ENCLOSURE 2D

NON-PROPRIETARY, REDACTED WESTINGHOUSE
RESPONSE TO NRC REQUEST FOR ADDITIONAL INFORMATION REGARDING
TECHNICAL SPECIFICATION IMPROVEMENT AND TUBESHEET INSPECTION
DEPTH FOR STEAM GENERATOR TUBES

LTR-CDME-06-13-NP, Revision 0

# Responses to NRC Requests for Additional Information on WCAP-16208-P, Rev. 1, "NDE Inspection Length for CE Steam Generator Tubesheet Region Explosive Expansions"

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# DEFINITIONS

APS – Arizona Public Service.

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 steam generator), Palo Verde Unit 3 and the Plant CG replacement steam generators

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.

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.

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 Palo Verde Unit 3.

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 Palo Verde Unit 3.

TTS – Top of the tubesheet.

# 1.0 INTRODUCTION

## 1.1 BACKGROUND

The Westinghouse Owner's 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, Reference 1. This inspection length is commonly referred to as C* ("C-Star"). Reference 1 was submitted by APS to the NRC as part of their request for a license amendment.

The NRC has reviewed the Reference 1 document. In October 2005, the NRC issued a list of RAIs (Reference 2). This document provides responses to RAIs 4, 5, 7 and 8. The RAIs have not been formally issued at the time that these responses were provided.

## 1.2 SUMMARY

The responses presented in this document:

- Clarify how the data supports the analytical adjustment to account for the axial load resistance provided by the differential thermal expansion effects.
- Clarify the use of leak rate data.
- Provide reasonable assurance that postulated accident induced leakage will remain within the limits of the accident analyses.
- Determine a new inspection depth to support the minimum detectable leak rate of [ ][a,c,e]. This revised inspection depth includes the actual rather than the nominal hot leg temperature and uses the "first slip" rather than the "maximum load" pullout data.
- Considers the cold leg as part of the overall leakage criteria

The responses to these RAIs result in a change in the recommended inspection depth from 11.6 inches to 12.6 inches below the bottom of the expansion transition for the Palo Verde Unit 3 original steam generators.

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 Palo Verde 3 Only)

| Plant | Leak Rate Based Inspection Length Adjusted for TS Dilation (inches) | Leak Rate Based Inspection Length Adjusted for TS Dilation and NDE (inches) |
|---|---|---|
| Palo Verde Unit 3 | 11.3 ⇒ 12.35 | 11.6 ⇒ 12.6 |

Table 6-15 from WCAP-16208-P: Inspection Length Based on Leakage (Amended for Palo Verde 3 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.) |
|---|---|---|---|---|
| Palo Verde Unit 3 | 4.3 | 6.57 | 11.3 ⇒ 12.35 | 11.6 ⇒ 12.6 |

Executive Summary Table from WCAP-16208-P (Amended for Palo Verde 3 Only)

| Plant | Leak Rate Based Inspection Length Corrected for Dilation and NDE (in.) |
|---|---|
| Palo Verde Unit 3 | 11.6 ⇒ 12.6 |

## 1.3 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 REQUESTS FOR ADDITIONAL INFORMATION

## 2.1 RAI #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.)*

### 2.1.1 Response to RAI #4

A fundamental objective of WCAP-16208-P was to establish a leakage based inspection depth to ensure that the total predicted leakage from the tubesheet at Palo Verde Unit 3 was no more than 0.1 gpm/SG assuming 10,000 tubes in service. On a per tube basis, this translates to a leak rate of $1.00\times10^{-5}$ gpm/tube. Thus, WCAP-16208-P established a leak rate criterion per steam generator as well as a leak rate criterion per tube.

The leak rate results provided in WCAP-16208-P are a range of leak rates as a function of joint length as determined by tube to tubesheet mockup testing. The test setup was established to provide a conservative minimum detectable leak rate of [ ]a,c,e If it is assumed that [ ]a,c,e is attributable to each of the 22,000 tube-tubesheet joints in each Palo Verde Unit 3 steam generator (a hot leg and a cold leg joint for each of the 11,000 tubes) then the leak rate criteria of 0.1 gpm/SG will be maintained.

Based on the information presented in Reference 4, a cold leg temperature of 555°F is assumed. The effect of the lower temperature on leak rate can be demonstrated. Section 4.6 of Reference 1 provides a correction for temperature [ ]a,c,e

[

]$^{a,c,e}$

Table 2-1 and Figure 2-1 present revisions to Table 4-7 and Figure 4-4 of WCAP-16208-P, respectively, to account for the change in temperature from 600°F to 555°F. The change in Figure 2-1 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 WCAP-16208-P (for 10000 tubes/SG at the assumed leak criteria of 0.1 gpm/SG), changes from 6.57 inches to 6.67 inches when applied to the cold leg.

