February 10, 2000

David J. Modeen, Director
Engineering, Nuclear Generation Division
Nuclear Energy Institute
1776 I Street, NW., Suite 400
Washington, DC 20006-3708

SUBJECT: GENERIC SAFETY EVALUATION - STEAM GENERATOR LEAK TIGHT SLEEVES DESIGNED BY ASEA BROWN BOVERI - COMBUSTION ENGINEERING

Dear Mr. Modeen:

On August 27, 1999, the NRC staff met with representatives of Nuclear Energy Institute (NEI), Electric Power Research Institute (EPRI), and industry (industry) to discuss issues regarding the implementation of the industry initiative entitled NEI 97-06 “Steam Generator Program Guidelines.” As part of that discussion, industry proposed that licensees may use alternate performance criteria, alternate repair criteria, and alternate repair methods approved generically by the NRC subject to the limitations and conditions set forth in the staff’s approving document. Each licensee’s demonstration of its satisfaction of the generic limitations and conditions must be documented in a safety evaluation prepared in accordance with 10 CFR 50.59.

Industry and staff also discussed several NRC-approved (plant-specific) alternate repair methods and criteria for which the industry would like generic approval. The staff agreed that it could review previously approved plant-specific alternate repair methods and criteria (industry would prioritize) and stated that it would provide industry a review schedule.

During subsequent phone conversations, industry provided the staff with three NRC-approved alternate repair methods and criteria which they requested be reviewed for generic use. Two of the NRC-approved reviews are currently on hold while the staff resolves open questions with the vendor (Westinghouse laser welded sleeves and W* alternate repair criteria).

The enclosed generic safety evaluation provides the staff’s review of a repair method for degraded steam generator tubes. The repair method uses leak-tight sleeves designed by Asea Brown Boveri - Combustion Engineering (ABB-CE). The design, analysis, qualification, and installation of the leak-tight sleeves are documented in two ABB-CE topical reports, “Repair of Westinghouse Series 44 and 51 Steam Generator Tubes Using Leak Tight Sleeves,” CEN-629-P, Rev. 3 (the sleeve in this topical report is applicable for installation in the Westinghouse model 44 and 51 steam generators) and “Repair of 3/4 O.D. Steam Generator Tubes Using Leak Tight Sleeves,” CEN-630-P, Rev. 2, (the sleeve in this topical report is applicable for installation in ABB-CE and Westinghouse steam generators that use 3/4-inch outer diameter tubing).

In the safety evaluation, the staff finds that the repair methodology of ABB-CE leak-tight sleeves as described in the previously mentioned ABB-CE topical reports is acceptable for use to restore degraded tubes to maintain reactor pressure boundary integrity. However, the staff's approval of the ABB-CE leak-tight sleeve repair methodology is subject to the conditions and/or clarifications outlined in the safety evaluation.

As previously discussed, this generic evaluation of a previously approved plant specific repair methodology is to be used by licensees provided they can demonstrate via 10 CFR 50.59 their plant specific application is bounded by the enclosed generic safety evaluation. Since the NRC has not endorsed, and licensees have not implemented the new regulatory framework associated with NEI 97-06, licensees are still required to submit technical specification changes to use this repair methodology. However, licensees can reference this generic safety evaluation and only need to provide justification for any deviations from the NRC's generic limitations and conditions in their technical specification change request. In the future, following NRC endorsement of NEI 97-06 (if found acceptable) and licensee implementation of the new regulatory framework (including technical specification changes), licensees would be able to use this repair methodology subject to the generic limitations and conditions without the need for a technical specification change. If a licensee were to deviate from the generic limitations and conditions, a letter documenting and justifying the deviation would have to be submitted to the NRC for review and approval.

As discussed with your staff, a similar letter has been sent to Mr. Don Streinz of ABB-CE. If you should have any questions regarding this generic safety evaluation, please contact Ted Sullivan at (301) 415-2796.

