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October 26, 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 Qustions on License Amendment Request for Technical Specification 5.5.10.e.6 and Topical Report BAW-2303P, Revision 4

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

In the above reference, 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 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. A telephone conference call to discuss the Oconee LAR submittal was conducted on October 24, 2000. NRC officials and representatives from Duke and Framatome Technologies, Inc. participated in this conference call. During the conference call, the NRC presented 14 questions. These questions, along with the response for each, are contained in the Attachment to this letter.

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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 requested such 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.

As stated in the Duke response to Question 2 in the Attachment, within this submittal document, Duke makes the following commitment:

> Duke will conduct subsequent inservice inspections of the re-roll area to insure that the re-roll remains free of defects.

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

Very truly yours,

M. S. Tuckman

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Attachment

xc w/Attachment:

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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 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. In order to continue its review, the NRC requested additional information during a conference call held on October 24, 2000 between NRC officials and representatives of Duke and Framatome Technologies, Inc. This request for additional information was in the form of 14 questions that were presented during the October 24, 2000 conference call. Listed below are the Duke responses to the NRC questions.

Questions specific to BAW-2303P, Revision 4

1. On page 1-1, Framatome states that eddy current inspections of OTSG tubes have resulted in the detection of indications within the upper and lower tubesheet region. Since this license amendment request seeks to remove the restriction on lower tube sheet area rerolling that was part of the NRC approval of prior reroll amendments, please discuss your detection of indications (if any) in lower tubesheet and characterization of the degradation.

Response:
Indications of volumetric IGA have been identified in the lower tubesheet crevice near the secondary face; however, most of these indications are in exclusion zones for the repair roll and therefore would not be candidates for application of repair roll.

2. On page 1-2, Framatome states that volumetric indications attributed to Intergranular Attack (IGA) have been identified in the unexpanded portion of the tube within the tubesheet crevice. Please discuss the impact of IGA on the rerolling operation and exclusion zones.

Response:
The presence of IGA in a tube does not exclude the tube from being repaired by re-roll. Re-roll repair can be implemented provided the re-roll is not installed in an exclusion zone and the re-roll itself is free of indications. Based on pre-installation ECT inspection, the selected re-roll area is free from indications and the re-roll area is inspected again after installation to verify that the area is free from indications. Duke will conduct subsequent inservice inspections of the re-roll area to insure that the re-roll remains free of defects.

3. On page 2-1, Framatome states that:

"There are three overlapping roll configurations that may be installed. The compressive load is minimized by installing an inboard roll followed by an overlapping outboard roll for a total addition compressive load of 21 lbs. Installing an outboard roll, followed by an overlapping inboard roll results in a total additional compressive load of 50 lbs."

Please provide an explanation as to why the sequence of rolling, i.e., inboard roll followed by overlapping outboard roll vis-a-vis outboard roll followed by overlapping inboard roll, would result in doubling the compressive load from 21 to 50 lbs.

Response:
If the inboard repair roll is installed first, the tube is "locked" into place resulting in a 21 lbs compressive load over the length of the tube; thus the second, outboard repair roll does not impart any additional compressive load over the length of the tube. If the outboard repair roll is installed first, 21 lbs of compressive load results, then the second, inboard roll imparts an additional 29 lbs of compressive load over the length of the tube due to material pushed out beyond the toe transition of the second roll. The compressive loads that result from installation of the repair rolls was based on test measurements

of tube elongation resulting from repair roll installation for the configurations noted above.

4. Comparing Table 3-1 "B&W OTSG Performance Characteristics" in BAW-2303P, Rev. 4 with Table 4.1 "B&W OTSG Performance Characteristics" in BAW-2303P, Rev. 3, please discuss the deletion of 25 psia secondary side pressure for MSLB and 15 psia for primary side pressure for SBLOCA.

Response:
In Revision 4 of the repair roll topical report, the maximum pressure of either the primary or secondary side is conservatively taken as the primary-to-secondary pressure difference; thereby, maximizing the pressure difference. The MSLB secondary pressure of 25 pisa and SBLOCA primary side pressure of 15 psia were conservatively ignored when establishing the design pressure differences.

