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OTSG REPAIR ROLL QUALIFICATION REPORT
ADDENDUM A

FTI NON-PROPRIETARY

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RECORD OF REVISION

Revision	Date	Section	Description
0	3/5/99	All	Original Issue
1	3/16/99	Section 1	Changed 2nd paragraph

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1.0 INTRODUCTION

Florida Power Corporation (FPC) plans to implement a steam generator tube repair roll program at Crystal River 3 (CR3). The existing qualification report (BAW-2303P, Revision 3) for the OTSG tube repair rolling process documents the results of the qualification program performed to verify the acceptability of this repair technique for the B&W type nuclear power plants. At the time this qualification program was performed, the main steam line break (MSLB) transient was believed to produce the bounding tube loads for all the B&W plants. The acceptance criteria for both structural and leakage performance was therefore based on this transient.

Subsequent to completion of the existing qualification report (BAW-2303P), an issue was raised concerning tube loads that could be generated by a small break loss of coolant accident (SBLOCA). The RELAP 5/MOD 2-B&W computer code was used to analyze several SBLOCA scenarios. The time dependent pressures and tube-to-shell temperature data from the limiting case was then used to determine the maximum tensile tube loads. The results of the SBLOCA evaluation showed a maximum possible tube load of [ ](c), which exceeds the [ ](c) MSLB load for CR-3. This larger axial load was therefore evaluated to ensure that the repair roll continues to meet the design requirement of preventing tube slippage during the worst case faulted condition loading. The results of this evaluation are included in this addendum to support FPC's submittal of a License Amendment Request (LAR) for the repair roll to the NRC for review. It is noted that the MSLB continues to be the limiting condition for leakage performance (the SBLOCA secondary pressure is greater than the primary pressure at the time of maximum load).

The evaluation is performed by comparing the postulated tube load (based on transient analysis) to the maximum load carrying capability of the repair roll. These comparisons are performed as a function of radius and elevation within the upper tubesheet. The scope of this work focuses on the span [ ](b) below the upper tubesheet primary face because this is the desired location for installation of a repair roll and the targeted position for all OTSG repair rolls installed to date.

This document serves as an addendum to the Reference 2.1 qualification report and addresses the effects of SBLOCA only. All testing and analysis relating to other transient conditions documented in Reference 2.1 remain valid for CR-3.

2.0 REFERENCES

2.1 FTI Document No. (BAW) 43-2303P-03, "OTSG Repair Roll Qualification Report", 10/97 [FTI Proprietary].

3.0 METHODOLOGY

The load carrying capability of the repair roll is a function of the amount of contacting surface area, the coefficient of friction, and the contact pressure between the tube and the tubesheet. When comparing room temperature test conditions to various OTSG operating conditions, changes in surface area and coefficient of friction are considered insignificant when compared to the change in contact pressure.

The load testing summarized in Section 5.2 of Reference 2.1 was performed in tubesheet mockups with "as fabricated" bore diameters. In this condition, the contact pressure between the tube and tubesheet is derived from the amount of springback in the tube. Springback is the term given to the radial interference between the unstressed OD of a rolled tube and the ID of the surrounding tubesheet bore. It is produced by the radial and circumferential deformation caused by the roll expansion process. From testing, it was determined that the average amount of springback due the repair roll process is [ ](d) inches [Ref. 2.1, page 5-11] and results in a 95% 1-sided lower tolerance limit load carrying capability of [ ](d) [Ref. 2.1, page 5-10].

During certain operating conditions, temperature and pressure changes may reduce the contact pressure between the tube and tubesheet, resulting in less load carrying capability. Changes in contact pressure are a direct result of changes in the amount of net radial interference. Differential dilation is therefore defined as the average change in the relative difference in the dilation between the tube OD and the tubesheet bore ID. Zero differential dilation refers to the condition where the tube-to-tubesheet joint is in the "as installed" condition, which means the only component affecting load carrying capability is the [ ](d) tube average springback. The differential dilation is equal to the tubesheet bore dilation due to tubesheet bowing and free thermal growth minus the dilation of the tube due to internal pressure and free thermal growth.

The average differential dilations and axial tube loads associated with the most limiting SBLOCA are utilized in this evaluation. The load carrying capability of the repair roll is calculated by first reducing the test load carrying capability [ ](d) to account for the effect of the elevated temperature on the tube modulus of elasticity. This load carrying capability is then reduced proportionally to the amount of differential dilation. Because the repair roll installation results in [ ](d) of springback, the load carrying capability is reduced 10% for every [ ](d) of differential dilation. It is assumed that a differential dilation of [ ](d) results in no load carrying capability.

The load carrying capability is computed as a function of the tube centerline radial position and the distance below the primary face of the upper tubesheet. If the calculated load carrying capability is greater than the predicted axial tube load due to the postulated SBLOCA, then the repair roll is considered acceptable. The evaluation focuses on placing the repair roll from [ ](b) below the primary face of the upper tubesheet.