Sincerely,

Jack R. Strosnider, Director ***/ra/***
Division of Engineering
Office of Nuclear Reactor Regulation

Enclosure: As stated

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Enclosure: As stated

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GENERIC SAFETY EVALUATION

FOR LEAK TIGHT SLEEVES IN STEAM GENERATORS

DESIGNED BY

ASEA BROWN BOVERI-COMBUSTION ENGINEERING

1. INTRODUCTION

This generic safety evaluation provides staff approval of a repair method for degraded steam generator tubes subject to certain conditions identified herein. The repair method uses leak-tight sleeves designed by Asea Brown Boveri-Combustion Engineering (ABB-CE). The design, analysis, qualification, and installation of the leak-tight sleeves are documented in two ABB-CE topical reports. One report is "Repair of Westinghouse Series 44 and 51 Steam Generator Tubes Using Leak Tight Sleeves," CEN-629-P, Rev. 3 (Reference 1). The sleeve in this topical report is applicable for installation in the Westinghouse model 44 and 51 steam generators. The second report is "Repair of 3/4 O.D. Steam Generator Tubes Using Leak Tight Sleeves," CEN-630-P, Rev. 2 (Reference 2). The sleeve in this topical report is applicable for installation in ABB-CE and Westinghouse steam generators that use 3/4-inch outer diameter tubing.

2. BACKGROUND

Steam generator tubes form a part of reactor coolant pressure boundary. The tubes in References 1 and 2 were fabricated with mill annealed alloy 600 material. After a period of use, the tubes may degrade and, thus, require repair or be removed from service. The following are NRC regulations and industry standards that apply to tube repair using sleeves.

The sleeve repairs a part of the degraded reactor coolant pressure boundary (i.e., steam generator tubes). As such, General Design Criterion (GDC) 14 of Appendix A to 10 Code of Federal Regulations (CFR) Part 50 applies. GDC 14 requires that the reactor coolant pressure boundary be designed, fabricated, erected, and tested so as to have an extremely low probability of abnormal leakage, of rapidly propagating failure, and of gross rupture.

To satisfy GDC 14, the sleeve is required to satisfy several sections of the ASME Boiler and Pressure Vessel Code. The sleeve is qualified for service in accordance with IWA-4000 in Section XI of the ASME Code. In addition, Section XI references Section III of the ASME code for component design requirements, which govern the original steam generator tubes and are applicable to the design of the sleeve. The sleeve is analyzed to appropriate Section III criteria for structural integrity considering design, operating, and accident loading conditions. The resulting stresses in the sleeve and sleeve wall thickness satisfy corresponding Section III allowables. The leak tight sleeve requires welding which satisfies the qualification standard for welding procedures, welders, and welding operators in Section IX of the ASME Code.

Regulatory Guide (RG) 1.121, “Bases for Plugging Degraded PWR Steam Generator Tubes,” provides guidance for determining minimum tube wall thickness beyond which the degraded tube should be plugged (i.e., plugging limits). The sleeve is a part of a repaired tube; therefore, RG 1.121 applies to the development of sleeve plugging limits.

The staff has approved the use of ABB-CE designed leak-tight sleeves in U.S. nuclear plants. Details of prior staff evaluations of leak tight sleeves may be found in the staff safety evaluations for Waterford Steam Electric Station, Unit 3, docket number 50-382, dated December 14, 1995; Byron Nuclear Power Station, Units 1 and 2 and Braidwood Nuclear Power Station, Units 1 and 2, docket numbers 50-454, 50-455, 50-456 and 50-457, dated April 12, 1996; Kewaunee Nuclear Power Plant, docket No. 50-305, dated June 7, 1997; Prairie Island Units 1 and 2, docket numbers 50-282 and 50-306, dated November 4, 1997; Beaver Valley Unit 1, docket number 50-334, dated November 25, 1997; San Onofre Units 2 and 3, docket numbers 50-361 and 50-362, dated August 26, 1998 and Palo Verde Units 1, 2 and 3, docket numbers 50-528, 50-529, and 50-530, dated August 5, 1999.

