ENCLOSURE 7

LICENSE AMENDMENT REQUEST REGARDING TUBESHEET INSPECTION DEPTH FOR STEAM GENERATOR TUBE INSPECTIONS AT PALISADES NUCLEAR PLANT

NON-PROPRIETARY VERSION

LTR-CDME-06-40-NP, "COMMENTS ON THE APPLICATION OF WCAP-16208-P, REVISION 1, 'NDE INSPECTION LENGTH FOR THE CE STEAM GENERATOR TUBESHEET REGION EXPLOSIVE EXPANSIONS' TO THE PALISADES NUCLEAR PLANT," DATED MAY 2006

52 Pages Follow

LTR-CDME-06-40-NP, Revision 1

Comments on the Application of WCAP-16208-P, Revision 1, "NDE Inspection Length for CE Steam Generator Tubesheet Region Explosive Expansions" to the Palisades Nuclear Power Plant

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DEFINITIONS

BET – Bottom of the explansion transition.

BTA – Bore Trepanning Association process for machine boring. A process improvement employed for tubesheet drilling applicable to Plant CE2 (only one SG), CE3 and the Palisades replacement SGs.

Collar - Tubesheet mockups were fabricated from tubesheet bar stock material SA-508, Class 3. The machined bar stock in which a tube was explosively expanded was referred to in this project as a collar.

C* - The CE design explansion joint inspection distance.

EOC – End of Cycle.

Explansion – Explosive expansion of tubing into a Combustion Engineering steam generator tubesheet.

[

]a,c,e

Joint – The tube and tubesheet contact surface area created by the explansion process.

Maximum load – The largest force encountered while pulling the tube out of the tubesheet.

NMC – Nuclear Management Company.

NODP – Normal operating differential pressure = RCS pressure minus SG pressure at normal full power operating conditions.

[

]a,c,e

RAI - Request for additional information.

Rough bore – The machined surface on the inside diameter of each laboratory specimen rough bore collar was drilled on a lathe to a surface roughness not greater than 250 micro-inches (AA) to mockup the gun-drilled tubesheet hole surface. Not applicable to Palisades.

SLB or MSLB – The design basis event known as main steam line break.

Smooth Bore - The machined surface on the inside diameter of each laboratory specimen smooth bore collar was drilled on a lathe to a surface roughness not greater than 250 micro-inches (AA) and then reamed to increase smoothness to mockup the BTA process tubesheet hole surface. Applicable to the Palisades steam generators.

TTS – Top of the tubesheet.

1.0 INTRODUCTION

1.1 BACKGROUND

Palisades intends to implement the C* alternate inspection and repair criterion (as described in Reference 1).

The PWR Owners Group program to provide recommended tubesheet region inspection lengths, for plants with Combustion Engineering supplied steam generators with explosive expansions, was documented in report WCAP-16208-P and updated in a Revision 1 (Reference 1). This inspection length is referred to as C* ("C-Star"). Reference 1 has been previously submitted to the NRC by other participants within the PWR Owners Group program.

NRC has issued requests for additional information (RAI) supporting reviews of C* license amendment requests by other utilities. This document provides a compilation of all RAIs issued by NRC and responses to those RAIs that are applicable to Palisades.

1.2 RAIS APPLICABLE TO PALISADES

Appendices A-D list all of the RAIs that were issued to utilities that have submitted C* license amendment requests to the NRC. The RAIs that are relevant to Palisades are provided in bold font. These relevant RAIs can be grouped into broad topics as in Table 1 below:

Table 1: RAIs Relevant to Palisades

	Appendix:	A	B	C	D
Response Provided in Section	Topic	St. Lucie-2	Waterford	SONGS-2/3	Palo Verde-3
2.1	Pressure Effects	1	7		7
2.2	Data Usage	3	8		8
2.3	Hot Leg Temperature	5			
2.4	First Slip Criteria	6	5	3	5
2.5	Operating Parameters		2	1	2
2.6	Reporting		6	4	6
2.7	Condition of Joint		3	8	3
2.8	Accident Induced Leakage Limit	4a	4	6a	
2.9	Location of BET Relative to TTS			7	1

1.3 LEAK RATE CRITERION PER TUBE

The C* leak rate criterion used in Reference 1 is based on the generic allowable leakage technical specification limiting condition for operation of 0.5 gpm per steam generator. Operational assessment calculations include assumptions for undetected flaw populations and

determine acceptable plant run-time based in part on acceptable EOC leakage. The C* criterion was conservatively established as 0.1 gpm for this single type of flaw (tubesheet region cracking).

WCAP-16208-P established a leakage based inspection depth to ensure that the total predicted leakage from the tubesheet at Palisades was no more than 0.1 gpm/SG, assuming 7911 tubes in service. On a per tube basis, this translates to a leak rate of 1.26×10^{-5} gpm/tube. This is a conservative leak rate, but a smaller leak rate criterion per tube can be established.

The leak rate results provided in WCAP-16208-P were determined by tube to tubesheet mockup testing using a reciprocating positive displacement pump to supply fluid to each mockup sample. Leak rates were determined by multiplying the pump stroke volume by the number of pump strokes during a test period, then dividing by the length of the test period. The minimum detectable leak rate is conservatively determined by assuming that a single pump stroke occurs over the minimum test period. Using the maximum measured pump stroke volume of [ ]^{a,c,e} If it is assumed that [ ]^{a,c,e} is attributable to each of the 7846 hot leg tube-tubesheet joints in each Palisades steam generator (Reference 9) then the leak rate criteria of 0.1 gpm/SG will be maintained. The value of [ ]^{a,c,e} is used in the discussions that follow.

1.4 SUMMARY

RAIs applicable to Palisades were addressed and the required C* inspection distance has been calculated to include the NRC requested effects. The updated C* distance is 12.5 inches below the bottom of the tube to tubesheet expansion transition. This value applies to each tube inspected at the hot leg tubesheet region using the Plus Point™ coil for the Palisades steam generator tube inspection.

Table 2-1, Table 6-15 and the Executive Summary table of Reference 1 are thus amended as follows:

Table 2-1 from WCAP-16208-P: Leakage Based Inspection Length Including Tubesheet Deflection and NDE Corrections (Amended for Palisades Only)

Plant	Leak Rate Based Inspection Length Adjusted for TS Dilation (inches)	Leak Rate Based Inspection Length Adjusted for TS Dilation and NDE (inches)
Palisades	11.3 ⇒ 12.2	11.6 ⇒ 12.5

Table 6-15 from WCAP-16208-P: Inspection Length Based on Leakage
(Amended for Palisades Only)

Plant	Burst Based Inspection Length Corrected for Dilation and NDE (in.)	Uncorrected Joint Length that Meets Leakage Criteria (inches)	Interpolated Leak Rate Based Inspection Length Corrected for Dilation (in.)	Leak Rate Based Inspection Length Corrected for Dilation and NDE (in.)
Palisades	4.6	6.56 ⇒ 6.60	11.3 ⇒ 12.2	11.6 ⇒ 12.5

Executive Summary Table from WCAP-16208-P
(Amended for Palisades Only)

Plant	Leak Rate Based Inspection Length Corrected for Dilation and NDE (in.)
Palisades	11.6 ⇒ 12.5

1.5 QUALITY ASSURANCE

The work that is presented in this document was completed and reviewed under the requirements of the Westinghouse Quality Assurance Program (Reference 3).

2.0 RESPONSES TO RAIS RELEVANT TO PALISADES

2.1 PRESSURE EFFECTS

In the March 31, 2005 response to request for additional information (RAI) number 12 (see Reference 7), *all available data were used to support the analytical adjustment to account for the axial load resistance provided by the differential thermal expansion effects. However, it is not clear whether all of the available data was used to support the analytical adjustment to account for the axial load resistance provided by internal pressure. For example, specimens 8 and 12 from the Task 1154 program were run at room temperature with internal pressure; however, an analysis of this data (similar to what was done for the elevated temperature data point) was not provided. Please evaluate all data in which internal pressure (above ambient pressure) was applied to support the basis for the analytical adjustments to account for the internal pressure. With respect to the analysis of the pressure effects provided in your response, please provide additional details on how the axial force resistance due to the internal pressure of 1435 psi was calculated and discuss how the effect of the residual contact pressure was taken into account in your analysis. (The actual pullout force was nearly the same as the pullout resistance expected analytically from the internal pressure effects. As a result, if the residual contact pressure was not included in this assessment, it would appear that the analytical adjustments for internal pressure are too high).*

2.1.1 Response A to RAI

Specimens 8 and 12 are not used in any analyses reported in WCAP-16208-P or responses to NRC questions because the load during the pullout test exceeded the tube yield. When the pull force exceeds the yield strength of the tube the data reflects the tube strength and not the joint strength. The data is then independent of the joint length and does not add meaningful or useful information. Specimens 8 and 12 from the Task 1154 program (Reference 4) were both tested at room temperature and an internal pressure of 2575 psi. The load test results for specimens 8 and 12 were both in excess of the tube yield strength.