Using the conservative minimum detectable leak rate of [ ]$^{a,c,e}$, the 'Uncorrected Joint Length that Meets Leakage Criteria' is 6.58 inches at 600°F and is 6.68 inches at 555°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,

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

where: $\alpha_t$, $\alpha_c$ = thermal expansion coefficient for the tube and tubesheet respectively,
$\Delta T$ = 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 2.3.2.

Using a temperature of 555°F instead of 600°F, reduces the 'RCS Pressure and Diff. Thermal Axial Force' term used in Table 6-7 and 6-13 of Reference 1 by [
]$^{a,c,e}$

Section 2.2 (RAI #5) 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. For the cold leg, Table 2-5 presents a cold leg revision to Table 6-13 of WCAP-16208-P. The cold leg inspection depth to meet the minimum detectable leak rate of [ ]$^{a,c,e}$ is 12.35 inches. After including consideration of NDE error, the cold leg inspection depth is 12.6 inches.

## 2.2 RAI #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.*

### 2.2.1 Background for Response to RAI #5

The pullout load data that was used in WCAP-16208-P (Reference 1) was taken from Reference 5 (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 6 uses a definition that [
]$^{a,c,e}$ This criterion eliminates the bias that was associated with the 'first move' criteria.

Section 2.1.1 (Response to RAI #4) provided a discussion of the 'Uncorrected Joint Length that Meets Leakage Criteria' for both the hot leg and the cold leg of each tube, as well as the reduction in the 'RCS Pressure and Diff. Thermal Axial Force' term for the cold leg.

### 2.2.2 Rough Bore Samples

The Palo Verde Unit 3 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 2-2 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 2-2 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 2-2 presents a plot of the Table 2-2 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 2-3 presents a plot comparing the first slip data of Table 2-2 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).

### 2.2.3 Response to RAI #5 (Smooth Bore Samples)

The Palo Verde Unit 3 steam generator tubesheet holes are of the smooth bore type. A discussion of rough bore holes is provided in Section 2.2.2.

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 2-3, provides a means in which to project the Ringhals "first slip" values. Figure 2-4 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 2-4. Table 2-3 lists the "first slip" data for the smooth bore data.

Figure 2-5 presents a plot of the Table 2-3 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 2-4 presents the revised WCAP-16208-P Table 6-13 to account for the Figure 2-5 lower bound. Table 2-5 presents a table that is similar to Table 2-4 except that the 'RCS Pressure and Diff. Thermal Axial Force' term has been reduced by [ ]a,c,e to make it applicable to the cold leg (as was discussed in Section 2.1 for RAI #4).

The 'Uncorrected Joint Length that Meets Leakage Criteria' values of 6.58 inches for the hot leg and 6.68 inches for the cold leg (determined in Section 2.1.1 using the conservative minimum detectable leak rate of [ ]a,c,e ) interpolates to a dilation-corrected inspection length of 12.20 inches for the hot leg and 12.35 inches for the cold leg. After correcting this value for NDE error of [ ]a,c,e, the inspection depth becomes 12.5 inches for the hot leg and 12.6 inches for the cold leg after incorporating 'first slip' pullout data.

Performing the same analysis used to create Table 6-7 of Reference 1, using the "first slip" load, results in the values shown in Table 2-6. The pullout load criterion of [ ]a,c,e (Table 6-1 of Reference 1) is exceeded with a joint length of 4.75 inches, as indicated by the bold values in the table.

### 2.2.4 Most Limiting Case for Pullout

The most limiting specimen shown in Figure 2-5 has a pullout load of [ ]a,c,e The most limiting specimen would also be located on the cold leg, with a reduction in the 'RCS Pressure and Diff. Thermal Axial Force' term for the cold leg by [ ]a,c,e Repeating the analyses presented in Table 2-6 using the quarter-inch incremental contact loads for the fourth column of values, yields a required engagement length of less than 4.75 inches to resist the 3NODP pullout load of [ ]a,c,e (see Table 2-7).

Considering the extremely conservative case of no residual contact pressure (that would otherwise be a result of the explosive expansion installation of the tube into the tubesheet), the tubesheet hole dilation is offset only by differential thermal expansion and internal pressure. The no residual contact pressure case bounds all other scenarios. In this case (shown in the last three columns of Table 2-7), the required engagement length to resist the 3NODP pullout load of [ ]$^{a,c,e}$ is less than 6.50 inches.

The revised Palo Verde Unit 3 results of Table 6-8 of Reference 1 are provided in Table 2-8. The [ ]$^{a,c,e}$ NDE axial position uncertainty is included. The proposed inspection length and the leak rate based inspection distances both bound the most limiting specimen even when it is evaluated using load at first slip. They also bound the extremely conservative case of no residual load by a considerable margin.

## 2.3 RAI #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.).*

### 2.3.1 Response A to RAI #7

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.

### 2.3.2 Background for Responses B and C to RAI #7

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

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

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, $\mu$:

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

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:

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

In this equation, $\xi$ 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 7.

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 8).

