this generic letter [e.g., alternative probability of detection (POD) calculations]. However, licensees should recognize that pursuing such alternatives could have significant schedular implications, since the NRC staff would be required to review and approve the associated information and analyses.

Discussion

1. Overview of the Voltage-Based Approach

In order to use the voltage-based repair criteria, licensees should complete the following actions:

- Perform an enhanced inspection[1] of tubes, particularly at the TSP intersections.
- Utilize NDE data acquisition and analysis procedures that are consistent with the methodology used to develop the voltage-based repair criteria.
- Repair tubes that exceed the voltage limits.
- Determine the beginning-of-cycle (BOC) voltage distribution.
- Project the end-of-cycle (EOC) voltage distribution.
- For the projected EOC voltage distribution, calculate both the primary-to-secondary leakage under postulated accident conditions and the conditional burst probability. As an alternative, the actual measured EOC voltage distribution can be used when it is impractical to complete the projected

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[1] Steam generator tube inspection involves both bobbin coil and rotating pancake coil inspection. For the purposes of this guidance, rotating pancake coil inspection also includes the use of comparable or improved nondestructive examination techniques.

EOC calculation prior to returning the steam generators to service for the purpose of determining whether the reporting criteria in GL Sections 6.a.1 and 6.a.3 apply.

2. Generic Letter Applicability

The criteria in this generic letter are only applicable to predominantly axially oriented ODSCC indications located at the tube-to-TSP intersections in Westinghouse-designed steam generators with alloy 600 steam generator tubing. These criteria are not applicable to other forms of steam generator tube degradation, nor are they applicable to ODSCC that occurs at other locations within a steam generator. The voltage-based repair criteria can be applied only under the following constraints:

- The repair criteria of this generic letter apply only to Westinghouse-designed steam generators with 1.9-cm [3/4-inch] and 2.2-cm [7/8-inch] diameter alloy 600 tubes and drilled-hole TSPs.
- The repair criteria of this generic letter apply only to predominantly axially oriented ODSCC confined within the tube-to-TSP intersection (refer to Section 1.a of Attachment 1 for further guidance).
- Certain intersections are excluded from the application of the voltage-based repair criteria, as discussed in Section 1.b of Attachment 1.

3. Voltage Repair Limits

The voltage repair limits are:

- Indications less than the lower voltage repair limit, as measured by bobbin coil, may remain in service. For 2.2-cm [7/8-inch] diameter tubes, the lower voltage repair limit is 2.0 volts. For 1.9-cm [3/4-inch] diameter tubes, the lower voltage repair limit is 1.0 volt.
- Indications greater than the lower limit and less than or equal to the upper voltage repair limit, as measured by bobbin coil, can remain in service if rotating pancake coil (RPC) inspections do not confirm the indications. The methodology for calculating the upper voltage repair limit is specified in Section 2.a.2 and 2.a.3 of Attachment 1.
- Indications greater than the lower limit and less than or equal to the upper voltage repair limit, as measured by bobbin coil, that are confirmed by RPC, and indications greater than the upper voltage repair limit, as measured by bobbin coil, must be repaired.

The voltage-based repair limits in this generic letter were determined considering the entire range of design basis events that could challenge tube integrity. The voltage-based repair criteria ensure structural and leakage integrity for all postulated design basis events. The structural criteria are intended to ensure that indications subjected to the voltage repair limits will be able to withstand pressure loadings consistent with the criteria of RG 1.121. The leakage criteria ensure that for degradation subjected to the voltage repair criteria, induced leakage under worst-case MSLB conditions calculated using licensing basis assumptions, will not result in offsite and control room dose releases that exceed the applicable limits of 10 CFR Part 100 and GDC 19.

Requested Actions

Implementation of the guidance in this generic letter is voluntary. A licensee that chooses to implement these criteria should include all of the following in the proposed program:

- Implementation of the applicability requirements discussed in Section 1 of Attachment 1. The applicability requirements ensure that the repair criteria are applied only to those intersections for which the voltage-based repair criteria were developed.

- Implementation of the inspection guidance discussed in Section 3 of Attachment 1. The inspection guidance ensures that the techniques used to inspect the steam generator tubes are consistent with the techniques used to develop the voltage-based repair criteria.

- Calculation of leakage according to the guidance discussed in Section 2.b of Attachment 1. This calculation, in conjunction with the use of licensing basis assumptions for calculating offsite and control room doses, enables licensees to demonstrate that the applicable limits of 10 CFR Part 100 and GDC 19 continue to be met. This calculation is performed using the projected EOC voltage distribution for the next cycle of operation. If it is not practical to complete this calculation prior to returning the steam generators to service, the measured EOC voltage distribution can be used (from the previous cycle of operation) as an alternative (refer to Section 2.c of Attachment 1) for the purposes of determining whether the reporting criteria of Section 6.a.1 apply.

- Calculation of conditional burst probability according to the guidance discussed in Section 2.a of Attachment 1. This is a calculation to assess the voltage distribution for the next cycle of operation. The results are compared against a threshold value. This calculation is performed using the projected EOC voltage distribution for the next cycle of operation. If it is not practical to complete this calculation prior to returning the steam generators to service, the measured EOC voltage distribution can be used (from the previous cycle of operation) as an alternative (refer to Section 2.c) for the purposes of determining whether the reporting criteria of Section 6.a.3 apply.

- Implementation of the operational leakage monitoring program according to the guidance discussed in Section 5 of Attachment 1. The operational leak rate monitoring program is a defense-in-depth measure that provides a means for identifying leaks during operation to enable repair before such leaks result in tube failure.

- Acquisition of tube pull data according to the guidance discussed in Section 4 of Attachment 1.

- Reporting of results according to the guidance discussed in Section 6 of Attachment 1.

- Submittal of a technical specification (TS) amendment request that commits to the preceding actions and provides TS pages according to the guidance discussed in Attachment 2, including the associated "no significant hazards consideration" (10 CFR 50.92) and supporting safety analysis.

Licensees planning to adopt this TS amendment are encouraged to follow the guidance discussed in Attachments 1 and 2. Whenever practical, the staff requests that licensees following the guidance of this generic letter submit their TS amendment request at least 90 days prior to the beginning of the outage during which the alternate repair criteria are to be implemented.

Backfit Discussion

Licensee action to propose TS changes under the guidance of this generic letter is voluntary; therefore, such action is not a backfit under the provisions of 10 CFR 50.109.

Paperwork Reduction Act Statement

The voluntary information collections contained in this request are covered by the Office of Management and Budget clearance number 3150-0011, which expires July 31, 1997. The public reporting burden for this voluntary collection of information is estimated to average 120 hours per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this voluntary collection of information, including suggestions for reducing this burden, to the Information and Records Management Branch (T-6 F33), U.S. Nuclear Regulatory Commission, Washington, D.C. 20555-0001, and to the Desk Officer, Office of Information and Regulatory Affairs, NEOB-10202 (3150-0011), Office of Management and Budget, Washington, D.C. 20503.