5. On page 4-13, Framatome states:

"Differential dilation is a term that is used to refer to the interface between the tube OD and the tubesheet bore diameter, which allows a comparison of the relative interface of the joint for any transient condition. The differential dilation is equal to the tubesheet bore dilation (due to tubesheet bowing and free thermal growth) minus the tube dilation (due to internal pressure and free thermal growth). A positive value indicates that the increase in bore diameter is greater than the increase in the tube OD with a reduced interference within the rolled joint. A negative value indicates that the tube free expansion would be greater than the bore expansion resulting in an increase in the interference pressure of the rolled joint. The differential dilations are expressed as diametrical changes along two perpendicular axes. "Radial" refers to the dilation along the radius from OTSG center to the tube centerline and "circumferential" refers to the dilation perpendicular to the radial dilation."

In Tables 5-3 to 5-8, please clarify the physical representation of both the major and minor differential dilations having positive values. Does this mean that there is reduced (or no) contact between the tube and tubesheet at this point. Please clarify the relationship between the "major and minor" differential dilations

(Tables 5-1, 5-2, 5-3, 5-4, 5-6) and "radial and circumferential" differential dilations (Tables 4-1 and 4-2).

Response:
Positive differential dilations in both directions indicate the contact is reduced in both directions. "Major" and "minor" are related to the magnitude of the dilations, with the larger dilation (larger reduction in contact) referred to as the major dilation. "Radial" and "circumferential" relate to the direction of the dilation in the generator. "Radial" dilation refers to the dilation along the radius from the SG center to the tube centerline. The "circumferential" dilation refers to the direction perpendicular to the radial dilation. The major dilation may be in either the radial or circumferential direction depending on the location of the tube in the SG. Regarding qualification of the repair roll, the magnitude of the dilations is evaluated (referenced as major and minor) with the direction of the dilation having no impact on the results.

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

> "However, the lower tubesheet crevice is known to contain solid particles in the sludge that collects in this region. Previous testing had demonstrated that leak rates are much higher for repair rolls without crevice deposits. Therefore, leak tests performed without crevice deposits provided conservative leak rates for upper tubesheet and lower tubesheet repair rolls. In addition, previous testing has shown that the joint strength is higher for rolled joints with deposits. Therefore, testing without crevice deposits is conservative for both leakage and structural integrity."

This license amendment request seeks to remove the restriction on lower tube sheet area rerolling. The NRC staff has noted in a RAI for a previous reroll submittal that operating experience with rerolled tubes in other PWRs indicates that crevice deposits may be a significant contributor to a reduction in the leakage integrity of rerolled tubes. Please discuss the basis for the assumption of superior leakage integrity and joint strength for repair rolls with crevice deposits. Provide the results of the previous testing cited in the above discussion. Include a discussion of any actual inspection

results of pulled tubes and/or upper tubesheet crevice areas.

Response:
Please see the response for Question 7 below.

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 samples 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 performed using the same roll installation process as that used for the currently operating OTSGs.

Leak test data from testing conducted in 1999 was evaluated that included samples with and without crevice deposits, pre-fatigue and post-fatigue. The test results clearly show that for the OTSG 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 11 times greater than the leak rate from the packed crevice samples (with or without fatigue). 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.

Attachment

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.

Since the current qualification allows the joint to slip, qualification of the repair roll is based primarily on leakage, with joint strength as a secondary factor. Therefore, the test configuration (clean crevice) 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. In addition, the leak rates are applied very conservatively by assuming a 360°, 100% TW circumferential crack at the heel transition (primary side) of every repair roll and taking no credit for the seal weld.

8. On page 9-1, Framatome states that:

> "Two single 1-inch repair rolls or any overlapping repair roll that results in a maximum of 50 lbs additional compressive load may be installed at a qualified location in any one tube. Additional repair rolls may be installed on a case-by-case basis by evaluating for acceptable compressive tube loads."
>
> The license amendment request seeks to remove the limitation of only one reroll per SG tube. Please discuss how to evaluate acceptable maximum compressive tube loads, to determine how many additional repair rolls may be installed in a single tube.