3.0 EVALUATION

The staff has reviewed the following areas of the sleeve repair method: design, material selection, structural integrity, sleeve acceptance inspection, corrosion tests and plugging limits. These topics are discussed below:

3.1 Design

The ABB-CE leak tight sleeve is welded to the parent tube by autogenous gas-tungsten arc welding. The leak tight sleeves can be grouped into two types of sleeves: the expansion/roll transition zone (ETZ) sleeve and the tube support plate (TS) sleeve. One type of the ETZ sleeve is welded to the parent tube at the upper and lower end of the sleeve. The lower end of the sleeve is in the tubesheet. The other type of the ETZ sleeve is welded to the tube at the upper end and the lower end is hard rolled to the tube in the tubesheet. The TS sleeve spans the degraded area of the tube at a tube support or in a free span section of tube. Both the upper and lower end of a TS sleeve are welded to the parent tube.

The welding process uses automatic autogenous gas tungsten arc welding which was qualified and demonstrated during laboratory tests by full scale mock-ups in accordance with the specifications of the ASME Code, Section IX.

3.2 Materials of Construction

The sleeve material, thermally treated (TT) Alloy 690, is a nickel-iron-chromium alloy. It is an ASME Code approved material, specified in ASME SB-163, and is incorporated in ASME Code Case N-20. The staff has determined that the use of Alloy 690 TT material is an improvement over the Alloy 600 material used in the parent tube. Corrosion tests conducted under Electric Power Research Institute (EPRI) sponsorship confirm that Alloy 690 TT resists corrosion better than Alloy 600. As a result of these laboratory corrosion tests, the staff has concluded that Alloy 690 TT satisfies the guidelines in Regulatory Guide 1.85, “Materials Code Case Acceptability ASME Section III, Division 1,” Revision 24, dated July 1986. The staff has approved Alloy 690 TT tubing in previous sleeving applications.

The leak tight sleeve in References 1 and 2 is designed and qualified to repair degraded mill annealed Alloy 600 tubing. The staff concludes that, considering differences in thermal expansion and strength among different tube materials, licensees need to submit additional technical basis for staff review and approval if the leak-tight sleeve is used to repair degraded tubes other than mill annealed Alloy 600 tubing.

3.3 Structural Integrity

ABB-CE performed a structural analysis of sleeve-tube assembly in accordance with the ASME Code, Section III, and 10 CFR Part 50, Appendix B. Based on ABB-CE calculations, for the conditions covered by References 1 and 2, the leak-tight sleeves satisfy the safety margins in the ASME Code and the requirements in NRC regulations.

ABB-CE performed mechanical tests on mock-up sleeve-tube assemblies. These tests include axial load, collapse, burst and thermal cycling capability. Loads were applied until failure or, in the case of cyclic loading, until the number of cycles exceeded the expected number of cycles for the plant. For the conditions covered by References 1 and 2, these tests confirmed that sleeve-tube assemblies satisfy ASME code Section III allowables for normal operating and accident conditions.

For new, first time applications of the subject sleeves, licensees shall perform an assessment in accordance with 10 CFR 50.59 demonstrating that the loading conditions and temperatures for their steam generator tubes are bounded by those covered in References 1 and 2. These conditions include differential pressures, axial loadings, and temperatures under design, nominal operating steady state, and accident conditions. Should the loading conditions and temperatures considered in References 1 and 2 not be bounding, licensees shall submit a revised structural assessment for staff review and approval prior to implementing the subject sleeve repairs.

3.4 Sleeve Acceptance Inspections

During the spring 1996 refueling outage, the licensee of a domestic nuclear plant detected eddy current test (ET) indications in the weld joints of ABB-CE leak tight sleeves. The weld defects were caused by entrapped oxides and/or weld shrinkage within the sleeve-to-tube weld. The cause of these weld defects was traced to inadequate tube cleaning. Although the defects did not significantly impair the structural integrity (strength) of the welds and did not cause leakage, they did increase the probability of leakage.

To minimize potential weld defects, ABB-CE has improved tube cleaning as a part of the sleeving installation procedures. Prior to installing a sleeve, the inner surface of the parent tube at the desired weld location is cleaned of service-induced oxides using motorized wire brushes.