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 |
| $\nu$ | = | 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.

### 2.3.3 Response B to RAI #7

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 discussion portion of section 6.3 in Reference 1 provided an analytical adjustment for internal pressure for a specific test. In this 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 2-6 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

### 2.3.4 Response C to RAI #7

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, this RAI 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 2-7 and Figure 2-8 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 the very conservative definition of "First Move" that is different from the rest of the data provided in Figure 5-3 of WCAP-16208-P. [

]a,c,e

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 6 uses a definition that [

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

[

]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 2-7 and Figure 2-8 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 2-9.

Use of 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

[

]a,c,e

## 2.4 RAI #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?*

### 2.4.1 Response to RAI #8

It is assumed that that staff is actually referring to Table 4-2 of WCAP-16208-P (Revision 1) instead of Table 4-1. 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.

Table 2-1: 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<br>L<br>Joint Length (inches) | Raw Data<br>Q<br>Leak Rate (gpm) | Transformed<br>$L-L_{avg}$<br>Joint Length (inches) | Transformed<br>$Q-Q_{avg}$<br>Leak Rate (gpm) |
|---|---|---|---|---|---|
| | | | | | |
| | | | | | |
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Table 2-2: 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" First Slip Load(lbf) (adj for grip slip) | Note |
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Table 2-3: 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) |
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Table 2-4: WCAP-16208-P, Table 6-13: Effect of Tubesheet Deflection for Palo Verde 3 Steam Generators: Revised for Use of First Slip Loads (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) |
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Table 2-5: Effect of Tubesheet Deflection for Palo Verde 3 Steam Generators: Revised for Use of First Slip Loads and Reduced Differential Thermal Expansion for the Cold 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 2-6: WCAP-16208-P, Table 6-7: Tubesheet Deflection Analysis Results, Reduction in Contact Load for Palo Verde 3 Steam Generator: Revised for Use of 'First Slip' Loads

a,b,c

| Depth into Tubesheet (inches) | 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) |
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Table 2-7: Tubesheet Deflection Analysis Results, Reduction in Contact Load for Palo Verde 3 Steam Generator: Limiting Load Cases

| | | | | First Slip Limiting Sample | | | No Residual Load | | |
|---|---|---|---|---|---|---|---|---|---|
| Depth into Tube sheet (in) | Fx Dilation Load (lbf) | Fz Dilation Load (lbf) | RCS Pressure and Diff. Thermal Axial Force (lbf) | Fz Contact Load (lbf) | Fz net (lbf) | Cumulative Fz Net Loads (lbf) | Fz Contact Load (lbf) | Fz net (lbf) | Cumulative Fz Net Loads (lbf) |
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a,b,c

Table 2-8: WCAP-16208-P, Table 6-8: Burst Based Inspection Length Including Tubesheet Deflection and NDE Corrections, Revised for Palo Verde Unit 3

| Plant | Burst Based Inspection Length Corrected for Dilation (inches) | Burst Based Inspection Length Corrected for Dilation and NDE Axial Position Uncertainty | | |
|---|---|---|---|---|
| | | Using the Lower Bound (inches) | Using the Most Limiting Data (inches) | Assuming No Residual Load (inches) |
| Palo Verde Unit 3 | 4.00 ⇒ 4.75 | 4.3 ⇒ 5.0 | 4.6 ⇒ 5.0 | 6.8 |

"⇒" Indicates the revision to the value using 'First Slip' data

Table 2-9: Loads and Forces at First Move, First Slip and Maximum Load

a,b,c

| Criteria | | Sample 1 | Sample 3 | Sample 4 |
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a,b,c

Figure 2-1: Revised WCAP-16208-P, Figure 4-4: Plot of Leak Rate vs. Joint Length at 555°F, ΔP=SLB

a,b,c

Figure 2-2: First Slip Pullout Force for 48 mil Wall Rough Bore Task 1154 Tests

a,b,c

[ ]

Figure 2-3: Linear Relationship Between First Slip and Maximum Load for Rough Bore Samples

a,b,c

Figure 2-4: Linear Relationship Between First Slip and Maximum Load for Smooth Bore Samples

a,b,c

Figure 2-5: First Slip Pullout Force for 42 mil Wall Smooth Bore Tests

a,b,c

Figure 2-6: Sample 1 Blowout During Room Temperature Leak Test (1-Inch Joint Length)

a,b,c

Figure 2-7: Sample 3 Pullout Screening Test (2-Inch Joint Length)

a,b,c

Figure 2-8: Sample 4 Pullout Screening Test (3-Inch Joint Length)

# 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. "Request for Additional Information: C* - Arizona Public Service Company, Palo Verde Nuclear Generating Station, Units 1, 2 and 3," e-mail from Mel Fields, NRC to Tom Weber, APS dated October 31, 2005.

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

4. EPRI Steam Generator Degradation Database. Website http://sgdd.epri.com/sgdd. "Current Plant Operation - CL Temp" Data for Palo Verde Unit 3 as of April 10, 2006.