2.1.2 Background for Responses B and C to RAI

The net contact pressure, P_C, between the tube and the tubesheet during operation or accident conditions is given by,

$$P_C = P_0 + P_P + P_T - P_B \quad (1)$$

where P_B is the loss of contact pressure due to dilation of the tubesheet holes, P_0 is the installation preload, P_P is the pressure induced load, and P_T is the thermal induced contact load.

In the case of the laboratory samples tested at room temperature, both P_T and P_B are zero.

The pullout force that is attributable to any of these components, F_x of contact pressure is calculated by multiplying the applicable contact pressure, P_x, by the contact area, A, and the coefficient of friction, μ:

$$F_x = P_x A \mu \quad (2)$$

When the inside of the tube is pressurized, P, some of the pressure is absorbed by the deformation of the tube within the tubesheet and some of the pressure is transmitted to the OD of the tube, P_P, as a contact pressure with the ID of the tubesheet:

$$P_P = P\xi \quad (3)$$

In this equation, ξ is the transmittance factor. The magnitude of the transmittance factor is found by considering the relative flexibilities of the tube and the tubesheet. The following discussion of flexibilities was obtained from Reference 5.

Flexibility, f, is defined as the ratio of deflection relative to applied force. It is the inverse of stiffness that is commonly used to relate force to deformation. There are three flexibility terms associated with the radial deformation of a cylindrical member depending on the surface to which the loading is applied and the surface for which the deformation is being calculated (e.g., for transmitted internal pressure one is interested in the radial deformation of the OD of the tube and the ID of the tubesheet). The deformation of the OD of the tube in response to the external pressure provided by the contact pressure is also of interest. These flexibility terms are derived from equations for radial displacement in thick-walled cylinders (Reference 6).

The flexibility of the tubesheet, designated herein by the subscript c, in response to an internal pressure, P_{ci}, is found as,

a,c,e

[ ] Tubesheet (4)

where,

r_{ci}	=	inside radius of the tubesheet and outside radius of the tube,
r_{co}	=	outside radius of the tubesheet hole unit cell,
E_c	=	the elastic modulus of the carbon steel tubesheet material, and
ν	=	Poisson's ratio for the tubesheet material.

Here, the subscripts on the flexibility stand for the component, c for tubesheet (and later t of tube), the surface being considered, i for inside or o for outside, and the surface being loaded, again, i for inside and o for outside.

The flexibility of the tube in response to the application of an external pressure, P_{to}, e.g., the contact pressure within the tubesheet, is,

a,c,e

[ ] Tube (5)

where E_t is the elastic modulus of the tube material. Poisson's ratio is the same for the tube and the tubesheet.

Finally, the flexibility of the outside radius of the tube in response to an internal pressure, P_{ti}, is,

[ ]a,c,e Tube (6)

where r_{ti} is the internal radius of the tube.

The transmittance factor in equation (3) is found by:

[ ]a,c,e (7)

The denominator of the fraction is also referred to as the interaction coefficient between the tube and the tubesheet. The contact pressure does not increase by as much as the amount of internal pressure that is transmitted through the tube alone, because the tubesheet acts as a spring and the interface moves radially outward in response to the increase in pressure.

2.1.3 Response B to RAI

There are three cases reported in WCAP-16208-P of tube movement during testing with pressure applied inside the tube. All pullout screening tests were conducted with internal pressure. Only Sample 3, with a 2 inch joint length, and Sample 4, with a three inch joint length, experienced tube displacement during a pullout screening test. The tube blowout (another form of tube displacement) of Sample 1, with a joint length of 1 inch, occurred during room temperature leak testing. Samples 1, 3 and 4, like all of the samples documented in WCAP-16208-P, were explosively expanded into the tubesheet mock-up.

The response to RAI #12 in Reference 7 provided an analytical adjustment for internal pressure for a specific test. In the RAI #12 example, the resistance to movement provided by internal pressure was [ ]a,c,e However, this value was calculated for a sample that was tested at SLB pressure and is not applicable to the lower pressures of Samples 1, 3 and 4.

The blowout of Sample 1 was an unintended (but was considered possible and was thus monitored) consequence of a room temperature leak test. Figure 1 presents a plot of the internal pressure versus a relative time scale. Prior to the blowout, Sample 1 held an average pressure of [

]a,c,e

Sample 1 used 48 mil wall tubing. Using the nominal dimensions of the tubesheet collar, the calculated values for the flexibility terms in equations (4), (5) and (6) are:

[

]a,c,e

2.1.4 Response C to RAI

The purpose of the pullout screening tests was to demonstrate that a given joint could withstand a 3NODP load without movement (see Section 5.0 of Reference 1). This differed from the purpose of the pullout testing conducted in Task 1154 (Reference 4), which was performed to assess the maximum strength of the joint.

[

]a,c,e The pullout

screening and blowout test results were only provided in Figures 5-1 through 5-3 of WCAP-16208-P for a ballpark comparison with the Task 1154 data and were not used in the regression analysis. Nevertheless, RAI #1 seeks to assess relevant information from these tests rather than a simple pass/fail value. To provide a thorough explanation, a review of the pullout screening test data is presented here.

Figure 2 and Figure 3 present the screening pullout test data for Samples 3 and 4, respectively. The plots provide load and internal pressure data as a function of displacement. Load is plotted against the left side abscissa and internal pressure is plotted against the right side abscissa. The figures also demonstrate where various definitions of load may be read.

In Table 5-1 and Figure 5-3 of WCAP-16208-P, both the Sample 3 and Sample 4 data that is reported use a very conservative definition of "First Move" that is different from the rest of the data provided in Figure 5-3 of WCAP-16208-P and from the criteria used in response to the First Slip Criteria RAI in Section 2.4. [

]a,c,e

The "First Slip" criterion, provided in the response in Section 2.4, is appropriate for the determination of contact pressure. [

]a,c,e

Table 5-1 of WCAP-16208-P provides the "Axial Force From Internal Pressure". For Sample 1, this is based on the blowout pressure of [ ]a,c,e For Samples 3 and 4, the values provided in Table 5-1 of WCAP-16208-P are based on the nominal internal NODP pressure of [ ]a,c,e Figure 2 and Figure 3 show that the actual internal pressures were slightly less than nominal. Load and actual internal pressures, as well as the calculated values for Axial Force from Internal Pressure (using the [ ]a,c,e value from equation 8) and the Pullout Force (the sum of the External Applied Load and the Axial Force from Internal Pressure) are provided in Table 2.

Using the actual internal pressure and "First Slip" load, rather than the nominal internal pressure of [ ]a,c,e and "First Move" load, is appropriate for the evaluation of analytical adjustments to account for the internal pressure.

The Sample 3 Pullout Screening test had an internal pressure of [ ]a,c,e The external load was applied after the internal pressure was applied, without movement.

Sample 3 used 42 mil wall tubing. Using the nominal dimensions of the tubesheet collar, the calculated values for the flexibility terms in equations (4), (5) and (6) are:

[

]a,c,e

Adjusting the data in Figure 5-1 through 5-3 for the "First Slip" criterion rather than the "Maximum Load" criterion that was used, would only lower the regression and lower bound curves, thus the evaluations provided above would remain valid.

2.2 DATA USAGE

It is the NRC Staff's understanding that not all data was included in Appendix B of WCAP-16208-P, Rev. 1 (i.e., some data was not included since it was well outside the targeted

temperatures and pressures.) It is also the staff's understanding that some data in Appendix B were not included in Table 4-2 of WCAP-16208-P, Rev. 1 (which was used in determining the leak rate as a function of joint length). Please confirm the staff's understanding and discuss the basis for not including all of the Appendix B data in Table 4-2. For example, was data from Appendix B not included in Table 4-2 when steady state was never reached although the temperatures and pressures were within the desired range?

2.2.1 Response to RAI

As a point of clarification, Table 4-1 of WCAP-16208-P (Revision 0) became Table 4-2 in Revision 1. Section 4.4 of WCAP-16208-P (Revision 1) introduces Table 4-2. Section 4.4 states the following:

"There was an effect of time in the leak rate data. Most of the samples started with a relatively high leak rate and did not achieve a steady leak rate for a period of several minutes. The higher leak rate observed during the start of testing is uncharacteristic of leakage that would be observed in an operating steam generator. The data in Appendix B were reviewed to identify those data that had reached steady, or established, values under SLB conditions. Table 4-2 provides a summary of all the established elevated temperature leak rate values. The data in this table consists of valid leak rates (all parameters within specification and close to the targeted parameters), that have demonstrated some degree of an established or steady value. It also provides the basis for the selection of each point."

