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February 03, 2005

U. S. Nuclear Regulatory Commission
Attn: Document Control Desk
Washington, DC 20555

SUBJECT: COMANCHE PEAK STEAM ELECTRIC STATION (CPSES) UNIT 1, DOCKET NO. 50-445, TECHNICAL BASIS FOR THE EFFECTIVENESS OF CURRENT INSERVICE INPECTION METHODS IN SLEEVED STEAM GENERATOR TUBES

REF:
1. TXU Power letter, logged TXX-03102, from C. L. Terry to the U. S. Nuclear Regulatory Commission, dated July 21, 2003.
2. TXU Power letter, logged TXX-04045, from Mike Blevins to the U. S. Nuclear Regulatory Commission, dated March 8, 2004.
3. NRC letter from Mr. Mohan C. Thadani to Mike Blevins, dated March 24, 2004.

Gentlemen:

The design of the Alloy 800 steam generator tubesheet transition zone sleeves installed in the TXU Generation Company LP (TXU Power) CPSES Unit 1 (as authorized by License Amendment 112 of Reference 3), includes a narrow nickel band applied to a portion of the sleeve's outside diameter. This thin nickel coating is intended to increase the leakage resistance through the sleeve-to-tube interface at the lower hard-rolled joint of the sleeve/tube assembly. However, the presence of a nickel coating in this region can complicate eddy current interpretation of the area and can prevent detection of a parent steam generator tube flaw located radially adjacent to this nickel band.

The purpose of this letter is to provide a technical basis supporting TXU Power's position that in-service non-destructive examination of a parent steam generator tube adjacent to the nickel band region of an Alloy 800 repair sleeve is not required to support continued operability of the sleeved tube.

A-047

TXU Power acknowledges that the nickel band region of the Alloy 800 sleeve/tube assembly is part of the pressure boundary of the repaired tube, and as such is normally subject to routine in-service inspection. However, it is TXU Power's position that for a postulated condition of degradation in the parent tube radially adjacent to the sleeve's nickel band, the remaining tube/sleeve hardroll joint length above the nickel band will provide anchorage consistent with the design requirement. Therefore, in-service inspection capabilities within the parent tube due to the presence of the sleeve nickel band is not required to ensure structural or leakage integrity of the tube/sleeve hardroll joint.

In addition, all tubes sleeved in the tubesheet transition zone (TZ) in CPSES Unit 1 were first inspected and verified free of detectable tube degradation at the tube/sleeve joint region prior to sleeve installation. Unit 1 steam generators are currently scheduled for replacement at the end of the next operating cycle (Spring 2007), and future Primary Water Stress Corrosion Cracking (PWSCC) within the nickel band region of the sleeve/tube assembly is unlikely. Given this limited lifetime of the installed sleeve/tube assembly, current inspection techniques are adequate to identify any indications of PWSCC that may extend above or below the nickel band and that could potentially affect leakage integrity of the joint.

The enclosure to this letter contains an engineering position paper developed for the Westinghouse Owners Group (WOG) to support this position.

If there are any questions concerning this submittal, please contact Mr. Bob Kidwell at (254) 897-5310.

This communication contains no new licensing basis commitments regarding CPSES Unit 1.

Sincerely,

TXU Generation Company LP
By: TXU Generation Management Company LLC,
Its General Partner

Mike Blevins

By: [signature]
Fred W. Madden
Director, Regulatory Affairs

RJK
Enclosure

c - B. S. Mallett, Region IV
W. D. Johnson, Region IV
M. C. Thadani, NRR
CPSES Resident Inspectors

WOG-04-518

Engineering Position Paper On NDE Issues Related to TIG and Alloy 800 Sleeves with Regard to Sleeve Nickel Band NRC Discussion

Dated October, 2004

NDE Issues Related to TIG and Alloy 800 Sleeves
With Regard to Sleeve Nickel Band NRC Discussion
(PA-MSC-0190)

Background

NRC has questioned NDE capabilities regarding the SG parent tube adjacent to installed TIG and Alloy 800 sleeve nickel band regions. Recent inspection results from C-E plants indicate a potential for PWSCC degradation at this elevation. The parent tube in the hardroll joint area is considered part of the pressure boundary and thus subject to routine in service inspection.

A telecom between NRC and industry was conducted on August 3, 2004 in which a generalized position was discussed. NRC issued several questions via email on August 9, 2004 in response to this telecom. The discussion provided below attempts to answer these questions.

Pertinent Issues

Typical sleeve design criteria address structural anchorage of the sleeve within the tube and leakage characteristics.

