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Docket No.: 50-364 10 CFR 50.90

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

Joseph M. Farley Nuclear Plant - Unit 2
Response to L* Request for Additional Information

Ladies and Gentlemen:

By letter dated August 12, 1996, the NRC issued an RAI concerning the L* steam generator tube repair criteria proposed for use at Farley Unit 2. Responses to the RAI, with the exception of question 23, are provided in Attachment 1. The response to question 23 will be provided at a later [illegible]. Attachment 2 provides technical specification pages for the permanent L* repair crit[illegible]. The marked-up pages also reflect the deletion of the cycle-specific L* repair criteria. Removal of the cycle-specific L* repair criteria, which expire at the start of the next Unit 2 refueling outage, does not affect the conclusions of the significant hazards evaluation which was provided with the original L* submittal.

The L* amendment was originally based on Report NSD-JLH-6114 and appropriate revisions. Subsequent to the submittal of report NSD-JLH-6114, this report was issued as WCAP-14697. Consequently, report NSD-JLH-6114 has been superseded by WCAP-14697 and should no longer be utilized. Copies of WCAP-14697 and WCAP-14698 (non-proprietary) are provided in Attachment 4. Copies of NSD-JLH-6114 and appropriate revisions should be destroyed.

The proprietary information for which withholding is being requested in WCAP-14697 is further identified in affidavit CAW-96-988 (Attachment 3), signed by the owner of the proprietary information, Westinghouse Electric Corporation. The affidavit, which accompanies this letter, sets forth the basis on which the information may be withheld from public disclosure by the Commission and addresses with specificity the considerations listed in paragraph (b)(4) of 10CFR Section 2.790 of the Commission's regulations. Correspondence with respect to the proprietary aspects of the application for withholding or the Westinghouse affidavit should reference CAW-96-988 and should be addressed to Nicholas J, Liparulo, Manager, Nuclear Safety Regulatory & Licensing Activities.

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If you have any questions, please advise.

Respectfully submitted,

SOUTHERN NUCLEAR OPERATING COMPANY

D. N. Morey

Dave Morey

Sworn to and subscribed before me this 8th day of October 1996

Martha Gayle Dow
Notary Public

My Commission Expires: November 1, 1997

REM/clt:LSTARRAI.doc

Attachments:
1. Responses to RAI Regarding Technical Specification Amendment for S/G L* Tubesheet Criteria - Unit2
2. Unit 2 Technical Specification Pages
3. Westinghouse Affidavit CAW-96-988
4. WCAP-14697 and WCAP-14698

cc: M.. S. D. Ebneter, Region II Administrator
Mr. J. I. Zimmerman, NRR Project Manager
Mr. T. M. Ross, Plant Sr. Resident Inspector
Dr. D. E. Williamson, State Department of Public Health

Attachment 1

RESPONSES TO REQUEST FOR ADDITIONAL INFORMATION
REGARDING TECHNICAL SPECIFICATION AMENDMENT
FOR STEAM GENERATOR L* TUBESHEET CRITERIA FOR
JOSEPH M. FARLEY NUCLEAR PLANT- UNIT 2

Attachment 1

REQUEST FOR ADDITIONAL INFORMATION
REGARDING THE TECHNICAL SPECIFICATION AMENDMENT
FOR STEAM GENERATOR L* TUBESHEET REPAIR CRITERIA
JOSEPH M. FARLEY NUCLEAR PLANT- UNIT 2

Questions related to the proposed TS changes and their responses:

1. TS section 4.4.6.3.c.13 defines the L* length that includes an eddy current measurement uncertainty. However, the value of the uncertainty was not specified. You should either specify the value or identify the document where the value is maintained in this subsection.

   SNC Response: The following sentence has been added to the technical specifications, "The allowance for eddy current uncertainty is documented in the steam generator eddy current inspection procedure."

2. TS section 4.4.6.3.c.14.(a) specifies that the L* tube is "a tube with degradation equal or greater than 40% below the L* length and not degraded within the L* length." For clarification, the staff recommends that the wording be changed to "a tube having degradation equal or greater than 40% through wall that is below the L* length..."

   SNC Response: The suggested wording has been incorporated.