4.0 EVALUATION

The load carrying capability of the repair roll over the span [ ](b) from the primary face of the tubesheet is plotted as a function of tubesheet radius. These calculations are performed by using the methodology of section 3. The SBLOCA axial load is also plotted as a function of radius in order to determine where the roll is calculated to be able to carry the SBLOCA load.

Figure 1

(d)

The [ ](b) span is chosen because this is the current default span of the repair roll. In order for the roll to be able to carry a predicted load, the repair roll must have a load carrying capability greater than or equal to the predicted load. A conservative margin of](d) is added to the SBLOCA load and used to determine any exclusion zones for the [ ](b) repair roll. The figure shows that the repair roll is capable of carrying the predicted loads [ ](d)

In an effort to find a depth that is less limiting, the load carrying capability for a [ ][(b)] repair roll is determined as a function of radius for depths down to the secondary face. The repair roll load carrying capability is then compared to the predicted load [ ][(d)] at each location. Figure 2 shows the results of this evaluation. The "x" axis is the radial position within the OTSG upper tubesheet and the "y" axis is the distance from the primary face. If the predicted SBLOCA load is greater than the load carrying capability, then the location is shaded. [

][(d)]

Figure 2
Upper Tubesheet Single Repair Roll Exclusion Zone

(d)

In accordance with Reference 2.1, a double overlapping roll can be used to form the new pressure boundary. [

]^(b) The double overlapping repair roll proposed for use at CR-3 will be utilized for tubes that are located within the exclusion area for the [ ]^(b) repair roll. The length of the [ ]^(b) rolls is determined by the physical length of the mechanical roll expanders. The over-all length of the double roll is determined by the use of mechanical hard stops during the installation process. The double overlapping repair roll proposed for installation at CR-3 will not take credit for any portion of the existing or original roll joint, nor will the double roll overlap the existing or original roll joint as currently proposed in BAW-2303P, Revision 3.

The undilated load carrying capability of the double repair roll is calculated by multiplying the load carrying capability of the single roll [ ]^(d) The double roll location is over the nominal span [ ]^(b) from the primary face of the tubesheet. The dilated load carrying capability is determined by first calculating [ ]^(b) and then using the methodology of section 3. The SBLOCA axial load is also plotted as a function of radius in order to determine where the roll is calculated to be able to carry the SBLOCA load.

Figure 3

(d)

The [ ]^(b) span is chosen because it overlaps the current default span of the single repair roll. In order for the double roll to be able to carry a predicted load, it must have a load carrying capability greater than or equal to the predicted load. The SBLOCA load [ ]^(d) is used to determine any exclusion zones for the [ ]^(b) repair roll. The figure shows that the repair roll is capable of carrying the predicted loads [ ]^(d) for all locations. The double roll can therefore be utilized for tubes [ ]^(d) to remove the repair roll exclusion zone identified for the [ ]^(b) roll.

The previous figures show that the type of repair roll needed is a function of the radial position of the tube. To aid in repair process planning, Table 1 is provided below. Table 1 displays the number of OTSG tubes as a function of radius. [ ]^(d)

Table 1

(c)

For completeness, the load carrying capability of the [ ][b] repair roll is determined as a function of radius for depths down to the secondary face. The repair roll load carrying capability is then compared to the predicted load [ ][d] at each location. Figure 4 shows the results of this evaluation. The "x" axis is the radial position within the OTSG upper tubesheet and the "y" axis is the distance from the primary face. If the predicted SBLOCA load is greater than the load carrying capability, then the location is shaded.[ ][d]

Figure 4
Upper Tubesheet Double Repair Roll Exclusion Zone

(d)

5.0 RESULTS AND CONCLUSIONS

The purpose of this addendum is to evaluate the effects of a SBLOCA transient on the load carrying capability of the repair roll. If the repair roll is limited to installation such that the span is [ ]$^{(b)}$ from the primary face of the tubesheet, the SBLOCA evaluation limits application to tubes [ ]$^{(d)}$ The exclusion zone can be eliminated through the use of a double repair roll [ ]$^{(b)}$ in this region.

In conclusion, by utilizing the following guidelines, all tubes can be repair rolled and maintain a load carrying capability that is at least [ ]$^{(d)}$ greater than the maximum SBLOCA load (at that radial position):

- apply a single repair roll that [ ]$^{(b,d)}$, and
- apply a [ ]$^{(d)}$ double repair roll [ ]$^{(b,d)}$

Other locations within the steam generator may also be acceptable for carrying the SBLOCA load. If it is necessary to place a repair roll at a different depth, then the figures (Figures 2 and 4) should be utilized to determine if the desired type of roll is capable of carrying the SBLOCA load at the position of interest.