Enclosure 1

Revised Technical Specification Pages

4.4.6.4 Acceptance Criteria

a. As used in this Specification:

1. Imperfection means an exception to the dimensions, finish or contour of a tube or sleeve from that required by fabrication drawings or specifications. Eddy-current testing indications below 20% of the nominal wall thickness, if detectable, may be considered as imperfections.

2. Degradation means a service-induced cracking, wastage, wear or general corrosion occurring on either inside or outside of a tube or sleeve.

3. Degraded Tube means a tube, including the sleeve if the tube has been repaired, that contains imperfections greater than or equal to 20% of the nominal wall thickness caused by degradation.

4. % Degradation means the percentage of the tube or sleeve wall thickness affected or removed by degradation.

5. Defect means an imperfection of such severity that it exceeds the plugging or repair limit. A tube or sleeve containing a defect is defective.

6. Plugging or Repair Limit means the imperfection depth at or beyond which the tube shall be repaired (i.e., sleeved) or removed from service by plugging and is greater than or equal to 40% of the nominal tube wall thickness. For a tube that has been sleeved with a mechanical joint sleeve, through wall penetration of greater than or equal to 31% of sleeve nominal wall thickness in the sleeve requires the tube to be removed from service by plugging. For a tube that has been sleeved with a welded joint sleeve, through wall penetration greater than or equal to 37% of sleeve nominal wall thickness in the sleeve between the weld joints requires the tube to be removed from service by plugging. This definition does not apply to tube support plate intersections for which the voltage-based plugging criteria are being applied. Refer to 4.4.6.4.a.11 for the plugging limit applicable to these intersections.

For a tube with an imperfection or flaw in the tubesheet below the lower joint of an installed elevated laser welded sleeve, no repair or plugging is required provided the installed sleeve meets all sleeved tube inspection requirements

7. Unserviceable describes the condition of a tube or sleeve if it leaks or contains a defect large enough to affect its structural integrity in the event of an Operating Basis Earthquake, a loss-of-coolant accident, or a steam line or feedwater line break as specified in 4.4.6.3.c, above.

For a tube with a tube sheet sleeve installed, the point 'of entry' is the bottom of the tube sheet sleeve below the lower sleeve joint.

8. Tube Inspection means an inspection of the steam generator tube from the point of entry (hot leg side) completely around the U-bend to the top support of the cold leg. For a tube that has been repaired by sleeving, the tube inspection should include the sleeved portion of the tube.

9. Tube Repair refers to mechanical sleeving, as described by Westinghouse report WCAP-11178, Rev. 1, or laser welded sleeving, as described by Westinghouse report WCAP-12672, which is used to maintain a tube in service or return a tube to service. This includes the removal of plugs that were installed as a corrective or preventive measure.

or, for elevated sleeves, Southern Nuclear letters dated August 23, 1996, and November 6, 1996,

10. Preservice Inspection means an inspection of the full length of each tube in each steam generator performed by eddy current techniques prior to service to establish a baseline condition of the tubing. This inspection shall be performed after the field hydrostatic test and prior to initial POWER OPERATION using the equipment and techniques expected to be used during subsequent inservice inspections.

11. Tube Support Plate Plugging Limit is used for the disposition of a steam generator tube for continued service that is experiencing outside diameter stress corrosion cracking confined within the thickness of the tube support plates. These criteria are applicable for the fourteenth operating cycle only. At tube support plate intersections, the repair limit is based on maintaining steam generator tube serviceability as described below:

a. Degradation attributed to outside diameter stress corrosion cracking within the bounds of the tube support plate with bobbin voltage less than or equal to 2.0 volts will be allowed to remain in service.

b. Degradation attributed to outside diameter stress corrosion cracking within the bounds of the tube support plate with a bobbin voltage greater than 2.0 volts will be repaired or plugged except as noted in 4.4.6.4.a.11.c below.

c. Indications of potential degradation attributed to outside diameter stress corrosion cracking within the bounds of the tube support plate with a bobbin voltage greater than 2.0 volts but less than or equal to 5.6 volts may remain in service if a rotating pancake coil inspection does not detect degradation. Indications of outside diameter stress corrosion cracking degradation with a bobbin voltage greater than 5.6 volts will be plugged or repaired.

For a tube with an imperfection or flaw in the tube sheet below the lower joint of an installed elevated laser welded sleeve, no repair or plugging is required provided the installed sleeve meets all sleeved tube inspection requirements.

6. Plugging or Repair Limit means the imperfection depth at or beyond which the tube shall be repaired (i.e., sleeved) or removed from service by plugging and is greater than or equal to 40% of the nominal tube wall thickness. This definition does not apply for tubes that meet the F*/L*## criteria. For a tube that has been sleeved with a mechanical joint sleeve, through wall penetration of greater than or equal to 31% of sleeve nominal wall thickness in the sleeve requires the tube to be removed from service by plugging. For a tube that has been sleeved with a welded joint sleeve, through wall penetration greater than or equal to 37% of sleeve nominal wall thickness in the sleeve between the weld joints requires the tube to be removed from service by plugging. This definition does not apply to tube support plate intersections for which the voltage-based repair criteria are being applied. Refer to 4.4.6.4.a.16 for the repair limit applicable to these intersections.

7. Unserviceable describes the condition of a tube or sleeve if it leaks or contains a defect large enough to affect its structural integrity in the event of an Operating Basis Earthquake, a loss-of-coolant accident, or a steam line or feedwater line break as specified in 4.4.6.3.c, above.

For a tube with a tube sheet sleeve installed, the point of entry is the bottom of the tube sheet sleeve below the lower sleeve joint.

8. Tube Inspection means an inspection of the steam generator tube from the point of entry (hot leg side) completely around the U-bend to the top support of the cold leg. For a tube that has been repaired by sleeving, the tube inspection should include the sleeved portion of the tube.

