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November 10, 2000

U. S. Nuclear Regulatory Commission
Washington, D.C. 20555-0001

ATTENTION: Document Control Desk

Subject: Duke Energy Corporation
Oconee Nuclear Station, Units 1, 2, and 3
Docket Nos. 50-269, 50-270, and 50-287
Response to NRC Questions on License Amendment Request for Technical Specification 5.5.10.e.6 and Topical Report BAW-2303P, Revision 4

Reference:
1) Letter, Duke Energy Corporation to U.S. Nuclear Regulatory Commission, ATTENTION: Document Control Desk, Dated September 12, 2000, SUBJECT: Oconee Nuclear Station Units 1, 2, & 3 - License Amendment Request for Technical Specification 5.5.10.e.6, Steam Generator Tube Surveillance Program (TSCR 2000-07)

2) Letter, Duke Energy Corporation to U. S. Nuclear Regulatory Commission, ATTENTION: Document Control Desk, Dated October 26, 2000, SUBJECT: Oconee Nuclear Station, Units 1, 2, & 3 - Response to NRC Questions on License Amendment Request for Technical Specification 5.5.10.e.6 and Topical Report BAW-2303P, Revision 4

In Reference 1, Duke Energy Corporation submitted a license amendment request (LAR) applicable to Oconee Technical Specification (TS) 5.5.10.e.6. This LAR proposed changes to the TS requirements for the Oconee Steam Generator Tube Surveillance Program, including the applicable revision of the referenced topical report. A request for NRC approval

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of this topical report, BAW-2303P, August 2000, *OTSG Repair Roll Qualification Report*, Revision 4, was also included in the September 12, 2000 Oconee LAR. In Reference 2, Duke responded to NRC questions on the September 12, 2000 submittal. A telephone conference call to discuss the Oconee LAR submittal and Duke's October 26, 2000 response to the NRC questions contained in Reference 2 was conducted on November 1, 2000. NRC officials and representatives from Duke, Framatome Technologies, Inc., and other B&W Owners Group member utilities participated in this conference call. During the conference call, and subsequently, additional NRC questions were discussed. These questions, along with the response for each, are contained in the Attachment to this letter.

Duke is maintaining its originally requested approval date for this LAR. Based upon the current End-of-cycle 19 Outage schedule for Oconee Unit 1, Duke has requested that the NRC review and approve this LAR by December 1, 2000. This approval date is being requested in order that the repair techniques addressed by BAW-2303P, Revision 4 may be used during this upcoming Oconee Unit 1 outage. Implementation of the changes proposed in this LAR at Oconee will preclude the need to plug numerous tubes in the Unit 1 steam generators prior to their scheduled replacement in 2003.

Within this submittal document, Duke agrees to accept the condition stated below that will be added to the Oconee Facility Operating Licenses Nos. DPR-38, DPR-47, and DPR-55 upon NRC issuance of the LAR contained in Reference 1.

<u>New Oconee License Condition:</u>

"3. In addition, until the steam generators are replaced, the license is amended to add the following License Condition:

5. Steam Generator Circumferential Crack Report

New Oconee License Condition (Continued):

Following each inservice inspection of steam generator tubes, the NRC shall be notified of the following prior to returning the steam generators to service:

a. Indication of circumferential cracking in the secondary side roll (lower roll in the upper tubesheet or upper roll in the lower tubesheet) if rerolled.

b. Indication of circumferential cracking in the original roll or heat affected zone adjacent to the tube-to-tubesheet seal weld if no reroll is present.

c. Determination of the best-estimate total leakage that would result from an analysis of the limiting Large Break Loss of Coolant Accident (LBLOCA) based on circumferential cracking in the original tube-to-tubesheet rolls, tube-to-tubesheet rerolls, and heat affected zones of seal welds as found during each inspection.

d. Prior to the use of the re-roll license amendment for the end-of-cycle 20 outage at Unit 1, or the use of the amendment at Units 2 and 3, the licensee will provide the NRC a methodology and acceptance criteria for analyzing the total leakage from a LBLOCA, for item C above, for review and approval. The acceptance criteria shall be consistent with the

New Oconee License Condition (Continued):

> technical bases established for the approval of the use of Topical Report BAW-2374."

