VIRGINIA ELECTRIC AND POWER COMPANY

RICHMOND, VIRGINIA 23261

April 8, 1993

U.S. Nuclear Regulatory Commission
Attention: Document Control Desk
Washington, D.C. 20555

Serial No. 93-112
NL&P/JBL: R3
Docket No. 50-339
License No. NPF-7

Gentlemen:

VIRGINIA ELECTRIC AND POWER COMPANY
NORTH ANNA POWER STATION UNIT 2
PROPOSED TECHNICAL SPECIFICATIONS CHANGES
STEAM GENERATOR TUBE REPAIR USING LASER WELDED SLEEVES

Pursuant to 10 CFR 50.90, Virginia Electric and Power Company requests an amendment, in the form of changes to the Technical Specifications, to Facility Operating License NPF-7 for North Anna Power Station Unit 2 to allow steam generator tube sleeving in accordance with the Westinghouse laser welding process discussed in the enclosures. A discussion of the proposed changes is provided in Attachment 1 and the proposed changes to the Technical Specifications are presented in Attachment 2.

In general, the North Anna Unit 2 steam generators have experienced some tube degradation related to corrosion phenomena such as wastage, pitting, intergranular attack, and stress corrosion cracking. Tubes that experience excessive degradation reduce the integrity of the primary-to-secondary pressure boundary. These tubes are considered defective and currently must be removed from service by plugging.

The installation of plugs in a steam generator tube removes the heat transfer surface of the plugged tube from service. Extensive tube plugging leads to a reduction in the primary coolant flow available for core cooling and may ultimately reduce the power generation capability of the unit. The laser welded sleeving process described in the enclosures is a steam generator tube repair method that secures a length of smaller diameter tubing (sleeve) on the inside of the steam generator tube spanning the degraded region. The laser welded sleeve restores tube integrity and installation of sleeves does not significantly affect the heat transfer capability or the reactor coolant flow rate through the sleeved tube. Therefore, a significant number of sleeves can be installed without affecting the operation of the reactor coolant system.

The enclosed Westinghouse evaluation provides the necessary information to determine the sleeved-tube to plugged-tube flow resistance equivalence to address the effects of steam generator tube plugging and sleeving. The evaluation assumes that the equivalent steam generator tube plugging level does not restrict flow to less than the minimum reactor coolant system flow rate. The current Technical

A054 1/10 sets Pol & NP

Change: NRC PDR ltr 1 Encl 1 NP
NSIC 1 1 NP

Specification minimum reactor coolant system total flow rate limit is 284,000 gpm. However, this proposed change request for steam generator tube sleeving has also been evaluated for a reduced minimum reactor coolant system total flow rate of 275,300 gpm which was submitted to the NRC for approval by letter Serial No. 92-721, dated December 4, 1992.

Enclosed are ten copies each of Westinghouse Electric Corporation Reports WCAP-13088, Rev. 1, (Proprietary) and WCAP-13089, Rev. 1, (Non-Proprietary), "Westinghouse Series 44 and 51 Steam Generator Generic Sleeving Report - Laser Welded Sleeves." WCAP-13088, Rev. 1, is provided with a Westinghouse application letter for withholding proprietary information, CAW-93-416, with accompanying affidavit, Proprietary Information Notice, and Copyright Notice (Attachment 3) . Also enclosed are ten copies each of Westinghouse Electric Corporation Reports WCAP-13619 (Proprietary) and WCAP-13620 (Non-Proprietary), "Specific Application of Laser Welded Sleeves for North Anna Unit 2 Steam Generators." WCAP-13619 is also provided with a Westinghouse application letter for withholding proprietary information, CAW-93-415, with accompanying affidavit, Proprietary Information Notice, and Copyright Notice (Attachment 4) .

As WCAP-13088, Rev. 1, and WCAP-13619 contain information proprietary to Westinghouse Electric Corporation, they are supported by affidavits signed by Westinghouse, the owner of the information. These affidavits set forth the basis on which the information may be withheld from public disclosure by the Commission and addresses with specificity the considerations listed in paragraph (b)(4) of 10 CFR 2.790. Accordingly, it is respectfully requested that the information which is proprietary to Westinghouse be withheld from public disclosure in accordance with 10 CFR 2.790. Correspondence with respect to the supporting Westinghouse affidavits should reference CAW-93-415 or CAW-93-416, as appropriate, and should be addressed to Nicholas J. Liparulo, Manager of Nuclear Safety and Regulatory Activities, Westinghouse Electric Corporation, P.O. Box 355, Pittsburgh, Pennsylvania 15230-0355.

This proposed Technical Specifications change request has been reviewed and approved by the Station Nuclear Safety and Operating Committee and the Management Safety Review Committee. It has been determined that this request does not involve an unreviewed safety question as defined in 10 CFR 50.59 or a significant hazards consideration as defined in 10 CFR 50.92. The basis for our determination that this change does not involve a significant hazards consideration is provided in Attachment 5.

North Anna Unit 2 is scheduled to conclude Cycle 9 operations and begin a refueling outage on September 4, 1993. It is expected that the steam generator inspection conducted during this outage will result in additional defective steam generator tubes. Approval of this proposed change request will provide the option to repair these tubes by sleeving versus plugging. Therefore, we request approval of these proposed Technical Specifications changes prior to the beginning of this planned outage (i.e., by September 4, 1993).

Should you have any questions or require additional information, please contact us.