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

6. "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.

7. 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.

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

ENCLOSURE 3A

REVISED TS MARKUP PAGE

Insert 5.5.9, sheet 2 of 3

3. The operational LEAKAGE performance criterion is specified in LCO 3.4.14, "RCS Operational LEAKAGE."

c. Provisions for SG tube repair criteria. Tubes found by inservice inspection to contain flaws with a depth equal to or exceeding 40% of the nominal tube wall thickness shall be plugged.

d. Provisions for SG tube inspections. Periodic SG tube inspections shall be performed. The number and portions of the tubes inspected and methods of inspection shall be performed with the objective of detecting flaws of any type (e.g., volumetric flaws, axial and circumferential cracks) that may be present along the length of the tube, from the tube-to-tubesheet weld at the tube inlet to the tube-to-tubesheet weld at the tube outlet, and that may satisfy the applicable tube repair criteria. The tube-to-tubesheet weld is not part of the tube. In addition to meeting the requirements of d.1, d.2a, d.2b, and d.3 below, the inspection scope, inspection methods, and inspection intervals shall be such as to ensure that SG tube integrity is maintained until the next SG inspection. An assessment of degradation shall be performed to determine the type and location of flaws to which the tubes may be susceptible and, based on this assessment, to determine which inspection methods need to be employed and at what locations.

1. Inspect 100% of the tubes in each SG during the first refueling outage following SG replacement.

2a. Original SGs with Alloy 600 MA tubes: Inspect 100% of the tubes at sequential periods of 60 effective full power months. The first sequential period shall be considered to begin after the first inservice inspection of the SGs. No SG shall operate for more than 24 effective full power months or one refueling outage (whichever is less) without being inspected.

2b. Replacement SGs with Alloy 690 TT tubes: Inspect 100% of the tubes at sequential periods of 144, 108, 72, and, thereafter, 60 effective full power months. The first sequential period shall be considered to

**ENCLOSURE 3B**

**REVISED RETYPED TS PAGE**

**5.5-7**

5.5 Programs and Manuals (continued)

5.5.9 Steam Generator (SG) Program (continued)

shall not exceed the leakage rate assumed in the accident analysis in terms of total leakage rate for all SGs and leakage rate for an individual SG. Leakage is not to exceed 0.5 gpm per SG and 1 gpm through both SGs.

3. The operational LEAKAGE performance criterion is specified in LCO 3.4.14, "RCS Operational LEAKAGE."

c. Provisions for SG tube repair criteria. Tubes found by inservice inspection to contain flaws with a depth equal to or exceeding 40% of the nominal tube wall thickness shall be plugged.

d. Provisions for SG tube inspections. Periodic SG tube inspections shall be performed. The number and portions of the tubes inspected and methods of inspection shall be performed with the objective of detecting flaws of any type (e.g., volumetric flaws, axial and circumferential cracks) that may be present along the length of the tube, from the tube-to-tubesheet weld at the tube inlet to the tube-to-tubesheet weld at the tube outlet, and that may satisfy the applicable tube repair criteria. The tube-to-tubesheet weld is not part of the tube. In addition to meeting the requirements of d.1, d.2a, d.2b, and d.3 below, the inspection scope, inspection methods, and inspection intervals shall be such as to ensure that SG tube integrity is maintained until the next SG inspection. An assessment of degradation shall be performed to determine the type and location of flaws to which the tubes may be susceptible and, based on this assessment, to determine which inspection methods need to be employed and at what locations.

1. Inspect 100% of the tubes in each SG during the first refueling outage following SG replacement.

2a. Original SGs with Alloy 600 MA tubes: Inspect 100% of the tubes at sequential periods of 60 effective full power months. The first sequential period shall be

(continued)

**ENCLOSURE 3C**

**REVISED TS BASES PAGE MARKUP**

**INSERT New Bases B 3.4.18, Page B 3.4.18-3**

LCO (continued)

tube-to-tubesheet weld at the tube outlet. The tube-to-tubesheet weld is not considered part of the tube.

An SG tube has tube integrity when it satisfies the SG performance criteria. The SG performance criteria are defined in Specification 5.5.9, "Steam Generator Program," and describe acceptable SG tube performance. The Steam Generator Program also provides the evaluation process for determining conformance with the SG performance criteria.

There are three SG performance criteria: structural integrity, accident induced leakage, and operational LEAKAGE. Failure to meet any one of these criteria is considered failure to meet the LCO.