This generic letter requires no specific action or written response. If you have any questions about this matter, please contact the technical contact listed below or the appropriate Office of Nuclear Reactor Regulation (NRR) project manager.

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Attachments:
1. Guidance for a Proposed License Amendment to Implement an Alternate Steam Generator Tube Repair Limit for Outside Diameter Stress Corrosion Cracking at the Tube Support Plate Intersections
2. Model Technical Specifications
3. List of Recently Issued NRC Generic Letters

Attachment filed in Jacket

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Guidance for a Proposed License Amendment to Implement an Alternate Steam Generator Tube Repair Limit for Outside Diameter Stress Corrosion Cracking at the Tube Support Plate Intersections

1. Introduction

This guidance is the NRC staff position on the implementation of the voltage-based repair criteria in steam generators designed by Westinghouse for outside diameter stress corrosion cracking (ODSCC) located at the tube-to-TSP intersections. This guidance is not applicable to other forms of steam generator (SG) tube degradation nor is it applicable to ODSCC that occurs at other locations within the SG. The voltage-based repair criteria have been developed for, and are currently applicable only to, Westinghouse designed SGs with 2.2-cm [7/8-inch] or 1.9-cm [3/4-inch] diameter alloy 600 tubes with drilled-hole TSPs. Application of the alternate repair criteria to other vendor designed SGs would require both the development and NRC staff review and approval of a comparable data base and the associated correlations for each vendor's SG type.

The NRC staff emphasizes that although the NRC has approved the implementation of the voltage-based repair criteria (described in this generic letter) as a short-term measure, this guidance should not be construed as discouraging the development and use of better acquisition techniques, eddy current technology, and eddy current data analysis techniques. The staff strongly encourages the industry to continue to improve the nondestructive examination (NDE) of SG tubes.

1.a ODSCC

The voltage-based repair criteria are applicable only to indications at TSP intersections where the degradation mechanism is dominantly axial ODSCC with no NDE detectable cracks extending outside the thickness of the support plate.

For purposes of this guidance, ODSCC refers to degradation whose dominant morphology consists of axial stress corrosion cracks which occur either singularly or in networks of multiple cracks, sometimes with limited patches of general intergranular attack (IGA). Circumferential cracks may sometimes occur in the IGA affected regions producing a grid-like pattern of axial and circumferential cracks, termed "cellular corrosion." Cellular corrosion is assumed to be relatively shallow (based on data from tube specimens removed from the field), transitioning to dominantly axial cracks as the cracking progresses in depth. The circumferential cracks are assumed (based on available data) to be of insufficient size to produce a discrete, crack-like circumferential indication during field NDE inspections. Thus, the failure mode of ODSCC is axial and the burst pressure is controlled by the geometry of the most limiting axial crack or array of axial cracks.

It is also assumed for purposes of this guidance that the ODSCC is confined to within the thickness of the TSP, based on data from tube specimens removed from the field. Very shallow microcracks are sometimes observed on these specimens to initiate at locations slightly outside the thickness of the TSP; however, these microcracks are small compared to the cracks within the thickness of the TSP and are too small to produce an eddy current response.

The degradation mechanism should be confirmed as dominantly axial ODSCC by periodically removing tube specimens from the SGs and by examining and testing them as specified in Section 4 of this guidance. The acceptance criteria should consist of demonstrating that the dominant degradation mechanism affecting the burst and leakage properties of the tube is axially oriented ODSCC. In addition, results of inservice inspections with rotating pancake coil (RPC) probes should be evaluated in accordance with Section 3.b of this guidance to confirm the absence of detectable crack-like circumferential indications and detectable ODSCC indications extending outside the TSP thickness.

1.b Exclusion of Intersections

The voltage-based repair criteria of this guidance do not apply to intersections meeting the criteria specified below.

1.b.1 The repair criteria do not apply to tube-to-TSP intersections where the tubes with degradation may potentially collapse or deform as a result of the combined postulated loss-of-coolant accident and safe shutdown earthquake loadings (e.g., intersections near the wedge supports at the upper TSPs). Licensees should perform or reference an analysis that identifies which intersections are to be excluded.

1.b.2 The repair criteria do not apply to tube-to-TSP intersections having dent signals greater than 5.0 volts as measured with the bobbin probe.

1.b.3 The repair criteria do not apply to intersections at which there are mixed residuals of sufficient magnitude to cause a 1.0 volt ODSCC indication (as measured with a bobbin probe) to be missed or misread.

1.b.4 The repair criteria do not apply to intersections with interfering signals from copper deposits.

1.b.5 The repair criteria do not apply to the tube-to-flow distribution baffle plate intersections except as discussed in Section 2.a.3.

2. Tube Integrity Evaluation

Licensees should perform an evaluation to confirm that the SG tubes will retain adequate structural and leakage integrity until the next scheduled inspection. The first portion of this evaluation, referred to as the "conditional burst probability calculation," assesses the voltage distribution left in service against a threshold value of 1×10^{-2} probability of rupture under postulated main steamline break (MSLB) conditions. The conditional burst probability calculation is intended to provide a conservative assessment of tube structural integrity during a postulated MSLB occurring at the end of cycle[2] (EOC). It is used to determine whether the NRC needs to focus additional attention on the particular voltage repair limit application. If the calculated conditional burst probability exceeds 1×10^{-2}, the licensee should notify the NRC according to the guidance in Section 6.

The second portion of the tube integrity evaluation is intended to ensure that the total leak rate from the affected SG during a postulated MSLB occurring at EOC would be less than a rate that could lead to radiological releases in excess of the licensing basis for the plant. If calculated leakage exceeds the allowable limit determined by the licensing basis dose calculation, licensees can either repair tubes, beginning with the largest voltage indications until the leak limit is met, reduce reactor coolant system specific iodine activity [refer to example technical specification (TS) pages of Attachment 2], or reduce the length of the operating cycle. The analyses discussed above may incorporate or reference previous analyses, or portions thereof, to the extent that they continue to bound the conditions of the SG as determined by inspection.

For plants in which the TSs do not require the pressurizer power-operated relief valves (PORVs) to be operable during power operation, these tube integrity analyses should be conducted for an assumed differential pressure across the tube walls equal to the pressurizer safety valve setpoint plus 3 percent for the valve accumulation, less atmospheric pressure in faulted SGs. For plants in which the TSs do require the PORVs to be operable, the assumed differential pressure for the conditional burst probability calculation may be based on the PORV setpoint in lieu of the safety valve setpoint with similar adjustments. The TS requirements for operation with PORV block valves closed due to leaking PORVs should be in accordance with Enclosure A of Generic Letter 90-06, "Resolution of Generic Issue 70, 'Power-Operated Relief Valve and Block Valve Reliability,' and Generic Issue 94, 'Additional Low-Temperature Overpressure Protection for Light-Water Reactors,' Pursuant to 10 CFR 50.54(f)." That is, electrical power to the block valves must be maintained to allow continued operation with the block valves closed, as required in the sample technical specification Section 3.4.4 of GL 90-06.