Structural anchorage has evaluated both (upper and lower) sleeve joint independently against axial forces developed commensurate with draft RG 1.121; that is, both the upper and lower joint should provide anchorage consistent with axial forces developed through end cap loading at a pressure differential of three times normal operating conditions pressure differential ($3\Delta P_{NO}$). This requirement includes a large inherent conservatism (for all cases except a potentially severed tube at the top of tubesheet) since the upper and lower joints of the sleeve are obviously coupled, and both joints react end cap loading at $3\Delta P_{NO}$.

Leakage characteristics for abnormal joint lengths have been determined by test, and past qualifications have shown that both typical and abnormal hardroll configurations of the lower sleeve joint to be leak tight at steam line break (SLB) conditions.

The qualification and performance of the sleeve joint is predicated on "presence" of a tube, thus the tube should be considered as part of the pressure boundary. The technical discussion provided below will show that postulated degradation within the parent tube coincident to the nickel band does not prevent the joint from meeting the design requirement, thus a basis can be formed to reduce the NDE requirements for the parent tube adjacent to the nickel band.

The original sleeve stress evaluation prepared in the supporting WCAP reports is not affected by this evaluation as the ASME Code stress evaluation applies to the non-expanded sleeve lengths.

Issue Resolution

The NRC questions transmitted by email on 8/3/2004 involved several topics. These topics can be summarized as

- Load bearing capability of the TIG and Alloy 800 sleeve joint for limited effective joint lengths
- Consistency of TIG and Alloy 800 sleeve joint design and performance with existing HEJ test data
- Overall tube anchorage in the tubesheet
- Leakage integrity of postulated limited effective length TIG and Alloy 800 sleeve joints

The discussion provided below addresses these topics.

<u>**Load Bearing Capability of TIG and Alloy 800 sleeve joint for limited effective joint lengths**</u>

It is the industry position that the inherent robust characteristics of mechanical roll joints satisfy the structural design requirement in the presence of postulated PWSCC degradation of the parent tube outboard of the sleeve nickel band region. This statement is supported by previous testing work performed as part of the hybrid expansion joint (HEJ) sleeve qualification. In this program "abnormal" joint conditions were tested to determine structural and leakage characteristics. The HEJ sleeve design does not include a nickel band or microlok band as do the TIG or Alloy 800 sleeve designs. The microlok region in particular is intended to increase the coefficient of friction between the tube and sleeve thus creating a greater reactionary load capability, thus the HEJ results presented below are expected to be conservative. Westinghouse data shows that coefficient of friction values for the microlok region can be bounded at the lower end by a value of 0.3, which is greater than the value of 0.2 typically used for previously performed similar evaluations regarding rolled joints. Also, particularly for the explosively expanded tube to tubesheet joint configuration, the sleeve mechanical roll "embeds" the sleeve into the tube ID surface, creating a mechanical interference fit between the sleeve and tube ID. Thus, not only must the sleeve to tube interface friction resistance be overcome to result in relative motion between the tube and sleeve, but the mechanical interference at the upper edge of the hardroll expansion must be overcome also.

The nominal hardroll flat length for the TIG sleeve is 1.25" with a nominal installation torque value 130 in-lb and an acceptable torque range of 90 to 175 in-lb. The nominal hardroll flat length for the Alloy 800 sleeve is 1.1" with a nominal installation torque value of 130 in-lb and an acceptance torque range of 100 to 160 in-lb. These values are consistent for 3/4" and 7/8" OD tubing installations. The typical wall thinning achieved in these sleeves is 3 to 6%. If it is assumed that the nickel band area supplies no axial load bearing capability, the effective lengths of the two joint designs are 0.625" for the TIG sleeve and 0.55" for the Alloy 800 sleeve. It should be noted that degradation of the parent tube would not be expected to result in a condition where the tube section with degradation has no residual preload capacity. The tube in tubesheet expansion process results in a residual preload between the tube and tubesheet. If the tubesheet could be removed, the tube OD would expand to a larger diameter. This would be the case even for a tube with a single 100%TW axial indication that extends for the entire length of the nickel band. In this case the free ends of the tube would tend to be driven apart by the residual stress in the tube. As the tubesheet would restrain this motion, a preload condition will exist. The subsequent sleeve installation would provide a path to transfer the hardroll expansion loads to the tubesheet through the tube material. While the axial load bearing characteristics of such a condition would not be expected to be consistent with a non-degraded tube, neglecting this condition is conservative.