The structural integrity performance criterion provides a margin of safety against tube burst or collapse under normal and accident conditions, and ensures structural integrity of the SG tubes under all anticipated transients included in the design specification. Tube burst is defined as, "The gross structural failure of the tube wall. The condition typically corresponds to an unstable opening displacement (e.g., opening area increased in response to constant pressure) accompanied by ductile (plastic) tearing of the tube material at the ends of the degradation." Tube collapse is defined as, "For the load displacement curve for a given structure, collapse occurs at the top of the load versus displacement curve where the slope of the curve becomes zero." The structural integrity performance criterion provides guidance on assessing loads that have a significant effect on burst or collapse. In that context, the term "significant" is defined as "An accident loading condition other than differential pressure is considered significant when the addition of such loads in the assessment of the structural integrity performance criterion could cause a lower structural limit or limiting burst/collapse condition to be established." For tube integrity evaluations, except for circumferential degradation, axial thermal loads are

(continued)

# Enclosure 4

## Safety Assessment of the U3R12 SG Tubesheet Inspection Results

**Introduction**

In letter no. 102-05171, dated October 28, 2004, Arizona Public Service Company (APS) provided a safety assessment for the steam generator (SG) tube inspections for Palo Verde Nuclear Generating Station (PVNGS) Unit 3 Cycles 11, and 12. The basis of the assessment was the program elements of C* as conservatively implemented by APS. The same elements have been applied to the Unit 3 Refueling 12 (U3R12) SG tube inspection, as modified to reflect the greater C* inspection extent supported by the Westinghouse information provided in Enclosure 2B. The following information summarizes the inspection program and results for U3R12 and concludes that no safety or operability issues exist for Unit 3 Cycle 13. As indicated in Enclosure 2A, Unit 3 Cycle 13 is the last cycle of operation for the Alloy 600 SGs at PVNGS.

**U3R12 Tubesheet Inspection Program**

The inspection program for U3R12 included a 100% Plus Point C* inspection of the in-service tubes on the hot leg of both PVNGS Unit 3 Alloy 600-tube steam generators (SGs). As reported in Enclosure 2A, the C* inspection distance for the Unit 3 SGs has been determined to be 12.6 inches below the bottom of the expansion transition (BET). The Plus Point examination criterion imposed by PVNGS was 14 inches from the top of the tubesheet landmark for added conservatism and program implementation. The average acquired inspection depth was 15.31 inches for SG 31 and 15.41 inches for SG 32. The minimum requirement of 13 inches below the BET was verified for each inspected tube. A 100% full length bobbin inspection of all inservice tubing was also conducted.

A 20% Plus Point sample of the Cold Leg tubesheet region was conducted in U3R12 and no SCC flaws were reported. APS has been conducting Plus Point Cold Leg sample inspections of the tubesheet transition region and into the tubesheet since 1996. To date, no SCC flaws have been identified in the cold leg tubesheet region any of the PVNGS Units. The basis for the cold leg inspection program was the reported findings of SCC at other Combustion Engineering (CE) designed steam generators. Based on the PVNGS specific findings, APS has not identified a condition adverse to quality within the cold leg tubesheet region that requires the cold leg region to be programmatically included as part of the C* inspections. As such, C* criteria will not be applied to the cold-leg tubesheets.

As with previous inspections, all detected flaws, within the tubesheet, regardless of location, are removed from service. All detected flaws are also evaluated for in situ pressure testing, with no credit taken for the tubesheet within the C* distance. Flaws found outside (below) the C* distance are presumed to be bounded by the 360°, 100% through-wall flaws assumed in the WCAP 16208-P analysis.

***Inspection Results***

Prior to a return to service, APS completed a condition monitoring assessment of the U3R12 inspection results with respect to structural and leakage integrity during U3C12 and to ensure that the basis and assumptions contained in WCAP 16208-P are valid for U3C13. As indicated in Enclosure 2A, Cycle 13 is the last cycle of operation for the Unit 3 Alloy 600 MA steam generators and, as such, is the last cycle for C* implementation at PVNGS. As requested by the NRC Staff in RAI 6, summary tables providing the number of total indications, location of indication, orientation of each indication, size of each indication and whether the indications initiated from the inside or outside surface has been provided for the tubesheet region in Tables 2, 3, 4, and 5. Tables 2 and 4 also denote as to whether the circumferential flaw was beyond the C* (i.e., >12.6 inch) depth.

The same information for the remainder of the steam generator is currently required in response to PVNGS Technical Specification 5.6.8 (e.g., Reference 4 of Enclosure 2A) and as such will not be provided in this response. This item was discussed with the NRC Staff during the March 29, 2006 phone call.

Table 1 provides a comparison of the U3R12 collective steam generator results with the U3R11 results for the purposes of comparing the Cycle 12 operational assessment end-of-cycle projections with the expected Cycle 13 condition.