Very truly yours,

W. L. Stewart
Senior Vice President - Nuclear

Attachments

1. Discussion of Changes
2. Proposed Technical Specifications Changes
3. Westinghouse letter, Application for Withholding Proprietary Information from Public Disclosure, CAW-416
4. Westinghouse letter, Application for Withholding Proprietary Information from Public Disclosure, CAW-415
5. Significant Hazards Consideration

Enclosures

1. Westinghouse Electric Corporation Report, WCAP-13088, Rev. 1, "Westinghouse Series 44 and 51 Steam Generator Generic Sleeving Report - Laser Welded Sleeves" (Proprietary) (10 Copies)
2. Westinghouse Electric Corporation Report, WCAP-13089, Rev. 1, "Westinghouse Series 44 and 51 Steam Generator Generic Sleeving Report, Laser Welded Sleeves" (Non-Proprietary) (10 Copies)
3. Westinghouse Electric Corporation Report, WCAP-13619, "Specific Application of Laser Welded Sleeves for North Anna Unit 2 Steam Generators" (Proprietary) (10 Copies)
4. Westinghouse Electric Corporation Report, WCAP-13620, "Specific Application of Laser Welded Sleeves for North Anna Unit 2 Steam Generators" (Non-Proprietary) (10 Copies)

cc: U.S. Nuclear Regulatory Commission
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Commissioner
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COMMONWEALTH OF VIRGINIA)
)
COUNTY OF HENRICO)

The foregoing document was acknowledged before me, in and for the County and Commonwealth aforesaid, today by W. L. Stewart who is Senior Vice President - Nuclear, of Virginia Electric and Power Company. He is duly authorized to execute and file the foregoing document in behalf of that Company, and the statements in the document are true to the best of his knowledge and belief.

Acknowledged before me this 8TH day of April, 1993.

My Commission Expires: May 31, 1994.

Vicki L. Hull
Notary Public

(SEAL)

ATTACHMENT 1

DISCUSSION OF CHANGES

VIRGINIA ELECTRIC AND POWER COMPANY

Discussion of Changes

Steam Generator Tube Repair Using Laser Welded Sleeves
North Anna Power Station Unit 2

SUMMARY

This safety evaluation addresses the operation of the North Anna Power Station Unit 2 following the installation of Westinghouse laser welded tube sleeves to repair degraded steam generator tubes, as described in WCAP-13088, Rev. 1, (Reference 1) and WCAP-13619 (Reference 2). WCAP-13088, Rev. 1, is a generic analysis of a laser welded sleeved tube assembly which envelops the operating regimes of all plants with Westinghouse Series 44 and 51 steam generators. WCAP-13619 is a supplemental evaluation which utilizes conditions specific to North Anna Unit 2 for identifying applicable margin compared to the generic analysis and to develop a sleeve plugging limit based on conditions considered bounding for North Anna Unit 2.

Operating histories throughout the industry, including North Anna Unit 2, have shown a potential for tube wall degradation in the expanded portion of the tube in the tubesheet, in the tube expansion transition above the tubesheet, and at the tube support plate intersections. To maintain tube integrity consistent with the margin of safety used as the bases for the Technical Specifications, an allowable level of tube wall degradation referred to as plugging limit is established. Tubes which have eddy current indications of degradation in excess of the plugging limit must be repaired or plugged. The information provided in Reference 1 defines the portion of the tube and the sleeve for which indications of wall degradation must be evaluated.

The laser welded steam generator tube sleeving process involves the installation of thermally treated Alloy 690 sleeves in steam generator tubes in the tubesheet region and at the tube support plate elevations. Once installed, the laser welded sleeve returns the integrity of the tube to its original design condition.

This evaluation assumes upon installation of the laser welded sleeves, that the equivalent steam generator tube plugging level (in terms of number of plugged tubes) does not exceed the analyzed plant plugging level. Reference 1 provides the necessary information to determine the sleeved tube-to-tube plug flow resistance equivalence to address the effects of and level of steam generator tube plugging which would be expected to be bounded by the licensed minimum reactor coolant flow rate. Currently, the North Anna Unit 2 steam generators are at approximately 7% (average) tube plugging, and the reactor coolant flow rate was verified at 293,321 gpm on April 29, 1992. The current Technical Specification minimum reactor coolant system total flow rate limit is 284,000 gpm. However, Virginia Electric and Power Company has submitted a Technical Specification change request to reduce the minimum reactor coolant flow rate to 275,300 gpm (Reference 3) to accommodate the system effects associated with potential steam generator tube plugging.

BACKGROUND

Pressurized water reactor steam generators have experienced tube degradation related to corrosion phenomena such as wastage, pitting, intergranular attack, and stress corrosion cracking. Tubes that experience excessive degradation reduce the integrity of the primary-to-secondary pressure boundary. These tubes are considered defective and must be repaired or removed from service. The installation of steam generator tube plugs removes the heat transfer surface of the plugged tube from service and leads to a reduction in the primary coolant flow available for core cooling. Sleeving is a steam generator tube repair method that secures a length of smaller diameter tubing (sleeve) on the inside of the steam generator tube spanning the degraded region. Installation of steam generator sleeves does not significantly affect the heat transfer capability or the primary coolant flow rate through the tube being sleeved. Therefore, a large number of sleeves can be installed without significantly affecting the operation of the reactor coolant system. The sleeve spans the degraded section of the tube and maintains the structural integrity of the steam generator tube under normal and accident conditions and prevents leakage if a through hole in the tube wall should develop.