Since this submittal document constitutes a supplement to a previously submitted LAR, an affidavit is also included in this letter. Pursuant to 10CFR50.91, a copy of this letter is being sent to the State of South Carolina Department of Health and Environmental Control for their review, and as appropriate, consultation with the NRC Staff.

Please address questions to J. S. Warren at (704) 382-4986.

Very truly yours,

W. A. Coley

xc w/Attachment:

L. A. Reyes, Regional Administrator
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2600 Bull Street
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AFFIDAVIT

W. A. Coley, being duly sworn, states that he is a President of Duke Energy Corporation; that he is authorized on the part of said corporation to sign and file with the Nuclear Regulatory Commission this revision to the Oconee Nuclear Station Licenses Nos. DPR-38, DPR-47, and DPR-55; and that all statements and matters set forth therein are true and correct to the best of his knowledge.

W. A. Coley, President

Subscribed and sworn to me: Nov 10, 2000
Date

Notary Public: Mary P. Nelms

My Commission Expires: JAN 22, 2001
Date

SEAL

bxc w/Attachment:

J. S. Forbes
M. K. Nazar
W. W. Foster
L. E. Nicholson
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D. P. Rochester
J. S. Warren
ONS Master File - ON03DM
NRIA/ELL
BWOG Tech Spec Committee (N. T. Clarkson)
NSRB (P. H. Cox)

NRC COMMITMENT

Attachment

Duke Energy Corporation
Oconee Nuclear Station, Units 1, 2, and 3
Docket Nos. 50-269, 50-270, and 50-287
Response to Additional NRC Questions on License Amendment Request for Oconee Technical Specification 5.5.10.e.6 (TSCR 2000-07) and Topical Report BAW-2303P, Revision 4

By letter dated September 12, 2000, Duke Energy Corporation submitted for NRC review a license amendment request applicable to Oconee Technical Specification (TS) 5.5.10.e.6, Steam Generator Tube Surveillance Program (TSCR 2000-07). Topical Report BAW-2303P, Revision 4 was included as the technical justification for this license amendment request. Duke initially responded to NRC questions on the September 12 submittal by letter dated October 26, 2000. However, additional NRC questions were asked during a conference call held on November 1, 2000 between NRC officials and representatives of Duke, Framatome Technologies, Inc., and other B&W Owners Group member utilities. The Duke responses to these November 1 questions are provided below.

Additionally, the NRC subsequently asked for additional information on the Duke response to Question #7 contained in the October 26, 2000 Duke letter to the NRC. This additional information is also provided below. In each case, the NRC question is restated, followed by the Duke response.

QUESTIONS DISCUSSED DURING THE NOVEMBER 1, 2000 CONFERENCE CALL

We understand thermal conduction in the tubesheet region for a steam line break was calculated with the following modeling:

1. Two-dimensional nodalization was used as shown in Figure 4-1 with no variation in the horizontal plane (which would provide a 3 dimensional nodalization).

2. RELAP 5 provided primary and secondary side fluid conditions and the resulting temperatures and film coefficients were input as boundary conditions for the conduction calculation.

3. Tube to tube sheet heat transfer was calculated with a constant conductance between the tube outer diameter and the tube sheet.

Attachment

We further understand that maximum calculated tube sheet temperature non-uniformity between the tubes and the center of the ligaments was about 6 F.

We have the following questions:

1. Are the above understandings correct?

Response:

Yes, the above understandings are correct with the following clarifications:

Statement #2:
The tubesheet temperatures were imposed as the primary fluid temperature. See further discussion below under Question #2.

Statement #3:
Rather than a "constant" conductance, a more applicable description is "an isothermal condition between the tube and tubesheet."

Sentence following statement #3 above:
A conservative assessment of the MSLB transient was performed to determine the temperature difference between the tube and adjacent tubesheet ligament. At the time of maximum tube load and dilations (~605 seconds), the temperature difference was 0°F in the rolled portion of the tube and 15°F in the unrolled portion. Additional discussion on this issue is provided under Question #2 below.