9. Tube Repair refers to mechanical sleeving, as described by Westinghouse report WCAP-11178, Rev. 1, or laser welded sleeving as described by Westinghouse report WCAP-12672, which is used to maintain a tube in service or return a tube to service. This includes the removal of plugs that were installed as a corrective or preventive measure.

, or, for elevated sleeves, Southern Nuclear letters dated August 23, 1996 and November 6, 1996

L* Criteria is applicable to Cycle 11 only.

15. Tube Expansion is that portion of a tube which has been increased in diameter by a rolling process such that no crevice exists between the outside diameter of the tube and the hole in the tubesheet.

16. Tube Support Plate Repair Limit is used for the disposition of an alloy 600 steam generator tube for continued service that is experiencing predominately axially oriented outside diameter stress corrosion cracking confined within the thickness of the tube support plates. At tube support plate intersections, the repair limit is based on maintaining steam generator tube serviceability as described below:

a. Steam generator tubes, whose degradation is attributed to outside diameter stress corrosion cracking within the bounds of the tube support plate with bobbin voltages less than or equal to the lower voltage repair limit [2.0 volts], will be allowed to remain in service.

b. Steam generator tubes, whose degradation is attributed to outside diameter stress corrosion cracking within the bounds of the tube support plate with a bobbin voltage greater than the lower voltage repair limit [2.0 volts], will be repaired or plugged except as noted in 4.4.6.4.a.16.c below.

c. Steam generator tubes, with indications of potential degradation attributed to outside diameter stress corrosion cracking within the bounds of the tube support plate with a bobbin voltage greater than the lower voltage repair limit [2.0 volts] but less than or equal to the upper voltage repair limit*, may remain in service if a rotating probe inspection does not detect degradation. Steam generator tubes, with indications of outside diameter stress corrosion cracking degradation with a bobbin voltage greater than the upper voltage repair limit*, will be plugged or repaired.

Tube expansion also refers to that portion of a sleeve which has been increased in diameter by a rolling process such that no crevice exists between the outside diameter of the sleeve and the parent steam generator tube.

* The upper voltage repair limit is calculated according to the methodology in Generic Letter 95-05 as supplemented.

4.4.6.4 Acceptance Criteria

a. As used in this Specification:

1. Imperfection means an exception to the dimensions, finish or contour of a tube or sleeve from that required by fabrication drawings or specifications. Eddy-current testing indications below 20% of the nominal wall thickness, if detectable, may be considered as imperfections.

2. Degradation means a service-induced cracking, wastage, wear or general corrosion occurring on either inside or outside of a tube or sleeve.

3. Degraded Tube means a tube, including the sleeve if the tube has been repaired, that contains imperfections greater than or equal to 20% of the nominal wall thickness caused by degradation.

4. % Degradation means the percentage of the tube or sleeve wall thickness affected or removed by degradation.

5. Defect means an imperfection of such severity that it exceeds the plugging or repair limit. A tube or sleeve containing a defect is defective.

6. Plugging or Repair Limit means the imperfection depth at or beyond which the tube shall be repaired (i.e., sleeved) or removed from service by plugging and is greater than or equal to 40% of the nominal tube wall thickness. For a tube that has been sleeved with a mechanical joint sleeve, through wall penetration of greater than or equal to 31% of sleeve nominal wall thickness in the sleeve requires the tube to be removed from service by plugging. For a tube that has been sleeved with a welded joint sleeve, through wall penetration greater than or equal to 37% of sleeve nominal wall thickness in the sleeve between the weld joints requires the tube to be removed from service by plugging. This definition does not apply to tube support plate intersections for which the voltage-based plugging criteria are being applied. Refer to 4.4.6.4.a.11 for the plugging limit applicable to these intersections. For a tube with an imperfection or flaw in the tube sheet below the lower joint of an installed elevated laser welded sleeve, no repair or plugging is required provided the installed sleeve meets all sleeved tube inspection requirements.

7. Unserviceable describes the condition of a tube or sleeve if it leaks or contains a defect large enough to affect its structural integrity in the event of an Operating Basis Earthquake, a loss-of-coolant accident, or a steam line or feedwater line break as specified in 4.4.6.3.c, above.

8. Tube Inspection means an inspection of the steam generator tube from the point of entry (hot leg side) completely around the U-bend to the top support of the cold leg. For a tube with a tubesheet sleeve installed, the point of entry is the bottom of the tube sheet sleeve below the lower sleeve joint. For a tube that has been repaired by sleeving, the tube inspection should include the sleeved portion of the tube.

9. Tube Repair refers to mechanical sleeving, as described by Westinghouse report WCAP-11178, Rev. 1, or laser welded sleeving, as described by Westinghouse report WCAP-12672, or, for elevated sleeves, Southern Nuclear letters dated August 23, 1996 and November 6, 1996, which is used to maintain a tube in service or return a tube to service. This includes the removal of plugs that were installed as a corrective or preventive measure.

10. Preservice Inspection means an inspection of the full length of each tube in each steam generator performed by eddy current techniques prior to service to establish a baseline condition of the tubing. This inspection shall be performed after the field hydrostatic test and prior to initial POWER OPERATION using the equipment and techniques expected to be used during subsequent inservice inspections.

11. Tube Support Plate Plugging Limit is used for the disposition of a steam generator tube for continued service that is experiencing outside diameter stress corrosion cracking confined within the thickness of the tube support plates. These criteria are applicable for the Fourteenth operating cycle only. At tube support plate intersections, the repair limit is based on maintaining steam generator tube serviceability as described below:

    a. Degradation attributed to outside diameter stress corrosion cracking within the bounds of the tube support plate with bobbin voltage less than or equal to 2.0 volts will be allowed to remain in service.

    b. Degradation attributed to outside diameter stress corrosion cracking within the bounds of the tube support plate with a bobbin voltage greater than 2.0 volts will be repaired or plugged except as noted in 4.4.6.4.a.11.c below.

    c. Indications of potential degradation attributed to outside diameter stress corrosion cracking within the bounds of the tube support plate with a bobbin voltage greater than 2.0 volts but less than or equal to 5.6 volts may remain in service if a rotating pancake coil inspection does not detect degradation. Indications of outside diameter stress corrosion cracking degradation with a bobbin voltage greater than 5.6 volts will be plugged or repaired.