In addition, ABB-CE specifies three visual inspections in References 1 and 2 to ensure the integrity of the welds. The first visual inspection is performed after the brush cleaning of the weld region inside surface of the tube. ABB-CE specifies that the visual inspection for cleanliness of all repaired tubes is to be performed as an interim measure until sufficient field experience is gained to consider adoption of statistical sampling for visual inspection in the future. The staff concludes that this interim measure shall apply until licensees determine in

accordance with 10 CFR 50.59 and based on vendor's recommendations that there is sufficient field experience to support a statistically based sampling plan for visual inspection.

The second visual inspection, which ABB-CE suggests as optional, is performed after completion of the weld and is conducted as a VT-1 inspection in accordance with Section XI of the ASME Code. The VT-1 inspection is also performed for re-welds. The third visual inspection, which ABB-CE specifies as non-optional, is a VT-1 inspection performed on the lower weld of full depth tubesheet sleeve. Based on the staff review of the inspection data, the staff concludes that licensees need to perform visual inspection after tube cleaning in accordance with References 1 and 2. Licensees need to perform a VT-1 inspection of each sleeve-to-tube weld until sufficient data has been obtained with UT and ET techniques to show that these techniques are capable of detecting and resolving uncertainties in the weld joint.

In a separate case in the mid-1990's, during an installation of welded sleeves in another domestic nuclear plant, weld zone indications were identified visually that were not detected by either ET or ultrasonic testing (UT). The original UT procedure for the sleeve weld joint was based upon the absence of a mid-wall reflection. In an acceptable sleeve-to-tube weld, the mid-wall reflection (mid-wall of the fused sleeve and tube) would not appear because no interface would exist. Previous field experience showed that lack of fusion was not detected by the original UT procedure.

ABB has revised the UT procedure which has been incorporated in References 1 and 2. In the improved UT procedure, the back wall signal from the outside of the parent tube is also monitored for presence in the fused area. Additionally, the back wall signal strength is examined for excessive attenuation. Attenuation beyond the normal signal strength, along with other signal artifacts, can be used to detect unacceptable welds. ABB-CE has also improved its ET by specifying the use of the plus point probe for a baseline and acceptance inspection. ABB-CE has qualified the plus point probe for sleeve inspections in accordance with EPRI Steam Generator Inspection Guidelines. The staff concludes that licensees need to conduct UT and ET examinations after the completion of the sleeve-to-tube weld for all installed sleeves in accordance with References 1 and 2. In addition, licensees need to perform inservice inspection of sleeves with appropriate sample size in accordance with the latest revision of the EPRI report, "Steam Generator Examination Guidelines," TR-107569.

3.5 Corrosion Tests

ABB-CE has performed a number of bench and autoclave tests to evaluate the corrosion resistance of the welded sleeve-tube joint. The corrosion tests were conducted to determine the effect of the mechanical expansion and weld residual stresses and the condition of the weld and weld heat affected zone. ABB-CE performed accelerated corrosion tests on actual sleeve samples whose inside surface and outside surface were subjected to corrosive solutions. The corrosion tests showed that Alloy 690 material performs significantly better than Alloy 600 material in terms of corrosion resistance. The staff concludes that Alloy 690 leak-tight sleeves have a relatively high resistance to corrosion compared to the original mill annealed alloy 600 tubing and are suitable for tube repair.

3.6 Plugging limit

The sleeve plugging limit is defined as the imperfection depth in the sleeve at or beyond which the sleeved tube shall be removed from service. The sleeve plugging limit is calculated from the minimum acceptable sleeve wall thickness to maintain structural integrity. RG 1.121 and ASME Code Section III provide guidance on the calculations. Based on the ABB-CE topical reports, the percentages of allowed sleeve degradation due to structural considerations are 52% of the sleeve wall thickness for sleeves in Reference 1. For sleeves in Reference 2, the plugging limits are 48% for ABB-CE plants and 50% for Westinghouse plants. In addition to structural considerations, RG 1.121 also addresses the need to account for an allowance for nondestructive examination (NDE) uncertainty and postulated growth of degradation in calculating the sleeve plugging limit. Based on the above, the staff concludes that the licensee's design basis documents (e.g., Technical Requirements Manual) shall include the applicable required limit for the sleeves. The applicable plugging limit shall be no more than 32% of sleeve wall thickness for sleeves installed in accordance with Reference 1. The applicable pugging limit shall be no more than 28% of sleeve wall thickness for sleeves installed in ABB-CE plants and 30% of sleeve wall thickness for sleeves installed in Westinghouse plants in accordance with Reference 2.