2. The tube to tube sheet configuration is illustrated in Figure 2-1, where the tube is in intimate contact with the tube sheet over an inch or so as shown at the top of the figure, but the remaining almost two feet is separated by a gap that will provide poor heat transfer in comparison to the intimate contact region. What is the effect of this configuration in comparison to the configuration you assumed.

Response:

The actual configuration, including the gap between the tube and tubesheet bore, was considered in the detailed transient analysis. As stated above, an assessment of the tube-to-tubesheet bore interface was performed. Based on that assessment, it was concluded that it was conservative to assume that the perforated portion of the tubesheet follows the temperature of the primary fluid that passes through it. The effect of the gap between the tube and tubesheet was considered in the analysis and was determined to have a negligible effect on the temperature of the tubesheet at the time of interest for the MSLB transient. Therefore, the model was simplified to assign the temperature of the primary fluid to the entire tubesheet. Additional substantiation of this method is provided below.

The temperature profile of the tubesheet is a function of four interdependent factors:

1) The relative heat transfer of the tubesheet surface area and the tube bore surface area,

2) The radial gradient between the tube wall to tubesheet ligaments (horizontal direction),

3) The change in primary fluid temperature through the thickness of the tubesheet (vertical direction), and

4) The thermal gradient through the tubesheet thickness (vertical direction).

<u>Relative Heat Transfer Areas</u>

Due to the massive surface area of the tubesheet bores, the temperature of the fluid within the tubes controls the temperature of the tubesheet. The temperature of the fluid/steam on the primary and secondary faces of the tubesheet does not contribute significantly to the temperature of the tubesheet. A simple calculation (approximate values) of the relative heat transfer areas shows that the surface area of the bores is 60 times greater than the surface area of the tubesheet face. (Dimensions are provided in inches.)

Attachment

tubesheet surface area = $\pi(58^2) - (\pi/4)(0.635^2)15500 = 5660\ in^2$

tube bore surface area = $\pi(0.635)(24)15500 = 742107\ in^2$

percent of area on tubesheet face = 1.5% or 0.75% per face

percent of area within tubesheet bore = 98.5%

ratio of tube bore area to tubesheet face area = 66 to 1

Based on the relative heat transfer areas shown above, the radial heat transfer of the fluid within the tube is the controlling factor for the temperature profile of the tubesheet. Specifically, the temperature of the tubesheet ligaments is a function of the heat transfer of the primary fluid to the tube ID, conductance across the tube wall, conductance across the nominal 0.005 annulus between the tube OD and the tubesheet bore ID (for unrolled sections only), and conductance of the tubesheet ligaments. Further discussion of the temperature profile between the tube and tubesheet ligaments follows.

Radial Thermal Gradient Between the Tube and Tubesheet Ligament

A detailed one-dimensional heat transfer analysis of both the rolled and unrolled portions of the tube was performed to determine the radial gradient between the tube and the tubesheet ligament. The evaluation of the unrolled portion of the tube conservatively assumed a steam-filled 0.005-inch gap between the tube OD and the tubesheet bore. The analysis was conservative in that it did not credit any radiant heat transfer across the gap, did not credit any condensation that may take place, and also did not credit any convection of the steam within the annulus. All of these processes would increase the heat transfer and reduce the temperature lag between the tubesheet and the tube (or bulk fluid temperature).

The results of the Oconee MSLB time history evaluation show that the maximum radial gradient between the tube wall and the center of the tubesheet ligament occur early in the MSLB transient (first 100 seconds) as shown in the table below.

Attachment

Radial Temperature Gradients Between the Tube and Tubesheet Ligament

Time	Tube to Tubesheet Ligament Gradient, °F		Comment
0 - 100 sec	Rolled Portion	5°	Early in Transient, No significant tube load
	Unrolled Portion	80°	
605 sec	Rolled Portion	0°	Time of Maximum Tube Thermal Load
	Unrolled Portion	15°	

The difference in the radial gradient between the rolled portion of the tube and the unrolled portion of the tube produces a through-thickness gradient in the tubesheet, which is discussed further below.