6. Plugging or Repair Limit means the imperfection depth at or beyond which the tube shall be repaired (i.e., sleeved) or removed from service by plugging and is greater than or equal to 40% of the nominal tube wall thickness. This definition does not apply for tubes that meet the F*/L*## criteria. For a tube that has been sleeved with a mechanical joint sleeve, through wall penetration of greater than or equal to 31% of sleeve nominal wall thickness in the sleeve requires the tube to be removed from service by plugging. For a tube that has been sleeved with a welded joint sleeve, through wall penetration greater than or equal to 37% of sleeve nominal wall thickness in the sleeve between the weld joints requires the tube to be removed from service by plugging. This definition does not apply to tube support plate intersections for which the voltage-based repair criteria are being applied. Refer to 4.4.6.4.a.16 for the repair limit applicable to these intersections. For a tube with an imperfection or flaw in the tubesheet below the lower joint of an installed elevated laser welded sleeve, no repair or plugging is required provided the installed sleeve meets all sleeved tube inspection requirements.

7. Unserviceable describes the condition of a tube or sleeve if it leaks or contains a defect large enough to affect its structural integrity in the event of an Operating Basis Earthquake, a loss-of-coolant accident, or a steam line or feedwater line break as specified in 4.4.6.3.c, above.

8. Tube Inspection means an inspection of the steam generator tube from the point of entry (hot leg side) completely around the U-bend to the top support of the cold leg. For a tube with a tube sheet sleeve installed, the point of entry is the bottom of the tube sheet sleeve below the lower sleeve joint. For a tube that has been repaired by sleeving, the tube inspection should include the sleeved portion of the tube.

9. Tube Repair refers to mechanical sleeving, as described by Westinghouse report WCAP-11178, Rev. 1, or laser welded sleeving as described by Westinghouse report WCAP-12672, or, for elevated sleeves, Southern Nuclear letters dated August 23, 1996 and November 6, 1996, which is used to maintain a tube in service or return a tube to service. This includes the removal of plugs that were installed as a corrective or preventive measure.

L* Criteria is applicable to Cycle 11 only.

15. Tube Expansion is that portion of a tube which has been increased in diameter by a rolling process such that no crevice exists between the outside diameter of the tube and the hole in the tubesheet. Tube expansion also refers to that portion of a sleeve which has been increased in diameter by a rolling process such that no crevice exists between the outside diameter of the sleeve and the parent steam generator tube.

16. Tube Support Plate Repair Limit is used for the disposition of an alloy 600 steam generator tube for continued service that is experiencing predominately axially oriented outside diameter stress corrosion cracking confined within the thickness of the tube support plates. At tube support plate intersections, the repair limit is based on maintaining steam generator tube serviceability as described below:

    a. Steam generator tubes, whose degradation is attributed to outside diameter stress corrosion cracking within the bounds of the tube support plate with bobbin voltages less than or equal to the lower voltage repair limit [2.0 volts], will be allowed to remain in service.

    b. Steam generator tubes, whose degradation is attributed to outside diameter stress corrosion cracking within the bounds of the tube support plate with a bobbin voltage greater than the lower voltage repair limit [2.0 volts], will be repaired or plugged except as noted in 4.4.6.4.a.16.c below.

    c. Steam generator tubes, with indications of potential degradation attributed to outside diameter stress corrosion cracking within the bounds of the tube support plate with a bobbin voltage greater than the lower voltage repair limit [2.0 volts] but less than or equal to the upper voltage repair limit*, may remain in service if a rotating probe inspection does not detect degradation. Steam generator tubes, with indications of outside diameter stress corrosion cracking degradation with a bobbin voltage greater than the upper voltage repair limit*, will be plugged or repaired.

* The upper voltage repair limit is calculated according to the methodology in Generic Letter 95-05 as supplemented.

Enclosure 2

Westinghouse letter NSD-JLH-6202, Summary of Farley LWS Lower Joint Development - TM & C Qualification /Testing, dated June 25, 1996

JUN 28 NSD-JLH-6202

FROM: Steam Generator Design and Analysis
WIN: 224-5689
DATE: June 25, 1996

SUBJECT: SUMMARY OF FARLEY LWS LOWER JOINT DEVELOPMENT - TASK C QUALIFICATION TESTING

To: G.Whiteman
Cc: B.Nair L.Markle ECW232D D.Kaniowski
R.Gold

References:

1. Letter ALA-96-527, W, D.Kaniowski, to D.Morey, Southern Nuclear Operating Company, "Southern Nuclear Operating Company Joseph M.Farley Nuclear Plant Units 1 and 2 Elevated and Tube Mouth LWS Lower Joint Development", 3/5/96

2. STD-QP-1996-7740 Rev. 0, Farley Laser Welded Elevated Tubesheet Sleeve: Lower Hard Roll Qualification Procedure, 5/96

3. Handout at Southern Nuclear Operating Company-Westinghouse Meeting at Pittsburgh, L.A. Nelson, 3/16/96

4. Letter NSD-JLH-6135, Summary of Farley LWS Lower Joint Development - Task C Scoping Testing, 4/30/96

5. WCAP-11178, J.M.Farley Units 1 and 2 Steam Generator Sleeving Report - Mechanical Sleeves, 5/86

6. Letter, NSD-JLH-6209, Farley ETS Contact Pressures, A.Thurman, to L.Nelson, 6/26/96

This letter summarizes the qualification of the lower joint for sleeves elevated in the tubesheet (ETSs) for Farley Unit 1. This task is shown in the first three references as Task C.