**Table 1**
**Unit 3 Plugging Results and Projections**

| DEGRADATION CATEGORY | U3R11 | | U3R12 Projections | | U3R12 | |
|---|---|---|---|---|---|---|
| | SG 31 | SG 32 | SG 31 | SG 32 | SG 31 | SG 32 |
| Circumferential Indications (Tubesheet) | 2 | 5 | 30 | 52 | 5 | 19 |
| Axial Indications (Arc Region) | 49 | 42 | 110 | 108 | 8 | 9 |
| Axial Indications (Tubesheet) | 12 | 19 | 30 | 50 | 2 | 22 |
| Axial Indications (01H-06H Supports, Lower bundle) | 5 | 18 | 8 | 22 | 1 | 24 |
| Other (e.g., Wear, preventative, volumetric, loose parts) | 63 | 67 | 20 | 20 | 12 | 12 |
| **Totals** | **131** | **151** | **198** | **252** | **28** | **86** |

As indicated, the total plugging results for U3R12 were significantly lower than projections provided in the U3C12 Operational Assessment and observed in U3R11. The projected combined probability of burst for Cycle 12 was calculated to be less than 0.02 at 3NODP in the Operational Assessment. The combined 95/95 leakage at MSLB conditions was predicted to be less than 0.11 gpm which was less than the allowable of 0.4 gpm per steam generator. During U3R12, no defects found exceeded the screening criteria specified in the EPRI *In Situ Pressure Test Guidelines*. As such, both the number and severity of defects found were conservatively bounded by the U3C12

Operational Assessment. The U3C13 Operational Assessment (for defects in the steam generators not covered by C*) is under development. However, the results are expected to be conservatively bounded by the Cycle 12 projections based on the U3R12 results in comparison to U3R11.

The positive results in U3R12 are believed to be the benefit of chemical cleaning conducted in 2003 and the fact that, in general, tubesheet SCC is not a progressing damage mechanism. That is, most of the defects detected are outside previously inspected elevations. Additionally, in the case of SG 31, no circumferential SCC was found outside the tubesheet transition region (See Table 4). For SG 32, the distribution of circumferential SCC indicates that most of the detected flaws are beyond the inspection depth performed in U3R11.

With respect to the tubesheet flaws, APS continues to attribute 0.1 gpm accident leakage per steam generator to the 100%, 360° flaw in every tube C* assumption. The remaining allowable accident induced leakage (0.4 gpm) is applied to the remainder of the steam generator.

Based on the results from U3R12 and using the OPCON Operational Assessment software module, the projected Cycle 13 accident induced leak rate (@ 95/50) for flaws within the C* distance is calculated to be 0.0273 gpm. This leak rate assumes no credit for tubesheet flow restriction. By assuming the C* inspection represents a 50% inspection sample, the model projects less than 300 inservice flaws in the uninspected region of the tubesheet. Even if each of these flaws were 100% PDA flaws, the calculated accident leakage contribution would be 0.001362 gpm.

**Summary**

Based on the on testing and analysis contained in Westinghouse Report WCAP-16208-P, Revision 1, *NDE Inspection Length for CE Steam Generator Tubesheet Region Explosive Expansions*, and as supplemented by the responses to RAIs 4, 5, 7 and 8, in Enclosure 2B, and the information provided by APS in the Generic Letter 2004-01 safety assessment provided in APS letter 102-05171, dated October 28, 2004, and as supplemented by the assessment presented in this Enclosure, APS concludes that no safety or operability issues exist for Unit 3 Cycle 13 based on current program elements with respect to inspection and integrity assessment of the tubesheet region.