2.a Conditional Probability of Burst During an MSLB

For this generic letter, the conditional probability of burst refers to the probability that the burst pressures associated with one or more indications in the faulted SG will be less than the maximum pressure differential associated with a postulated MSLB assumed to occur at EOC. A methodology should be submitted for NRC approval for calculating this conditional burst probability. After the NRC approves a method for calculating conditional probability of burst, licensees may reference the approved method. This methodology should involve (1) determining the distribution of indications as a function of their voltage response at the beginning of cycle (BOC) as

[2] For the purposes of this guidance, "cycle" refers to the operating cycle between two scheduled steam generator inspections. Operating cycle and inspection cycle are used interchangeably.

discussed in Section 2.b.1, (2) projecting this BOC distribution to an EOC voltage distribution based on consideration of voltage growth due to defect progression between inspections as discussed in Section 2.b.2(2) and voltage measurement uncertainty as discussed in Section 2.b.2(1), and (3) evaluating the conditional probability of burst for the projected EOC voltage distribution using the correlation between burst pressure and voltage discussed in Section 2.a.1. The solution methodology should account for uncertainties in voltage measurement [Section 2.b.2(1)], the distribution of potential voltage growth rates applicable to each indication [Section 2.b.2(2)], and the distribution of potential burst pressures as a function of voltage (Section 2.a.1). Monte Carlo simulations are an acceptable approach for accounting for these various sources of uncertainty.

2.a.1 Burst Pressure Versus Bobbin Voltage

An empirical model, for 7/8-inch or 3/4-inch diameter tubing, as applicable, should be used to relate burst pressure to bobbin voltage response for purposes of estimating the conditional probability of burst during a postulated MSLB. The model should consider, at a minimum, the scale factors for the coordinate system (e.g., linear or logarithmic), the detection and treatment of outliers, the order of the regression equation, the potential influence of measurement errors in the variables, and the evaluation of the residuals following the development of a relationship. This model should explicitly account for burst pressure uncertainty as indicated by scatter of the supporting test data and should also account for the parametric (i.e., slope and intercept) uncertainty of the regression fit of the data. Currently, an approved model consists of determining a linear first-order equation between the burst pressure and the logarithm (base 10) of the bobbin voltage amplitude with standard least-squares linear regression analysis. The model may need to be changed as additional information is acquired; however, such changes should be submitted to the NRC staff for approval. The supporting data sets for 7/8-inch diameter and 3/4-inch diameter tubing should contain all applicable data consistent with the latest revision of the industry data base as approved by the NRC. The currently approved data base for burst pressure as a function of voltage is given in Reference 7, as supplemented by References 1 and 2.

2.a.2 Determination of the Upper Voltage Repair Limit for TSP Intersections

From the regression relationship (discussed above in Section 2.a.1), a lower 95-percent prediction bound should be determined for the burst pressure as a function of bobbin voltage amplitude. The lower 95-percent prediction interval is further reduced to account for the lower 95/95-percent tolerance bound for tubing material properties at 650 °F. Using this reduced lower prediction bound curve, the structural limit is determined for a free span burst pressure of 1.4 times MSLB differential pressure (DP_{MSLB}) consistent with the structural limits in RG 1.121.

To determine the upper voltage repair limit, the structural limit is reduced to account for flaw growth and voltage measurement uncertainty. The method for determining the flaw growth allowance is discussed in Section 2.b.2(2) and should be a plant-specific average growth rate or 30-percent per effective full power year (EFPY), whichever is larger. The voltage measurement uncertainty allowance should be the 95-percent cumulative probability value for the voltage measurement uncertainty models. Eddy current voltage measurement uncertainty is discussed in Section 2.b.2(1). Currently the 95-percent cumulative probability value is 20 percent of the BOC voltage amplitude. The upper voltage repair limit should be determined prior to each outage, using the most recently approved NRC data base.

2.a.3 Determination of the Upper Voltage Repair Limit for Flow Distribution Baffle Plate Intersections

Because of the greater diametral clearances at the flow distribution baffle plate and the potential for higher voltage growth rates at these intersections, different tube repair limits may be necessary for indications at the flow distribution baffle plate. To determine if the voltage-based repair criteria can be applied to flow distribution baffle plate intersections, the causal factors for the high voltage growth rates and the applicability of these conditions at the plant should be assessed. This assessment should be provided to the NRC for approval along with the original amendment request.

If the assessment indicates that the voltage-based repair criteria can be applied to indications at the flow distribution baffle plate, the methodology used for calculating the upper voltage repair limit for the flow distribution baffle plate intersections should be identical to the methodology discussed in Section 2.a.2, except as noted below:

- The tube structural limit should be determined for a free span burst pressure of 3 times normal operational differential pressure (ΔP_{NO}) or $1.4\Delta P_{MSLB}$, whichever is more limiting, because of the greater diametral clearances at the flow distribution baffle plate.

- The growth rate of the indications at the flow distribution baffle plate should be determined and should be compared to the growth rates of indications at TSP elevations to determine if the growth rate at the flow distribution baffle is considerably different from the growth rate at the TSPs. If the growth rate of indications at the flow distribution baffle plate is higher than the remainder of the indications, this growth rate, or a higher one, should be use for determining the upper voltage repair limit for flow distribution baffle plate indications. The growth rate should not be less than 30-percent per EFPY, as discussed in Section 2.a.2. The upper voltage repair limit for the flow distribution baffle should be determined before each outage using the most recently approved NRC data base.

2.b Total Leak Rate During MSLB

A leak rate methodology is approved in Reference 8 and is described in Reference 9. Licensees may reference the approved method. The leak rate methodology involves (1) determining the distribution of indications as a function of their voltage response at BOC as discussed in Section 2.b.1, (2) projecting this BOC distribution to an EOC voltage distribution based on consideration of voltage growth due to defect progression between inspections as discussed in Section 2.b.2(2) and voltage measurement uncertainty as discussed in Section 2.b.2(1), and (3) evaluating the total leak rate for the projected EOC voltage distribution using a probability of leakage (POL) model, as discussed in Section 2.b.3(1), and the conditional leak rate model, as discussed in Section 2.b.3(2). The solution methodology should account for uncertainties in voltage measurement [Section 2.b.2(1)], the distribution of potential voltage growth rates applicable to each indication [Section 2.b.2(2)], the uncertainties in the probability of leakage as a function of voltage [Section 2.b.3(1)], and the distribution of potential conditional leak rates as a function of voltage [Section 2.b.3(2)]. Monte Carlo simulations are an acceptable method for accounting for these sources of uncertainty, provided that the calculated total leak rate reflects an upper 95-percent quantile value at an upper 95-percent confidence bound.