Background:

Reference 1 provided the technical description of a program to develop three mechanical interference fit (MIF), two-roll-pass, non-welded sleeve lower joints. One of the MIF joints will be used for full length tubesheet sleeves (FLTSs) and two will be used with ETSs. Both types of sleeves will be used in both units. The engineering part of this program is being performed in four tasks. (There is a separate part of this program, i.e., the licensing information such as the Safety Evaluation Checklist, being performed by Regulatory and Licensing Initiatives {Nuclear Safety.})

Task C, the subject of this communication, is being performed first and it addresses the lower joint in Unit 1 for a tube which is undegraded in the joint area. (Degradation of a tube in the joint area is defined as tube ID corrosion at the elevation of the portion of the joint which provides the pullout and leakage resistance, i.e, the roll expansion.)

Development of the lower joint for this ETS is based on selection of the "roll last" sleeve installation sequence. In this sequence, the sleeve-to-tube weld is performed before the lower joint roll expansion. Based on development of previous elevated joints for laser welded sleeves (LWSs), the "roll first" sequence was known to produce lower joints of greater tightness than those made by the reverse of this sequence, i.e., by the "roll last" sequence. The roll last sequence was selected because installation productivity for that sequence is higher than for the roll first sequence. In the roll last sequence, the sleeve is immobilized by the weld earlier in the process, thereby facilitating some of the subsequent process steps. In the two-roll-pass process selected for this design, the lower elevation pass is performed first, followed by the upper pass.

Reference 2, the procedure written for the qualification test, specifies criteria for three types of tests for the lower joint, 1) primary-to-secondary leak resistance testing, 2) secondary-to-primary "onset of significant leakage testing" (OSL) and 3) sleeve pullout testing. The purpose of the primary-to-secondary leak resistance testing is to determine the leakage for normal operation, for feedline break/steamline break (FLB/SLB) and for a higher pressure which approximates the SG initial primary side hydrostatic pressure test. The secondary-to-primary OSL test is performed to determine the sleeve-to-tube interference fit radial contact pressure (CP). It involves the use of fluid pressure to determine the MIF, "metal-to-metal" pressure, or simply, "metal" pressure, between the sleeve and tube. At the pressure level where the fluid pressure equals the metal pressure, and in the absence of significant axial scratches or other axially linear degradation on the sleeve OD and/or on the tube ID in the roll expansion, significant leakage will occur. The higher pressures used in this test are far higher than any pressures in the SG during any Technical Specification condition. The MIF pressure is multiplied by the area of contact of the sleeve with the tube and by the appropriate coefficient of friction, based on pullout tests for this joint and on previous tests for the same materials, to provide the sleeve pullout resistance.

Sleeve pullout testing is a direct determination of the resistance to pullout of the sleeve joint.

Design Aspects of Lower Joint:

For the sake of commonality, it is desirable that all three of the FLTS and ETS lower joints be of the same axial length. On this premise, the effective axial length of the joints would be determined by the axial space available in the vicinity of the tubemouth of Unit 1. (The effective length of a roll expanded joint is the finished axial length of the inner structure {for instance, sleeve} which is in high pressure contact with the outer structure {for instance, tube}. In this example the finished, rolled, inside surface or diameter (ID) of the sleeve will be essentially uniform throughout the effective length; the transitions from the expanded {rolled} to the unexpanded {non-rolled} portions of the sleeve are excluded.) Therefore, the sleeve roll common effective length for the entire project would be essentially limited by the length of the tube partial depth roll expansion of Unit 1.

This is because a uniform sleeve ID will generally be unattainable if the effective length is partially placed in the factory rolled portion and partially in the explosive expanded (WEXTEX-ed", or simply WEXTEX) portion. The nominal axial length of the Unit 1 tube factory roll expansion is 2.75 inches. However, part of that length was rolled to a small amount of thinning and part of that portion is also below the bottom face of the tubesheet and adds a smaller amount of integrity, compared to the hardrolled portion of the tube, to the sleeve-to-tube joint. Therefore, the actual effective length of the sleeve-to-tube joint is limited to approximately 2.56 inches and 0.125 inch was subtracted from that to accommodate variability in the 2.75 inch nominal, tube factory roll, value. Therefore, the actual maximum effective length of the sleeve joint is approximately 2.43 inches. Above the factory roll length, the remainder of the tube within the tubesheet hole of Unit 1 was WEXTEX-ed. The tube wall in the roll portion is thinned several percent; the tube wall in the WEXTEX portion is thinned to a lesser extent. Similarly, the rolled portion was coldworked to a certain extent in the factory; the WEXTEX portion was coldworked to a lesser extent. Due to the difference between these two processes, and especially due to the differing resulting IDs, it is good practice to avoid attempting to make a higher integrity MIF joint by locating it partly in both portions of the tube and that's why the sleeve joint will be located in the rolled portion.

The elevated joints of both units are not limited in axial effective length by being in two different types of factory joints. In Unit 1, the elevated joint will be completely within the WEXTEX; in Unit 2, the elevated joint will be completely within the factory tube roll expansion. Therefore, although there are implementation advantages of a common joint length, there were compelling reasons to make the elevated joints somewhat longer than the joints in the vicinity of the tubemouth. The effective length of the elevated joints is 2.65 inches.

Everything else being equal, it is expected that the integrity of the joint installed in a WEXTEX tube, the subject of this task, will be higher than in a rolled tube. Therefore, the performance of the joint made in the WEXTEX tube is expected to bound the performance of the same joint made in a rolled tube and the roll last, undegraded, factory rolled tube configuration was not scheduled for testing. (The "same" joint is defined as the joint made using the same roll expander, torque, roller rpm, roll pass sequence, effective length, as well as tube, tubesheet and sleeve material and strength parameters.)