Two types of laser welded sleeves have been evaluated in this report: tubesheet sleeves and tube support plate sleeves. Laser welded tubesheet sleeves span from the end of the tube, at the bottom surface of the tubesheet, to a point above the secondary side surface of the tubesheet. Tubesheet sleeves can vary from 27 to 36 inches in length. The North Anna Unit 2 tubesheets are approximately 21 inches thick. Tube degradation historically has occurred in the tube adjacent to the tube support plates, at the top of the tubesheet, or within the section of tube adjacent to the tubesheet. Tube support plate sleeves are 12 inches in length, and are approximately centered about the tube support plate intersection. Tube degradation at the tube support plate intersection is generally confined to the thickness of the tube support plate.

Tubesheet sleeves are secured by first performing a hydraulic expansion of the upper and lower portions of the sleeve. The hydraulic expansion serves to bring the sleeve to contact with the parent tube to optimize weld performance. At the lower joint, a mechanical roll expansion is performed which provides sleeve structural integrity and leaktightness during all plant conditions. A laser produced weld is implemented in the area of the hydraulic expansion region of the upper joint. This weld structurally supports the sleeve in addition to forming a leaktight seal. Each joint provides the necessary structural requirements with regard to the structural integrity acceptance criteria which includes inherent safety factors within the ASME Code criteria. The hybrid expansion joint (HEJ) performed at the lower joint of the tubesheet sleeve has been previously qualified, and is implemented in the majority of the greater than 25,000 sleeves Westinghouse has installed in the field. The HEJ, being a mechanical seal, has not historically been considered leaktight, although the test data for Alloy 690 HEJ sleeves support the joint as being leaktight at operating and accident temperatures and pressures. An optional laser produced seal weld may be applied to the tubesheet sleeve lower joint for additional maintenance of joint leaktightness.

Tube support plate sleeves are similarly first hydraulically expanded in place at the upper and lower joint areas, then, a laser weld which provides sleeve/tube structural and leakage integrity is produced within the hydraulic expansion regions.

A structural analysis of the sleeve and sleeve joints using bounding temperature and pressure differences for Series 44 and 51 steam generators, corrosion testing and both mechanical and leak testing of prototypic sleeve test specimens have been completed. The results of these evaluations and test programs are summarized in this evaluation, and fully support the regulatory requirements outlined below.

The results of eddy current testing (ECT) evaluations are used to develop a list of candidate tubes which may be repaired. Tooling access and location of the degradation warranting repair ultimately define which tubes can be sleeved.

DESCRIPTION OF SPECIFIC CHANGES

The proposed amendment would modify the surveillance requirements of Specification 3/4.4.5 and their associated bases to allow laser welded sleeving in the tube support plate and tubesheet regions of steam generator tubes in accordance with the Westinghouse processes (References 1 and 2). The following proposed changes revise the surveillance requirements and bases to identify sleeving as a repair method for defective tubes:

Surveillance Requirement 4.4.5.0 has been revised to change the word "required" to "requirements of." This is an editorial change.

Surveillance Requirement 4.4.5.2 has been revised to include an exception to the degraded tube inspection requirements for tubes that have been repaired by sleeving. A footnote is also added which describes the sleeve as a part of the tube if the tube has been repaired.

Surveillance Requirement 4.4.5.2.b has been revised to incorporate sleeved tubes in the sample of tubes required to be inspected during each inservice inspection. Item 1 has been revised to include sleeves with detectable wall penetrations greater than 20%, Item 3 has been renumbered to Item 4, and a new Item 3 is inserted that specifies the required population of sleeved tubes to be inspected.

Surveillance Requirement 4.4.5.2.c has been revised to include sleeves in the criteria for partial tube inspection during the second and third inservice inspections. Item 1 includes an editorial change.

The Category C-2 inspection results classification description (of Surveillance Requirement 4.4.5.2) includes an editorial change and the note has been revised to address sleeves.

Surveillance Requirement 4.4.5.4.a, Items 1, 2, 3, and 4 have been revised to include sleeves in the steam generator acceptance criteria definitions. Item 5 has been revised to address tube repair in the definition of defect. Item 6 has been changed to include the sleeve imperfection depth plugging limits. Item 9 has been renumbered to

Item 10 and a new Item 9 has been added to define "tube repair" as laser welded sleeving.

Surveillance Requirement 4.4.5.4.b has been revised to include tube repair and the superfluous phrase "and all tubes containing through-wall cracks" has been removed from the parenthetical clause.

Surveillance Requirements 4.4.5.5.a and 4.4.5.5.b have been revised by including tube repair by sleeving in steam generator tube inspection reports.

Table 4.4-2 has been revised to include tube repair in the actions required for Categories C-2 and C-3. The table also includes an editorial change.

Bases 3/4.4.5, Steam Generators, has been revised by including the basis for repair of degraded steam generator tubes by sleeving.

LICENSING BASIS

In accordance with 10 CFR 50.55a, the NRC requires components which are a part of the primary pressure boundary to be built to the requirements of Section III of the ASME Boiler and Pressure Vessel Code. Section 5.2.1.1 of the Standard Review Plan, entitled "Compliance with the Codes and Standards Rule, 10 CFR 50.55a," provides an outline of the standards used for evaluation by the NRC staff. Any modification, repair or replacement of these components must also meet the requirements of the ASME Code to assure that the basis on which the unit was originally evaluated is unchanged. The design of the sleeve is predicated by the requirements of Section III, NB-3200, "Analysis" and NB-3300, "Wall Thickness." The ASME Boiler and Pressure Vessel Code provides criteria for evaluation of the stress levels in the tubes for design, normal operating, and postulated accident conditions. The margin of safety is provided, in part, by the inherent safety factors in the criteria and requirements of the ASME Code.