Abnormal joint length test data for HEJ sleeves for 7/8" diameter tubes is provided in WCAP-13088. Joint lengths of 3/4" and 1" were used however; it cannot be determined if these joint lengths were prepared by machining a nominal joint to these lengths or whether the joints were produced with only these lengths of engagement between the sleeve and roller. For purposes of this evaluation, it is assumed that these joints were produced by engaging the sleeve and roller over the listed joint length, which is quite conservative when torque per unit area is compared below for the various designs.

For 1 inch HEJ lengths tested at room temperature, first slip loads were approximately 5000 lb, and peak load capability was approximately 8500 lb. For 3/4 inch HEJ lengths, first slip load was 3190 lb with a peak load of 8340 lb. These peak loads are consistent with full length HEJs. These data confirm that peak load is relatively independent of joint length. At the onset of slippage galling between the tube and sleeve produces peak loads that are reduced to a function of the material properties. If the available first slip data are plotted and a curve fit to this data, at 0.55 inch joint length the expected first slip load is approximately 2000 lb. Peak load capability would be expected to be slightly reduced from the peak load data discussed above, but not significantly, and would remain well above the $3\Delta P_{NO}$ design requirement. Based on the available data peak load capability at 0.55 inch is expected to exceed 7000 lb. At operating temperatures the thermal expansion characteristics of the tubesheet, tube, and sleeve result in a radial preload condition that is elevated above room temperature. Thus, the expected elastic joint anchorage characteristics would be expected to be increased for operating temperature conditions.

Further abnormal joint condition testing work was performed using rolling torques well below the acceptable level. In these tests a 1.44" roll joint length was used with an 80 in-lb applied torque. Axial load capability testing performed at 600°F shows the peak tensile load capacity was approximately 7500 lb, which is consistent with typical tube/sleeve hardroll joints. This data suggests that axial load capability is relatively constant for tube/sleeve joint assemblies that provide apparent wall thinning within the specified ranges. Comparison of room temperature and elevated temperature data shows the elevated temperature axial load capabilities are approximately 10% higher than the room temperature data. The increase in radial contact load more than compensates for the reduction in material properties.

The supporting WCAP reports note that tests were also conducted using tubes with 360° circumferential separations of the parent tube near the top of the hardroll joint region but did not quantify the length of the joint. The load capability data for this condition is consistent with non-degraded parent tubes. Leakage testing also showed no leakage at SLB pressure differential following fatigue testing. Leakage testing was performed at 600°F. A postulated circumferential flaw in the parent tube would not significantly affect the axial load capability of the tube/sleeve joint as the tube would continue to provide positive radial preload with the tubesheet, and thus with the sleeve.

WCAP-14157 and WCAP-14641 present axial load capability data for degraded freespan HEJs in 7/8 inch OD tubing. In this program load-bearing capability of the joint was established for assumed circumferential cracking within the parent tube. The freespan HEJ hardroll flat length is 1" long. Since the joint is produced in the freespan the rolling process does not achieve a torque out condition; the final joint configuration is determined by the maximum expansion afforded by the roller tool. As the freespan HEJ does not have the benefit of the tubesheet to increase the radial interface pressure, this data can be used to show the benefit of the mechanical interference inherent between the tube and sleeve. Typical joints were prepared and the tubes were circumferential separated near the bottom of the hardroll flat length by machining. For tubes separated at the bottom of the hardroll joint thus creating an interference of about 0.020", peak load capacity of the joint exceeded the axial load capability of the sleeve itself, and the sleeves failed in tension at approximately 8000 lb. For interferences of 0.002" to 0.005" the peak axial load capability of the joint was 4100 to 5400 lb, the condition most representative for the tubesheet region hardroll joint. For this condition (mechanical interference between sleeve and tube) the effective contact length is mostly secondary with regard to load capacity as the sleeve is essentially drawn through the interference fit. This interaction inherently involves large axial load capability as shown above. For these tests the interference dimension is defined as the difference between the cut tube ID and the sleeve OD. For the above discussed tests the cut tube was pulled over the sleeve.

For the in-generator condition the tube at the interface between the tube and sleeve would be reinforced by the tube length above this elevation, and axial load capabilities would be expected to be increased for equal interferences.

If it is postulated that an axial PWSCC indication was present in the tube prior to sleeve installation and this indication is located entirely within the bounds of the sleeve nickel band, the above data demonstrates that the lower joint region will continue to provide an anchorage consistent with the design requirement if it is assumed that no contribution to anchorage is provided by the sleeve/tube assembly in the nickel band region. This assumption is quite conservative since the tubesheet restrains the tube radially, and postulated axial degradation of the parent tube will still provide some measure of radial load capability when the sleeve is installed.