3. TS section 4.4.6.3.c.14.(e) specifies the inspection of a minimum of 3.1 inches of the tube measuring down from the top of the tubesheet or bottom of the rolled transition, whichever is lower. This distance was not addressed in Westinghouse report, NSD-JLH-6114, Rev. 1. Was this distance calculated based on the data on page 20 of the Westinghouse report? If not, please provide the basis for this inspection distance.

   SNC Response: The assumed axial length of the two single bands of degradation (SBDs) in the above reference was conservatively increased from 0.25 inch to 0.5 inch, as noted in the Request for Enforcement Discretion. The total RPC inspection length from page 20 of the above reference (2.51 inches plus roundup, or 2.6 inches) therefore increases by 0.5 inches, to 3.1 inches.

4. TS section 4.4.6.3.c.14.(f) specifies that no more than two bands of tube degradation in the form of axial cracking must be found. The TS should specify a minimum allowable distance between the two bands of degradation in the axial direction. You should demonstrate that this axial distance satisfies the structural and leakage integrity of the L* tube on the basis of Regulatory Guide 1.121.

SNC Response: The minimum allowable distance between two bands of degradation is based on the potential for interaction of adjacent bands of cracks. The minimum allowable length of sound roll expansion (SRE) between bands of degradation is 0.5 inch, which is a factor of 10 times the tube wall thickness of 0.050 inch. Based on the J-integral fracture mechanics technique, which was used to estimate the onset of crack tearing, stresses decrease rapidly from the crack tips, hence, with the given spacing, no interaction would occur and the structural and leakage integrity of the multiple bands of degradation would be no worse with respect to Regulatory Guide 1.121 than for a single band of degradation.

5. TS section 4.4.6.3.c.14.(f) specifies that "a minimum aggregate of 1.74 inches plus allowance for eddy current measurement uncertainty, of sound roll expanded tube distance with no more that [sic] 1 band of tube degradation in the form of axial cracking must be found in the inspected portion of the tube..." (1) There should be a connection between the axial cracking referenced in this subsection and the crack orientation mentioned in subsection (b). The staff suggests the following wording: "a minimum aggregate of 1.74 inches plus allowance for eddy current measurement uncertainty, of sound roll expanded tube distance with no more than [sic] 1 band of tube degradation in the form of axial cracking, which is limited to less than 30 degrees from the axial direction, must be found in the inspected portion of the tube..."; (2) You should either specify the uncertainty value or reference the document that maintains the uncertainty in this subsection; and (3) The typographical error identified should be corrected.

SNC Response: The suggested wording has been incorporated. A statement similar to that used in 1 above has been incorporated. The typographical error has been corrected

6. The Westinghouse qualification test shows the cracks (15 and 30) were neatly parallel to each other in a band. However, in the field the cracks may not be neatly parallel to each other. Therefore, TS section 4.4.6.3.c.14 should specify the minimum allowed distance among the individual cracks in a band of degradation. You should demonstrate that this distance satisfies the structural integrity and leakage integrity of the L* tube.

SNC Response: This is not a concern regarding the leakage integrity of the L* tube because the L* length of the tube is above the degradation without regard for the nature of the degradation below the L* length, i.e., relative to leakage the tube could be severed.

The structural issue is more complex to resolve and relies heavily on understanding the analysis of the model, which is an ideal array of parallel cracks. The NRC concern is that real cracks in a tube likely do not lie in a neat array parallel to one another. To evaluate

this situation, it is supposed that all of the cracks but one are aligned parallel to each other. The evaluation may then be visualized by considering a subset of the array consisting of three total cracks, two which are nominally aligned with the misaligned crack between them. Three categories for three cracks may be considered as follows:

1) The cracks are nominally oriented and appear as ///.

2) The center crack is rotated relative to the other two and may appear as /|/.

3) The center crack is significantly rotated relative to the nominal orientation, appearing as /\/. Another variant of this would be an appearance as /_/, i.e., U-shaped, however, cracks with this configuration are not permitted to remain in service by the L* criterion.