The guidelines of Section IX of the ASME Code, Subsection QW, and Section XI, including Code Case N-395, define the laser weld qualification requirements. Section XI, IWB-4334 of the 1989 Edition, 1989 Addenda, of the ASME Code defines the extent of examination requirements for installation of laser welded sleeves.

Regulatory Guide 1.121, issued for comment, entitled "Bases for Plugging Degraded PWR Steam Generator Tubes," addresses tubes with both part throughwall and throughwall cracking. The requirements of Regulatory Guide 1.121 are extended to the laser welded sleeve in order to determine the level of degradation which will require removal of the sleeve from service by plugging. By utilizing the requirements for sleeve design according to the ASME Code and Regulatory Guide 1.121 to define acceptance criteria, the sleeve meets the requirements of General Design Criterion (GDC) 14, "Reactor Coolant Pressure Boundary," GDC 15, "Reactor Coolant System Design," and GDC 31, "Fracture Prevention of Reactor Coolant Pressure Boundary."

Regulatory Guide 1.83, "Inservice Inspection of Pressurizer Water Reactor Steam Generator Tubes" (and the North Anna Unit 2 Technical Specifications) is used as the basis to determine the inservice inspection requirements for the sleeve.

Total plant allowable primary-to-secondary leakage rates, derived from the requirements of 10 CFR 100, are determined on a plant specific basis. Offsite doses during either a main steam line break or tube rupture event are not to exceed a small fraction of the 10 CFR 100 limits per the Bases to the North Anna Unit 2 Technical Specifications.

The effects of sleeving, as evaluated herein, will be shown to not adversely affect the dose consequence estimates established by the North Anna Power Station UFSAR. Installation of tube sleeves, based on test results, will not contribute to offsite dose consequences for a postulated steam line break event. The consequences of a steam generator tube rupture event, as evaluated in the North Anna Power Station UFSAR, are unaffected by tube sleeving.

EVALUATION

Sleeve Design and Ana sis

The installation of the laser welded sleeves (both tubesheet and tube support plate sleeves) has been reviewed for impact on safe plant operation, i.e., maintenance of steam generator tube and leaktightness integrity during all plant conditions. The sleeve joint design is qualified through laboratory testing and analysis per Reference 1. Analytical verification per Reference 1 has been performed using design and operating transient parameters selected to envelop loads imposed during normal operation, upset and accident conditions for all plants with Westinghouse Series 44 and 51 steam generators, including those in North Anna Unit 2. The function of the sleeve is to restore the integrity of the pressure boundary in the region between the sleeve joints to a level which is consistent with the original tube. The sleeve has been designed according to Section III, Subsection NB-3300, of the ASME Boiler and Pressure Vessel Code. Fatigue and stress analyses of sleeved tube assemblies have been completed in accordance with the requirements of the ASME Boiler and Pressure Vessel Code, Section III, Subsection NB-3200. The analyses include a primary stress intensity evaluation, primary plus secondary stress intensity range evaluation, and a fatigue evaluation for mechanical and thermal conditions which umbrella the loading conditions for the North Anna Unit 2 steam generators. For all analyzed conditions, the calculated stress levels and fatigue usage factors for both the sleeve and weld were found to be bounded by the ASME Code allowable values. The analysis conditions considered use bounding values, which envelop the operating regimes of all Westinghouse Series 44 and 51 steam generators. In addition, the load cycles used in the fatigue analysis represent 40 year life cycle conditions, and therefore are considered conservative for operating plants. As noted above, Sections IX and XI of the ASME Code, including Code Case N-395, are utilized to address the laser weld qualification process. The results of the qualification testing, analyses and plant operating experience demonstrate that the sleeving process is an acceptable means of restoring steam generator tube integrity.

Sleeved Tube Assembly Corrosion Resistance

Corrosion testing was performed in high temperature-high pressure autoclaves. A primary-to-secondary pressure differential which bounds the conditions in the North Anna Unit 2 steam generators was applied, and a doped steam environment was utilized to accelerate crack propagation. Results of the accelerated corrosion tests (Reference 1) indicate that a free span laser welded joint even without post weld heat treatment is less susceptible to primary water stress corrosion cracking (PWSCC) than mechanical roll expanded tube joints at the rolled to unrolled transition. If post weld heat treatment is applied, test results indicate a resistance to corrosion of greater than 10 times that of rolled tube transitions. A laser produced seal weld of the tubesheet sleeve lower joint (if used) will be performed according to the identical process control parameters as for the upper joint. Test results of these weld configurations show corrosion resistance enhancement of three to four times over roll expansion transitions.

Sleeve Plugging Limits

Sleeve Minimum Wall Thickness Determination

The sleeve minimum acceptable wall thickness is determined using the criteria of Regulatory Guide 1.121 and the pressure stress equation of Section III of the ASME Code. With respect to the design of the sleeve, the limiting requirement of Regulatory Guide 1.121 which applies to part throughwall degradation is that the minimum acceptable wall must maintain a factor of safety of three against tube failure under normal operating conditions. A bounding set of input conditions which envelops the operating parameters of all Series 44 and 51 steam generators was used for the minimum wall thickness evaluation in the generic evaluation. The minimum acceptable tube wall thickness determined by the Regulatory Guide 1.121 evaluation is 48% of the original sleeve wall thickness. Evaluation of the minimum acceptable wall thickness for postulated combined accident condition loadings, per Regulatory Guide 1.121 recommendations, shows that the minimum wall requirement for SLB/FLB + SSE loadings is bounded by the normal operating condition requirement of 48% minimum wall thickness (Reference 1). From Section III of the ASME Code, the stress limit for upset conditions requires that the membrane stress should not exceed the yield stress at temperature. The minimum wall thickness which satisfies the pressure loading conditions during a Loss of Load transient, which has the highest pressure differential for upset conditions is bounded by the minimum wall thickness required for maintenance of a factor of safety of three against failure at normal operating conditions. Therefore, the minimum acceptable tube wall thickness that satisfies Regulatory Guide 1.121 criteria based on generic conditions is 48% of the nominal tube wall thickness.