In addition, there are a set of notes on the page following Table 4-2 (see page 4-17 of WCAP-16208-P – Reference 1) that describes the basis for selecting the data in Table 4-2. The basis for using "established" data was elaborated upon in section 4.4 of Reference 1.

[

]^{a,c,e} However, the established leak rates in Table 4-2 are only for those tests conducted at SLB pressure and 600°F.

- Leak rate data that was obtained well outside the targeted temperatures or pressures was not included in Appendix B of Reference 1 (see section 4.4 of Reference 1), therefore it was not included in Table 4-2 of Reference 1.
- Leak rate data obtained from tests conducted at conditions other than the target pressure differential of 2560 psi and the target temperature of 600°F, was not included in Table 4-2 of Reference 1.
- The remaining leak rate data (all taken at 2560 psi, 600°F) was considered on a test set by test set basis to determine if an established or steady value was reached. Justification for each data point in Table 4-2 is provided on page 4-17 of WCAP-16208-P (Reference 1). Thus, the remaining leak rate data in Appendix B of Reference 1 was considered in determining the established leak rate, for each unique set of tests.

2.3 HOT LEG TEMPERATURE

Please confirm that the hot-leg temperature (at Palisades) is greater than that assumed in the tubesheet deflection analysis (600-degrees Fahrenheit) and in determining the increase in contact pressure as a result of differential thermal expansion between the tube and the tubesheet.

2.3.1 Response to RAI

The contact loads calculated in WCAP-16208-P, Rev. 1 (Reference 1) for tubesheet dilation effects were based on a temperature of 600°F. The leak rates were also based on an operating temperature of 600°F. Section 4.3 of Reference 1 provides a discussion of this temperature selection.

The Palisades steam generators operate with a hot leg temperature of 583°F (Reference 2). This 17°F difference from the generic temperature used in Reference 1 has a small effect on the inspection distance, as is discussed below.

Section 4.6 of Reference 1 provides a correction for temperature [ ]a,c,e

[

]a,c,e

Table 3 and Figure 4 are revisions to Table 4-7 and Figure 4-4 of WCAP-16208-P (Reference 1), respectively, to account for the change in temperature from 600°F to 583°F. The change in Figure 4 is minor. The result is that the 'Uncorrected Joint Length that Meets Leakage Criteria', that was provided in Tables 4-9 and 6-15 of Reference 1 (based on 7911 tubes/SG, but now 7846 tubes/SG, at the assumed leak criteria of 0.1 gpm/SG), changes from 6.56 inches to 6.60 inches when using the hot leg temperature of 583°F. Using the conservative minimum detectable leak rate of [ ]a,c,e, the 'Uncorrected Joint Length that Meets Leakage Criteria' is 6.61 inches at 583°F.

When the temperature increases from ambient conditions to operating conditions the differential thermal expansion of the tube relative to the tubesheet increases the contact pressure between the tube and the tubesheet. The mismatch in expansion between the tube and the tubesheet, δ, is

given by,

$$\delta = (\alpha_t - \alpha_c)\Delta T r_{to}$$

where: α_t, α_c = thermal expansion coefficient for the tube and tubesheet respectively,
ΔT = the change in temperature from ambient conditions

The change in contact pressure due to the increase in temperature relative to ambient conditions, P_T, is given by,

[ ]a,c,e

The equations for the terms f_{cii} and f_{too} are provided in Section 2.1.2.

Using a temperature of 583°F instead of 600°F, reduces the 'RCS Pressure and Diff. Thermal Axial Force' term used in Table 6-5 and 6-11 of Reference 1 from a value of [ ]a,c,e

Section 2.4 addresses an issue that affects the implementation of the 'Uncorrected Joint Length that Meets Leakage Criteria' and the reduction in the 'RCS Pressure and Diff. Thermal Axial Force' term. The revised distance developed in this section is incorporated with the change developed and provided in Section 2.4.

2.4 FIRST SLIP CRITERIA

Please clarify whether the load at first slip was reported and plotted in Figures 5-1 through 5-3 of WCAP-16208-P, Revision 1 or whether the maximum load was plotted. If the load at first slip was not used in all cases, please discuss the effect on the required inspection distance if the load at first slip was used. In addition, if the load at first slip was not used in Table 6-8 of WCAP-16208-P, Rev. 1 ("Burst Based Inspection Length"), please provide Table 6-8 values to confirm that the 12 inch proposed inspection distance is still bounded when the most limiting specimen is evaluated using load at first slip.

2.4.1 Background for Response to RAI

The pullout load data that was used in WCAP-16208-P (Reference 1) was taken from Reference 4 (Task 1154 report). A review of the Task 1154 data determined that 'maximum load' data was used. The use of the 'maximum load' was consistent with the intent of the Task 1154 approach (which was a pullout strength-limited inspection depth rather than a leak rate-limited inspection depth). The data that is plotted in Figures 5-1 through 5-3 of Reference 1 is based on the 'maximum load' encountered during each pullout test.

The leakage-limited inspection depth provided in WCAP-16208-P uses the pullout force to assess the contact pressure of the joint, which in turn is used to provide a tubesheet hole dilation

adjustment to the depth at which the leak rate criteria is met. For this purpose, a 'first slip' criterion provides the relevant pullout force. Reference 8 uses a definition that [

]^{a,c,e} This criteria eliminates the bias that was associated with the 'first move' criteria.

Section 2.3 provided a discussion of the 'Uncorrected Joint Length that Meets Leakage Criteria' and the reduction in the 'RCS Pressure and Diff. Thermal Axial Force' term for the reduced hot leg temperature from the generic 600°F used in WCAP-16208.

2.4.2 Rough Bore Samples

The Palisades steam generator tubesheet holes are of the smooth bore type. However, a discussion of rough bore holes is relevant to the discussion of smooth bore holes.

The rough bore pullout data provided in Table 5-2 of WCAP-16208-P was obtained directly from Tables 4-2 and 4-3 of the Task 1154 report. Re-examination of the Table 4-2 data showed that only those tests in which a leak test was performed were included in the table (compare with Table 3-3 of the Task 1154 report). Appendix D of the Task 1154 report lists all the Boston Edison samples that were pullout tested. As part of the response to this RAI, all of the Boston Edison pullout tests are considered, not just those that were leak tested.

In addition, the Task 1154 report provides the nominal or target joint lengths for each sample. Reference 29 from the Task 1154 report provided the actual joint lengths for each sample. The actual joint lengths were used in this response.

The Boston Edison pullout tests, as well as the Task 1154 Sample 20 and 21 collar samples, were performed with the load cell test rig shown in Figure 3.11 of the Task 1154 report. This rig was attached to the tube by means of a gripper. The amount of gripper slippage was assumed to be equal to the difference between the actual joint length and the distance that the hydraulic cylinder traveled. [

]^{a,c,e}

The pullout tests conducted in Windsor used fittings that were welded to the sample. These fittings had threaded ends that fit into threaded receptacles on the tensile tester. It was assumed that there was no gripper slippage in the tests conducted at the Windsor facilities.

Table 4 provides all of the room temperature, ambient pressure pullout data for rough bore samples from Task 1154, using the 'first slip' criteria. The data in Table 4 has been scaled in the same manner as described in Section 5.3 of WCAP-16208-P. In all cases, 'first slip' forces were less than 'maximum load' forces. Four of the samples exceeded the yield strength of the tubing material at the 'first slip' point. Another three samples exceeded the yield strength of the tubing material before the 'first slip' point, but then the load dropped below the yield strength of the tubing when the 'first slip' point had been reached.

Figure 5 presents a plot of the Table 4 rough bore data. Data that had exceeded the yield strength of the tube is plotted separately and was not included in the regression analysis. The lower 95% prediction bound is also included.

Figure 6 presents a plot comparing the first slip data of Table 4 with the relevant maximum load data from Table 5-2 of Reference 1. There is a strong linear relationship between the first slip and maximum load data that passes through the origin (i.e. there is zero first slip load when there is zero maximum load).

2.4.3 Response to RAI (Smooth Bore Samples)

The Palisades steam generator tubesheet holes are of the smooth bore type. A discussion of rough bore holes is provided in Section 2.4.2.

The smooth bore pullout data provided in Table 5-3 of WCAP-16208-P was obtained directly from Tables 4-1 and 4-4 of the Task 1154 report. The objective of the Ringhals pullout tests (listed in Table 4-1 of the Task 1154 report) was to determine the maximum load only. For the Ringhals samples, the load was monitored, but the tube-tubesheet displacement was not a necessary measurement to determine the maximum load and thus was not monitored. Without a monitored tube-tubesheet displacement, the load after 0.25 inch of displacement ("first slip" load) cannot be measured directly. However, for the Task 1154 collar specimen pullout tests (listed in Table 4-4 of the Task 1154 report), the tube-tubesheet displacement was monitored. The strong linear relationship between first slip and maximum load, demonstrated for the rough bore samples in Figure 6, provides a means in which to project the Ringhals "first slip" values. Figure 7 presents a comparison between the measured "first slip" data and the measured "maximum load" data for the Task 1154 smooth bore collar specimens. This linear relationship from the smooth bore collar specimens is used to project the "first slip" loads for the Ringhals specimens, also shown in Figure 7. Table 5 lists the "first slip" data for the smooth bore data.