Primary Side Testing:

Rolled Joint Geometry and Torque:

A larger amount of coldwork is required to minimize primary-to-secondary leakage in this joint because of the lack of coldwork in the WEXTEX tube. The large amount of coldwork can be best accomplished with a high-coldwork roller and a high torque. Everything else being equal, a three-pin rolling tool provides significantly more coldwork per unit of torque than a four-pin tool.

A roll expansion torque of 145 inch-lbs. was selected as the nominal value. This selection was based on the results of "scoping" tests documented in Ref. 4. The "nominal" torque is bounded by a range of +/- 10 inch-lbs. This torque is applied to a three pin roll expander having an effective rolling length of 2.00 inches. Two rolling passes were made with a roller overlap of 0.75 inch. The nominal rolled joint is made with the top of the upper roll pass positioned 2.65 inches above the top of the sleeve eddy current taper, thus producing an effective length of 2.65 inches. This roll expander positioning leaves 0.60 inch of the roller extending below the sleeve eddy current taper during the initial roll pass. This rolled joint geometry is identified as "2.0/1.4-2.65" on the attached test data sheets.

A small number of tests were made with rollers having an effective rolling length of 1.4 inches, and an overlap of 0.15 inch. Not a baseline geometry, leak test results for these joints, identified as "1.4/1.4-2.65", are listed for comparison, but are not included in the data averages. Individual test samples were also made using a single pass with a 1.4 inch roller, two rolling passes at a 120 inch-lb. roller torque setting, and an "embedded roller" condition producing a joint having an effective rolled height of 3.15 inches. Leak test results for these joints are listed for comparison, but are not included in the data averages.

Primary-to-Secondary Side Leakage Testing:

Twenty three primary-to-secondary side "process qualification" leak tests were performed using a total of 19 test samples. Because the primary side testing tends to be non-destructive of the samples, four of the test samples were rerolled at a higher torque, and leak tested a second time. All samples exhibited small amounts of leakage.

Leak test results should be compared with the leak rate criteria value of 0.500 drops per minute per sleeve (dpm) specified in Ref. 2.[(1)] (There are approximately 75,000 drops in one gallon.) The maximum leakage recorded at the primary-to-secondary differential pressure applicable to normal operation (1900 psi) was 0.100 dpm for the "nominal" tubesheet hole diameter (as compared with an overall average leak rate value of 0.045 dpm). The maximum leakage recorded at the primary-to-secondary differential pressure applicable to normal operation (1900 psi)[(2)] was 0.160 dpm for the "maximum" tubesheet

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(1) This leakage criterion is conservatively taken as a fraction of the leakage criterion proposed in Ref. 1. The criterion proposed is an average of 1.22 dpm per sleeve, an arbitrary allocation of one-third of the 140 gallon per day (gpd) primary-to-secondary Technical Specifications limit, apportioned to 2,000 of these sleeves per SG. The 140 gpd limit applies to the bounding unit, Unit 1; the Unit 2 limit is 150 gpd.

(2) This pressure differential is used as the normal operation {N.Op.} value; it is used in this room temperature test so that direct comparisons (not shown here) can be made with data previously recorded at prototypical temperatures for the N.Op. condition for tubemouth joints. The 1900 psi primary side pressure resulted in the water being subcooled as it entered the potential leak path between the sleeve and tube. In some previous testing, two-phase entering flows potentially caused inaccuracies. These potential inaccuracies were avoided in this testing. All leak testing was performed at room temperature. This has been determined to be conservative, relative to prototypical, elevated temperatures, due to a lack of beneficial effects for joint integrity at room temperature. This effect is shown for the sleeve lower joints in Ref. 5, a joint which is very similar to this joint.

hole diameter (as compared with an overall average leak rate value of 0.056 dpm).

The following test geometries and torque values are well outside the tolerance band, but are presented as an indication of the overall effectiveness of the "baseline" joint. The low torque value of 120 inch-lbs produced a leak rate of 0.062 dpm at 1900 psi. The short (2.15 inch roll height) setups produced leak rates of 0.056 and 0.042 dpm at 1900 psi. The embedded (3.15 inch roll height) setup produced a leak rate of 0.094 dpm at 1900 psi. A single 1.4 inch roll pass produced a leak rate of 0.118 dpm at 1900 psi.

In the laboratory room temperature leakage testing, the most stringent location in the tubesheet, where the upward bending causes the most tubesheet hole dilation, 0.65 inch below the elevation of the sleeve joint top, was addressed. In this testing, the thermal growth mismatch contribution to increasing contact pressure and the decrease in contact pressure due to tubesheet bending loosening, in going from the as-installed condition to normal operation (N.Op.), were absent. The differential pressure tightening was present. Therefore, the test joint was approximately (788 - 895 = -107 psi) 107 psi "too tight". This is a non-conservative effect. However, the 107 psi is a small fraction of the average as-installed interference fit contact pressure, expected to approximate 5,000 psi, plus the 788 psi N.Op. effects, for a total contact pressure of approximately 5,788 psi; the 107 psi is less than 2.0 percent of this value. Therefore the effect on leak resistance would be negligible and no adjustment needs to be made in leakage prediction. (The as-installed contact pressure, 5,000 psi, the average of all of the OSL testing, is shown in the appropriate section below.)

Contributions to Sleeve-to-Tube Contact Pressure
for
Comparison of Laboratory Test Configuration with Plant Configuration

Parameter	*Contact Pressure, psi	Note
Thermal growth mismatch	+921	Beneficial effect
Differential pressure tightening	+1033	"
Tubesheet bow loosening	-1166	Detrimental effect
Net Effect	+788	

* Location in tubesheet: At maximum-rotation radius from bundle vertical centerline, 0.65 inch below top of sleeve joint. See Reference 6.

Leakage Testing Conclusions:

A torque of 145 +/- 10 inch-lbs is suitable, based on minimization of primary-to-secondary leakage.