Response:
We evaluated the worst case compressive tube load, which occurs in the periphery during heat-up, and allowed the compressive load on that tube to increase an additional 50 lbs. This is not a significant increase compared to the compressive load due to the transient and therefore was concluded to be acceptable.

Compressive loads in the center of the SG are less than the compressive loads in the periphery; and there is no reason to limit the tube load at these locations to less than that allowed in the periphery. Therefore, additional repair rolls could be

installed in the center of the SG as long as the total resulting load is less than the load in the worst case periphery tube. Additional repair rolls in the center would be evaluated on a case-by-case basis, depending on the transient load for that tube. Duke Energy has decided to limit repair rolls at the Oconee plants to a configuration resulting in a maximum of 50 lbs additional compressive load for any location.

9. What is the Finite Element (FE) computer code used for analyzing the general structural behavior of the OTSG during the various operating and accident transients? Describe in detail how the computer code was validated, benchmarked, or compared.

Response:
Version 5.4 of the "ANSYS" finite element software code was used for determining the OTSG tubesheet-to-tube differential dilations and tube loads.

Per FTI procedures, computer programs such as ANSYS must be independently verified as performing properly. To independently demonstrate the correct execution of the ANSYS program, several small problems are executed using the same software, software features, and hardware that were used in the final solution runs. The types of problems are chosen to confirm behavior of the same types of elements and loads as is employed in the transient/structural analysis of the OTSG.

In addition, the resulting average shell temperature and tube-to-shell ΔT from the ANSYS thermal analysis were compared to those resulting from the detailed thermal hydraulic analysis of the accident transients (RELAP results).

There is no actual OTSG tube load or dilation data to benchmark against.

10. Describe the difference between the finite element analysis used in BAW-2303P, Rev. 3 and that used in Rev. 4 of the same report. Explain why, for Oconee Units 1, 2, and 3 MSLB transient case, the results are so much different, particularly in regard to the extent of the repair roll exclusion zones.

Response:
The dilations and loads for Oconee MSLB used in the Rev 03 of the topical report were not taken directly from a finite element analysis. They were based on extrapolation and interpolation of finite element analysis results of a cooldown transient performed in the late 1980's. The finite element model used for the cooldown event was constructed for the sole purpose of determining tube loads and as a result only contained a very coarse mesh representation of the tubesheets, heads, shell, and support skirt.

The dilations and loads used in Rev 04 of the topical are based on a detailed finite element analysis of the plant specific transients. The finite element model used for the analysis was constructed to provide both loads and dilations. Therefore, the mesh used to represent the tubesheets, heads, shell, and support skirt was very refined.

The difference in loads between the Rev 03 topical and Rev 04 topical is attributed to the additional detail obtained by using the finite element model. The thermal gradients in the heads, shell, and tubesheet rings from the relatively quick MSLB event are much different than those associated with a slow cooldown event. These thermal gradient differences result in differences in the rotational effects of the tubesheet ring, head, and shell. These rotational effects result in changes in the tube axial loads and dilations. Since the Rev. 03 loads and dilations were based on a ratio of the cooldown results, the rotational effects were not as precise as those available through the newer finite element analyses results.

The use of the new loads and dilations from the finite element analysis result in a change of exclusion zones provided in the previous revision of the topical. In addition, some of the changes in exclusion zones are a result of the recently defined SBLOCA transient and the inability to test dilations greater than 1.0 x 0.5 mils. Therefore, there are several things that contributed to the difference in exclusion zones between Rev 03 and Rev 04 of the topical.

11. In Section 4.1 related to the development of the finite element (FE) model of the BAW-2303P, Revision 4, it is stated that the vertical support provided to the tube support plate (TSP) by the tie-rods and spacers was not included in the model. Describe how the 42 tie-rods and spacers are distributed and connected to the upper and lower tubesheets. For the case of MSLB transient at Oconee Units 1, 2, and 3, in the absence of actual representation of the tie-rods and spacers in the FE model, provide the basis for your description of the behavior of the tie-rods and spacers under the MSLB dynamic and thermal conditions, and their effects on the tubesheets in general. Specifically, discuss the predicted effects of these tie-rods and spacers on the tubesheets in the local area surrounding the tie-rods and spacers for the determination of maximum tube load, differential dilations (radial and circumferential) and, therefore, on the determination of the repair roll exclusion zones.