Figure 8 presents a plot of the Table 5 smooth bore data. None of the smooth bore sample data exceeded the yield strength of the tube. The lower 95% prediction bound is also included.

Table 6 presents the revised WCAP-16208-P Table 6-11 to account for the Figure 8 lower bound and a hot leg temperature of 583°F.

Section 2.3 presented 'Uncorrected Joint Length that Meets Leakage Criteria' lengths of 6.60 inches and 6.61 inches for leakage criteria of 0.1 gpm/SG for 7846 tubes/SG and [ ]^{a,c,e}, respectively. Using the table, this interpolates to 'Joint Length that Meets Leakage Criteria' values of 12.24 inches and 12.25 inches, respectively. Adding NDE axial position uncertainty of [ ]^{a,c,e} to both values yields and inspection length of 12.5 inches for both criteria. Note that this length is measured from the bottom of the expansion transition, not the top of the tubesheet.

Section 7.0 of Reference 2 notes that NODP is 1334 psid, thus 3NODP is 4002 psid and the required pullout load criteria for a [ ]^{a,c,e} Repeating the analyses presented in Table 6-5 of Reference 1 using the "first-slip" quarter-inch incremental

contact loads for the fourth column of values, yields a required engagement length of less than 5 inches to resist the 3NODP pullout load of [ ]^{a,c,e} (see Table 7). Adding NDE positional error yields a 'Burst Based Inspection Length Corrected for Dilation and NDE' of 5.3 inches.

The most limiting specimen shown in Figure 8 has a pullout load of [ ]^{a,c,e} Repeating the analyses presented in Table 7 using the quarter-inch incremental contact loads for the fourth column of values, yields a required engagement length of less than 5.25 inches to resist the 3NODP pullout load of [ ]^{a,c,e} Adding NDE positional error yields a 'Burst Based Inspection Length Corrected for Dilation and NDE Using the Most Limiting Data' of 5.5 inches. The revised Palisades results of Table 6-8 of Reference 1 are provided in Table 9.

Under the most extreme case where there is no as-installed explansion residual contact pressure, a condition which does not exist in the Palisades steam generators, the only contact pressure between the tube and the tubesheet would be a result of differential thermal expansion and the transmittance of internal pressure through the tube wall. This case is also provided in Table 9, which shows that a length of 6.75 inches will resist the 3NODP pullout load, even without explansion residual contact pressure.

The 12.5 inch leak rate based inspection distance bounds the most limiting specimen even when it is evaluated using load at first slip or with no residual contact pressure.

2.5 OPERATING PARAMETERS

Please confirm that your operating parameters will always be bounded by the conditions for which the C distance was determined in WCAP-16208-P, Revision 1 (e.g. temperature, pressure; etc.) . If the conditions will not always be bounded, what controls are in place to ensure an adequate depth of inspection in the tubesheet?*

2.5.1 Response to RAI

All Palisades operating parameters were determined to always be conservatively bounded by the conditions for which the hot-leg C* distances were determined in WCAP-16208-P, Revision 1 (Reference 1), with one exception (the normal operating hot leg temperature). The normal operating hot leg temperature at Palisades is conservatively bounded by 583°F, so the generic C* analysis (that uses 600°F) was modified to consider the Palisades-specific temperature. This modification was presented in Sections 2.3 and 2.4.

There are several conservative number rounding operations employed in the calculation of the C* distance in Sections 2.3 and 2.4. The C* distance of 12.5 inches can be justified down to a hot leg temperature of 552°F, using the same methodology as presented in Sections 2.3 and 2.4, simply by using full digit representation, rather than conservative rounded values, in the calculations.

For accident leakage, WCAP 16208-P uses a limiting accident pressure of 2560 psid. The basis for the limiting condition is provided in Section 4.3 of the WCAP. The accident pressure is

bounding for Palisades and for the value assumed for condition monitoring and operational assessment for the accident induced leakage performance criteria. A change to this condition would require a change to the Palisades licensing basis and would require NRC approval.

2.6 REPORTING

Please discuss your plans to revise your TS to include the reporting requirements listed below:
(a) Number of total indications, location of each indication, orientation of each indication, size of each indication, and whether the indications are initiated from the inside or outside surface.
(b) The cumulative number of indications detected in the tubesheet region as a function of elevation within the tubesheet.
(c) Projected end-of-cycle (EOC) accident-induced leakage from tubesheet indications. This leakage shall be combined with the postulated EOC accident induced leakage from all other sources. If the preliminary estimated total projected EOC accident-induced leakage from all sources exceeds the leakage limit, the NRC staff shall be notified prior to unit restart.

2.6.1 Response to RAI

For the NRC staff recommended reporting requirements (a) and (b) above, NMC has previously submitted equivalent reporting requirements in Reference 10 (NMC Application for Technical Specification Improvement Regarding Steam Generator Tube Integrity).

NMC does not think there is value in the above listed reporting requirement (c), for this particular Technical Specification Change Request for the following reasons:

1. Within the inspected region in the hot leg tubesheet, all detected indications above the C* inspection depth are "plugged upon detection". These indications are not a contributing source in projection of accident induced leakage for the next cycle of operation.

2. Within the uninspected region in the hot leg tubesheets, the projection of accident induced leakage for the next cycle of operation is an essentially unchanging, "worst case" analysis assumption is 0.1 gallons per minute (gpm). This unchanging worst case value is the C* analysis assumption that ALL tubes are assumed to be degraded by 100% throughwall 360 degree circumferential cracks, all located immediately below the inspected length of the tube. Note that all detected indications below the C* inspection depth in the hot leg tubesheet that are left in-service are part of the analysis assumption for the uninspected region.

2.7 CONDITION OF JOINT

Please describe the expected condition of the tube-to-tubesheet crevice, such as the amount of corrosion product and sludge at the top of the tubesheet. Discuss the effects of these conditions on tube-to-tubesheet contact pressure and the potential for leakage.

2.7.1 Response to RAI

The expected condition of the Palisades steam generator crevices are similar to or exceed the extent of corrosion products that may have been present in the C* program test specimens. Thus, the C* program test sample tube-to-tubesheet contact pressure and leakage performance are bounding. This expectation is based on the following:

a. During refueling outages, the top-of-tubesheet is exposed to an oxygen atmosphere for several days during the steam generator secondary side inspection/maintenance activities. This is similar to conditions experienced with the C* test specimens. It is expected that these conditions would add to the probability that corrosion products develop in the tube-to-tubesheet crevice, similar to the C* program test samples.

b. Sludge management at Palisades has been effective; however a small sludge pile region has developed. Application of scale conditioning agents is planned for the 2007 outage to attempt to soften the accumulated sludge prior to lancing. During the 1992, 1993, and 1995 sludge lancing operations, only about 15 lb of sludge was removed from each SG. During the 1996 sludge lancing operations, an upper bundle flush was also performed and the quantity of sludge removed slightly increased from SG A and SG B to 82.5 lbs and 83.5 lbs, respectively. Sludge lancing was not performed for the 1998 outage, but was performed at the 1999 outage as well as upper bundle flush. Only about 6 lbs of sludge was removed from each SG. Sludge lancing and upper bundle flushing was again performed in the 2001 with 8 lbs of sludge was removed from each SG. In the 2003 and 2004 refueling outages sludge lancing equipment design for tri-pitch C-E tubing was used. Average (per SG) removal amounts were 20.5 lbs in the 2003 outage, 14 lbs in the 2004 outage and 14.5 lbs in the 2006 outage. These results indicate a probability that corrosion products could develop in the tube-to-tubesheet crevice as in the C* program test samples.

2.8 ACCIDENT INDUCED LEAKAGE LIMIT

The LCO leakage rate in your technical specifications limits the amount of primary-to-secondary leakage during normal operation (i.e., normal operating leak rate limit). The staff is inferring that your UFSAR accident analysis (e.g., steam line break) assumes that the amount of primary-to-secondary leakage during the accident is identical to your LCO leakage limit. If this is correct, please address the following:

During a steam line break the differential pressure across the tubes is greater than the differential pressure during normal operation. As a result, the primary-to-secondary leakage may be greater during a steam line break than during normal operation. Since you could be operating with leakage as high as your normal operating leakage limit (0.3 gpm), the amount of leakage during a steam line break (or other postulated accidents) could be greater than that assumed in your accident analyses. If so, please discuss what controls are in place to ensure that you do not exceed your accident induced leakage limit simply as a result of normal operating leakage. In addition, discuss your plans for modifying your technical specification normal operating leakage limit to be consistent with your accident induced leakage limit assumed in

your UFSAR accident analyses. Alternatively, discuss your plans for modifying your accident analyses to account for this phenomenon.

