WESTINGHOUSE CLASS 3 (Non-Proprietary)

Westinghouse Energy Systems

WESTINGHOUSE CLASS 3 (Non-Proprietary)

Westinghouse Energy Systems

WESTINGHOUSE CLASS 3

WCAP-13620

SPECIFIC APPLICATION OF LASER WELDED SLEEVES FOR NORTH ANNA UNIT 2 STEAM GENERATORS

February 1993

WESTINGHOUSE ELECTRIC CORPORATION
NUCLEAR SERVICES DIVISION
P.O. BOX 355
PITTSBURGH, PENNSYLVANIA 15230

WPF0884A:1b/021793

ABSTRACT

Under Plant Technical Specification requirements, steam generator tubes are periodically inspected for degradation using non-destructive examination techniques. If established inspection criteria are exceeded, the tube must be removed from service by plugging, or the tube must be brought back into compliance with the Technical Specification criteria. Tube sleeving is one technique used to return the tube to an operable condition. The purpose of this evaluation is to establish the applicability of a generic laser welding sleeving analysis for Series 44 and 51 steam generators (WCAP-13088, Rev. 1) to the North Anna Unit 2 steam generators.

All of the sleeve design, mechanical testing, stress corrosion resistance testing, installation processes and nondestructive examination discussed in the generic report apply directly to North Anna Unit 2.

Based on the combined results of this evaluation and the generic evaluation (WCAP-13088, Rev. 1), the laser welded sleeves are concluded to meet applicable ASME Boiler and Pressure Vessel Code and regulatory requirements for North Anna Unit 2. The allowable plugging margin for sleeve degradation is 33%. Based on the plant Administrative Leakage Limit, the allowable leak rate for North Anna Unit 2 steam generators is 50 gpd per steam generator. The leak rate limit corresponding to the installation of sleeves is a less restrictive 340 gpd per steam generator.

TABLE OF CONTENTS

LIST OF TABLES

1.0 INTRODUCTION

The purpose of this analysis is to evaluate the applicability of the generic laser welded sleeving analysis for Series 44 and 51 steam generators, documented in Reference (1), to the North Anna Unit 2 steam generators. In performing the generic analysis, transient loads are used that umbrella Series 44 and 51 steam generators. Included in the generic analysis are calculations to determine minimum wall thickness requirements for the sleeves. Also performed in the generic analysis are calculations to establish leak rate limitations under normal operation in order to satisfy leak before break requirements. These two sets of calculations are a function of plant operating parameters, which vary from plant to plant, and which can change with the implementation of operating or system modifications. The purpose of this evaluation then, is to compare the current set of transient and operating parameters for North Anna Unit 2 to those used in the umbrella analysis, with the intent of confirming that the generic analysis provides a bounding analysis for North Anna Unit 2, and to also remove any conservatism in the generic analysis for minimum wall thickness and leak rate requirements, if possible.

In establishing the structural adequacy of the laser welded sleeves in the generic analysis, criteria were evaluated for primary stress limits, maximum range of stress intensity and fatigue, and minimum wall thickness and leak rate requirements. The load conditions applicable to each of these areas are reviewed in this analysis to establish the applicability of the generic analysis. In general, the discussions to follow provide only a brief overview of each area. More in-depth discussions are contained in Reference (1) for the generic analysis.

2.0 SLEEVE DESIGN AND DESCRIPTION

The [

]^{a,c}.

3.0 ANALYTICAL VERIFICATION

3.1 Applicable Loading Conditions

The umbrella loading conditions for the generic analysis are defined in Reference (2), and are based on a review of the applicable design specifications for Series 44 and 51 steam generators. The

applicable loading conditions for North Anna Unit 2 steam generators are taken from the plant specific design specification, Reference (3). The following set of parameters corresponding to full power operation have been provided by the customer in Reference (4).

Normal Operation Parameter Ranges a,c

[ ]

In addition, the following conditions have been defined in Reference (4) for the Loss of Load Upset transient.

Primary Pressure = 2676 psia

Secondary Pressure = 1166 psia

3.2 Primary Stress Limits

A summary of the limiting pressure loads used in the generic analysis for evaluating the sleeve primary stresses are summarized in Table 1. In comparing the plant specific loads to the generic loads, the generic loads are found to umbrella the plant specific values.