In category 3, the misaligned crack is oriented in the opposite angular sense from the others and the three cracks for a tail-to-tip crack arrangement. Thus, in this case there would be no ligament strength over what would amount to two ligament widths. The analysis is based on the calculation of the lower bound limit load that would result in plastic bending of the slats between the cracks. In order for the tube to fail, rotation of the cracks must occur, however, because of the continuity of the material above the \/ portion and below the /\ portion of the /\/ shape, the material resisting moment will not be significantly changed and the limit load would not be expected to be significantly reduced. In this situation it may be that the mode of failure is dominated by the axial tensile load. In this case, several such shapes could be accommodated before the tensile strength of the tube would be decreased significantly relative to the requirements of Regulatory Guide 1.121. The eddy current response to such shapes would also likely imply a circumferential angle greater than that allowed by the L* criterion.

To resolve the issue relative to the occurrence of category 2 types of cracks, it is recalled that the expression for the critical load for n slats (material between cracks) is,

$$F_c = \frac{2\pi^2 R_m^2 t}{nl\cos\theta}\sigma_f \sin^2\theta_0 \qquad (1)$$

The spacing of the cracks in the network is obtained from geometry considerations as

$$s = \frac{2\pi R_m}{n} \qquad (2)$$

Thus, the expression for the critical force for slat i in terms of the spacing, s_i, is

$$F_i = \frac{s_i^2 t}{2l\cos\theta}\sigma_f \sin^2\theta. \qquad (3)$$

The total critical force is taken as the sum of the critical loads per slat. The lowest total critical load occurs when all of the s_i's are equal. Thus, small off-nominal alignments would be expected to increase the axial strength of the tube, rather than decrease it. This same result is obtained from consideration of the design curve. The smallest ligament of configuration 2, s_{min}, may be used to calculate larger number of effective cracks, n_s, which would nominally correspond to a weaker situation than the actual category 2 configuration. However, the criterion was developed using the number of cracks that resulted in a minimum load carrying capability for each particular slant angle, thus, a change in the effective number of cracks would result in an increase in the axial strength.

Finally, consider that the nominal array has a ϕ of 30° (slant angle), and thus a θ of 60° (angle from the horizontal). If one of the cracks has a slant angle of 45°, the tube is stronger, relative to the criterion, than if all of the cracks had a slant angle of 45°. Similarly, if the nominal slant angle is 45° and one crack has a slant angle of 30°, the configuration is stronger, relative to the criterion, than a configuration with all 45° angles.

In summary, based on the previous arguments, the criterion is conservative relative to mixed slant angle configurations.

7. TS section 4.4.6.3.c.14 should also specify the maximum allowed crack length in the axial direction and maximum allowed number of cracks in a single band. In the Significant Hazards Evaluation, in your April 22, 1996 submittal, you stated that each crack is limited to 0.5 inch in the axial direction and the number of the cracks in a band is limited to 15, but these values were not specified in the TS.

   SNC Response: The phrase "(15 flaws in a band of 0.5 inch or less in axial length)" has been added to the technical specification.

8. If the dimension of an indication in a band of degradation does not satisfy the L* criteria (e.g., the angle or length criterion), would the tube still be considered as an L* tube?

   If a flaw does not satisfy the L* criteria in the first two bands of degradation, the tube is not an L* tube. The tube would be either plugged or repaired.

However, if the L* criteria are met in the upper two bands of degradation,there are no criteria for degradation in the remainder of the tube in the tubesheet. This tube would be an L* tube regardless of the dimensions of flaws in the lower portion of the tube.

9. Clarify the relationship among the L* length of 0.5 inch specified in TS section 4.4.6.3.c.13, the distance of 3.1 inches specified in TS section 4.4.6.3.c.14.(e), and the distances of 1.74 and 1.87 inches specified in TS 4.4.6.3.c.14.(f). A diagram of a roll expansion joint with these distances and corresponding degradation identified would provide sufficient clarification. Note: The diagram is not required to be included in the TS.

   SNC Response: The L* length, which provides the leak limiting basis, is coincident with the pullout load reaction lengths (PLRLs) of 1.74 inches (for SBD) and 1.87 inches (for MBD). These lengths increased to 2.74 inches (SBD) and 2.87 inches. as noted in the response to Question 3. Figure 1 illustrates the factors included in the inspection length summation.