2.8.1 Response to RAI

The NMC Reference 10 submittal to NRC provides the Palisades steam generator tube integrity related technical specification license amendment request. LCO 3.4.13, item d., PCS Operational Leakage, states that operational leakage through any one steam generator shall be limited to 150 gallons per day. The accident induced leakage limit assumption based on main steam line break is 0.3 gallons per minute (432 gallons per day). Therefore the LCO leakage limit is less than the accident induced leakage limit.

2.9 LOCATION OF BET RELATIVE TO TTS

If the BET is located above the top of the tubesheet, less than 12.5 inches of expanded tube within the tubesheet (engaged tubing) could be inspected. Has the BET for each tube been located and confirmed to be below the top of the tubesheet? Similarly, if less than 12.5 inches of any tube is expanded into the tubesheet, the proposed specifications as written may exclude part of the tube needing to be inspected. If there are tubes with the BET above the TTS or less than 12.5 inches expanded into the tubesheet, discuss the requirements that will be in place to ensure these tubes are properly inspected.

2.9.1 Response to RAI

The Hot Leg Bottom of Expansion Transition (BET) location in every active tube in the Palisades steam generators has been determined and is recorded in Palisades eddy current data management records. Of the 15,663 tubes that remain in service, none have a BET that is above the top of tubesheet.

With respect to ensuring at least 12.5 inches of expanded tubing exists, NMC reviewed the design and data management records. The Palisades tubesheets are 20.5 inches in thickness. The lowest BET recorded for the Palisades replacement steam generators is less than one inch below the secondary face of the tubesheet. As such, there is greater than 19.5 inches of expanded tubing. Furthermore, all inspection records are reviewed to ensure that the required data below the BET is acquired in order to verify the minimum 12.5 inches length of expanded tube.

The NMC steam generator inspection program also requires that any tubes without tubesheet expansion (NTE) are to be inspected with Plus Point for the entire tubesheet thickness. For Palisades, there are no in-service hot leg tubes that fall into this category.

Table 2: Loads and Forces at First Move, First Slip and Maximum Load

a,b,c

Criteria		Sample 1	Sample 3	Sample 4

Table 3: WCAP-16208-P, Table 4-7: Transformed Leak Rate Data: Revised for Change of Temperature from 600°F to 555°F

a,b,c

Index	Sample	Raw Data		Transformed	
		L Joint Length (inches)	Q Leak Rate (gpm)	$L-L_{avg}$ Joint Length (inches)	$Q-Q_{avg}$ Leak Rate (gpm)

Table 4: Rough Bore 'First Slip' Pullout Test Data from Task 1154 (Room Temperature, Ambient Internal Pressure)

a,b,c

Tube ID	Test Lab	As-Built Engaged Length(in.)	0.25 in. First Slip Load(lbf) (adj for grip slip)	Note

Table 5: Smooth Bore Pullout Test "Maximum Load" and "First Slip" Loads (Room Temperature, Ambient Internal Pressure)

a,b,c

Sample Source	Specimen Number	Joint Length (in)	Maximum Load (lbs)	First Slip (lbs)

Table 6: WCAP-16208-P, Table 6-11: Effect of Tubesheet Deflection for Palisades Steam Generators: Revised for Use of First Slip Loads and 583°F Hot Leg

a,b,c

Depth in Tubesheet (in)	TS Joint Axial Force (lbf)	RCS Pressure and Diff. Thermal Axial Force (lbf)	Initial Axial Force (lbf)	Dilation Axial Force (lbf)	Net Axial Force (lbf)	Net / Initial Ratio	Equiv. No-Dilate Length (in)	Cum. No-Dilate Length (in)

Table 7: WCAP-16208-P, Table 6-5: Effect of Tubesheet Deflection for Palisades Steam Generators: Revised for Use of First Slip Loads and 583°F Hot Leg

a,b,c

Depth into Tubesheet (in.)	Fx Dilation Load (lbf.)	Fz Dilation Load (lbf.)	Fz Contact Load (lbf.)	RCS Pressure and Diff. Thermal Axial Force (lbf.)	Fz net (lbf)	Cumulative Fz net Loads (lbf)

Table 8: WCAP-16208-P, Table 6-5: Tubesheet Deflection Analysis Results, Reduction in Contact Load for Palisades Steam Generator: Revised for Use of 'First Slip' Loads

Depth into Tubesheet (inches)	Fx Dilation Load (lbf)	Fz Dilation Load (lbf)	RCS Pressure and Diff. Thermal Axial Force (lbf)	First Slip Limiting Sample			No Residual Load		
				Fz Contact Load (lbf)	Fz net (lbf)	Cumulative Fz net Loads (lbf)	Fz Contact Load (lbf)	Fz net (lbf)	Cumulative Fz net Loads (lbf)

a,b,c

Table 9: WCAP-16208-P, Table 6-8: Burst Based Inspection Length Including Tubesheet Deflection and NDE Corrections, Revised for Palisades Only

Plant	Burst Based Inspection Length Corrected for Dilation (inches)	Burst Based Inspection Length Corrected for Dilation and NDE (inches)	Burst Based Inspection Length Corrected for Dilation and NDE Using the Most Limiting Data (inches)
Palisades	4.25⇒ 5.00	4.6⇒ 5.3	5.3⇒ 5.5

a,b,c

Figure 1: Sample 1 Blowout During Room Temperature Leak Test (1-Inch Joint Length)

a,b,c

Figure 2: Sample 3 Pullout Screening Test (2-Inch Joint Length)

a,b,c

Figure 3: Sample 4 Pullout Screening Test (3-Inch Joint Length)

a,b,c

Figure 4: Revised WCAP-16208-P, Figure 4-4: Plot of Leak Rate vs. Joint Length at 583°F, ΔP=SLB

a,b,c

Figure 5: First Slip Pullout Force for 48 mil Wall Rough Bore Task 1154 Tests

a,b,c

Figure 6: Linear Relationship Between First Slip and Maximum Load for Rough Bore Samples

a,b,c

Figure 7: Linear Relationship Between First Slip and Maximum Load for Smooth Bore Samples

a,b,c

Figure 8: First Slip Pullout Force for 42 mil Wall Smooth Bore Tests

3.0 REFERENCES

1. Westinghouse Report, WCAP-16208-P, Revision 1, "NDE Inspection Length for CE Steam Generator Tubesheet Region Explosive Expansions," May 2005.

2. Westinghouse Report SG-SGDA-06-5, Revision 1, "Palisades Nuclear Plant Steam Generator Degradation Assessment REFOUT 18 Refueling Outage," April 2006.

3. "Nuclear Services Policies & Procedures," Westinghouse Quality Management System - Level 2 Policies and Procedures, Effective 12/15/05.

4. Westinghouse Report WCAP-15720, Revision 0, "NDE Inspection Strategy for Tubesheet Regions in CE Designed Units," CEOG Task 1154, July 2001.

5. Westinghouse Report LTR-CDME-05-180, Revision 2, "Steam Generator Tube Alternate Repair Criteria for the Portion of the Tube Within the Tubesheet at Catawba 2," December 2005.

6. W. C. Young and R. G. Budynas, "Roark's Formulas for Stress and Strain," Seventh Edition, Mc-Graw-Hill, New York, New York, 2002.

7. Westinghouse Report LTR-CDME-05-14, Revision 1, "Responses to NRC Requests for Additional Information on WCAP-16208-P, Rev. 0, 'NDE Inspection Length for CE Steam Generator Tubesheet Region Explosive Expansions,' (Proprietary/Non-Proprietary)," February 14, 2005.

8. "Braidwood Station, Units 1 and 2 – Issuance of Exigent Amendments RE: Revision of Scope of Steam Generator Inspections for Unit 2 Refueling Outage 11 (TAC NOS. MC6686 and MC6687)," NRC Letter from G.F. Dick to C.M. Crane (Excelon), April 25, 2005.

9. Palisades Document EM-09-05, Attachment 8, Revision 11, "Steam Generator Tube Plugging Notification," April 24, 2006.

10. NMC letter L-HU-06-001 dated February 16, 2006; Edward J. Weinkam (NMC) to U.S. Nuclear Regulatory Commission; Application for Technical Specification Improvement Regarding Steam Generator Tube Integrity.