Pullout Testing:

Pullout test results should be compared with the criteria of the larger of three times the maximum endcap load during normal operation, ($3\Delta P$) or 1.43 times the endcap load during FLB/SLB. The larger of these two loads is usually the N.Op. case and for this summary, this load will be used for comparison with the test results. For this plant, the maximum N.Op. pressure differential is 1506 psi; therefore, the maximum endcap load during N.Op. is approximately 2,892 lbs. Six pullout test samples were fabricated, all at torque values of 145 inch-lbs. All of the four samples rolled at the 2.0/1.4-2.65 had pullout "breakaway" values between 3,850 and 4,150 lbs. force. The "short" sample rolled at 2.0/1.4-2.15 had a breakaway of 3,250 lbs. force, while the "embedded" sample rolled at 2.0/1.4-3.15 had a breakaway of 4,150 lbs. force. All of these test values exceeded the criterion of approximately 2,892 lbs. There is ample margin in this design, as determined by direct pullout testing, insofar as pullout resistance is concerned.

The testing was performed on sleeve/tube/tubesheet unit cells (collars) at ambient pressure and room temperature In the RT testing, all of the N.Op. effects, i.e., the +921 psi for thermal growth mismatch, the +1033 psi for differential pressure tightening and the -1166 psi for tubesheet bow loosening, were absent. Therefore, the test joint was "too loose" relative to the plant condition; this is a conservative effect. The joint would have more resistance to pullout in the plant than in the laboratory. Refer to the contact pressure table above.

Onset of Significant Leakage (Contact Pressure) Testing:

Secondary Side Pressure Testing:

Secondary Side leak testing does not prototype any operating condition, but is performed to determine, conservatively, the interfacial contact pressure between the rolled sleeve and the tube. These results are then used to calculate sleeve rolled joint pullout forces. As the interfacial contact pressure of the rolled portion of the sleeve is approached, a significant increase in leak rate will be observed. In this type of test, the leak test pressures are raised to exceed the collapse pressure of the sleeve away from the roll expansion, collapse initiates and propagates to the rolled portion of the joint, resulting in premature failure of the joint. In order to remove this artifact of the test method and to measure the OSL, the current test uses a loose fitting internal plug to reinforce the sleeve in the region away from the rolled joint. This prevents the interference of collapse with measurement of joint integrity. The summaries of the results are shown below.

The minimum interfacial contact pressure value is calculated on the basis of a coefficient of friction of 0.2, a typical large tube ID of 0.800 inch and the $3\Delta P$ value of 2,892 lbs (from above). The resulting minimum allowable contact pressure value is approximately 2,171 psi. (The consideration of end effects on the sleeve portion in contact with the tube in the joint would increase the 2,171 psi slightly, reducing the ample margin slightly.) The test results are summarized below.

Onset of Significant Leakage (Sleeve-to-Tube Contact Pressure)
For
Nominal Diameter Tubesheet Hole Sizes:

Torque, inch-lbs.	OSL, psi, Minimum	Note:
135	All >5,000	
145	One 4,000 & one >5,000	-Nominal torque case -4,000 psi case was out of range; with a short effective roll length
155	All >5,000	

Onset of Significant Leakage (Sleeve-to-Tube Contact Pressure)
For
Maximum Diameter Tubesheet Hole Sizes:

Torque, inch-lbs.	OSL, psi, Minimum	Note:
135	One >4,500, Two @ 5,500	
145	One 4,000 & two @ >5,500	Nominal torque case
155	All >5,000	

All secondary side OSL test values exceed the limiting criterion value by a wide margin.

Conclusion on Contact Pressure Qualification Test Results:

Adequate pullout resistance, with adequate margin, will be provided by this joint at the nominal torque, 145 inch-lbs and within the torque range of 135 through 155 inch-lbs.

Conclusion on Leakage and Contact Pressure Qualification Test Results:

The test results show that the "2.0/1.4-2.65" joint identified above meets all design criteria. It is to be installed with the specific roll expander used in the qualification and a roll torque value of 145 inch-lbs. +/- 10 inch-lbs.

If you have any comments on this summary, please contact us ASAP.