Therefore, it is the industry position that for a postulated condition of degradation in the parent tube radially adjacent to the sleeve nickel band, that the remaining tube/sleeve hardroll joint length above the nickel band will provide anchorage consistent with the design requirement, and that reduced NDE capabilities within the parent tube due to the presence of the sleeve nickel band is not required to ensure structural or leakage integrity of the tube/sleeve hardroll joint.

It should be noted that recent Alloy 800 sleeve installations have included a Plus Point coil examination of the parent tube in the tube/sleeve hardroll joint region prior to sleeve installation to verify that the tube is free of detectable degradation in this area. For these cases, future PWSCC development of the parent tube is unlikely for the following reasons. First, the tube/sleeve interface will isolate the parent tube from the primary fluid, thus effectively eliminating one contributor to PWSCC initiation. Second, previous testing and analysis performed by Westinghouse indicates that for the expanded tube condition, that residual stresses are compressive, and thus are not of the appropriate direction for PWSCC development. While full depth roll expanded SG tube designs have developed PWSCC degradation at the roll overlap elevations, the axial extent of these indications is limited to the stress field created by the overlap length (1/4 inch). The only plant with full depth roll expanded tube in tubesheet joints that has installed TIG and Alloy 800 sleeves is Comanche Peak Unit 1. These tubes were shotpeened prior to operation from above the top of tubesheet to just above the tube end. The incidence of expansion transition and tubesheet region PWSCC at Comanche Peak has been minimal. Finite element modeling of tube and sleeve joint conditions confirms that the tube ID will remain in a compressive residual stress condition with installation of a sleeve.

Consistency of TIG and Alloy 800 sleeve joint design and performance with existing HEJ test data.

The above abnormal HEJ joint tests involved sleeve wall thinning ranging from 4.0% to 8.6%. This range is consistent with the wall thinning associated with the TIG and Alloy 800 sleeves. As wall thinning is consistent for all sets it is reasonable to conclude that the TIG and Alloy 800 sleeve designs will provide axial load bearing capability consistent with the HEJ data on a unit length basis.

The HEJ abnormal joint test data include variations in effective joint length and applied torque. If the applied torque is divided by the effective contact area for each of the specimen configurations, the specimens exhibit values ranging from 22.4 in-lb per square-inch for the 1.44" joint length specimens to 72.6 in-lb per square-inch for the 3/4" joint specimens. As stated above, the exact installation configuration cannot be determined for the 3/4" and 1" joint length samples. If these samples were prepared by producing a nominal joint and machining to the indicated joint length the in-lb per square- inch value is 25.2. The TIG and Alloy 800 sleeve designs supply approximately 59.0 in-lb per square-inch based on the nominal installation torque. As the HEJ abnormal joint test data shows the peak load capacity is relatively unaffected over a wider range of torque per unit length, the same conclusions would apply to the TIG and Alloy 800 sleeves. Thus, it is acceptable to evaluate the TIG and Alloy 800 sleeve limited length configurations by comparison with the HEJ data.

Overall Tube Anchorage in the Tubesheet

The parent tube existing above the hardroll joint region would continue to provide additional support to the tube/sleeve joint region, even though this area is not considered part of the pressure boundary for the installed sleeve condition. Axial loads would continue to be transferred through the tube for the case of multiple axial indications in the parent tube at any elevation above the sleeve to tube hardroll joint. Circumferential degradation of the parent tube above the sleeve to tube hardroll joint could only affect tube anchorage if the degradation extends for approximately 280 degrees arc length with a depth of 100%TW over this length. For postulated circumferential indications below the top of tubesheet expansion transition the tube cannot experience a bending failure, thus the tube is loaded only in tension. Furthermore, the installation of the sleeve will isolate this portion of the tube from the primary fluid. Discussion provided above shows the residual stresses in the expanded tube below the expansion transition are compressive, and that an external stress riser then must be present for PWSCC flaw initiation. Such conditions are associated with localized anomalies. This discussion neglects the increased tube to tubesheet anchorage afforded by the installation of the sleeve.

For the case of postulated circumferential degradation of the parent tube adjacent to the nickel band, the inherent radial preload imparted by the tube expansion process and installation of the sleeve would not significantly be reduced due to the presence of circumferential degradation. As the tube radial preload, or a significant portion thereof would be preserved, the radial preload that in turn provides axial load bearing capability between the tube and the tubesheet would be maintained.