## Table 2 – SG 32 Circumferential Flaw Summary

| Number | SG | Row | Column | Flaw | LOC | Depth | ID/OD | SIZ Volts | Depth | Length | BET | >12.6 | In situ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 32 | 65 | 12 | SCI | TSH | -0.18 | ID | 0.69 | 35 | 0.3 | 0 | N | N1 |
| 2 | 32 | 103 | 78 | SCI | TSH | -0.02 | ID | 0.53 | 44 | 0.4 | -0.36 | N | N1 |
| 3 | 32 | 100 | 79 | SCI | TSH | -0.06 | ID | 0.46 | 61 | 0.3 | -0.28 | N | N1 |
| 4 | 32 | 105 | 90 | SCI | TSH | -0.04 | ID | 0.38 | 55 | 0.2 | -0.41 | N | N1 |
| 5 | 32 | 111 | 92 | SCI | TSH | -0.09 | ID | 0.59 | 28 | 0.3 | -0.22 | N | N1 |
| 6 | 32 | 67 | 94 | MCI | TSH | -23.39 | ID | 1.63 | 64 | 0.2 | -0.44 | Y | N2 |
| 7 | 32 | 67 | 94 | MCI | TSH | -14.25 | ID | 1.27 | 77 | 0.2 | -0.44 | Y | N2 |
| 8 | 32 | 111 | 94 | SCI | TSH | -0.06 | ID | 0.82 | 41 | 0.4 | -0.24 | N | N1 |
| 9 | 32 | 57 | 96 | MCI | TSH | -13.25 | ID | 0.84 | 95 | 0.3 | -0.32 | Y | N1 |
| 10 | 32 | 57 | 96 | MCI | TSH | -13.85 | ID | 0.45 | 89 | 0.2 | -0.32 | Y | N1 |
| 11 | 32 | 109 | 98 | SCI | TSH | -13 | ID | 1.51 | 88 | 0.4 | -0.17 | Y | N2 |
| 12 | 32 | 71 | 100 | MCI | TSH | -15.39 | ID | 1.07 | 99 | 0.3 | -0.23 | Y | N1 |
| 13 | 32 | 71 | 100 | MCI | TSH | -23.3 | ID | 3.26 | 97 | 0.3 | -0.23 | Y | N2 |
| 14 | 32 | 70 | 101 | MCI | TSH | -14.01 | ID | 16.07 | 94 | 0.4 | -0.44 | Y | N2 |
| 15 | 32 | 70 | 101 | MCI | TSH | -14.89 | ID | 7.7 | 93 | 0.3 | -0.44 | Y | N2 |
| 16 | 32 | 64 | 107 | SCI | TSH | -13.75 | ID | 1.16 | 96 | 0.2 | -0.33 | Y | N1 |
| 17 | 32 | 69 | 110 | MCI | TSH | -11.85 | ID | 0.64 | 37 | 0.2 | -0.26 | N | N1 |
| 18 | 32 | 69 | 110 | MCI | TSH | -11.89 | ID | 0.36 | 15 | 0.2 | -0.26 | N | N1 |
| 19 | 32 | 69 | 110 | MCI | TSH | -12.15 | ID | 0.79 | 97 | 0.2 | -0.26 | N | N1 |
| 20 | 32 | 69 | 110 | MCI | TSH | -13.69 | ID | 1.38 | 87 | 0.5 | -0.26 | Y | N2 |
| 21 | 32 | 64 | 117 | MCI | TSH | -14.17 | ID | 1.26 | 63 | 0.3 | 0 | Y | N2 |
| 22 | 32 | 64 | 117 | MCI | TSH | -23.3 | ID | 5.4 | 95 | 0.3 | 0 | Y | N2 |
| 23 | 32 | 95 | 120 | MCI | TSH | -14.99 | ID | 2.12 | 99 | 0.2 | -0.22 | Y | N2 |
| 24 | 32 | 95 | 120 | MCI | TSH | -16.39 | ID | 0.83 | 48 | 0.4 | -0.22 | Y | N1 |
| 25 | 32 | 76 | 129 | MCI | TSH | -8.48 | ID | 0.62 | 63 | 0.3 | 0 | N | N1 |
| 26 | 32 | 76 | 129 | MCI | TSH | -11.42 | ID | 0.54 | 44 | 0.2 | 0 | N | N1 |
| 27 | 32 | 76 | 129 | MCI | TSH | -12.09 | ID | 0.47 | 21 | 0.2 | 0 | N | N1 |
| 28 | 32 | 76 | 129 | MCI | TSH | -15.15 | ID | 0.23 | 63 | 0.2 | 0 | Y | N1 |
| 29 | 32 | 76 | 129 | MCI | TSH | -23.2 | ID | 2.2 | 95 | 0.2 | 0 | Y | N2 |
| 30 | 32 | 83 | 134 | MCI | TSH | -10.76 | ID | 1.02 | 87 | 0.3 | -0.14 | N | N1 |
| 31 | 32 | 83 | 134 | MCI | TSH | -12.44 | ID | 0.76 | 80 | 0.2 | -0.14 | N | N1 |
| 32 | 32 | 83 | 134 | MCI | TSH | -15.42 | ID | 2.29 | 98 | 0.2 | -0.14 | Y | N2 |
| 33 | 32 | 83 | 134 | MCI | TSH | -22.23 | ID | 2.15 | 98 | 0.6 | -0.14 | Y | N2 |
| 34 | 32 | 82 | 139 | SCI | TSH | -12.83 | ID | 1.04 | 82 | 0.3 | -0.28 | N | N1 |
| 35 | 32 | 69 | 142 | SCI | TSH | -23.12 | ID | 13.96 | 94 | 1.2 | 0 | Y | N2 |