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SG Design and Analysis

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snctest.135/laprcfal

Farley MIF AWT Task C Qual Test Results

Item	Ident.	Appar. W/T	Technique	Force	Elev. for AWT meas.	Roll Ht.	1910 psi leak: dpm	Primary 2650 psi leak: dpm	3110 psi leak: dpm	3110 psi leak: dpm	4000 psi leak: dpm	4500 psi leak: dpm	Secondary 5000 psi leak: dpm	Leak 5500 psi leak: dpm	6000 psi leak: dpm
Collar	lt. 1 unit 9														
Tube	8161-29	0.7618	Tube Hyd.	30114 psi											
Sleeve	48017-7	3.2061	Slv. Hyd.	15040 psi											
Sleeve	48017-7	6.4238	Slv. Roll	135 in.#	1.5										
Sleeve	48017-7	4.5695	Slv. Roll	135 in.#	2.5	1.4/1.4-2.65	0.020	0.020	0.020	0.050	0.044	0.050	0.058	OSL	
Sleeve	48017-7	6.2914	Re-Roll	155 in.#	1.5										
Sleeve	48017-7	4.9669	Re-Roll	155 in.#	2.5	2.0/1.4-2.65	0.022	0.036	0.034	0.022	0.036	0.036	0.036	0.054	OSL
Collar	lt. 1 unit 10														
Tube	9482-46	0.8008	Tube Hyd.	30037 psi											
Sleeve	48017-32	2.1560	Slv. Hyd.	15011 psi											
Sleeve	48017-32	5.3143	Slv. Roll	135 in.# wm	1.5										
Sleeve	48017-32	4.7959	Slv. Roll	135 in.# wm	2.5	2.0/1.4-2.65	0.018	0.020	0.020	0.020	0.024	0.028	0.040	OSL	
Collar	lt. 1 unit 11														
Tube	8161-32	-0.1783	Tube Hyd.	30036 psi											
Sleeve	48017-20	3.0013	Slv. Hyd.	15019 psi											
Sleeve	48017-20	4.0816	Slv. Roll	120 in.#	1.5										
Sleeve	48017-20	3.6866	Slv. Roll	120 in.#	2.5	1.4/1.4-2.65	0.032	0.060	0.086	0.116	0.178	0.744	OSL		
Sleeve	48017-20	5.0033	Re-Roll	145 in.#	1.5										
Sleeve	48017-20	4.6063	Re-Roll	145 in.#	2.5	2.0/1.4-2.65	0.050	0.060	0.062	0.072	0.116	0.140	0.188	OSL	
Collar	lt. 1 unit 12														
Tube	8161-30	1.5136	Tube Hyd.	30200 psi											
Sleeve	48017-21	2.8061	Slv. Hyd.	15031 psi											
Sleeve	48017-21	4.7244	Slv. Roll	145 in.#	1.5										
Sleeve	48017-21	4.5932	Slv. Roll	145 in.#	2.5	2.0/1.4-2.65	0.040	0.054	0.056	0.062	0.094	0.098	'Pull Test' breakaway - 4150 # force		
Collar	lt. 1 unit 13														
Tube	8161-33	1.5986	Tube Hyd.	30400 psi											
Sleeve	48017-24	2.5840	Slv. Hyd.	15088 psi											
Sleeve	48017-24	3.5146	Slv. Roll	145 in.#	1.5										
Sleeve	48017-24	2.1883	Slv. Roll	145 in.#	2.5	2.0/1.4-2.15	0.056	0.062	0.072	0.136	OSL		'Pull Test' breakaway - 3250 # force		
Collar	lt. 1 unit 14														
Tube	7368-30	1.4313	Tube Hyd.	30051 psi											
Sleeve	48017-26	2.1907	Slv. Hyd.	15033 psi											
Sleeve	48017-26	5.2989	Slv. Roll	145 in.# wm	1.5										
Sleeve	48017-26	5.1383	Slv. Roll	145 in.# wm	2.5	2.0/1.4-2.65	0.020	0.024	0.028	0.046	0.076		'Pull Test' breakaway - 4150 # force		
Collar	lt. 1 unit 15														
Tube	7368-31	0.5251	Tube Hyd.	30065 psi											
Sleeve	48017-28	3.5646	Slv. Hyd.	15041 psi											
Sleeve	48017-28	6.2706	Slv. Roll	135 in.# w	1.5										
Sleeve	48017-28	4.5545	Slv. Roll	135 in.# w	2.5	2.0/1.4-2.65	0.036	0.048	0.050	0.060	0.060	0.062	0.080	OSL	

Farley MIF AWT Task C Qual Test Results

Item	Ident.	Apper. W/T	Technique	Force	Elev. for AWT meas.	Roll Ht.	Primary 1910 psi leak: dpm	2850 psi leak: dpm	3110 psi leak: dpm	3110 psi leak: dpm	4000 psi leak: dpm	4500 psi leak: dpm	Secondary 5000 psi leak: dpm	Leak 5500 psi leak: dpm	6000 psi leak: dpm
Collar	lt. 1 unit 16														
Tube	7368-32	0.6926	Tube Hyd.	30061 psi											
Sleeve	48017-30	0.3628	Slv. Hyd.	15012 psi											
Sleeve	48017-30	6.6667	Slv. Roll	155 in. # w	1.5										
Sleeve	48017-30	5.0625	Slv. Roll	155 in. # w	2.5	2.0/1.4-2.65	0.064	0.062	0.074	0.054	0.076	0.078	0.098	OSL	
Collar	lt. 1 unit 18														
Tube	9482-41	1.7910	Tube Hyd.	30021 psi											
Sleeve	48017-33	2.0992	Slv. Hyd.	15051 psi											
Sleeve	48017-33	5.9779	Slv. Roll	155 in.# wm	1.5										
Sleeve	48017-33	5.0682	Slv. Roll	155 in.# wm	2.5	2.0/1.4-2.65	0.100	0.134	0.226	0.028	0.030	0.028	0.032	0.072	0.140
		5.2338	Average all 135 in.# 2.0/1.4 rolls				0.027	0.034	0.036	0.040	0.042	0.045	0.060		
		4.3837	Average all 145 in.# 2.0/1.4 rolls				0.042	0.050	0.055	0.080	0.095	0.119	0.047		
		5.6756	Average all 155 in.# 2.0/1.4 rolls				0.062	0.077	0.111	0.035	0.047	0.047	0.055		
		5.0032	Average all 'Nominal' 2.0/1.4 rolls				0.045	0.056	0.069	0.056	0.064	0.067	0.079		