Leakage Integrity

Leakage testing at 600^0 F for the 1 inch and 3/4 inch HEJ lengths shows no leakage at a pressure differential of 3106 psi following fatigue cycling. The 1.44 inch joint length with 80 in-lb applied torque shows no leakage at SLB pressure differential. Therefore, the TIG and Alloy 800 joint lengths considered would also be expected to provide similar leakage performance. Thus, the available HEJ abnormal joint test data suggests that the presence of the nickel band is not required for leakage integrity at a high probability. In the unlikely event that degradation of the parent tube adjacent to the sleeve nickel band is present the nickel band would be expected to further reduce the leakage probability.

Recent TIG sleeve operating performance shows a modest number of collapsed or potentially collapsed sleeves. The theory behind the collapse is that primary fluid enters the tube to sleeve annulus region during startup conditions prior to increasing temperature. The difference in thermal expansion characteristics produces a tighter configuration at operating temperatures. These occurrences are not believed to be related to potential degradation of the parent tube. The Comanche Peak experience has shown the highest percentage of collapsed or partially collapsed sleeves of about 8% of all installed TIG sleeves (approximately 60 out of 735). The Spring 2004 Alloy 800 sleeve installation at Comanche Peak involved a Plus Point examination of the parent tube in the sleeve hardroll joint region prior to installation. No degradation was reported at this location for the approximate 550 tubes that received Alloy 800 sleeves. Therefore, it is unlikely that 60 sleeves either collapsed or partially collapsed observed at the 2004 inspection contained parent tube indications. To date, less than 10 tubes out of over 18000 have been reported to contain PWSCC at the top of tubesheet hardroll expansion transition, which is the point of highest residual stress in the tube. Recent inspection results from SONGS 2 shows that for the length of tubing from 10 inch to 12 inch below the top of tubesheet, which is the approximate elevation of the sleeve hardroll joint, that only 41 indications were reported for over 17000 active tubes. For this inspection all tubes were inspected to at least 17 inches below the top of tubesheet. Therefore, it is unlikely that the 10 collapsed sleeves reported at this outage were influenced by PWSCC of the parent tube adjacent to the sleeve nickel band.

The source of the collapsed condition is believed to be related to several possible causes, a tooling issue related to a specific lot of roll expanders, localized geometry variations in the tube that are not overcome by the sleeve roll expansion, and disruption of the microlok and nickel band regions during sleeve insertion. Westinghouse is currently investigating the tooling issue. An ovalized tubehole could present a condition where the tube to sleeve interface presents a limited arc length region where leaktightness is reduced at ambient temperature but not present at operating temperature. If the sleeve OD surface is scratched or marred during installation a localized leak path may be produced, but again is eliminated at operating temperatures. While these postulated causes for sleeve collapse represent a subsequent inspection issue, they do not represent an operating or safety issue.

The available information indicates that there is no relation between the recently observed sleeve collapse occurrences and postulated degradation of the parent tube in the nickel band region.

Current NDE Capabilities

As axial indications within the parent tube adjacent to the sleeve nickel band do not affect the structural or leakage capability of the sleeve joint, detection of axial degradation does not affect the ability of the joint to continue to perform its design function. Evaluation of calibration standards with 100%TW axial EDM notches in the parent tube behind the nickel band shows these limited length notches are detectable with Plus Point RPC probes. While SCC indications offer a more challenging condition for detection compared to EDM notches, the condition that would potentially affect leakage integrity of the joint would be the case where the parent tube axial degradation extends from above to below the nickel band region. For this case, meaningful degradation of the parent tube is expected to be readily detectable using current techniques.

The observed circumferential degradation at significant depths below the top of tubesheet in units with sleeves or considering sleeving has involved limited arc lengths, and a postulated separated tube adjacent to the sleeve nickel band is not expected within these SGs. If this condition were assumed to be present, it is expected that this condition would be detectable despite the NDE challenges associated with the sleeve nickel band. Both a postulated separated tube, and tube with a 100%TW SCC flaw extending for an arc length commensurate tensile overload capacity of the tube at $3\Delta P_{NO}$ conditions (approximately 280 degrees arc length) are expected to be detectable using current eddy current techniques. The Plus Point amplitude responses for both of these would be substantially larger than the EDM notch response of the standard due to the SCC length at 100%TW. Therefore, circumferential degradation of the parent tube that could possibly influence the axial load transference capability of the tube is expected to be detected.

Conclusion

The above discussion supports a position that in service non destructive examination of the parent adjacent to the nickel band region of sleeve, for tubes with installed TIG or Alloy 800 sleeves is not required to support continued operability of the sleeved tube consistent with the original design requirements of the sleeve.