4. CONCLUSION

The staff finds that the repair methodology of ABB-CE leak-tight sleeves as described in References 1 and 2 is acceptable for use to restore degraded tubes to maintain reactor pressure boundary integrity. The staff approves the sleeve repair methodology documented in Reference 1 for application to Westinghouse Model 44 and 51 steam generators having mill annealed Ally 600 tubing. The staff also approves the sleeve repair methodology documented in Reference 2 for application to Westinghouse and Combustion Engineering steam generators with 3/4-inch diameter having mill annealed Alloy 600 tubing. However, the staff's approval of the ABB-CE leak-tight sleeve repair methodology is subject to the following conditions and/or clarifications:

1. "Sleeve repair methodology" refers to all aspects of the sleeve design, fabrication, field installation, and post-process inspection described in References 1 and 2. It also refers to all vendor recommendations in References 1 and 2. Any deviations from References 1 and 2, including new revisions to the topical reports, shall be submitted for NRC review and approval prior to implementation.

2. Prior to initial plant-specific implementation, licensees shall perform an assessment in accordance with 10 CFR 50.59 to demonstrate that plant-specific and location-specific (i.e., locations within the steam generators where sleeves are being installed) loading conditions (e.g., pressure and thermally induced loads) applicable to the sleeves under design, operational, transient, and accident conditions are bounded by the conditions for which the sleeves were designed and analyzed as documented in References 1 and 2. This assessment should consider the possibility that axial forces due to differential thermal expansion may be induced in the tubes due to lockup of the tubes at the tube support plates caused by corrosion product in the tube to tube support plate crevices.

3. The weld preparation procedure shall require, as an interim measure, visual inspection of each tube to be sleeved to confirm adequate surface cleaning prior to sleeve installation and welding. This interim measure shall apply until licensees determines in accordance with 10 CFR 50.59 and based on vendor's recommendations that there is sufficient field experience to support a statistically based sampling plan for visual inspection.

4. Post process weld inspection shall include VT-1 (visual) inspection in addition to ET and UT as described in Reference 1 and 2 as an interim measure until the licensee determines in accordance with 10 CFR 50.59 and based on vendor's recommendations that ET and UT are sufficient to confirm an adequate weld.

5. Sample size for inservice inspection of sleeves shall be selected in accordance with the most recent revision of the EPRI Steam Generator Examination Guidelines.

6. The licensee's design basis documents (e.g., Technical Requirements Manual) shall list the applicable plugging limits for the sleeves. The applicable plugging limit shall be no more than 32% of sleeve wall thickness for sleeves installed in accordance with Reference 1. The applicable pugging limit shall be no more than 28% of sleeve wall thickness for sleeves installed in ABB-CE plants and 30% of sleeve wall thickness for sleeves installed in Westinghouse plants in accordance with Reference 2.

7. Prior to implementing the subject sleeve repair method, the licensee shall update its design basis documents to identify the approved sleeving method and to place conditions/clarifications on its use in accordance with this safety evaluation.

8. If licensees intend to use sleeve repair methodology in a later revision to References 1 and 2, licensees need to submit for staff review and approval the later revision.

Note that with regard to Item 8, the staff will limit the scope of its review to only those aspects of the methodology which are being revised. Clear identification of the specific revisions being made to References 1 and 2 will expedite the staff review.

5. REFERENCES

1. Repair of Westinghouse Series 44 and 51 "Steam Generator Tubes Using Leak Tight Sleeves," CEN-629-P, Rev. 3, 1998 (Proprietary).

2. "Repair of 3/4 O.D. Steam Generator Tubes Using Leak Tight Sleeves," CEN-630-P, Rev. 2, June 1997 (Proprietary).