2.b.1 Distribution of Bobbin Indications as a Function of Voltage at BOC

The frequency distribution by voltage of bobbin indications actually found during inspection should be scaled upward by a factor of 1/POD to account for non-detected cracks which can potentially leak or rupture under postulated MSLB conditions during the next operating cycle. This adjusted frequency distribution minus detected indications for tubes that have been plugged or repaired should constitute, for purposes of the tube integrity analyses, the assumed frequency distribution of bobbin indications at BOC as a function of voltage. This can also be expressed as

$$N_t = (1/POD)(N_d) - N_r \qquad (1)$$

where:

N_t = assumed frequency distribution of bobbin indications
N_d = frequency distribution of indications actually detected
N_r = frequency distribution of repaired indications
POD = probability of detection of ODSCC flaws

POD should be assumed to have a value of 0.6, or as an alternative, an NRC approved POD function can be used, if such a function becomes available.

N_d includes all flaw indications detected by the bobbin coil, regardless of whether these indications are confirmed by rotating pancake coil (RPC) inspection. Alternatively, a fraction of bobbin indications at locations which have been inspected with an RPC probe, but where the RPC failed to confirm the bobbin indication, may be excluded from N_d subject to NRC approval.

If the steam generators have been chemically cleaned, the impact of the chemical cleaning on the BOC voltage distribution needs to be evaluated.

2.b.2 Projected End-of-Cycle (EOC) Voltage Distribution

As discussed above, the calculation of both conditional burst probability and leakage (during a postulated MSLB) requires the generation of the projected

EOC voltage distribution. To project an EOC voltage distribution from the BOC voltage distribution determined above, requires consideration of (1) eddy current voltage measurement uncertainty and (2) the addition of voltage growth to account for defect progression. Monte Carlo techniques are an acceptable means for sampling eddy current measurement uncertainty and the voltage growth distribution to determine the projected EOC voltage distribution. Eddy current measurement uncertainty and voltage growth are discussed below.

2.b.2(1) Eddy Current Voltage Measurement Uncertainty

Uncertainty in eddy current voltage measurements stems primarily from two sources:

- voltage response variability (i.e., test repeatability error) which stems primarily from probe wear
- voltage measurement variability among data analysts (i.e., measurement repeatability error)

Each of these uncertainties should be quantified. An acceptable characterization of these uncertainties is contained in EPRI TR-100407, Revision 1, Draft Report August 1993, "PWR Steam Generator Tube Repair Limits-Technical Support Document for Outside Diameter Stress Corrosion Cracking at the Tube Support Plates" (Reference 3), Sections 2.4.1, 2.4.2, and D.4.2.3, with the exception that no distribution cutoff should be applied to the voltage measurement variability distribution. (However, the assumed 15 percent cutoff for the voltage response variability distribution in Reference 3 is acceptable.)

2.b.2(2) Voltage Growth Due to Defect Progression

Potential voltage growth rates during the next inspection cycle (i.e., operating cycle between two scheduled SG inspections) should be based on voltage growth rates observed during the last one or two inspection cycles. For a given inspection, previous inspection results at tube-to-TSP intersections currently exhibiting a bobbin indication should be evaluated consistent with the data analysis guidelines in Section 3 below. In cases in which data acquisition guidelines employed during previous inspections differ from those discussed in Section 3, the evaluation of the previous data should be adjusted to compensate for the difference. Voltage growth rates should only be evaluated for those intersections at which bobbin indications can be identified at two successive inspections, except if an indication changes from non-detectable to a relatively high voltage (e.g., 2.0 volts).

The distribution of voltage growth rates (based on the change in voltage on an intersection-to-intersection basis) should be determined for each of the last one or two inspection cycles. When only the current or only the current and previous inspections employed data acquisition guidelines similar to those discussed in Section 3, only the growth rate distribution for the previous cycle should be used to estimate the voltage growth rate distribution for the next inspection cycle. If both of the two previous inspections employed such similar guidelines, the most limiting of the two previous growth rate distributions should be used to estimate the voltage growth rate distribution for the next inspection cycle. However, the two distributions should be combined if one or both of the distributions is based on a minimal number (i.e., < 200) of indications. If the growth rate distribution, or combined distribution from two cycles, consists of fewer than 200 indications, a bounding probability distribution function of growth rates should be used based on consideration of experience to date at similarly designed and operated units.

It is acceptable to use a statistical model fit of the observed growth rate distribution as part of the tube integrity analysis provided that the statistical model conservatively accounts for the tail of the distribution. It is also acceptable that the voltage growth distribution be in terms of D volts rather than percent D volts, provided the conservatism of this approach continues to be supported by operating experience. For the purposes of assessing the conditional probability of burst and conditional leak rate, negative growth rates should be included as zero growth rates in the assumed growth rate distribution. However, for the purposes of determining the upper voltage repair limit in accordance with Sections 2.a.2 and 2.a.3, it is appropriate to consider negative growth rates as part of the estimate for average growth rate.

If the steam generators have been chemically cleaned, the impact of the chemical cleaning on voltage growth rates needs to be evaluated.

2.b.3 Calculation of Projected MSLB Leakage

Once the projected EOC voltage distribution is determined, the leakage for the postulated MSLB is calculated utilizing the EOC voltage distribution and the use of two models: (1) the probability of leakage model and (2) the conditional leak rate model. As previously discussed in Section 2.b, Monte Carlo techniques are an acceptable approach for accounting for the uncertainties implicit in these models. These models are discussed below.

2.b.3(1) Probability of Leakage as a Function of Voltage

An empirical model, for 7/8-inch and 3/4-inch diameter tubing as applicable, should be used to relate the probability of leakage (POL) to the bobbin voltage response. This model should explicitly account for parameter uncertainty of the POL functional fit of the data (i.e., "model fit" uncertainty). Currently, the staff has approved a model which uses a log-logistic function to fit the data. This model may need to be changed as additional leakage data is acquired. Revisions to this model should be submitted to the NRC for review and approval.

The supporting data sets for 2.2-cm (7/8-inch) diameter and 1.9-cm (3/4-inch) diameter tubing should include all applicable data consistent with the latest revision of the industry data base as approved by the NRC. The currently approved data base for POL as a function of voltage is given in Reference 7, as supplemented by References 1 and 2.