10. For the case of the two-band degradation, clarify (1) if the L* criteria would be applied to a tube in which the angles of the cracks in both bands are not slanted in the same direction. For example, the cracks in the upper degradation band are slanted in the clockwise direction, but the cracks in the lower degradation band are slanted in the counterclockwise direction, and (2) do the cracks in both bands have to be slanted by the same degree before the L* criteria could be applied?

   SNC Response: Since the tube rollers always rotate in the same direction, it is expected that the degradation bands would be oriented in the same direction. With a minimum length of 0.5 inch between bands of degradation, no interaction between bands is expected to occur, regardless of differences in the orientation of the cracks in each band, as stresses decrease rapidly from the crack tips (see the response to Question 5). Therefore, the bands do not have to be slanted by the same degree, nor do they have to be oriented in the same direction.

   Per Section 7.2 of letter NSD-JLH-6114, Rev. 1, yielding of the crack arrays due to an axial load proceeds by plastic bending of the ligaments between cracks within each band and subsequent rotation of the cracks toward the longitudinal axis of the tube. As yielding occurs, strain hardening of the ligaments within the upper band of degradation and of the undegraded portion of the tube between bands of degradation could occur, prior to yielding of a "lower" (further from the top of tubesheet) band of degradation. The

intermediate band of sound tube decreases the axial pull force seen by the 'lower" degraded band, and, therefore, decreases the likelihood of crack growth for the lower band of degradation. Even so, the pull force design curve for 7/8 inch tubing, shown in Figure 6 of NSD-JLH-6114, Rev. 1, shows that the pull strength of cracks with slant angles of up to 45° exceed the axial pull force associated with 3ΔP. Since the multiple crack bands are required to be spaced such that interaction between bands should not occur, and since the pull strength of cracks within each band are well above the axial forces associated with the limiting condition, 3ΔP, orientation of the cracks in 2 adjacent bands relative to each other is not a factor in determining whether the L* criteria apply.

Questions related to Westinghouse Report, NSD-JLH-6114, Rev. 1 (proprietary)

11. Page 5. Second paragraph. (1) Clarify how the 600 tubes for the L* criteria were derived; (2) In this paragraph you stated that based on commercial and operational considerations the initial leak acceptance criterion for normal operation would be based on having the total leakage from L* tubes to be one-fourth of the 150 gpd. Clarify how the criterion of one-fourth of the 150 gpd is derived, and (3) the Farley TS also implemented the voltage-based alternate repair criteria. Have you assessed the impact of the leakage of L* tubes to the voltage-based alternate repair criteria? That is, if the L* criteria and voltage-based repair criteria are applied to the same tube, do you add the leakage from the L* criteria to the leakage from the voltage-based criteria?

SNC Response: Parts (1) and (2): Allocation of one-fourth of the normal operation primary-to-secondary side allowable leakage limit (ALL) of 150 gpd per steam generator (SG) to tubes using the L* criteria was arbitrary. It was used to demonstrate conservatively that the leakage from a reasonable number of L* tubes per SG would not cause a plant shutdown based on exceeding allowable leakage limits with reasonable allocations for other degradation mechanisms.

Selection of a maximum appropriate, number of L* tubes, for example, 600 per SG, results in a projected leakage of less than 23.4 percent of the "allocation" of one-fourth of the ALL. Expressed another way, this would be less than 9 gpd, or less than 6 percent of the ALL. This postulated leakage is based on the tube having at least one throughwall crack within at least one of the degraded roll expansion portions of the RPC length of the L* tube, a bounding assumption which is expected to be rarely encountered. In the absence of throughwall cracks in this portion of the tube, leakage is impossible.

Part (3): Although this question apparently addresses the normal operation condition, the implication is that combining the ARC, L* and tubesheet sleeve nonwelded joint potential leakage at the faulted (SLB/FLB) condition should be considered.

In the response to question 13 of this RAI letter, it is shown that for 600 L* tubes in a given SG, all with throughwall degradation within at least one of the degradation bands of the RPC inspection length of the tube, a bounding assumption, that the aggregate faulted condition leakage would be approximately 0.11 gpm. This is less than one percent of the 11.4 gpm for the leakage limit in the faulted SG. Therefore, it is recommended that 0.11 gpm be allocated for L* for the faulted condition and the remaining 11.29 gpm, rounded off to 11.3 gpm, be allocated to ARC.