Primary Fluid Temperature Change through the Tubesheet Thickness

Since the tube length within the tubesheets is not directly exposed to the secondary side fluid temperature, the change in primary fluid temperature through the relatively short distance of the tubesheet thickness (24-inches) is negligible. Based on NRC questions regarding the fluid temperature gradient through the tubesheet thickness, FTI developed a detailed model to quantify the maximum change in temperature as the primary fluid passes through the tubesheet. These simulations showed a change in fluid temperature of less than 2°F from the primary face to the secondary face at any time during the transient. Therefore, the change in the temperature of the primary fluid through the thickness of the tubesheet has a negligible effect of the temperature profile of the tubesheet.

Thermal Gradient through the Thickness of the Tubesheet

As stated above, the primary fluid contained within the tubes of the tubesheet controls the temperature profile of the tubesheet. Since there is very little temperature variation of the primary fluid within the tubesheet, any temperature gradient across the

thickness of the tubesheet is equal to the difference in radial heat transfer between the rolled and unrolled portions of the tubes. As provided in the preceding discussion, the radial gradient in the rolled portion of the tube is less than 5°F throughout the MSLB transient. In the unrolled portion of the tube, the radial gradient is approximately 80°F at the beginning of the MSLB transient and only 15°F at the time of maximum tube load and dilation. Thus, the majority of the tubesheet thickness (23 of 24 inches) will be at the uniform temperature associated with the unrolled portion of the tube and only a very small length (1 inch) will have a temperature associated with the rolled portion of the tube. This produces a through-thickness gradient of 80°F early in the transient and 15°F at the time of maximum tube loads with the primary face being cooler than the secondary face in both cases (for the upper and the lower tubesheets).

To provide quantitative support for the uniform temperature applied in the transient analysis, an assessment of the effects of through-thickness gradients on the previously calculated tube loads and dilations has been performed. The FEA model described in Section 4.0 of the topical report was used and solved for the gradient conditions at the time points mentioned above for the Oconee MSLB transient. The model was solved twice:

1) utilizing the engineering judgement that the tubesheet metal is at primary fluid temperature (i.e. no through thickness gradients) and
2) adding the through-thickness tubesheet gradients to the model (i.e. as an alternative to the engineering judgement of assigning tubesheet temperatures).

The key results of the two solutions, axial tube load and tube hole dilations, were compared to isolate the effect of the tubesheet through-thickness gradients. A summary of the comparison is shown in the following table.

Attachment

Comparison of Oconee MSLB tube loads and dilations As analyzed (no tubesheet gradient) case versus tubesheet gradient case				
Transient Time Point	Description	Through-Thickness Gradient Modeled	% Difference in Max. Axial Tube Load	% Difference in Max. Bore Dilation
1 minute	Time of max. through-thickness gradient	80°F	-0.8% (including gradient reduces max. load)	-10% (including gradient reduces max. dilation)
		0°F [1]		
10 minutes	Time of max. tube load/dilation	15°F	-0.1% (including gradient reduces max. load)	-3% (including gradient reduces max. dilation)
		0°F [1]		
Note: 1) The analysis assigns the tubesheets a uniform temperature equal to the temperature of the contained primary fluid				

The results of the comparative analysis indicate that both the tube axial loads and the dilations are smaller when the through-thickness gradients are applied. The results also show that the gradients have only a minor effect on the maximum tube loads and dilations. Therefore, the assumption that the tubesheet temperature equals the primary fluid temperature, which was used in determining tube loads and dilations for the repair roll topical report, is not only valid, but also conservative.

3. There are a number of "inert" tubes because they have been plugged. What is the effect of these tubes on your tube sheet response calculations?

Response:

Plugged tubes result in a global effect on the general behavior of the tubesheet and a local effect on the difference in temperature between the tube and adjacent tubesheet ligament.

The global effect of plugged tubes on the general behavior of the tubesheet was directly evaluated as part of the tube load analysis. As stated in Section 4.7 of the topical report, two different cases of 25% plugged tubes and a 0% plugging case were considered for the general behavior of the tubesheet and the resulting tube loads and dilations. The loads and dilations used for qualification of the repair roll reflect the bounding plugging conditions.