APPENDIX A – ST. LUCIE UNIT 2 RAIS

Florida Power and Light (FPL) was presented with a set of RAIs following their request to implement C*, as described in WCAP-16208 (Revision 0), for the St. Lucie Unit 2 station. The following set of RAIs (formally issued on November 23, 2005) actually represents the second set of RAIs for this document. The first set of RAIs (formally issued on December 16, 2004) was addressed in Westinghouse document LTR-CDME-05-14 (Revision 1). The responses in LTR-CDME-05-14 (Revision 1) were incorporated into WCAP-16208 (Revision 0) to create WCAP-16208 (Revision 1). FPL did not submit WCAP-16208 (Revision 1) to the NRC for review. The responses to all of the second set of RAIs (those listed below) were provided in Westinghouse document LTR-CDME-05-257 (Revision 1).

Those RAIs deemed relevant to Palisades are in **bold font**.

1. **In the March 31, 2005 response to request for additional information (RAI) number 12, all available data were used to support the analytical adjustment to account for the axial load resistance provided by the differential thermal expansion effects. However, it is not clear whether all of the available data was used to support the analytical adjustment to account for the axial load resistance provided by internal pressure. For example, specimens 8 and 12 from the Task 1154 program were run at room temperature with internal pressure; however, an analysis of this data (similar to what was done for the elevated temperature data point) was not provided. Please evaluate all data in which internal pressure (above ambient pressure) was applied to support the basis for the analytical adjustments to account for the internal pressure. With respect to the analysis of the pressure effects provided in your response, please provide additional details on how the axial force resistance due to the internal pressure of 1435 psi was calculated and discuss how the effect of the residual contact pressure was taken into account in your analysis. (The actual pullout force was nearly the same as the pullout resistance expected analytically from the internal pressure effects. As a result, if the residual contact pressure was not included in this assessment, it would appear that the analytical adjustments for internal pressure are too high).**

2. The NRC is currently reviewing an amendment to permit the installation of sleeves at St. Lucie 2. In some cases, the sleeve joint may be established greater than 10.1 inches below the top of the tubesheet or the bottom of the expansion transition, whichever is lower. As such, Technical Specification 4.4.5.4.a.8 would no longer require the sleeve or tube to be inspected in this region. However, this is in potential conflict with a proposed requirement to inspect both the tube and sleeve over their full length. That is, it could lead to the incorrect interpretation that only the portion of the sleeve above 10.1 inches from the top of the tubesheet was required to be inspected. Similarly, there is a potential conflict of the tube plugging (or repair) limit in Technical Specification 4.4.5.4.a.6 since the plugging limit is not applicable below 10.1 inches from the top of the tubesheet despite the fact that the expectation is that any degradation in the pressure boundary portion of the sleeve/tube assembly below 10.1 inches from the top of the tubesheet is plugged on detection. Please correct these apparent conflicts/discrepancies in your proposed Technical Specifications.

3. **In the March 31, 2005 responses to RAI 16 and 22, you discussed various data that was not included in Appendix B; however, some data in Appendix B was not included in Table 4-1 (which is used in determining the leak rate as a function of joint length). Please discuss the basis for not including all of the Appendix B data in Table 4-1. For example, was data not included in Appendix B when it was well outside the targeted temperatures or pressures? Furthermore, was data from Appendix B not included in Table 4-1 when steady state was never reached although the temperatures and pressures were within the desired range?**

4. In Attachment 1 to your November 8, 2004 submittal, it was indicated that (as part of another amendment request) the Limiting Condition for Operation (LCO) leakage rate was being reduced from 0.5 to 0.15 gallons per minute (gpm) per steam generator. You further state that this modification will reduce the margin between the assumed primary to secondary leakage rate of WCAP-16208-P (0.1 gpm) and the reduced LCO leakage rate utilized in the UFSAR accident analyses (0.15 gpm). The LCO leakage rate in your technical specifications limits the amount of primary-to-secondary leakage during normal operation (i.e., normal operating leak rate limit). Based on your statements, the staff is inferring that your UFSAR accident analyses (e.g., steam line break) assumes that the amount of primary-to-secondary leakage during the accident is identical to your LCO leakage limit (i.e., 0.15 gpm). If this is correct, please address the following:

   (a) **During a steam line break the differential pressure across the tubes is greater than the differential pressure during normal operation. As a result, the primary-to-secondary leakage may be greater during a steam line break than during normal operation. Since you could be operating with leakage as high as your normal operating leakage limit (0.15 gpm), the amount of leakage during a steam line break (or other postulated accidents) could be greater than that assumed in your accident analyses. If so, please discuss what controls are in place to ensure that you do not exceed your accident induced leakage limit simply as a result of normal operating leakage. In addition, discuss your plans for modifying your technical specification normal operating leakage limit to be consistent with your accident induced leakage limit assumed in your UFSAR accident analyses. Alternatively, discuss your plans for modifying your accident analyses to account for this phenomenon.**

   (b) As part of the C* amendment, you will be assuming that there is 0.1 gpm accident induced primary-to-secondary leakage as a result of flaws within the tubesheet region. In addition, you may have accident induced leakage from other sources such as sleeves or other tube degradation. This latter amount of leakage will need to be limited to 0.05 gpm to ensure you do not exceed your accident induced leakage limits in your UFSAR. Since the source of any normal operating leakage is not known (i.e., it could be from sources other than the tubesheet or sleeves or other defects assumed to leak in your operational assessment) and it could be as high as 0.15 gpm (or even higher during some postulated accidents for the reason discussed above), it is not clear that you will be able to stay within your accident induced leakage limits unless you change your technical specification normal operating leakage limit or your UFSAR accident analysis leakage limit. Please discuss whether you will be able to stay within your accident induced

leakage limit given your normal operating leakage limit and your proposed C* inspection requirements.

5. **Please confirm that the hot-leg temperature at St. Lucie Unit 2 is greater than that assumed in the tubesheet deflection analysis (600-degrees Fahrenheit) and in determining the increase in contact pressure as a result of differential thermal expansion between the tube and the tubesheet.**

6. **Please clarify whether the load at first slip was reported and plotted in Figures 5-1 through 5-3 or whether the maximum load was plotted. If the load at first slip was not used in all cases, please discuss the effect on the required inspection distance if the load at first slip was used. In addition, if the load at first slip was not used in your March 31, 2005 response to RAI 10, please confirm that the 10.1-inch proposed inspection distance is still bounded when the most limiting specimen (using load at first slip) is evaluated.**

APPENDIX B – WATERFORD RAIS

Entergy was presented with a set of RAIs following their request to implement C*, as described in WCAP-16208 (Revision 1), for the Waterford station. The following set of RAIs (formally issued in October 2005) were addressed by both Entergy and Westinghouse. Westinghouse provided responses to RAIs 5, 7 and 8 in document LTR-CDME-06-16 (Revision 0).

Those RAIs deemed relevant to Palisades are in **bold font**.

1. Throughout the submittal, WCAP-16391-P is referenced. To the staff's knowledge, this was never formally submitted to the NRC. Please confirm that the information in WCAP-16391-P is fully consistent with WCAP-16208-P, Revision 1, or with WCAP-16208-P, Revision 0, as supplemented by the FPL letter dated March 31, 2005. Alternatively, please provide a copy of WCAP-16391-P for the staff's review.

   In the following questions, the staff assumes your proposed TS changes, which are based on WCAP-16208-P, Revision 0, and WCAP-16391-P, are fully consistent with WCAP-16208-P, Revision 1.

2. **Please confirm that your operating parameters will always be bounded by the conditions for which the C* distance was determined in WCAP-16208-P, Revision 1 (e.g. temperature, pressure; etc.). If the conditions will not always be bounded, what controls are in place to ensure an adequate depth of inspection in the tubesheet?**

3. **Please discuss the expected condition of the tube-to-tubesheet joint. For example, discuss the amount of corrosion expected at the top of the tubesheet (similar to what may have been present in some of the test specimens) and whether there is sludge buildup at the top of the tubesheet.**

4. The letter dated March 15, 2005, compares the Nuclear Energy Institute (NEI) report 97-06 primary-to-secondary accident-induced leakage limit to the 720 gallon per day (gpd) operational leakage limit in TS 3.4.5.2. Since you are comparing the NEI accident-induced leakage limit to your TS operational leakage limit, the staff assumes that, at the time this application was submitted, your operational leakage limit was the same as your accident-induced leakage limit. Please confirm the staff's understanding.

   The letter dated March 15, 2005, discusses a change in the assumed accident-induced leakage rate from 720 gpd to 540 gpd. The staff understands this to mean that, although the accident-induced leakage rate in the licensing basis was720 gpd at the time the C* amendment was submitted, the accident analyses was in the process of being revised in support of your extended power uprate and alternative source term amendments. This revised analysis would require that you limit the amount of accident-induced leakage to 540 gpd. Please confirm the staff's understanding.

   The staff notes that your current TS operational leakage limit is 75 gpd. Assuming 540 gpd (0.375 gallons per minute (gpm)) is your current accident-induced leakage limit, it is the staff's understanding that no more than 0.275 gpm could come from sources other

than implementation of C* (since implementation of C* assumes that accident-induced leakage is 0.1 gpm). Other sources could include sleeves, plugs, and other flaws in the SG. Please confirm the staff's understanding.