**Table 3 – SG 32 Axial Flaw Summary**

| Number | SG | Row | Column | Flaw | LOC | Depth | ID/OD | SIZ Volts | Depth | Length | In Situ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 32 | 12 | 1 | SAI | TSH | -0.55 | ID | 0.9 | 45 | 0.3 | N3 |
| 2 | 32 | 35 | 80 | SAI | TSH | -0.17 | ID | 1.06 | 67 | 0.2 | N3 |
| 3 | 32 | 81 | 92 | SAI | TSH | -6.52 | ID | 1.04 | 29 | 0.3 | N3 |
| 4 | 32 | 112 | 93 | SAI | TSH | 0.2 | OD | 0.33 | 37 | 0.2 | N3 |
| 5 | 32 | 55 | 94 | SAI | TSH | -0.25 | ID | 0.68 | 60 | 0.2 | N3 |
| 6 | 32 | 48 | 97 | SAI | TSH | -0.29 | ID | 0.87 | 44 | 0.2 | N3 |
| 7 | 32 | 102 | 97 | SAI | TSH | 0.4 | OD | 0.36 | 40 | 0.3 | N3 |
| 8 | 32 | 63 | 98 | SAI | TSH | 0.44 | OD | 0.26 | 37 | 0.2 | N3 |
| 9 | 32 | 48 | 101 | MAI | TSH | -0.92 | ID | 0.3 | 33 | 0.2 | N3 |
| 10 | 32 | 48 | 101 | MAI | TSH | -0.65 | ID | 1.1 | 22 | 0.3 | N3 |
| 11 | 32 | 48 | 101 | MAI | TSH | -0.38 | ID | 0.62 | 15 | 0.3 | N3 |
| 12 | 32 | 70 | 103 | SAI | TSH | -0.58 | ID | 0.66 | 64 | 0.2 | N3 |
| 13 | 32 | 92 | 115 | SAI | TSH | -15.82 | ID | 1.74 | 47 | 1 | N4 |
| 14 | 32 | 117 | 116 | SAI | TSH | 0.42 | OD | 0.43 | 42 | 0.3 | N3 |
| 15 | 32 | 40 | 117 | SAI | TSH | -16.48 | ID | 1.49 | 51 | 1.1 | N4 |
| 16 | 32 | 58 | 119 | SAI | TSH | -1.46 | ID | 0.56 | 51 | 0.4 | N3 |
| 17 | 32 | 27 | 120 | SAI | TSH | -1.26 | ID | 0.59 | 60 | 0.2 | N3 |
| 18 | 32 | 60 | 123 | SAI | TSH | -0.35 | ID | 0.78 | 59 | 0.2 | N3 |
| 19 | 32 | 86 | 135 | SAI | TSH | -11.98 | ID | 0.85 | 55 | 0.2 | N3 |
| 20 | 32 | 102 | 135 | SAI | TSH | -0.43 | ID | 0.94 | 33 | 0.2 | N3 |
| 21 | 32 | 22 | 157 | SAI | TSH | -13.27 | ID | 1.11 | 43 | 0.3 | N3 |
| 22 | 32 | 45 | 160 | MAI | TSH | -13.16 | ID | 1.73 | 63 | 0.3 | N3 |
| 23 | 32 | 45 | 160 | MAI | TSH | -13.54 | ID | 1.03 | 60 | 0.2 | N3 |
| 24 | 32 | 45 | 160 | MAI | TSH | -13.77 | ID | 1.09 | 49 | 0.2 | N3 |
| 25 | 32 | 81 | 172 | SAI | TSH | -0.26 | ID | 0.85 | 57 | 0.2 | N3 |

**Table 4 – SG 31 Circumferential Flaw Summary**

| Number | SG | Row | Column | Flaw | LOC | Depth | ID/OD | SIZ Volts | Depth | Length | BET | >12.6 | In situ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 31 | 55 | 112 | SCI | TSH | -0.1 | ID | 0.28 | 40 | 0.2 | 0 | N | N1 |
| 2 | 31 | 48 | 113 | MCI | TSH | -0.1 | ID | 0.57 | 30 | 0.3 | -0.06 | N | N1 |
| 3 | 31 | 48 | 113 | MCI | TSH | -0.12 | ID | 0.12 | 64 | 0.4 | -0.06 | N | N1 |
| 4 | 31 | 55 | 114 | SCI | TSH | -0.06 | ID | 0.22 | 43 | 0.2 | -0.34 | N | N1 |
| 5 | 31 | 54 | 115 | MCI | TSH | -0.03 | ID | 0.28 | 30 | 0.2 | 0 | N | N1 |
| 6 | 31 | 54 | 115 | MCI | TSH | -0.04 | ID | 0.34 | 55 | 0.6 | 0 | N | N1 |

**Table 5 SG 31 Axial Flaw Summary**

| Number | SG | Row | Column | Flaw | LOC | Depth | ID/OD | SIZ Volts | Depth | Length | In Situ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 31 | 37 | 64 | SAI | TSH | 0.11 | OD | 0.26 | 27 | 0.2 | N3 |
| 2 | 31 | 46 | 125 | SAI | TSH | -0.46 | ID | 0.7 | 45 | 0.2 | N3 |

**In Situ Screening Notes**

**N1 – Circ Defect Criteria -** Flaw Length is less than $CA_{TWSL}$ (1.5 inches) and less than $V_{THR-L}$ (1.25 volts)

**N2 – Circ Defect Criteria -** Flaw Length is less than $CA_{TWSL}$ (1.5 inches) and Flaw is located outside C* Distance

**N3 – Axial Defect Criteria –** Flaw Length is less than LSTR (0.43 inches) and less than $V_{THR-L}$ (2.50 volts)

**N4 – Axial Defect Criteria –** Flaw depth is less than $MD_{THR-P}$ (64%) and less than $V_{THR-L}$ (2.5 volts)