The local effects of plugging were not directly evaluated in the finite element analysis. During the MSLB transient, plugged tubes remain hot while unplugged tubes are rapidly cooled. Thus, plugged tubes could result in a slight increase in the temperature difference between the tube and the tubesheet ligament, thus increasing the tube-to-tubesheet differential dilations and decreasing the interference in the repair roll joint. For tubes with repair rolls that are adjacent to only a couple of plugged tubes, the effect is concluded to be minimal; while the maximum effect occurs for a repair roll that is surrounded by plugged tubes. The periphery in the Oconee OTSGs would be most influenced by the local effects of adjacent plugs due to the density of plugging in this area.

<u>Effect on Repair Roll Joint Strength</u>

Small changes in dilations could affect the load-carrying capability of the repair roll. However, the qualification for repair roll in the Oconee OTSGs assumes that all of the repair rolls in the periphery will slip during a MSLB transient and applies a conservative post-slip leak rate to these locations. Therefore, a slight increase in differential dilations for those tubes does not affect the conclusions of joint strength. For non-periphery tubes, the tube loads and delta dilations due to the general behavior of the tubesheet are smaller than those at the periphery (refer to Figure 4-5 and 4-7 of the topical). A slight increase in the differential dilations in the tube bundle (non-peripheral tubes) would only result in a slightly decreased margin between the axial tube load and the joint strength.

Attachment

Effect on Leak Rates

Test results show that leakage is driven primarily by the pressure differential and varies minimally as a function of differential dilations and tube loads. Therefore, a slight increase in differential dilations at any location would have a negligible effect on the leak rates applied to the repair rolls.

As noted previously, the applied leak rates are very conservative. The leak rates assume a 360°, 100% through-wall circumferential flaw at the heel transition of each repair roll and no credit is taken for the original roll joint or the tube-to-tubesheet weld. Since most of the degradation in the roll transitions is small, axial crack-like indications attributed to PWSCC, this is a very conservative approach. In the same manner, all tubes with an axial load in excess of the tested joint strength load are assumed to slip and a post-slip leak rate is applied without taking credit for the original roll or the tube-to-tubesheet weld. The tube loads and dilations are based on a conservative thermal hydraulic analysis that maximizes feedwater flow, minimizes feedwater temperatures, and does not isolate feedwater to the broken steam generator. Finally, the leak rates were evaluated at the maximum pressure differential, though the maximum pressure differential does not occur until late in the transient after the time of maximum tube loads and dilations and assumes no operator intervention. The pressure differential through most of the transient is less than 1200 psi. The bounding leak rates are conservatively applied to repair rolls in both OTSGs. The conservatism described above bounds any increase in leak rates due to slightly increased differential dilations due to the local effects of plugged tubes.

Therefore, the local effects of plugged tubes do not impact the results and conclusions of the repair roll qualification.

4. We have no information on RELAP 5 nodalization. Typically, tubes are modeled in RELAP 5 with nodes that are several feet long. Is that the case here? If so, is that a fine enough nodalization to predict tube sheet behavior?

Your response should address the thermal expansion effects in conjunction with tube sheet response to pressure difference.

Response:

FTI does not use RELAP 5 to predict the structural behavior of the tubesheet. As described in response to question #2, the primary fluid temperature was assigned to the tubesheet, T_{HOT} for the upper tubesheet and T_{COLD} for the lower tubesheet. The primary fluid temperatures were taken directly from the RELAP 5 analysis.

Based on NRC questions regarding the primary fluid temperature gradient through the tubesheet thickness, FTI developed a detailed model to quantify the maximum fluid temperature change as the fluid passes through the tubesheet. These simulations showed a temperature change of less than 2°F at any time during the transient as discussed in response to question #2.

5. For MSLB transient, describe the flow behavior from the break initiation to the complete secondary side depressurization in the region below the upper tubesheet and above the cylindrical baffle (flow distribution, single or two phase flow, maximum flow velocity, etc.). Provide the potential flow-induced loadings on the steam generator tubes (individual tubes and tube bundle as a whole) and the cylindrical baffle, methods of analysis, and the summary of the calculated results. Provide the reference for the detailed analysis report from which the summary was made.