For the only other potential source of leakage which should be considered, i.e., the nonwelded mechanical interference fit (MIF) lower joints of tubesheet sleeves, the potential leakage is expected to be a maximum of approximately 0.100 dpm per sleeved tube. Therefore, a reasonable maximum number of tubesheet sleeves with MIF joints in one SG, i.e., 1000, would only account for 100 dpm, (0.001333 gpm). This is a negligible flow when compared to the 11.4 gpm faulted condition permissible flow.

In summary, because the sleeve MIF joint potential leakage is negligible and the L* potential leakage is approximately 0.1 gpm for a conservative number (600) of tubes with throughwall indications in the RPC inspection length, it is recommended that 0.1 gpm of the total allowable SLB leak rate be allocated to L*. For the current Farley SG leak limit of 11.4 gpm, 11.3 gpm would be available for other ARCs.

12. Page 5. Bottom of the Page. Clarify how the primary-to-secondary leakage for the faulted condition was derived.

SNC Response: The maximum primary-to-secondary pressure differential across the tube for faulted conditions is associated with a postulated feedline break (2650 psi). Hence, a differential pressure of 2650 psi was used in the roll expansion leak tests summarized in Table 1. The average leakage at 2650 psi for a roll expansion length of L* = 0.5 was calculated to be 13.26 drops per minute (dpm), based on the seven data points for 7/8" tubes at 2650 psi. Since there are approximately 75,000 drops in one gallon, this corresponds to an average FLB leak rate of 13.26 / 75,000 = 0.000177 gpm per tube end. For 600 tube ends, this results in leakage of approximately 0.1 gpm at the limiting faulted condition pressure differential.

The limiting allowable leak rate for faulted conditions occurs for the steam line break event, which has the most stringent radiological conditions. A site specific determination of acceptable leakage during a SLB event using the criteria of 10CFR100 resulted in the primary-to-secondary leakage in the SG in the faulted loop being 11.4 gpm (the value of 11.2 cited at the bottom of page 5 is incorrect, but nevertheless, conservative). A June 4,1992 submittal by Southern Nuclear to the NRC documented a SLB leakage limit of 5.7 gpm, which was based on a dose equivalent steady state limit of 1 μCu/gram of Iodine-131 and a transient limit of 60 μCu/gram of Iodine-131. Since that time, the site has adopted limits of 0.5 μCu/gram of Iodine-131 for the steady state limit and a transient limit of 30 μCu/gram of Iodine-131, which results in a SLB leak rate limit of twice the original value, or 11.4 gpm.

Assuming that 1/4 of the total leakage in the SG results from L* tube ends, the leakage limit for faulted conditions would be 2.8 gpm. Dividing this by the average leak rate per L* tube end of 0.00018 gpm shows that more than 15,800 tube ends could be dispositioned under the L* criteria. Hence, the 600 tube ends set by the normal operation condition on page 5 of NSD-JLH-6114, Revision 1 is a very small fraction of the total required to approach the faulted conditions leak rate limit.

13. Page 6. Third paragraph. Clarify how the primary-to-secondary pressure differential for the faulted condition was derived.

SNC Response. The limiting allowable leak rate for faulted conditions occurs for the steam line break event, which has the most stringent radiological conditions. However, the maximum steam line break primary-to-secondary pressure differential of 2560 psi is bounded by the feedline break condition. The maximum primary-to-secondary pressure differential across the tube for faulted conditions is 2650 psi for a postulated feedline break.

14. Page 8. The third paragraph provides a description of how a tube having a single band of degradation fails under the pullout load. (1) Clarify if the failure sequence for the single band degradation tube applies to a tube having multiple bands of degradation, especially if the cracks in one band are slanted in a different angle than the cracks in another band. (2) Clarify if there is any effect in terms of ligament tearing of multiple bands of cracks that would affect the overall pullout load of the L* tube.