Farley MIF AWT Task C Qual Test Results

Item	Ident.	Apper. W/T	Technique	Force	Elev. for AWT meas.	Roll Ht.	1910 psi leak: dpm	Primary 2650 psi leak: dpm	3110 psi leak: dpm	3110 psi leak: dpm	4000 psi leak: dpm	4500 psi leak: dpm	Secondary 5000 psi leak: dpm	Leak 5500 psi leak: dpm	6000 psi leak: dpm
Collar	It. 2 unit 9														
Tube	7368-29	1.5480	Tube Hyd.	30006 psi											
Sleeve	48017-18	3.9591	Slv. Hyd.	15028 psi											
Sleeve	48017-18	6.3165	Slv. Roll	135 in.#	1.5										
Sleeve	48017-18	6.3165	Slv. Roll	135 in.#	2.5	1.4/1.4-2.65	0.036	0.022	0.022	0.028	0.050	0.050	0.054	OSL	
Sleeve	48017-18	6.7154	Re-Roll	155 in.#	1.5										
Sleeve	48017-18	6.0505	Re-Roll	155 in.#	2.5	2.0/1.4-2.65	0.030	0.040	0.042	0.038	0.060	0.064	0.080	0.134	OSL
Collar	It. 2 unit 10														
Tube	7368-33	0.8795	Tube Hyd.	30009 psi											
Sleeve	48017-19	5.4313	Slv. Hyd.	15062 psi											
Sleeve	48017-19	4.1892	Slv. Roll	145 in.#	1.5										
Sleeve	48017-19	4.3243	Slv. Roll	145 in.#	2.5	2.0/1.4-2.65	0.070	0.084	0.090	0.182	OSL		'Pull Test' breakaway - 3650 # force		
Collar	It. 2 unit 11														
Tube	7368-34	1.6393	Tube Hyd.	30098 psi											
Sleeve	48017-22	3.8486	Slv. Hyd.	15113 psi											
Sleeve	48017-22	5.6037	Slv. Roll	145 in.# w	1.5										
Sleeve	48017-22	4.5364	Slv. Roll	145 in.# w	2.5	2.0/1.4-3.15	0.094	0.118	0.118	0.150	0.232		'Pull Test' breakaway - 4150 # force		
Collar	It. 2 unit 12														
Tube	7368-35	0.4092	Tube Hyd.	30127											
Sleeve	48017-23	4.5830	Slv. Hyd.	15036 psi											
Sleeve	48017-23	1.8865	Slv. Roll	145 in.#	1.5										
Sleeve	48017-23	5.3872	Slv. Roll	145 in.#	2.5	/1.4 - 1.4	0.118	0.102	0.104	0.104	0.152	0.246	OSL		
Sleeve	48017-23	5.2525	Re-Roll	145 in.#	1.5										
Sleeve	48017-23	5.3872	Re-Roll	145 in.#	2.5	2.0/1.4-2.65	0.160	0.200	0.196	0.186	0.300	0.400	0.520	OSL	
Collar	It. 2 unit 13														
Tube	7368-36	1.2123	Tube Hyd.	30286 psi											
Sleeve	48017-25	3.8168	Slv. Hyd.	15078 psi											
Sleeve	48017-25	5.4894	Slv. Roll	145 in.#	1.5										
Sleeve	48017-25	5.7540	Slv. Roll	145 in.#	2.2	1.4/1.4-2.15	0.042	0.042	0.040	0.050	0.080	0.078	0.112	OSL	
Collar	It. 2 unit 14														
Tube	7368-34	1.5001	Tube Hyd.	30204 psi											
Sleeve	48017-27	3.8363	Slv. Hyd.	15065 psi											
Sleeve	48017-27	5.7181	Slv. Roll	135 in.# w	1.5										
Sleeve	48017-27	4.5213	Slv. Roll	135 in.# w	2.5	2.0/1.4-2.65	0.064	0.080	0.096	0.126	0.196	OSL			
Collar	It. 2 unit 15														
Tube	7368-35	0.4288	Tube Hyd.	30065 psi											
Sleeve	48017-29	3.2010	Slv. Hyd.	15028 psi											
Sleeve	48017-29	5.6217	Slv. Roll	155 in.# w	1.5										
Sleeve	48017-29	4.8280	Slv. Roll	155 in.# w	2.5	2.0/1.4-2.65	0.034	0.036	0.036	0.044	0.056	0.056	0.074	OSL	

Farley MIF AWT Task C Qual Test Results

Item	Ident.	Apper. W/T	Technique	Force	Elev. for AWT meas.	Roll Ht.	1910 psi leak: dpm	Primary 2650 psi leak: dpm	3110 psi leak: dpm	3110 psi leak: dpm	4000 psi leak: dpm	4500 psi leak: dpm	Secondary 5000 psi leak: dpm	Leak 5500 psi leak: dpm	6000 psi leak: dpm
Collar	lt. 2 unit 16														
Tube	7368-36	0.8277	Tube Hyd.	30073 psi											
Sleeve	48017-31	4.0281	Slv. Hyd.	15109 psi											
Sleeve	48017-31	5.2632	Slv. Roll	145 in.# wm	1.5										
Sleeve	48017-31	4.7302	Slv. Roll	145 in.# wm	2.5	2.0/1.4-2.65	0.016	0.022	0.030	0.080	0.090		'Pull Test' breakaway - 4050 # force		
Collar	lt. 2 unit 17														
Tube	9482-42	2.7129	Tube Hyd.	30035 psi											
Sleeve	48017-34	2.8061	Slv. Hyd.	15008 psi											
Sleeve	48017-34	6.1680	Slv. Roll	155 in.# wm	1.5										
Sleeve	48017-34	5.5118	Slv. Roll	155 in.# wm	2.5	2.0/1.4-2.65	0.016	0.020	0.018	0.080	0.050	0.060	OSL		
Collar	lt. 2 unit 18														
Tube	9482-45	1.6008	Tube Hyd.	30022 psi											
Sleeve	48017-35	2.9412	Slv. Hyd.	15025 psi											
Sleeve	48017-35	5.1383	Slv. Roll	135 in.# wm	1.5										
Sleeve	48017-35	4.6113	Slv. Roll	135 in.# wm	2.5	2.0/1.4-2.65	0.020	0.020	0.020	0.016	0.020	0.030	0.080	OSL	
		4.8973	Average all 135 in.# 'Max. Dia.' 2.0/1.4 rolls				0.0420	0.0500	0.0580	0.0710	0.0200	0.0300	0.0800		
		4.9108	Average all 145 in.# 'Max. Dia.' 2.0/1.4 rolls				0.0764	0.0932	0.0952	0.1296	0.1758	0.2390	0.3160		
		5.8159	Average all 155 in.# 'Max. Dia.' 2.0/1.4 rolls				0.0267	0.0320	0.0320	0.0473	0.0553	0.0600	0.0513		
		5.2317	Average all 'Max. Dia.' 2.0/1.4 rolls				0.0560	0.0689	0.0720	0.0980	0.1255	0.1220	0.1885		

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Enclosure 3

Steam Generator Sleeving Integration Report, WCAPs 13115 and 13116