Sleeve Plugging Limit Determination

According to Regulatory Guide recommendations, an allowance for non-destructive evaluation (NDE) uncertainty and operational growth of existing tube wall degradation within the sleeve must be accounted for in determining a sleeve plugging limit based

on NDE. While there have been no reported Westinghouse HEJ sleeves which have been plugged due to degradation of the sleeve, a conservative tube wall degradation growth rate of 10% through-wall per cycle and an eddy current uncertainty of 10% has been assumed for determining the sleeve Technical Specification plugging limit.

The sleeve wall degradation extent based on bounding generic conditions, determined by eddy current examination, which would require plugging sleeved tubes is defined to be 32%. The plugging limit is determined by subtracting the eddy current uncertainty and assumed crack growth rate for an additional cycle from the through wall penetration of degradation which corresponds to the minimum acceptable wall thickness. Removal of tubes from service when degradation reaches the plugging limit assures that the minimum acceptable wall thickness will not be exceeded during the next subsequent cycle of operation.

A 33% (depth of penetration) through wall sleeve plugging limit is established for North Anna Unit 2. The difference in allowable throughwall extent is due to a smaller primary-to-secondary pressure differential at operating conditions for North Anna Unit 2 compared to the generic analysis. For North Anna, a primary-to-secondary pressure differential of 1490 psia (primary pressure = 2250 psia, secondary pressure = 760 psia) was used to determine the minimum allowable wall thickness. This pressure differential will bound all current and estimated plant conditions. The current Technical Specification minimum measured flow value for North Anna Unit 2 is 284,000 gpm. Virginia Electric and Power Company has submitted a Technical Specification change request to lower this value to 275,300 gpm. A steam pressure of 760 psia should bound the actual steam pressure at the plugging level associated with a minimum measured flow of 275,300 gpm.

The specification of the areas to which the plugging limit applies to the sleeve and to the sleeved portion of the tube are defined in Reference 1 and are consistent with the design evaluation.

LOCA Flow Margin Effects

The installation of a sleeve into a tube results in an additional flow restriction within the primary system, with an associated increase in pressure drop in the steam generator. The effects of this flow restriction on plant operation are evaluated in the same manner that tube plugging effects are analyzed. Reference 1 identifies the reduction in primary coolant flow caused by the projected sleeving under normal operating conditions and identifies the number of sleeves or combination of sleeves which result in a flow reduction equivalent to one plugged tube. The postulated accidents assessed for the impact of sleeving include both LOCA and non-LOCA transients. The large break LOCA analysis for the minimum reactor coolant system flow rate will bound the effects on all core and system parameters for a combination of plugging and sleeving up to the equivalent resistance associated with the minimum reactor coolant flow rate. The consequences of the installation of a sleeve can be summarized as a restriction of the flow through steam generator tube, a small reduction in primary volume, and a small reduction in the heat transfer capacity of the tube. The hydraulic equivalency must be determined for the post-sleeving condition and compared to the current analyzed minimum reactor coolant flow rate to show that this level is not exceeded.

LABORATORY LEAK TESTING

Test Description

Test specimens were prepared in a manner that is expected to duplicate the field installation process. The test matrix included some welded and some non-welded HEJ joints in addition to welded free span joints. The sleeve samples tested were modified only to permit the sleeve to be internally pressurized. This was accomplished by welding a plug onto either end of the sleeve. It has been judged that the modification to permit internal pressurization in order to perform the leak rate testing had no effect on the structural integrity or leak rate characteristics of the sleeve (Reference 1). Leak testing was performed subsequent to fatigue and thermal cyclic loading. Test specimens were pressurized during the fatigue and thermal cyclic loading. The applied force during fatigue loading exceeded the expected pressure loads acting on the sleeve during a postulated steam line break.

Leak Test Results

The acceptance criterion for the leak rate testing was no observable leakage for a 10 to 20 second period. All samples tested at 600°F, which included welded free span joints, welded tubesheet sleeve lower joints, non-welded tubesheet sleeve lower joint specimens and non-welded abnormal condition tubesheet sleeve lower joint specimens met this criterion. Leak test specimens were tested at 1485, 2485 and 3110 psi primary-to-secondary pressure differentials. Therefore, it can be concluded that primary-to-secondary steam line break leakage through the non-welded sleeve joints will be zero, or insignificant at normal operating temperatures (Reference 1). The UFSAR dose evaluations for accident conditions which result in secondary steam release to the environment will not be affected due to the installation of laser welded tube sleeves. The test condition of 3110 psi represents a greater pressure differential than steam line break conditions (~2500 psid most limiting pressure difference). Operator action following a postulated SLB event can further limit the true primary-to-secondary ΔP. Immediately following the event, primary system pressure drops coincidentally with secondary side pressure. Primary system pressure is reestablished with introduction of safety injection. The primary-to-secondary pressure differential is not expected to exceed 2335 psi based on operator action to terminate safety injection (SI) within the proper time period. If SI is not terminated, primary system pressure would most likely be limited to the setpoint of the pressurizer power operated relief valves (PORVs), approximately 2350 psi. If the PORVs are not available, primary system pressure would be limited to the pressurizer safety valve setpoint, approximately 2500 psia. Based on the data that no leakage was detected at 600°F and pressure differentials of up to 3110 psia, it is unlikely that leakage would occur at 0% power conditions (547°F T_{hot}). Tube sleeving will not increase primary coolant release rates during a postulated steam generator tube rupture event, and the installation of tube sleeves will not affect the response of the plant, outside of analyzed flow conditions.