SNC Response: Part (1): The failure sequence for multiple band degradation is essentially the same as that for single band degradation. Depending on its length and radial interference pressure, the undegraded portion(s) of tube between multiple bands of degradation (e.g., length "d" of Figure 1) could experience strain hardening and yielding prior to yielding of a "lower" (further from the top of tubesheet) band of degradation. The intermediate band of sound tube decreases the axial pull force seen by the "lower" degraded band, and therefore decreases the likelihood that the lower band of degradation will be limiting in terms of pullout load. The rotational effects described on page 8 principally refer to rotation of ligaments with respect to the longitudinal axis of the tube (reduction in f in Figure 1). Since the tube is relatively flexible torsionally, the orientation of the slants in the bands of degradation does not affect the pull force. (In practice, since the tube rollers always rotate in the same direction, it is expected that the degradation bands would be oriented in the same direction.)

Part (2): This question can be considered in terms of the potential for interaction of adjacent bands of cracks. The J-integral approach, which was used to estimate the onset of crack tearing, is a fracture mechanics technique. The minimum length of sound roll expansion (SRE) between bands of degradation is 0.5", or a factor of 10 times the tube wall thickness. Stresses decrease rapidly from the crack tips, and with the given spacing, no interaction would occur. Therefore, as formulated for L*, there is no difference between SBD and MBD failure modes.

15. Page 9. Fourth paragraph. Westinghouse stated that "for low numbers of cracks and small crack angles, yielding of the uncracked sections developed and pull strengths were limited by the tube-to-tubesheet welds." Is the tube-to-tubesheet weld considered as a primary pressure boundary in the design basis? Were the welds qualified as a Class I component? If so, how were they qualified, by what standards, and with what type of loads? Should the weld be damaged by loose parts in the steam generator, would the structural and leakage integrity of the L* tube still be maintained?

SNC Response: The tube-to-tubesheet welds are considered a primary pressure boundary for the design basis of the steam generators, and were qualified as Class I components. Section 3.5 of the 51 Series Steam Generator Stress Report provides a summary of the analysis of the tube-to-tubesheet weld. A detailed analysis of the effects of normal and upset condition transients and test conditions on the tube-to-tubesheet welds was performed using finite element techniques. Stress intensity ranges due to thermal and

pressure loads were compared to allowables from Section III of the ASME Code for Class I components, and a fatigue analysis was also performed. The resulting stresses and fatigue usage factors were shown to be less than Code allowables.

If the tube-to-tubesheet weld were damaged by loose parts impacting on the bottom of the tubesheet, the structural and leakage integrity of L* tubes would be maintained. The determination of resistance to leakage for L* tubes is not dependent on the presence or absence of the tube-to-tubesheet weld. The average leakage expected for a single L* tube end and for an aggregate number of tubes is shown to be less than the allowable leak rates for normal and faulted conditions; this evaluation does not rely on the presence of the tube-to-tubesheet weld. Similarly, the pullout resistance of the L* tubes does not rely on the tube-to-tubesheet weld. The tube axial loads are borne by the sound portion of the tube above L*, the uppermost degraded portion, the sound portions, other axial or near-axial degradation portions, if any, below the uppermost degraded portion and extending to (but not including) the tube-to-tubesheet weld. The pullout load reaction lengths (PLRLs) calculated in the L* evaluation are the necessary length of roll expanded tube, including bands of degraded and sound roll expansion, which will provide sufficient resistance to the axial pullout loads to preclude pullout without relying on the tube-to-tubesheet weld. Determination of the characteristics, e.g., ECI number, inclination angle, etc., of all of the degraded regions in a given tube joint would be necessary if the tube pullout load were to be applied to the tube-to-tubesheet weld. As it is, inspection of the length of 3.1 inches of tube, based on the limiting PLRL, precludes the need to quantify degradation below the inspection region to any greater extent than degradation is quantified below the F* distance.

16. Page 9. Fourth paragraph. Westinghouse mentioned fracture mechanics and J-integral approach to the tube cracking. What is the critical crack size for the Farley steam generator tubes?