Response:
Typically, the tie-rods are distributed with 6 rods (3 pairs - equally spaced in the circumferential direction) near the center of the tubesheet (& TSP's) @ R =4.5"; 12 rods (6 pairs - equally spaced in the circumferential direction) at an intermediate location with an approximate radius of 23" and 24 rods (12 pairs - equally spaced in the circumferential direction) toward the outer region at an approximate radius of 44".

The 42 tie-rods (5/8" diameter solid rods) are anchored at the lower tubesheet primary face by a 1/4" min. thickness plug weld. Each tie-rod extends from the lower tubesheet upward through 15 sets of 'tube support plate and associated vertical support spacer sleeve'. The upper end of the tie-rod is threaded and is anchored to the 15th tube support plates by a nut/washer combination. The overall length of the tie-rod is approximately 50'-6" and thus does not reach (or interface with) the upper tubesheet.

For an event such as a MSLB, the dynamic effects of the break occur relatively quickly. For example, the mechanical loads occurring due to the initial pressure wave occur in less than the first second. Subsequently, the hydraulic response of the OTSG secondary side results in a rapid blowdown. This blowdown

may take several seconds to a minute to complete. The shorter the time span, the greater the potential loading from differential pressures within the secondary side of the OTSG. Finally, the thermal response of the OTSG shell and tube material occurs over an even greater time span, which typically takes several minutes to reach its most severe loading. Because of this time-phasing of transient effects, the dynamic loads and thermal response loads do not occur simultaneously. Therefore, the thermal/pressure transient analysis performed to determine the maximum axial tube loads and associated hole dilations is not impacted by the presence of the tie-rods.

Moreover, the collective axial stiffness of the 42 tie-rods (5/8" dia x 50.5 ft long) is relatively very low. Thus, even if the tie-rods were to become loaded, they are not structurally capable of imparting a load significant enough to affect the flexure of the tubesheet (i.e., dilations are not affected).

For these reasons, the tie-rods were not included in the transient analysis for determining tube load and hole dilations.

12. The NRC staff is aware of repair roll cracking at Arkansas Nuclear One, Unit-1, that was characterized as "classical PWSCC" by the licensee. Please discuss your inspection findings for previous repair rolls.

Response:
Oconee has not identified any crack-like indications in the previously installed repair rolls. Only one small volumetric indication, which was present post-installation, has been identified.

13. You provided a previous submittal to implement an alternate repair criteria utilizing single rerolls, dated November 21, 1997. The qualification tests referenced in that submittal showed that if each of the tubes (about 15,500 tubes) in a steam generator was rerolled in the upper tubesheet and had a 100 percent through-wall flaw in the reroll, the total leakage from all flaws would be conservatively estimated at approximately 16.3 GPD under normal operating conditions. This was to show that the qualification testing indicated that normal and faulted leak rates would be well below the Technical Specification limit. Based on the higher average leakage values from the qualifications tests described BAW-2303P, Rev. 4, what

would be the total estimated leakage from all flaws under normal operating conditions?

Response:
The predicted steady-state leak rate is estimated at 2.1E-6 gpm for each repair roll. This is very conservative because the predicted leak rate assumes a 360°, 100% TW circumferential flaw at the heel transition of every repair roll and takes no credit for the original rolls or seal welds. The total leakage (and the total number of repair rolls allowed) would be limited by the plant's technical specification limits.

14. Please modify the proposed insert into the TS section to include reporting requirements to the NRC specifying that operational assessments will be provided when SG tube structural and leakage performance criteria are not met

Response:
Existing Oconee TS 5.6.8 contains steam generator tube inspection reporting requirements. This TS is currently implemented at Oconee. The identification of tubes that are plugged or repaired (including re-rolls) is included in these reports that are submitted to the NRC in compliance with this TS. Additionally, any impact of defective tubes (including any circumferential cracking found in tube re-rolls) on the continued operability of the Oconee steam generators is also included and discussed in these reports.