Effects of Abnormal Tubesheet Sleeve Lower Seal Weld Production

The tubesheet sleeve lower joint seal weld can be used to enhance HEJ leak tightness. Due to the inability of the UT process to confirm the width of the fusion zone between the sleeve and the tube in the tubesheet sleeve lower joint, because of interference caused by proximity to the tube end, the lower seal weld cannot be considered a structural load carrying member. A comparison of the metallurgical and mechanical test results of lower mechanical joints with and without seal welds, shows that the addition of a seal weld does not adversely affect the structural performance of the sleeve. However, since a determination of the fusion zone can not be reliably performed for the tubesheet sleeve lower seal weld, the extreme consequences of a non-optimum lower seal weld must be addressed.

To evaluate this scenario, the lower seal weld is assumed to not penetrate the tube wall. Shrinkage of the weld pool on the sleeve I.D. is assumed to result in a reduction of the residual stresses which reduce the retentive characteristics of the roll expansion in an area adjacent to the weld. Test data has shown that HEJs with lengths of sound roll expansion as short as 0.75 inches satisfy leak limiting and structural integrity requirements. For all cases, no primary-to-secondary leakage was detected after thermal and fatigue cycling at pressure differentials up to 3110 psi. Additionally, the breakaway force for these joints exceeded three times the acceptance criterion for mechanical loading of 2500 lb. The mechanical loading acceptance criterion is derived by determining the maximum pressure force acting on the sleeve cross section and applying a factor of safety of three. This criterion is identical to the mechanical loading criterion established for the F* and L* plugging criterion. While the F* or L* criteria are not applicable to North Anna Unit 2, conformance of the sleeve structural characteristics to these established criteria represents compliance with accepted criteria used to assess operability of degraded steam generator tubes. Torque inputs for these HEJ specimens were adjusted according to the hardroll length so that an equal amount of wall thinning was produced for each specimen of varying hardroll length. The minimum length of sound roll expansion which can be expected in a non-optimum tubesheet sleeve lower joint is approximately 1.75 to 2.0 inches and is much greater than the minimum acceptable value of 0.75 inches which based on test results has been shown to satisfy leaktightness and structural integrity requirements. It should be noted that sufficient controls (afforded by the process control equipment) are provided which would clearly indicate a non-optimum situation.

Tube Joint Evaluation for Incomplete Tube Hardroll Areas

The tube expansion process implemented at North Anna Unit 2 was a partial (2.75 inch deep) hard roll. The tube length throughout the remainder of the tubesheet was expanded using the WEXTEX expansion technique.

Prior sleeving campaigns have evaluated the potential for incomplete hardrolls within the first 2.75 inches of tube to affect the performance of the HEJ. Test results contained in Reference 1 indicate that incomplete hardroll areas within the first 2.75 inches of tube length do not adversely affect the structural integrity and leaktightness performance of the HEJ. Reduced tube hardroll lengths and a minimum sleeve hardroll length of 0.9" were used in the incomplete tube hardroll evaluation. No

leakage was detected after thermal and fatigue cycling. Compression and tensile test results indicate the joint axial strength far exceeded the structural requirements for the sleeve. The design requirements of the joint continue to be met for these extreme conditions. Therefore, if incomplete tube expansion exists within the first 2.75 inches of tube length, the sleeve will continue to perform its intended function.

JOINT STRUCTURAL REQUIREMENTS

The forces acting on a sleeve during operation are related to the pressure differential between the primary and secondary systems and the cross sectional area of the sleeve/tube assembly. Each joint of the sleeved tube assembly must supply the necessary structural characteristics to support this load. Test results indicate that the free span laser welded joints exhibit an axial strength of nearly three times the acceptance requirement loading. The acceptance requirement methodology uses guidance of Regulatory Guide 1.121, and includes a factor of safety of three applied to the pressure load obtained for normal operating conditions. The mechanical joint of the tubesheet sleeve lower joint also exhibits similar strength characteristics.

TUBE END CONDITIONS AT NORTH ANNA UNIT 2

At North Anna Unit 2, the tube end may protrude from 0.19 to 0.22 inches from the tubesheet cladding face. A fillet weld is produced at the corner intersection of the tube and clad. If the lower seal weld is implemented, it will be produced at the approximate midpoint of the tubesheet cladding, within the straight formed section of the sleeve.

REWELDING

In the event of an incomplete first cycle, or an unacceptable first cycle weld, a second weld cycle can be performed outboard of the original free span weld, provided that the original weld did not penetrate the tube O.D. Rewelded joints (2 complete cycles) must be heat treated. Tubesheet sleeve lower weld joints do not require rewelding since the hardroll area provides the necessary structural and leakage integrity.