Assuming (1) you were to operate at your TS operational leakage limit of 75 gpd (0.05 gpm), (2) that none of the operational leakage was a result of implementation of C*, and (3) that there was no accident-induced leakage expected from other sources, it is the staff's understanding that you would continue to have margin to your accident-induced leakage limit even after accounting for the increase in the amount of operational leakage, as a result of the higher differential pressures associated with various postulated accident conditions. Please confirm the staff's understanding.

5. **Please clarify whether the load at first slip was reported and plotted in Figures 5-1 through 5-3 of WCAP-16208-P, Revision 1, or whether the maximum load was plotted. If the load at first slip was not used in all cases, please discuss the effect on the required inspection distance if the load at first slip was used. In addition, if the load at first slip was not used in Table 6-8 of WCAP-16208-P, Revision 1 ("Burst Based Inspection Length"), please provide Table 6-8 values to confirm that the 10.4 inch proposed inspection distance is still bounded when the most limiting specimen is evaluated using load at first slip.**

6. **Please discuss your plans to revise your TS to include the reporting requirements listed below.**

   (a) **Number of total indications, location of each indication, orientation of each indication, severity of each indication, and whether the indications initiated from the inside or outside surface.**

   (b) **The cumulative number of indications detected in the tubesheet region as a function of elevation within the tubesheet.**

   (c) **Projected end-of-cycle (EOC) accident-induced leakage from tubesheet indications. This leakage shall be combined with the postulated EOC accident-induced leakage from all other sources. If the preliminary estimated total projected EOC accident-induced leakage from all sources exceeds the leakage limit, the NRC staff shall be notified prior to unit restart.**

7. **In WCAP-16208-P, Revision 1, it is not clear whether all of the available data were used to support the analytical adjustment to account for the axial load resistance provided by internal pressure. For example, specimens 8 and 12 from the Task 1154 program were run at room temperature with internal pressure; however, an analysis of this data (similar to what was done for the elevated temperature data point) was not provided. Please evaluate all data in which internal pressure (above ambient pressure) was applied to support the basis for the analytical adjustments to account for the internal pressure. With respect to the analysis of the pressure effects, please provide additional details on how the axial force resistance due to the internal pressure of 1435 pounds per square inch was calculated and discuss how the effect of the residual contact pressure**

was taken into account in your analysis. (The actual pullout force was nearly the same as the pullout resistance expected analytically from the internal pressure effects. As a result, if the residual contact pressure was not included in this assessment, it would appear that the analytical adjustments for internal pressure are too high.)

8. ***It* is the NRC staff's understanding that not all data was included in Appendix B of WCAP-16208-P, Revision 1 (i.e., some data was not included since it was well outside the targeted temperatures and pressures). It is also the staff's understanding that some data in Appendix B was not included in Table 4-1 of WCAP-16208-P, Revision 1 (which was used in determining the leak rate as a function of joint length). Please confirm the staff's understanding and discuss the basis for not including all of the Appendix B data in Table 4-1. For example, was data from Appendix B not included in Table 4-1 when steady state was never reached although the temperatures and pressures were within the desired range?**

9. The Waterford 3 TS (4.4.4.4.b) currently allow installation of leak-tight sleeves according to CENS Report CEN-605-P. Since sleeves could extend into the tubesheet below the C* distance, the proposed TS would not require an inspection of this portion of the sleeve ding the lower sleeve joint). Sleeves were not addressed in the testing and analysis to justify excluding part of the tube from inspection (WCAP-16208-P, Revision 1). What plans do you have to ensure the lower ends of sleeves (i.e., those within the tubesheet below the C* distance) will be inspected?

APPENDIX C – SONGS UNIT 2 AND UNIT 3 RAIS

Southern California Edison (SCE) was presented with a set of RAIs following their request to implement C*, as described in WCAP-16208 (Revision 1), for the SONGS Unit 2 and 3 stations. Responses to all of the following set of RAIs (formally issued on March 23, 2006) were provided in document LTR-CDME-06-27 (Revision 0).

Those RAIs deemed relevant to Palisades are in **bold font**.

1. **Please confirm that your operating parameters (e.g., temperature, pressure, etc.) will always be conservatively bounded by the conditions for which the hot-leg and cold-leg C* distances were determined in WCAP-16208-P, Revision 1 (including Supplement 1). If the conditions will not always be bounded, what controls are in place to ensure an adequate depth of inspection in the tubesheet?**

   For example, please confirm that the hot-leg temperature at SONGS, Units 2 and 3, is greater than that assumed (600 degrees Fahrenheit) in the tubesheet deflection analyses and in determining the increase in contact pressure as a result of differential thermal expansion between the tube and the tubesheet. If the hot-leg temperature in either unit is lower than 600 degrees, please discuss the effect on the C* distance.

2. The SONGS, Units 2 and 3, currently allow the installation of leak-tight sleeves according to Asea Brown Boveri/Combustion Engineering, Inc. (ABB/CE) Topical Report CEN-630-P, Revision 2. The proposed revision of TS 5.5.2.1 1 .h excludes from inspection the portions of the tube below the C* distance in the tubesheet. Since sleeves could extend into the tubesheet below the C* distance, the proposed TS would no longer require the sleeve or tube to be inspected in this region. Sleeves were not addressed in the testing and analysis used to justify excluding part of the tube from inspection (WCAP-16208-P, Revision 1, including Supplement 1). What plans do you have to ensure the lower ends of sleeves (i.e., those within the tubesheet below the C* distance) will be inspected, including the pressure-retaining portion of the parent tube in contact with the sleeve, the sleeve-to-tube weld, and the pressure retaining portion of the sleeve? Please discuss your plans to modify your TS to address this issue. Consider, for example, the following wording:

   For a tube with no portion of a sleeve extending below (a) 10.4 inches from the bottom of the hot-leg expansion transition or the top of the tubesheet (whichever is lower) or (b) 10.7 inches from the bottom of the cold-leg expansion transition or the top of the tubesheet (whichever is lower), a tube inspection means an inspection of the steam generator tube from 10.4 inches below the bottom of the hot-leg expansion transition or top of the tubesheet (whichever is lower) completely around the U-bend to 10.7-inches below the bottom of the cold-leg expansion transition or top of the tubesheet (whichever is lower).
   For all other tubes, a tube inspection means an inspection from the bottom of the sleeve completely around the U-bend to either (a) 10.4 inches below the bottom of the hot-leg expansion transition or top of the tubesheet (whichever is lower) or (b) 10.7 inches below the bottom of the cold-leg expansion transition or top of the tubesheet (whichever is lower), as appropriate.

3. **It is the NRC staff's understanding that load at first slip, rather than maximum load, was reported and plotted in Figure 5-1 of WCAP-16208-P, Revision 1. If the load at first slip was not used in all cases, please discuss the effect on the required inspection distance if the load at first slip was used. In addition, if the load at first slip was not used in Table 6-8 of WCAP-16208-P, Revision 1 ("Burst Based Inspection Length"), please provide Table 6-8 values to confirm the 10.4 inch (hot leg) and 10.7 inch (cold leg) proposed inspection distances are bounded when the most limiting specimen is evaluated using load at first slip. In addition, please discuss the effect on the leakage based inspection distance (Tables 6-9 and 6-1 5). If the leakage-based inspection length increased, discuss your plans to modify your TS accordingly.**

4. **Please discuss your plans to revise your TS to include the reporting requirements listed below:**

   (a) **Number of total indications, location of each indication, orientation of each indication, size of each indication, and whether the indications are initiated from the inside or outside surface.**

   (b) **The cumulative number of indications detected in the tubesheet region as a function of elevation within the tubesheet.**

   (c) **Projected end-of-cycle (EOC) accident-induced leakage from tubesheet indications. This leakage shall be combined with the postulated EOC accident induced leakage from all other sources. If the preliminary estimated total projected EOC accident-induced leakage from all sources exceeds the leakage limit, the NRC staff shall be notified prior to unit restart.**

5. The proposed revision of TS 5.5.2.11.f.l.f provides exceptions, based on the C* distance, to applying the tube Repair Limit within the hot-leg tubesheet for tubes that have not been repaired and tubes that have been repaired (sleeved). These exceptions are not included for the cold-leg tubesheet. It is, therefore, the NRC staff's understanding that any tube degradation detected below the bottom of the cold-leg expansion transition or cold-leg top-of-tubesheet, whichever is higher, shall be removed from service or repaired on detection. Please confirm or correct the staff's understanding. Please provide a justification for the difference in plugging/repair requirements for degradation in the hot-leg and cold-leg tubesheet in your proposed TS, or discuss your plans for modifying the proposed TS for consistency between the hot and cold-leg tubesheet repair requirements.