2.b.3(2) Conditional Leakage Rate under MSLB Conditions

An empirical model, for 7/8-inch or 3/4-inch diameter tubing as applicable, should be used to relate the conditional leak rate to the bobbin voltage response. This empirical model should account for both data scatter and parameter uncertainty of the empirical fit. Currently, an approved model consists of determining a linear first-order equation between the logarithm (base 10) of the conditional leak rate and the logarithm (base 10) of the bobbin voltage amplitude with standard least-squares linear regression analysis. The model may need to be changed as additional information is acquired; such changes should be submitted to the NRC staff for review and approval.

Use of the linear regression fit of the logarithm of the conditional leak rate to the logarithm of the bobbin voltage is subject to demonstrating that the linear regression fit is valid at the 5-percent level with a "*p*-value" test. If this condition is not satisfied, the linear regression fit should be assumed to have zero slope (i.e., the linear regression fit should be assumed to be constant with voltage).

The supporting data sets for 2.2-cm (7/8-inch) diameter and 1.9-cm (3/4-inch) diameter tubing should include all applicable data consistent with the latest revision of the industry data base as approved by the NRC. The currently approved data base for conditional leak rate as a function of voltage is given in Reference 7, as supplemented by References 1 and 2, with certain exceptions. Specifically, data excluded under criteria 3a, 3b, and 3c in References 1 and 2 should not be excluded pending NRC review and approval of these criteria. In addition, an MSLB leak rate of 2496 liters per hour should be utilized for the data point obtained from V.C. Summer tube R28C41, pending staff review and approval of any proposed alternative estimate.

2.b.4 Calculation of Offsite and Control Room Doses

For the MSLB leak rate calculated above, offsite and control room doses should be calculated utilizing currently accepted licensing basis assumptions. Licensees should note that Attachment 2 to this generic letter provides example TS pages for reducing reactor coolant system specific iodine activity limits. Licensees who wish to take credit for reduced reactor coolant system iodine activities (below 0.35 microcuries per gram dose equivalent I-131) in the radiological dose calculation should provide a justification supporting the request that evaluates the release rate data described in Reference 6. Reduction of reactor coolant iodine activity is an acceptable means for accepting higher projected leakage rates and still meeting the applicable limits of Title 10 of the *Code of Federal Regulations* Part 100 and GDC 19 utilizing licensing basis assumptions.

2.c Alternative Tube Integrity Calculation

As discussed above, licensees should calculate (1) primary-to-secondary leakage under postulated accident conditions and (2) conditional probability of burst given an MSLB, to confirm that the SG will retain adequate structural and leakage integrity until the next scheduled SG inspection. Section 6 of this attachment contains reporting guidance that recommends that licensees notify the staff prior to returning the SGs to service when conditional burst probability exceeds 1×10^{-2} or when calculated accident leakage exceeds the licensing limit. These calculations are to be performed using the projected EOC voltage distribution; however, it may not always be practical to complete these calculations prior to returning the SGs to service. Under these circumstances, it is acceptable to use the actual measured bobbin voltage distribution instead of the projected EOC voltage distribution to determine whether the reporting criteria in Section 6 of this guidance are satisfied. The actual measured bobbin voltage distribution should contain all bobbin indications detected, regardless of whether the RPC probe confirmed the degradation to be present and the NDE uncertainty distribution should be sampled. The postulated accident leakage and the conditional probability of burst should be calculated in accordance with Sections 2.a. and 2.b.3 of this attachment. This calculation is intended to assess whether the SGs can be returned to service and the plant can be operated until the full assessment (submitted within 90 days of restart) from the projected EOC voltage distribution is performed.

3. Inspection Criteria

The inspection scope, data acquisition, and data analysis should be performed in a manner consistent with the methodology utilized to develop the voltage limits (e.g., the methodology described in Reference 4, Appendix A, and Reference 5, Appendix A) with the exceptions and clarifications noted below.

3.a Bobbin Coil Inspection Scope and Sampling

The bobbin coil inspection should include 100 percent of the hot-leg TSP intersections and cold-leg intersections down to the lowest cold-leg TSP with known ODSCC. The determination of TSPs having ODSCC should be based on the performance of at least a 20-percent random sampling of tubes inspected over their full length.

3.b Rotating Pancake Coil (RPC) Inspection

RPC inspections should be conducted as discussed below for purposes of obtaining additional characterization of ODSCC flaws found with the bobbin probe and to inspect intersections with significant bobbin interference signals (due to copper, dents, large mix residuals) which may impair the detectability of degradation with the bobbin probe or which may unduly influence the bobbin voltage measurement. With respect to ODSCC flaw characterization, a key purpose of the RPC inspections is to ensure the absence of detectable crack-like circumferential indications and detectable indications extending outside the thickness of the TSP. The voltage-based repair criteria are not applicable to intersections exhibiting such indications, and special reporting requirements pertaining to the finding of such indications are described in Section 6.

3.b.1 RPC inspection should be performed for all indications exceeding 2.0 volts as measured by bobbin coil for 2.2-cm [7/8-inch] diameter tubes or 1.0 volt as measured by bobbin coil for 1.9-cm [3/4-inch] diameter tubes.

3.b.2 All intersections with interfering signals from copper deposits should be inspected with RPC. Any indications found at such intersections with RPC should cause the tube to be repaired.

3.b.3 All intersections with dent signals greater than 5 volts should be inspected with RPC. Any indications found at such intersections with RPC should cause the tube to be repaired. If circumferential cracking or primary water stress corrosion cracking indications are detected, it may be necessary to expand the RPC sampling plan to include dents less than 5.0 volts.

3.b.4 All intersections with large mixed residuals should be inspected with RPC. For purposes of this guidance, large mixed residuals are those that could cause a 1.0 volt bobbin signal to be missed or misread. Any indications found at such intersections with RPC should cause the tube to be repaired.

3.c Data Acquisition and Analysis

3.c.1 The bobbin coil should be calibrated against the reference standard used in the laboratory as part of the development of the voltage-based approach by direct testing or through use of a transfer standard.

3.c.2 Once the probe has been calibrated on the 20-percent through-wall holes, the voltage response of new bobbin coil probes for the 40-percent to 100-percent American Society of Mechanical Engineers (ASME) through-wall holes should not differ from the nominal voltage by more than ± 10 percent.

3.c.3 Probe wear should be controlled by either an inline measurement device or through the use of a periodic wear measurement. When utilizing the periodic wear measurement approach, if a probe is found to be out of specification, all tubes inspected since the last successful calibration should be reinspected with the new calibrated probe. Alternatives to this approach, which provide equivalent detection and sizing and are consistent with the tube integrity analyses discussed in Section 2, may be permitted subject to NRC approval.

3.c.4 Data analysts should be trained and qualified in the use of the analyst's guidelines and procedures. Data analyst performance should be consistent with the assumptions for analyst measurement variability [Section 2.b.2(1)] utilized in the tube integrity evaluation (Section 2).

3.c.5 Quantitative noise criteria (resulting from electrical noise, tube noise, calibration standard noise) should be included in the data analysis procedures. Data failing to meet these criteria should be rejected, and the tube should be reinspected.