INSPECTABILITY

Free span laser welds performed in the field will be inspected using an ultrasonic (UT) inspection technique. The UT will confirm and quantify the sleeve/tube fusion zone present in the joint. The UT will also verify the requirement for a minimum width of this fusion zone, which has been shown by analysis to satisfy all ASME Boiler and Pressure Vessel Code stress and fatigue usage loading criteria. UT inspection is required prior to the initial return to power following sleeve installation, and is not performed on a per outage basis. A visual examination (performed remotely) of the tubesheet sleeve lower seal weld (if implemented) will also be performed. The visual examination should identify a lower seal weld which has adequately fused the sleeve to the tube. While the visual examination cannot quantitatively ascertain this, it is believed that extreme cases would exhibit surface characteristics indicative of non-optimum performance and would be readily observable. As previously stated, both the upper and lower welds are performed according to the same process parameters, and that sufficient process control instrumentation is provided to alert the

operator to an abnormal situation. UT inspection of the tubesheet sleeve lower seal weld is not required since the function of this weld is only to provide a backup means for maintaining leaktightness of the joint. The hardroll region provides the necessary structural and leakage integrity requirements of the tubesheet sleeve lower joint.

The remainder of the sleeve, including the weld, is baseline inspected using an eddy current inspection coil which minimizes the effects of geometry and weld zone changes that circumvent the sleeve. Per Regulatory Guide 1.83, the results of subsequent eddy current inspections will be evaluated against baseline results. Subsequent eddy current inspection results will be evaluated against the sleeve plugging limit of 33% through-wall penetration.

LEAK BEFORE BREAK EVALUATION

An evaluation was performed for the sleeves which verified that the leakage characteristics during normal operation would not exceed the ability of the plant to be shut down safely prior to the critical crack length for sleeve rupture during postulated steam line break conditions. (This conservatively assumes no reinforcing effect from the tube.) The evaluation was performed at bounding conditions of primary pressure, secondary pressure, and T_{hot}. As described in Reference 1, leak-before-break for the sleeve is provided for these bounding conditions. Therefore, leak-before-break criteria are applicable for the laser welded sleeves to be installed in the North Anna Unit 2 steam generators.

SLEEVING OF PREVIOUSLY PLUGGED TUBES

The requirements for sleeving a degraded active tube would continue to apply to tubes returned to service by sleeving. Additionally, the area of the tube in which the tube plug was located must meet minimum surface finish requirements in order to produce a high quality seal. Requirements for minimum length that identified degradation can exist from structural weld joints must be adhered to (as for active tubes to be sleeved). A new "baseline" inspection of the tube would be required prior to returning the tube to service. The areas of tubes traditionally affected by degradation mechanisms which would cause the tube to be removed from service are not coincident with the location of the structural sleeve welds or the lower hardroll of the tubesheet sleeve.

ADDITIONAL SAFETY MARGINS IMPLIED USING NORTH ANNA UNIT 2 PLANT SPECIFIC LOADING CONDITIONS

North Anna Unit 2 Laser Welded Sleeve Plugging Limit

Based on the assumed input values (ΔP of 1490 psi, steam pressure = 760 psia), the percentage of degradation affecting the sleeve wall which requires removal of the sleeve from service was determined to be 33%. North Anna Unit 2 is currently licensed for a minimum measured flow of 284,000 gpm, but a license submittal has been made to lower this value to 275,300 gpm. The steam pressure of 760 psia bounds the estimated steam pressure for operation with a minimum reactor coolant system total rate of 275,300 gpm. Therefore, the 33% sleeve throughwall degradation

limit is conservative for estimated plant conditions at a minimum reactor coolant flow rate of 275,300 gpm.

Stress Limits and Fatigue Evaluation

The generic evaluation loading conditions are also conservative compared to the North Anna design specifications identified in Reference 2. The generic analysis considers a larger number of transients, and in general, more transient cycles than are applicable to North Anna Unit 2 The primary stress evaluation and fatigue evaluation inputs for the generic evaluation bound or are equal to the North Anna conditions for transients applicable to both the generic and North Anna Unit 2 specifications in both ΔP and number of cycles in all categories.

Leak Before Break Margin

Using the bounding conditions of the generic evaluation, leak-before-break was determined to be applicable for the Westinghouse laser welded sleeves. The North Anna Unit 2 plant specific conditions are bounded by the generic evaluation. The North Anna Unit 2 Technical Specifications provide primary-to-secondary leak rate limits. In addition, North Anna maintains administrative controls to further reduce the maximum allowable primary-to-secondary leak rate (Reference 4). The administrative controls bound leak-before-break concerns for both sleeved and unsleeved tubes for all plant operating conditions. These administrative limits were previously accepted by the NRC in letters dated March 7, 1991 and August 3, 1992 (References 5 and 6). The North Anna Unit 2 Technical Specifications and the administrative controls for primary-to-secondary leakage, combined with the conservatisms of the Westinghouse leak-before-break evaluation model, support leak-before-break for the implementation of laser welded tube sleeves at North Anna Unit 2.

ASSESSMENT OF UNREVIEWED SAFETY QUESTION

Based upon the following justification, operation of the North Anna Power Station Unit 2 steam generators subsequent to the installation of laser welded tube sleeves as described in WCAP-13088, Rev. 1, and WCAP-13619, does not involve an unreviewed safety question.

1. The proposed activity does not increase the probability of occurrence of an accident previously evaluated.

   Installation of laser welded sleeves as described in References 1 and 2, can be used to repair degraded tubes by returning the condition of the tubes to their original design condition (for tube integrity and leaktightness during all plant conditions). Tube bundle overall structural and leakage integrity will be increased with the installation of laser welded sleeves. The performance history of Westinghouse sleeves has shown that, to date, no sleeves have been removed from service due to corrosion degradation of the sleeve.