SNC Response: The critical crack size is a function of the crack orientation and material properties. Regardless of the orientation, the determination is based more on empirical data than on theory, although the data for circumferential cracks generally falls above theoretical solutions base on plastic instability or instability of the plastic zone at the tip of the crack. For a differential pressure of 3657 psi (ΔP_{SLB} divided by 0.7), the critical length of a throughwall axial crack is 0.57 inch for a tube with a lower tolerance limit flow stress property at 650°F. For a circumferential throughwall crack, the critical length would be about 280° to meet the Regulatory Guide 1.121 margin during a postulated

steam line break event, and about 240° to have a margin of safety of 3 against burst during normal operating conditions. The discussion of page 9 was with regard to establishing that the maximum loads were consistent with an applied J equal to a value of 3600 in-lb/in^2, which would then represent a critical value, i.e., J_c for this situation.

17. Page 14. Table 1 presents results of a roll expansion leakage test for the 3/4-inch tube and projected leakage for the 7/8 inch tube. The test tube has a single band of holes representing degradation. However, the Farley TS allows two bands of degradation. Clarify if the leakage test results from a single band of degradation bound the leakage from two bands of degradation.

    SNC Response: The leakage results for two (or more) bands of degradation are bounded by the tested condition, one band of degradation. For both SBD and MBD, the L* length defines the minimum axial length of sound, undegraded roll expansion between the BRT and the top of the highest-elevation degradation. The undegraded portion of roll expansion between the two bands of degradation in MBD represents an additional restriction to flow for leakage entering the crevice through cracks in the "lower" band of degradation.

18. Page 26. (1) Figure 6 provides a pull force design curve for 7/8-inch tubes. Clarify how the design curve was derived from Figure 5, which gives the test data of pullout loads for the 3/4-inch tubes, (2) In the qualification test, the slots were machined onto the test tube in a neatly parallel pattern. In the field, cracks may have a different pattern than the one in the test tube. Does the design curve bound those degradation patterns/configurations that are different than the one in the Westinghouse test tubes?

    SNC Response: The design curve for the 3/4" tube size was derived from theoretical considerations of an ideal model. The model and resulting criterion curve were validated by the test data. The design curve for the 7/8" diameter tubes was developed using the same theoretical considerations and ideal model. The response to RAI number 7 demonstrates that the ideal model is conservative relative to departures from the ideal model.

19. Page A-11. Westinghouse stated that "the results of the single band degradation [SBD] test were also applicable to the most stringent, i.e., uppermost band of multiple band degradation [MBD] in roll expanded tube joints." Intuitively, an MBD tube is structurally weaker than an SBD tube; therefore, the pullout load from the MBD tube should be less

than that of the SBD tube. The pullout load from the MBD tube should be the limiting load for the design curve for L* tubes (Figure A.4-7 or Figure 5). Clarify why the SBD test is applicable to MBD.

SNC Response: The L* criteria require that multiple bands of degradation be spaced at least 0.5 inch apart. Based on the J-integral fracture mechanics technique, it is judged that interaction of adjacent bands of degradation would not occur as stresses in the roll expansion diminish rapidly from the crack tips. It is conservatively assumed that each band of degradation must be capable of withstanding the axial pullout force associated with 3ΔP. In practice, the friction force between the tube and tubesheet in the upper L* length of 0.5 inch would bear a significant portion of this load. The first degraded band would react another portion of the pullout force, followed by the next band of sound roll expansion. Hence, each band of degradation in a tube with multiple bands of degradation would bear a portion of the load. The pull force design curve shows that single bands of degradation are capable of withstanding the axial pullout force associated with 3ΔP for crack angles of up to 45°. Multiple bands of degradation are not expected to interact with the required spacing, nor would they present a structurally weaker configuration relative to the SBD case. Therefore, the pull force design curve given in Figure 5 (based on a single band of degradation) is appropriate.

20. Page A-15, Table A.3-2 (and Figure A.4-3 on page A-25) showed results of axial loadbearing strength test of degraded roll expansions. The results showed that for specimen configuration B having a slot angle of 30 degrees, the specimen that has 15 slots resulted in a lower ultimate load than the specimen that has 30 slots. It seems that the 30-slot specimen should experience lower ultimate load than the 15-slot specimen because the 30-slot specimen is structurally weaker than the 15-slot specimen. Please explain why this is not the case.