   We understand the calculated initial response to the transient tube loads for MSLB involves permanent tube deformations. Provide the effects of this deformed state as the initial conditions for the input to the FE model thermal analysis for the determination of the axial tube loads and the data required to calculate tube and tubesheet bore dilations. Provide also the effects of tube deformed state on the determination of the repair roll exclusion zones for the upper and lower tubesheets, respectively.

Response:

During the first few seconds of the MSLB transient, there are significant cross-flow loads between the secondary face of the upper tubesheet and the cylindrical baffle due to a very large pressure differential between the OTSG secondary side and the downstream line break. The water inventory flashes to steam, resulting in some small liquid carryout that will generally cease by 10 seconds. After this time, no additional liquid carryout is expected. The magnitude of the liquid carryout is a strong function of depressurization rate, which diminishes with decreasing break size. Smaller break sizes (or the replacement OTSG with flow restricting venturi in the steam nozzles) will have little to no liquid carryout. The high cross flow velocities subside after a few seconds, which removes any potential for flow-induced tube vibration at the time of maximum axial tube load.

During the first few seconds, when the cross-flow loads are the highest, the primary-to-secondary pressure differential and tube-to-shell temperature difference is approximately that of normal operating conditions. During normal operation the RCS temperatures and pressures result in a small compressive axial load on the tubes and the differential dilations are negative (indicating increased interference between the tube and tubesheet bore). The cross-flow loads produce bending moments on the tubes due to the lateral restraint of the tubesheet and the tube support plates, which vary with elevation and are a maximum at the secondary face of the upper tubesheet. The cross-flow loads are highest on the periphery tubes. The bending moments result in bowing of the tubes and some plastic deformation of the tubes is predicted to occur. A 1997 analysis shows that the bowing of the tubes imparts an axial load of approximately 250 lbs tensile, which is 10 times less than the axial loads due to the Oconee maximum temperature differential that occurs approximately 10 minutes into the transient. The axial load due to cross-flow was calculated based on the maximum lateral displacement of the tubes (1.4 inches). Thus, the cross-flow loads do not have any appreciable impact on the integrity of the repair roll, compared to the thermal conditions that occur later in the transient. The axial component of the dynamic loads associated with the MSLB is approximately 16 lbs, which is negligible and occurs early in the transient.

After the initial overcooling and depressurization of the primary system, safety injection (HPI) begins to refill and repressurize the system. The affected OTSG is at atmospheric pressure due to the break, and the primary pressure continues to increase until the primary safety valve (PSV) setpoint is reached, or operator action is credited at 10 minutes to throttle back HPI. The analysis used for qualification of the repair roll takes no credit for operator action and allows the primary pressure to reach the PSV setpoint with an additional allowance for setpoint tolerance (2575 psi). The maximum pressure differential occurs late in the transient, after the time of maximum tube loads and dilations as described below.

The controlling factor in the development of the OTSG tube loads is the tube-to-shell temperature difference. The MSLB transient is an overcooling event, where the relatively cold HPI flow cools the tubes faster than the shell is cooling, resulting in tensile loads on the OTSG tubes. The tube-to-shell temperature difference steadily increases as the MSLB transient progresses and maximizes at approximately 10 minutes as shown in Figure 4-2 of the topical report. At the time of maximum tube-to-shell temperature difference, the primary-to-secondary pressure difference is approximately 1200 psi. Immediately after the time of maximum tube-to-shell temperature difference, the temperature difference decreases until the tube and shell temperatures are equalized. As described above, the model conservatively allows the primary-to-secondary pressure to continue to increase until the PSV setpoint is reached without credit for operator action.

The maximum tensile loads on the OTSG tubes vary along the radius of the OTSG with the highest tube loads resulting in the periphery where the tubesheets are attached to the shell and the tubes are restrained from contraction. The tube-to-shell temperature difference also results in dilations of the tubesheet bore due to the bowing of the tubesheet from the contraction of tubes in the center of the OTSG and the restraint on the tubesheet at the shell. A smaller component of the tubesheet bowing is due to the primary-to-secondary pressure difference.