3.c.6 Data analysts should review the mixed residuals on the standard itself and take action as necessary to minimize these residuals.

3.c.7 Smaller and larger diameter probes can be used to inspect tubes where it is impractical to utilize a nominal-size probe (i.e., 0.610 inch diameter for 3/4-inch tubing and 0.720 inch diameter for 7/8-inch tubing) provided that the probes and procedures have been demonstrated on a statistically significant basis to give an equivalent voltage response and detection capability when compared to the nominal-size probe. This can be demonstrated on a plant-specific or generic basis. Data supporting the use of alternate probe sizes should be submitted for NRC approval.

3.c.8 Data analysts should be trained on the potential for primary water stress corrosion cracking to occur at TSP intersections. The analysts should be sensitized to identifying indications attributable to primary water stress corrosion cracking.

4. Tube Removal and Examination/Testing

Implementation of voltage-based repair criteria should include a program of tube removals for testing and examination as described below. The purpose of this program is to (1) confirm axial ODSCC as the dominant degradation mechanism as discussed in Section 1.a; (2) monitor the degradation mechanism over time; (3) provide additional data to enhance the burst pressure, probability of leakage, and conditional leak rate correlations described in Sections 2.a.1, 2.b.3(1), and 2.b.3(2), respectively; and (4) assess inspection capability.

4.a Number and Frequency of Tube Pulls

Two pulled tube specimens with an objective of retrieving as many intersections as is practical (a minimum of four intersections) should be obtained for each plant either during the plant SG inspection outage that implements the voltage-based repair criteria or during an inspection outage preceding initial application of these criteria. On an ongoing basis, an additional (follow-up) pulled tube specimen with an objective of retrieving as many intersections as is practical (minimum of two intersections) should be obtained at the refueling outage following accumulation of 34 effective full power months of operation or at a maximum interval of three refueling outages, whichever is shorter, following the previous tube pull.

Alternatively, the request to acquire pulled tube specimens may be met by participating in an industry sponsored tube pull program endorsed by the NRC that meets the objectives of this guidance. Such a program would have to satisfy the following objectives: (1) to confirm the degradation mechanism for plants utilizing the generic letter for the first time, (2) to continue monitoring the ODSCC mechanism over time, (3) to enhance the burst pressure, probability of leakage, and conditional leak rate correlations, and (4) to assess inspection capability.

4.b Selection Criteria

Selection of the tubes to be removed should consider the following criteria:

4.b.1 There should be an emphasis on removing tube intersections with large voltage indications.

4.b.2 Where possible, the removed tube intersections should cover a range of voltages, including intersections with no detectable degradation.

4.b.3 As a minimum, selected intersections should ensure that the total data set includes a representative number of intersections with RPC signatures indicative of a single dominant crack as compared to intersections with RPC signatures indicative of two or more dominant cracks about the circumference.

4.c Examination and Testing

Removed tube intersections should be subjected to leak and burst tests under simulated MSLB conditions to confirm that the failure mode is axial and to permit enhancement of the supporting data sets for the burst pressure and leakage correlations. The systems for future tests should accommodate, and permit the measurement of, as high a leak rate as is practical, including leak rates that may be in the upper tail of the leak rate distribution for a given voltage. Leak rate data should be collected at temperature for the differential pressure loadings associated with the maximum postulated MSLB. When it is not practical to perform hot temperature leak tests, room temperature leak rate testing may be performed as an alternative. Burst testing may be performed at room temperature. The burst and leak rate correlations and/or data should be normalized to reflect the appropriate pressure and temperature assumptions for a postulated MSLB.

Subsequent to burst testing, the intersections should be destructively examined to confirm that the degradation morphology is consistent with the assumed morphology for ODSCC at the tube-to-TSP intersections. The destructive examinations should include techniques such as metallography and scanning electron microscope (SEM) fractography as necessary to characterize the degradation morphology (e.g., axial ODSCC, circumferential ODSCC, IGA involvement, cellular IGA, and combinations thereof) and to characterize the largest crack networks with regard to their orientation, length, depth, and ligaments. The purpose of these examinations is to verify that the degradation morphology is consistent with the assumptions made in Section 1.a of this attachment. This includes demonstrating that the dominant degradation mechanism affecting the tube burst and leakage properties is axially oriented, ODSCC.

5. Operational Leakage

5.a The operational leakage limit should be reduced in the TSs to 150 gallons per day (gpd) through each SG.

5.b Licensees should review their leakage monitoring measures to ensure that should a significant leak occur in service, it will be detected and the plant will be shut down in a timely manner to reduce the likelihood of a potential tube rupture. Specifically, the effectiveness of these procedures for ensuring the timely detection, trending, and response to rapidly increasing leaks should be assessed. The licensee should consider the appropriateness of alarm setpoints on the primary-to-secondary leakage detection instrumentation and the various criteria for operator actions in response to detected leakage.

5.c SG tubes with known leaks should be repaired prior to returning the SGs to service following an SG inspection outage.

6. Reporting Requirements

6.a Threshold Criteria for Requiring Prior Staff Notification To Continue With Voltage-Based Criteria

This guidance allows licensees to implement the voltage-based repair criteria on a continuing basis after the NRC staff has approved the initial TS amendment. However, in several situations, the NRC staff must receive notification to enable the staff to assess whether a licensee can continue with the implementation of the voltage-based repair criteria:

6.a.1 If the projected EOC voltage distribution results in an estimated leakage greater than the leakage limit (determined from the licensing basis calculation), then the licensee should notify the NRC of this occurrence and provide an assessment of its significance prior to returning the SGs to service. If it is not practical to complete this calculation prior to returning the SGs to service, the measured EOC voltage distribution can be used (from the previous cycle of operation) as an alternative (refer to Section 2.c). If it is determined that the projected calculated leakage will exceed the leakage limit (during the operating cycle) after the SGs are returned to service, then licensees should provide an assessment of the safety significance of the occurrence, describe the compensatory measures being taken to resolve the issue, and follow any other applicable reportability regulations.

6.a.2 If indications are identified that (1) extend beyond the confines of the TSP, or (2) appear to be circumferential in nature, or (3) are attributable to primary water stress corrosion cracking, the NRC staff should be notified prior to returning the SGs to service.

6.a.3 If the calculated conditional probability of rupture under postulated MSLB conditions based on the projected EOC voltage distribution exceeds 1×10^{-2}, licensees should notify the NRC and provide an assessment of the significance of this occurrence prior to returning the SGs to service. This assessment should address the safety significance of the calculated conditional probability and can account for operator actions to prevent primary pressure from reaching the PORV or safety valve setpoint provided that the assessment includes a probabilistic assessment of the operator actions. If it is not practical to complete this calculation prior to returning the SGs to service, the measured EOC voltage distribution can be used (from the previous cycle of operation) as an alternative (refer to Section 2.c).