SNC Response: The criterion curve shown on Figure A.4-3 was derived based on theoretical considerations of a lower bound model. As such, it would predict that the 30 slit specimen would be weaker than the 15 slit specimen in torsional bending. However, torsional bending may not be the final failure mode of the tube, i.e., the mode may be tensile tearing of the individual slats (material between slits). Thus, it is possible that tearing at the tips of the slits occurs in the 15 slit specimen, because the slat width is twice that of the 30 slit specimen, because of the bending resistance of the slats (proportional to s^2) is greater than the bending resistance of the 30 slit specimen. Put another way, because of the flexibility of the slat itself, the 30 slit specimen can accommodate the torsional bending of the individual slats without tip tearing occurring and then fail because

of a more significant direct influence of the axial load. For a slit angle of 15° there is no difference between 15 and 30 slits, implying a dominance of the axial load over the developed slat bending load. Thus, the 30 slit band specimen may straighten at a lower load, but require a greater total load for failure than the 15 slit band specimen.

21. Page A-22. Westinghouse derived an equation for estimating the axial load required to yield a tube with a band of slanted cracks. This equation correlates well with the test results of tubes having a single band degradation. Clarify if this equation is applicable to tubes having multiple bands of degradation since Westinghouse did not perform tests for tubes having multiple band degradation.

SNC Response: The L* structural integrity tests were performed with the grip at the top of the tube fixtured in a manner that would not prevent rotation of the tube about the longitudinal axis, i.e., torsion of the tube, during the test. This, in effect, models a zero torsional resistance for the length of tube from the degradation to the U-bend and for the portion of the tube below the degradation. Prevention of torsional rotation, e.g., by sound roll expansion in the field, would be expected to lead to higher structural integrity for all crack angles and numbers of cracks, hence, the testing conditions were conservative relative to potential field conditions, where significant resistance to torsional motion would be expected.

The critical loads determined under the test conditions are not subject to change due to the introduction of a second band of cracks below the first. To maintain equilibrium, the axial force applied to the top band must be transmitted without change to the lower band. In addition, the presence of the lower band cannot result in any change in the magnitude of the force applied to the upper band.

The rotation of the tube is due to the moment developed because the cracks are at an angle to the axis of the tube. If the cracks were aligned with the axis of the tube, no moments on the tube material between the cracks would be developed. When only one band of cracks is present, the portion of the tube below the cracks prevents torsional rotation of the bottom of the crack band, thus, the only rotation that occurs is associated with the deformation of the tube within the one crack band. The presence of a second, or lower, band of indications will result in the total rotation of the tube increasing because of the rotation associated with the lower band. While the total rotation of the tube will be greater with multiple bands (assuming the same sign for the angular direction of the slant of the cracks), the relative top-to-bottom rotations within the upper and lower bands will not change. It is the rotation of the tube over the length of the crack band, i.e., the

relative rotation of the top of the crack to the bottom of the crack, not the total rotation of the tube that is important in determining the structural integrity of the whole tube. In summary, the equations on page A-22 relate yield force and plastic displacement to a single band independent of the presence of additional bands.

22. Provide Reference 2 cited in the Westinghouse report: Letter NSD-JLH-6138, "L* Calculation Performed for Farley Unit 2," J. M. Hall to E. Paxson, dated 5-1-96.

SNC Response: Reference 2 in the subject report is the calculation note supporting the development of the L* criteria; a copy of the calculation note has been transmitted to the Westinghouse office in Rockville, MD and will be available for review there.

Questions related to Qualification of the Nondestructive Examination

23. Please provide for staff review the qualification of the nondestructive examination (i.e., eddy current) technique. The probe design should be submitted with associated qualification tests to demonstrate that the probe(s) is capable of detecting (1) the crack angle up to 30 degrees, (2) the angle for each individual crack among a band of 15 cracks, (3) the actual crack length, (4) the number of cracks in a band, (5) the minimum separation distance among individual cracks in a band, (6) the distance between two bands of the cracks in the axial direction, and (7) the L* distance. In addition, please provide the data analyst's qualifications and guidelines, and a description of the data acquisition hardware and software.

SNC Response: Response to be provided later.

Figure 1

Illustration of L* RPC Inspection Length for Multiple Band Degradation (Per Table 2-4D)