The finite element analysis assumed straight tubes. Tubes plastically deformed (bowed) due to cross-flow loads at the onset of the transient are permanently lengthened. This additional length results in a slight decrease in axial tube

loads at the time of maximum tube-to-shell temperature difference. Therefore, evaluation of the tubes without accounting for plastic deformation was a conservative approach.

The qualification of the repair roll was based on the times of maximum primary-to-secondary pressure differential and maximum tube-to-shell temperature differential with the bounding condition based on tube loads and differential dilations. All leakage is assessed at the maximum primary-to-secondary pressure differential and this conservative leakage is applied to repair rolls in both generators as discussed in the response to question #3.

REVISION TO THE RESPONSE TO QUESTION #7 CONTAINED IN THE DUKE LETTER TO THE NRC DATED OCTOBER 26, 2000

Additional information on question #7 (includes response to question #6).

7. On page 5-1, Framatome states that:

> "Previous testing has shown that cyclic loading associated with normal operating and steam generator transient conditions does not degrade the integrity of the repair roll. Cyclic loading has been shown to result in higher joint strength for both high yield and low yield tubing. Previous repair roll leak test resulted in higher leakage for test samples without deposits that were not subjected to cyclic loading prior to testing than for sample with deposits that were subjected to cyclic loading prior to testing. Therefore, all leak and load testing to support this qualification of the repair was conservatively performed on samples that were not subjected to cyclic loading."
>
> Please discuss the basis for the assumption of superior leakage integrity and joint strength for repair rolls subjected to cyclic loading. Provide the results of previous testing cited in the above discussion.

Response:
The test configuration was selected based on leak and load tests that were performed using the same repair roll installation

process as that currently used for the OTSGs. A review of the leak test data and joint strength data is provided below.

Leak Test Data

An evaluation was performed of leak test data from testing conducted in 1999 that included samples with and without crevice deposits, pre-fatigue and post-fatigue. The test results showed that for the OTSG repair roll installation process, a clean crevice leaks more than a packed crevice, both in the pre-fatigue and post-fatigue cases. The resulting leak rate from the clean crevice, pre-fatigue samples was an order of magnitude greater than the leak rate from the packed crevice samples (with or without fatigue). (See data table that follows.) The decreased leakage for the packed crevice is attributed to sludge providing a partial seal between the tube and tubesheet that would be an open flow path in a clean crevice.

FTI Tube Hole Dilation Leak Test Summary (TEST PRESSURE 2580 psi)

Average Leak Rate Without Crevice Deposits Dilated in^3/hr		Average Leak Rate With Crevice Deposits Dilated in^3/hr	
Pre-Fatigue	Post-Fatigue	Pre-Fatigue	Post-Fatigue
0.3152	0.0851	0.0094	0.0288

Joint Strength Data

An evaluation of joint strength test data from 1999 from testing performed on clean crevice samples for pre-fatigue and post-fatigue conditions and packed crevice samples for post-fatigue conditions showed a maximum of 10% difference in joint strength for the tested conditions. For the configurations tested, the results showed that the pre-fatigue, clean crevice sample resulted in the minimum joint strength. This is also the configuration that resulted in the maximum leakage.

Attachment

FTI Summary of Average Repair Roll Joint Strength

Condition	Average Joint Strength (lbs)
Post-Fatigue, Dilated, Without Deposits	4785
Post-Fatigue, Dilated, With Deposits	4408
Pre-Fatigue, No Dilations, Without Deposits	4296

Qualification of the repair roll is based primarily on leakage, with joint strength as a secondary factor. Therefore, the test configuration (clean crevice, pre-fatigue) was selected that resulted in the highest leakage. The test configuration results in conservative leak rates for the LTS and bounding leak rates for the UTS. The leak rates are applied very conservatively by assuming a 360°, 100% TW circumferential crack at the heel transition of every repair roll and taking no credit for any tube-to-tubesheet weld. Additional conservatism results from leak testing at the maximum pressure differential (2575 psi), which occurs late in the MSLB transient after the time of maximum tube loads and dilations. The pressure differential during most of the transient is less than 1200 psi. The conservative leak rate is applied to repair rolls in both generators.