A summary of the limiting stresses for primary stress limits are summarized in Tables 2 and 3. In performing the generic analysis, two conditions are evaluated relative to the tube integrity between the upper and lower welds for the tubesheet sleeve. [

]a,c

[

]a,c

Note that for primary stress, the limiting condition for the sleeve is with the [

]^{a,c}

3.3 Maximum Range of Stress and Fatigue

In evaluating the maximum range of stress and fatigue, the number of transients, as well as the temperature and pressure fluctuations are significant. A comparison of the transient cycles considered in the generic analysis to the applicable transients for North Anna Unit 2 is provided in Table 4. This comparison shows that the generic analysis considers a larger number of transients, and in general, more transient cycles, than are applicable to North Anna Unit 2.

Relative to the temperature and pressure fluctuations, the transient definitions for both the generic and North Anna Unit 2 design specifications are defined in terms of changes in applicable parameters from an initial starting point, typically normal operation. Comparison of the pressure fluctuations shows the generic analysis and North Anna Unit 2 values to be comparable. Because the generic analysis considers more transients and generally more transient cycles than North Anna Unit 2, the generic analysis is concluded to be applicable to North Anna Unit 2. (Note also that the fatigue usage for the generic analysis is quite low (<0.10)).

A summary of the limiting stress ranges is shown in Table 5, along with the accumulated fatigue usage for the limiting cross section.

3.4 Minimum Wall Thickness Requirements

The heat transfer area of steam generators in a PWR nuclear steam supply system (NSSS) comprises over 50 percent of the total primary system pressure boundary. The steam generator tubing, therefore, represents a primary barrier against the release of radioactivity to the environment. For this reason, conservative design criteria have been established for the maintenance of sleeve structural integrity under the postulated design-basis accident condition loadings in accordance with Section III of the ASME Code.

Over a period of time under the influence of the operating loads and environment in the steam generator, some sleeves may become degraded in local areas. To determine the condition of the

tubing, in-service inspection using eddy-current techniques is performed. Partially-degraded sleeves with net wall thicknesses greater than the minimum acceptable sleeve wall thickness are satisfactory for continued service, provided that leak before break is established, and that the minimum required sleeve wall thickness is adjusted to take into account possible uncertainties in the eddy current inspection, and an operational allowance for continued sleeve degradation until the next scheduled inspection. The amount of degradation recorded by eddy current testing is customarily expressed as a percentage of the design nominal sleeve wall thickness, and the acceptable degradation is referred to as the sleeve plugging margin. As a conservative measure, an allowance of 20% is included in the calculations for continued eddy current uncertainty and continued sleeve degradation until the next scheduled outage (10% for each effect).

In establishing the safe limiting condition of a sleeve in terms of its remaining wall thickness, the effects of loadings during both the normal operation and the postulated accident conditions must be evaluated. The applicable stress criteria are in terms of allowables for the primary membrane and membrane-plus-bending stress intensities.

The minimum required sleeve wall thickness, t_{min}, to sustain normal and accident condition loads is calculated assuming the surrounding sleeve is completely degraded over its entire length; that is, no design credit is taken for the residual strength of the sleeve. For computing t_{min}, the pressure stress equation NB-3324.1 of the ASME Code is used. That is,

$$t_{min} = \frac{\Delta P_i \times R_i}{P_m - 0.5 (P_i + P_o)}$$

Where:

P_i	=	Primary side pressure
P_o	=	Secondary side pressure
ΔP_i	=	Primary-to-secondary pressure differential
R_i	=	Sleeve inside radius
P_m	=	Allowable stress

A comparison of the calculations to determine the minimum required thickness for the generic effort and for North Anna Unit 2 is provided in Table 6. These results show the plugging margin for North

Anna Unit 2 to be slightly higher than the generic value, 33% of the nominal sleeve thickness for North Anna Unit 2 versus 32% for the generic analysis.

3.5 Burst Strength Requirements

The rationale behind this requirement is to limit the maximum allowable (primary-to-secondary) leak rate during normal operation such that the associated crack length (through which the leakage occurs) is less than the critical crack length corresponding to the maximum postulated accident condition pressure loading. Thus, on the basis of leakage monitoring during normal operation, unstable crack growth is not expected to occur in the unlikely event of the limiting accident.