2. The proposed activity does not increase the consequences of an accident previously evaluated.

   Any hypothetical sleeve failure is bounded by the consequences of a postulated steam generator tube rupture event. The use of laser welded sleeves will not increase the amount of primary-to-secondary leakage anticipated during a postulated steam line break or other analyzed accidents. Post thermal cycling and fatigue loading leak rate tests show no primary-to-secondary leakage through the sleeve joint during normal or accident conditions. Sleeve installation will result in a resistance to primary coolant flow through the tube. Depending on the assumed steam generator tube rupture location, the primary coolant flow through the ruptured tube can be reduced by the influence of sleeves installed below the break, thereby reducing the consequences to the public due to a steam generator tube rupture event. Steam generator tube sleeving has as a basis that the analyzed steam generator tube plugging level and associated reactor coolant flow rate, which incorporates the flow reduction effects for various sleeved tube combinations and their relation to a plugged tube with flow reduction effects, is not exceeded. Therefore, primary coolant flow area assumptions in the accident analyses are not affected and any consequences of a postulated loss of coolant accident would not be increased.

3. The proposed activity does not create the possibility of an accident of a different type than any previously evaluated.

   As noted previously, the effect of any hypothetical failure of the sleeve would be bounded by existing tube rupture analyses. No increase in leakage is anticipated during a postulated steam line break event. Structural analyses of the sleeve and sleeve joints shows the stress limits defined in the ASME Code are not exceeded during all plant conditions. Therefore, operation of the steam generators following installation of laser welded sleeves in the tubes of the North Anna Unit 2 steam generators will not result in an accident previously not analyzed in the UFSAR.

4. The proposed activity does not increase the probability of occurrence of a malfunction of equipment important to safety previously evaluated.

   Installation of laser welded sleeves will increase the leaktightness of the tube bundle in addition to enhancing overall steam generator tube bundle integrity by effectively removing from service tubes with significant localized tube wall degradation. Following installation of laser welded sleeves, steam generator tube integrity is restored to its original design basis. By restoring tube bundle leakage and structural integrity, no other components or equipment important to safety would be affected.

   Testing has shown that once installed, there is no mechanism for the sleeves to affect any portion of the steam generator other than the tubes in which they are installed. No other system or component connecting with the steam generator could be adversely affected by the operation of the steam generator following installation of laser welded tube sleeves.

5. The proposed activity does not increase the consequences of a malfunction of equipment important to safety previously evaluated.

   As stated in items 1, 2, and 3 above, the installation of laser welded sleeves does not increase the probability or consequences of any event or accident in excess of the effects due to the rupture of a non-sleeved tube. Current UFSAR analyses results bound the effects due to the installation of tube sleeves.

6. The proposed activity does not create the possibility of a malfunction of equipment important to safety of a different type than any previously evaluated.

   As previously noted, the effects of a hypothetical failure of the sleeve would be bounded by the results of a single tube rupture. Overall bundle integrity and leaktightness during all plant conditions are maintained through the installation of laser welded sleeves.

7. The proposed activity does not reduce the margin of safety as defined in the basis for any Technical Specification.

   The margin of safety with respect to maintenance of tube bundle integrity is provided, in part, by the safety factors included in the ASME Code, and is not reduced. Nondestructive examination of the sleeve length and non-sleeved tube sections still can be performed. Therefore, the recommendations of Regulatory Guide 1.83 can be implemented. The installation process for laser welded sleeves has been shown to provide a leaktight bond between the sleeve and the tube during all plant conditions, and as such would not contribute to the radiological consequences of a postulated steam line break event. Any combination of sleeving and plugging utilized at North Anna Unit 2 up to the level that the minimum measured reactor coolant flow rate is maintained per Technical Specification requirements, will be bounded by the accident analyses supporting the analyzed flow limit.

CONCLUSION

Based on the above evaluation, installation of laser welded sleeves into the North Anna Unit 2 steam generators will provide a level of leaktightness and individual tube integrity equal to that of a non-degraded tube, and as such will not adversely affect the safe operation of the steam generators or the entire plant. Therefore, implementation of the laser welded tube sleeving process in the North Anna Unit 2 steam generators does not result in an unreviewed safety question as defined in the criteria of 10 CFR 50.59.

REFERENCES

1) WCAP-13088, Rev. 1, "Westinghouse Series 44 and 51 Steam Generator Generic Sleeving Report - Laser Welded Sleeves," November 1992.

2) WCAP-13619, "Specific Application of Laser Welded Sleeves for North Anna Unit 2 Steam Generators," January 1993.

3) Virginia Electric and Power Company letter, Serial No. 92-721, "North Anna Power Station Unit 2 Proposed Technical Specifications Changes - Reduction in Minimum Measured RCS Flow Rate" (to 275,300 gpm), dated December 4, 1992.

4) Virginia Electric and Power Company letter, Serial No. N-92-11, Licensee Event Report No. 50-339/92-005-00, dated April 9, 1992.

5) NRC letter to Virginia Electric and Power Company, "Approval for Restart - Category C-3 Status of Steam Generators, North Anna Unit No. 1 (TAC No. 79783)," dated March 7, 1991.

6) NRC letter to Virginia Electric and Power Company, "North Anna Power Station, Unit No. 1 - Steam Generator Operating Cycle Evaluation (TAC No. M83715)," dated August 3, 1992.