6. According to Enclosure 3 to your November 3, 2005, submittal, the primary-to-secondary accident-induced leakage limit for SONGS, Units 2 and 3, is 0.5 gpm per steam generator (SG). For Unit 3, this limit is the same as the limiting condition for operation in your TS LC0 3.4.1 3.d since no sleeves are installed. For Unit 2, LCO 3.4.1 3.d specifies a maximum operational leakage rate of 0.1 gpm per SG since sleeves are installed. **Since the operational leakage limit is equal to the accident induced leakage limit, please address the following for Unit 3:**

(a) **During a steamline break the differential pressure across the tubes is greater than the differential pressure during normal operation. As a result, the primary-to-secondary leakage may be greater during a steamline break than during normal operation. Since you could be operating with leakage as high as your normal operating leakage limit (0.5 gpm), the amount of leakage during a steamline break (or other postulated accidents) could be greater than that assumed in your accident analyses. If so, please discuss what controls are in place to ensure that you do not exceed your accident-induced leakage limit simply as a result of normal operating leakage.**

(b) As part of the C* amendment, you will be assuming there is 0.2 gpm accident induced primary-to-secondary leakage as a result of flaws within the tubesheet region. In addition, you may have accident-induced leakage from other sources such as sleeves or other degradation. This latter amount of leakage will need to be limited to 0.3 gpm to ensure you do not exceed your accident-induced leakage limits in your updated final safety analysis report (UFSAR). Since the source of any normal operating leakage is not known (i.e., it could be from sources other than the tubesheet or sleeves or other defects assumed to leak in your operational assessment) and it could be as high as your TS limit of 0.5 gpm (or even higher during some postulated accidents due to the increased differential pressure), it is not clear that you will be able to stay within your accident-induced leakage limits unless you change your TS normal operating leakage or your UFSAR accident analysis leakage limit. Please discuss whether you will be able to stay within your accident-induced leakage limits and your proposed C* inspection requirements.

7. **Do all of the tubes in your SGs have adequate expansion in the tubesheet to meet the leakage and pullout criteria? That is, are all of the tubes nominally expanded for the full depth of the tubesheet? If any tubes are not nominally expanded for the full depth of the tubesheet, have you verified that the expansion length is adequate to ensure structural and leakage integrity consistent with the C* approach? For those tubes which may not have adequate expansion lengths, discuss how you will ensure structural and leakage integrity for these tubes (e.g., inspection of the tube-to-tubesheet weld). Also, discuss whether any changes are needed to your TSs to address this issue.**

8. **Please describe the expected condition of the tube-to-tubesheet crevice, such as the amount of corrosion product and sludge at the top of the tubesheet. Discuss the effects of these conditions on tube-to-tubesheet contact pressure and the potential for leakage.**

APPENDIX D – PALO VERDE UNIT 3 RAIS

Arizona Public Service (APS) was presented with a set of informal RAIs following their request to implement C*, as described in WCAP-16208 (Revision 1), for the Palo Verde Unit 3 station. The following set of RAIs (informally provided to APS by e-mail on October 31, 2005) were addressed by both APS and Westinghouse. Westinghouse provided responses to RAIs 4, 5, 7 and 8 in document LTR-CDME-06-13 (Revision 0).

Those RAIs deemed relevant to Palisades are in **bold font**.

1. **Technical Specification 5.5.9 references the excluded portion of the tube (the C* distance) from the bottom of the expansion transition (BET). This is also noted in the new Basis B 3.4.18. If the BET is located above the top of the tubesheet, less than 12 inches of expanded tube within the tubesheet (engaged tubing) could be inspected. Has the BET for each tube been located and confirmed to be below the top of the tubesheet? Similarly, if less than 12" of any tube is expanded into the tubesheet, the proposed specifications as written may exclude part of the tube needing to be inspected. If there are tubes with the BET above the TTS or less than 12" expanded into the tubesheet, discuss the requirements that will be in place to ensure these tubes are properly inspected.**

2. **Please confirm that your operating parameters will always be conservatively bounded by the conditions for which the C* distance was determined in WCAP-16208-P, Rev. 1 (e.g. temperature, pressure, etc.). If conditions are not always bounded, what controls are in place to ensure an adequate depth of inspection in the tubesheet?**

3. **Please discuss the expected condition of the tube-to-tubesheet joint. For example, discuss the amount of corrosion expected at the top of the tubesheet (similar to what may have been present in some of the test specimens) and whether there is sludge buildup at the top of the tubesheet.**

4. Technical Specification 5.5.9.d and Basis B 3.4.18 propose applying the C* criteria to both the hot-leg and cold-leg tubesheets. The contact loads calculated in WCAP-16208-P, Rev. 1 for tubesheet dilation effects were based on a temperature of 600°F. Since leakage estimates assume only the hot leg is affected, and the cold leg temperature is lower than 600° F, the model does not appear to account for conditions on the cold-leg. In addition, the 0.1 gpm referenced in WCAP-16208-Rev. 1 is based only on leakage from the hot leg. If both ends of the tube are to have a length of tubing excluded from inspection, as they are in proposed Technical Specification 5.5.9.d, both ends must be addressed by the leakage assessment. Alternatively, the proposed technical specifications and bases could be revised to require inspection on the cold leg (i.e., C* would not be applied on the cold leg.)

5. **Please clarify whether the load at first slip was reported and plotted in Figures 5-1 through 5-3 of WCAP-16208-P, Revision 1 or whether the maximum load was plotted. If the load at first slip was not used in all cases, please discuss the effect on the required inspection distance if the load at first slip was used. In addition, if the load at first slip was not used in Table 6-8 of WCAP-16208-P, Rev. 1 ("Burst Based Inspection**

Length"), please provide Table 6-8 values to confirm that the 12 inch proposed inspection distance is still bounded when the most limiting specimen is evaluated using load at first slip.

6. **Given the inherent assumption that neither structurally significant nor leakage significant flaws will develop within the C* distance, and assumptions on degradation below the C* distance, please discuss your plans to provide the information listed below following each inspection. Similarly, please discuss your plans to modify the technical specifications to include reporting this information.**

   (a) Number of total indications, location of each indication, orientation of each indication, size of each indication, and whether the indications initiated from the inside or outside surface.

   (b) The cumulative number of indications detected in the tubesheet region as a function of elevation within the tubesheet.

   (c) Projected end-of-cycle accident-induced leakage from tubesheet indications. This leakage shall be combined with the postulated end-of-cycle accident-induced leakage from all other sources.

7. **In WCAP-16208-P, Revision 1, it is not clear whether all of the available data were used to support the analytical adjustment to account for the axial load resistance provided by internal pressure. For example, specimens 8 and 12 from the Task 1154 program were run at room temperature with internal pressure; however, an analysis of this data (similar to what was done for the elevated temperature data point) was not provided. Please evaluate all data in which internal pressure (above ambient pressure) was applied to support the basis for the analytical adjustments to account for the internal pressure. With respect to the analysis of the pressure effects, please provide additional details on how the axial force resistance due to the internal pressure of 1435 psi was calculated and discuss how the effect of the residual contact pressure was taken into account in your analysis (The actual pullout force was nearly the same as the pullout resistance expected analytically from the internal pressure effects. As a result, if the residual contact pressure was not included in this assessment, it would appear that the analytical adjustments for internal pressure are too high.)**

8. **It is the NRC Staff's understanding that not all data was included in Appendix B of WCAP-16208-P, Rev. 1 (i.e., some data was not included since it was well outside the targeted temperatures and pressures.) It is also the staff's understanding that some data in Appendix B were not included in Table 4-1 of WCAP-16208-P, Rev. 1 (which was used in determining the leak rate as a function of joint length). Please confirm the staff's understanding and discuss the basis for not including all of the Appendix B data in Table 4-1. For example, was data from Appendix B not included in Table 4-1 when steady state was never reached although the temperatures and pressures were within the desired range?**

9. Section 5.2 (pages 6-7) of Enclosure 1 to the amendment application states in two places that leakage below the inspection length in the tubesheet can be neglected. Please confirm that your assessments of tube integrity (condition monitoring and operational assessment) will include 0.1 gpm leakage from indications in the hot leg below the C* distance, consistent with WCAP-16208-P, Rev. 1.

10. The second paragraph of Section 5.2 (page 6) of Enclosure 1 to the amendment application contains the following statement: "The proposed inspection length requirement 'from the tube-to-tubesheet weld to 12 inches below the bottom of the expansion transition' bounds the WCAP-16208-P recommended inspection lengths for both Unit 1 and Unit 3." Please confirm that you intended to say the proposal to <u>not inspect</u> "from the tube-to-tubesheet weld to 12 inches below the bottom of the expansion transition" is consistent with the inspection lengths in WCAP-16208-P, Rev. 1 for both Unit 1 and Unit 3.