6.b Information To Be Provided Following Each Restart

The following information should be submitted to the NRC staff within 90 days of each restart following an SG inspection:

(a) The results of metallurgical examinations performed for tube intersections removed from the SG. If it is not practical to provide all the results within 90 days, as a minimum, the burst test, leakage test and morphology conclusions should be provided within 90 days. The remaining information should be submitted when it becomes available.

(b) The following distributions should be provided in both tabular and graphical form. This information will enable the staff to assess the effectiveness of the methodology, determine whether the degradation is changing significantly, determine whether the data supports different voltage repair limits, and perform confirmatory calculations. The voltages reported should be adjusted to account for differences between the laboratory standard and the standard used in the field (i.e., transfer standard corrections should be made).

(i) EOC voltage distribution - all indications found during the inspection regardless of RPC confirmation
(ii) cycle voltage growth rate distribution (i.e., from BOC to EOC) - the data should indicate whether the distribution has been adjusted for the length of the operating interval, and the length of the operating interval should be provided (i.e., in EFPYs). The planned length of the next operating interval should also be provided (in EFPYs).
(iii) voltage distribution for EOC repaired indications - distribution of indications presented in (i) above that were repaired (i.e., plugged or sleeved)
(iv) voltage distribution for indications left in service at the beginning of the next operating cycle regardless of RPC confirmation - obtained from (i) and (iii) above
(v) voltage distribution for indications left in service at the beginning of the next operating cycle that were confirmed by RPC to be crack-like or not RPC inspected
(vi) non-destructive examination uncertainty distribution used in predicting the EOC (for the next cycle of operation) voltage distribution

(c) The results of the tube integrity evaluation (calculated accident leakage and conditional burst probability) described in Section 2, including the repair limits that were implemented (i.e., the upper voltage repair limit, the average growth rate at the tube support plates and flow distribution baffle, if applicable, the measurement variability allowance, and the correlation used). Note that if the leakage and conditional burst probability were calculated using the measured EOC voltage distribution for the purposes of addressing the 6.a.1 and 6.a.3 reporting criteria, then the results of the projected EOC voltage distribution should be given in this report.

7. References

1. Letter dated April 22, 1994, to Jack Strosnider, NRC, from David A. Steininger, EPRI, "Exclusion of Data from Alternate Repair Criteria (ARC) Data Bases Associated with 7/8 inch Tubing Exhibiting ODSCC."

2. Letter dated June 9, 1994, to Brian Sheron, NRC, from David J. Modeen, Nuclear Energy Institute.

3. EPRI TR-100407, Revision 1, Draft Report August 1993, "PWR Steam Generator Tube Repair Limits-Technical Support Document for Outside Diameter Stress Corrosion Cracking at the Tube Support Plates."

4. WCAP-12985, Revision 1, "Kewaunee Steam Generator Tube Plugging Criteria for ODSCC at Tube Support Plates," Westinghouse Electric Corporation, January 1993, Westinghouse Proprietary Class 2.

5. WCAP-13522, "V.C. Summer Steam Generator Tube Plugging Criteria for Indications at Tube Support Plates," Westinghouse Electric Corporation, Westinghouse Proprietary Class 2.

6. J. P. Adams and C. L. Atwood, "The Iodine Spike Release Rate During a Steam Generator Tube Rupture," Nuclear Technology, Vol. 94, p. 361 (1991).

7. EPRI Draft Report, NP-7480-L, "Steam Generator Tubing Outside Diameter Stress Corrosion Cracking at Tube Support Plates - Data Base for Alternate Repair Limits," Volume 1, Revision 1, September 1993, "7/8 Inch Diameter Tubing," and Volume 2, October 1993, "3/4 Inch Diameter Tubing."

8. Safety Evaluation by the Office of Nuclear Reactor Regulation Related to Amendment No. 54 to Facility Operating License NPF-72, Commonwealth Edison Company, Braidwood Station, Unit 1, Docket No. STN 50-456, as documented in an amendment package titled, "Issuance of Amendment (TAC NO. M89697)" dated August 18, 1994.

9. WCAP-14046, "Braidwood Unit 1 Technical Support for Cycle 5 Steam Generator Interim Plugging Criteria," Westinghouse Electric Corporation, Westinghouse Proprietary Class 2.

ABBREVIATIONS

ARC	alternate repair criteria
ASME	American Society of Mechanical Engineers
BOC	beginning of cycle
EFPY	effective full power year
EOC	end of cycle
EPRI	Electric Power Research Institute
GDCs	General Design Criteria
IGA	intergranular attack
MSLB	main steamline break
NDE	nondestructive examination
NEI	Nuclear Energy Institute
NRC	Nuclear Regulatory Commission
ODSCC	outside diameter stress corrosion cracking
POD	probability of detection
POL	probability of leakage
PORV	power-operated relief valve
PWR	pressurized-water reactor
RCPB	reactor coolant pressure boundary
RG	regulatory guide
RPC	rotating pancake coil
SEM	scanning electron microscope
SG	steam generator
STS	standard technical specifications
TS	technical specification
TSP	tube support plate

Model Technical Specifications

The model technical specifications (TSs) are based on the "Standard Technical Specifications (STS) for Westinghouse Pressurized Water Reactors," NUREG-0452, Revision 4a. The changes are indicated in italics. Note that the model TS changes described below also contain an example change to reduce reactor coolant system specific activity. The model TSs that appear below should be adopted consistent with the licensing basis. It should be noted that in the improved STS, some of these surveillance requirements have been relocated to the "Administrative Controls" section.

3/4.4.5 REACTOR COOLANT SYSTEM

4.4.5.2 Steam Generator Tube Selection and Inspection

[Add the following paragraphs:]

b. *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.*

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.*

4.4.5.4 Acceptance Criteria

a. As used in this specification:

6. Plugging Limit[3] means the imperfection depth at or beyond which the tube shall be removed from service and is equal to 40 percent of the nominal wall thickness. *This definition does not apply to tube support plate intersections for which the voltage-based repair criteria are being applied. Refer to 4.4.5.4.a.10 for the repair limit applicable to these intersections.*

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[3] For plants that have approved sleeving, "plugging" can be replaced with "repair" to allow tubes to be either plugged or sleeved when indications exceed applicable repair limits.