Leak rates for the sleeves are a function of sleeve geometry, material strength properties, and several operating parameters. The operating properties of significance are the primary and secondary side pressures and the primary side temperature. As part of the generic analysis effort, calculations were performed to determine the sensitivity of leak rate to t_{hot} and primary to secondary side ΔP. The results show the limiting set of conditions to correspond to the highest secondary side pressure combined with the highest value for t_{hot}. A comparison of t_{hot} and the primary-to-secondary side ΔP for the generic analysis to North Anna Unit 2 is provided in Table 7. The results show the two sets of values to be very similar. The current allowable leak rate values for the generic effort and for North Anna Unit 2 are also shown. The value for North Anna Unit 2 is an Administrative Leak Limit. The generic value represents the largest permissible value for a plant for the case where laser welded sleeves are installed. The 50 gpd per steam generator limit for North Anna Unit 2 is less than the specified generic limit of 340 gpd per steam generator, and is, therefore, acceptable.

3.6 Conclusions

Based on the results of the above evaluation, the generic analysis is concluded to form a bounding analysis for the North Anna Unit 2 steam generators for all conditions. Based on the combined results of this analysis and the generic evaluation, the following conclusions are made regarding the structural requirements for laser welded sleeves for the North Anna Unit 2 steam generators.

1. The laser welded sleeves are concluded to meet applicable code and regulatory requirements.

2. The allowable plugging margin for sleeve degradation is 33%.

3. Based on a plant administrative limit, as stated in Reference 4, the allowable leak rate for North Anna Unit 2 steam generators is 50 gpd per steam generator. The allowable leak rate limit corresponding to installation of laser welded sleeves is 340 gpd per steam generator.

4.0 MECHANICAL TESTS

The mechanical tests [

].[a,c] A portion of the mechanical tests in Section 4.0 of Reference (1) determined the resistance to primary-to-secondary leakage for tubesheet sleeve non-welded lower joints and the applicable leakage criteria.

5.0 STRESS CORROSION TESTING OF LASER WELDED SLEEVE JOINTS

The conclusions reached in Reference (1) for performance of laser welded joints, i.e., tubesheet sleeve lower joint, as well as free-span, apply directly to North Anna Unit 2.

6.0 INSTALLATION PROCESS DESCRIPTION

The outline of the installation processes in Reference (1) apply directly to North Anna Unit 2. The discussion in Reference (1) was intended to provide an overview; the detailed installation process verification steps are all specified in the individual applicable field service procedures that will be provided by Westinghouse as part of the job.

7.0 NONDESTRUCTIVE EXAMINATION (NDE) INSPECTABILITY

The NDE Section of Reference (1) was intended to specify the installation NDE plan logic and to define the principles of the NDE processes to be used. It applies directly to North Anna Unit 2.

8.0 REFERENCES

1. WCAP-13088, Rev. 1, "Westinghouse Series 44 and 51 Steam Generator Generic Sleeving Report - Laser Welded Sleeves," 1/93.

2. Design Specification 412A19, "Plants with Series 44 and 51 Steam Generators, Steam Generator Heat Transfer Tube Sleeving," ASME Boiler and Pressure Vessel Code, Section III, Code Case 1 Safety Class 1, 1) 12/17/92.

3. Design Specification 677307, Revision 4, "Virginia Electric and Power Company North Anna Power Station Unit Numbers 1 and 2, 51 Series Steam Generator," R. L. Sylvester, 10/15/84.

4. Letter, E. S. Throckmorton, Virginia Power, to J. L. Houtman, Westinghouse, 2/15/93, Transmittal of North Anna Internal Letter NSA-93030, "Key Parameter Values for Use in Westinghouse Report of SG Sleeving Application to North Anna Unit 2," K. L. Basehore to E. W. Throckmorton, 2/4/93 and results of North Anna Units 1 and 2 Standing Order No. 179.

Table 1
Umbrella Pressure Loads for
Design, Faulted, and Test Conditions

a,c

[

]

Table 2

Summary of Maximum Primary Stress Intensity

Full Length Tubesheet Laser Welded Sleeve

[ ]^{a,c}

a,c

Table 3

Summary of Maximum Primary Stress Intensity

Full Length Tubesheet Laser Welded Sleeve

[ ]^{a,c}

a,c

[

]

Table 4
Comparison of Transient Cycles
Generic Series 44 and 51 Steam Generators
versus North Anna Unit 2

a,c

[

]

Table 5
Maximum Range of Stress Intensity and Fatigue

a,c

[ ]

Table 6

Comparison of Minimum Wall Thickness Calculations for Sleeves

Generic Series 44 and 51 Steam Generators

versus North Anna Unit 2

a,c

[

]

Table 7
Comparison of Operating Parameters
for Leak Before Break Calculations

Generic Series 44 and 51 Steam Generators
versus North Anna Unit 2

[ ] a,c