10. *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 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 the 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 voltage greater than the upper voltage repair limit [Note 2] will be plugged or repaired.*

d. *[If applicable] Certain intersections as identified in [reference report] will be excluded from application of the voltage-based repair criteria as it is determined that these intersections may collapse or deform following a postulated LOCA + SSE event.*

e. *If an unscheduled mid-cycle inspection is performed, the following mid-cycle repair limits apply instead of the limits identified in 4.4.5.4.10.a, 4.4.5.4.10.b, and 4.4.5.4.10.c.*

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

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

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

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)*

Implementation of these mid-cycle repair limits should follow the same approach as in TS 4.4.5.4.10.a, 4.4.5.4.10.b, and 4.4.5.4.10.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 Generic Letter 95-xx as supplemented. V_{URL} may differ at the TSPs and flow distribution baffle.*

4.4.5.5 Reports

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 steamline break) for the next operating cycle.*

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.*

REACTOR COOLANT SYSTEM

3/4.4.6 REACTOR COOLANT SYSTEM LEAKAGE

3.4.6.2 Reactor Coolant System leakage shall be limited to:

a. No PRESSURE BOUNDARY LEAKAGE,

b. 1 GPM UNIDENTIFIED LEAKAGE,

c. *150 gallons per day of primary-to-secondary leakage through any one steam generator,*

d. 10 GPM IDENTIFIED LEAKAGE from the Reactor Coolant System, and

e. ___ GPM CONTROLLED LEAKAGE at a Reactor Coolant System pressure of 2235 ± 20 psig.

f. 1 GPM leakage at a Reactor Coolant System pressure of 2235 ± 20 psig from any Reactor Coolant System Pressure Isolation Valve specified in Table 3.4-1.

For licensees who want to reduce RCS specific iodine activity, the following TS pages apply:

REACTOR COOLANT SYSTEM

3/4.4.8 SPECIFIC ACTIVITY

3.4.8 The specific activity of the primary coolant shall be limited to:

a. Less than or equal to *[reduced value]* microcurie per gram DOSE EQUIVALENT I-131, and

b. Less than or equal to $100/\bar{E}$ microcuries per gram.

APPLICABILITY: MODES 1, 2, 3, 4, and 5.

ACTION:

MODES 1, 2, and 3*:

a. With the specific activity of the primary coolant greater than *[reduced value]* microcurie per gram DOSE EQUIVALENT I-131 for more than 48 hours ...

MODES 1, 2, 3, 4, and 5:

a. With the specific activity of the primary coolant greater than *[reduced value]* microcurie per gram DOSE EQUIVALENT I-131 or greater ...

[Revise Figure 3.4-1 to lower the line by a factor corresponding to the reduction in specific activity. The lowered line should parallel the original.]

REACTOR COOLANT SYSTEM

BASES

3/4.4.5 STEAM GENERATORS

The voltage-based repair limits of SR 4.4.5 implement the guidance in GL 95-XX and are applicable only to Westinghouse-designed steam generators (SGs) with outside diameter stress corrosion cracking (ODSCC) located at the tube-to-tube support plate intersections. The voltage-based repair limits are not applicable to other forms of SG tube degradation nor are they applicable to ODSCC that occurs at other locations within the SG. Additionally, the repair criteria apply only to indications where the degradation mechanism is dominantly axial ODSCC with no significant cracks extending outside the thickness of the support plate. Refer to GL 95-XX for additional description of the degradation morphology.

Implementation of SR 4.4.5 requires a derivation of the voltage structural limit from the burst versus voltage empirical correlation and then the subsequent derivation of the voltage repair limit from the structural limit (which is then implemented by this surveillance).

The voltage structural limit is the voltage from the burst pressure/bobbin voltage correlation, at the 95-percent prediction interval curve reduced to account for the lower 95/95-percent tolerance bound for tubing material properties at 650 °F (i.e., the 95-percent LTL curve). The voltage structural limit must be adjusted downward to account for potential flaw growth during an operating interval and to account for NDE uncertainty. The upper voltage repair limit; V_{URL}*, is determined from the structural voltage limit by applying the following equation:*

$$V_{URL} = V_{SL} - V_{Gr} - V_{NDE}$$

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-XX.*

The mid-cycle equation in SR 4.4.5.4.10.e should only be used during unplanned inspections 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-XX for situations which the NRC wants to be notified prior to returning the SGs to service. 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-XX for more information) when it is not practical to complete these calculations using the projected EOC voltage distributions prior to returning the SGs to service. Note that if leakage and conditional burst probability were calculated using the measured EOC voltage distribution for *the purposes of addressing the GL section 6.a.1 and 6.a.3 reporting criteria, then the results of the projected EOC voltage distribution should be provided per the GL section 6.b (c) criteria.*

3/4.4.6 LEAKAGE LIMITS

The leakage limits incorporated into SR 4.4.6 are more restrictive than the standard operating leakage limits and are 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 in service, it will be detected, and the plant shut down in a timely manner.

3/4.4.8 SPECIFIC ACTIVITY

Reduction of the RCS specific activity to levels less than 0.35 microcurie per gram DOSE EQUIVALENT I-131 requires an evaluation (provided with the TS amendment request) of the release rate data described in Reference 6 of GL 95-XX.

LIST OF RECENTLY ISSUED GENERIC LETTERS

Generic Letter	Subject	Date of Issuance	Issued To
92-01, REV. 1, SUPP. 1	REACTOR VESSEL STRUCTURAL INTEGRITY	05/19/95	ALL HOLDERS OF OLs (EXCEPT THOSE LICENSES THAT HAVE BEEN AMENDED TO POSSESSION-ONLY STATUS) OR CONSTRUCTION PERMITS FOR NUCLEAR POWER REACTORS.
95-04	FINAL DISPOSITION OF THE SYSTEMATIC EVALUATION PROGRAM LESSONS-LEARNED ISSUES	04/28/95	ALL HOLDERS OF OLs OR CPs FOR NUCLEAR POWER REACTORS.
95-03	CIRCUMFERENTIAL CRACKING OF STEAM GENERATOR TUBES	04/28/95	ALL HOLDERS OF OLs OR CPs FOR PRESSURIZED WATER REACTORS (PWRs).
95-02	USE OF NUMARC/EPRI REPORT TR-102348, "GUIDELINE ON LICENSING DIGITAL UPGRADES," IN DETERMINING THE ACCEPT-ABILITY OF PERFORMING ANALOG-TO-DIGITAL REPLACE-MENTS UNDER 10 CFR 50.59	04/26/95	ALL HOLDERS OF OLs OR CPs FOR NUCLEAR POWER REACTORS.
89-04, SUPP. 1	GUIDANCE ON DEVELOPING ACCEPTABLE INSERVICE TESTING PROGRAMS	04/04/95	ALL HOLDERS OF OLs OR CPs FOR NUCLEAR POWER REACTORS.
95-01	NRC STAFF TECHNICAL POSI-TION ON FIRE PROTECTION FOR FUEL CYCLE FACILITIES	01/26/95	ALL CURRENT LICENSEES & APPLICANTS FOR URANIUM CONVERSION & FUEL FABRICATION FACILITIES.

OL = OPERATING LICENSE
CP = CONSTRUCTION PERMIT
NPR = NUCLEAR POWER REACTORS