Docket File

UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D.C. 20555-0001

May 21, 1999

Mr. Garry L. Randolph
Vice President and Chief Nuclear Officer
Union Electric Company
Post Office Box 620
Fulton, Missouri 65251

SUBJECT: AMENDMENT NO. 132 TO FACILITY OPERATING LICENSE NO. NPF-30 - CALLAWAY PLANT, UNIT 1 (TAC NO. MA3954)

Dear Mr. Randolph:

The Commission has issued the enclosed Amendment No. 132 to Facility Operating License No. NPF-30 for the Callaway Plant, Unit 1. The amendment consists of changes to the Technical Specifications (TS) in response to your application dated October 27, 1998, as supplemented by letters in 1999 dated January 11, January 29, February 25, April 7 (two letters) and May 17.

The amendment revises TS 4.4.5.4, Table 4.4-3, and the associated Bases to allow the repair of Callaway Plant, Unit 1 steam generator tubes with the Electrosleeve tube repair method. As discussed in the enclosed safety evaluation, staff concerns with the qualification of non-destructive examination (NDE) techniques proposed for inservice examination of the Electrosleeves need to be addressed further. Consequently, this amendment includes a two cycle operating limit that requires all steam generator tubes repaired with Electrosleeves to be removed from service at the end of two operating cycles following installation of the first Electrosleeve. The staff considers the two cycle limitation acceptable based on Electrosleeve corrosion test results and the expected corrosion resistance of Electrosleeves relative to the steam generator tube material, Alloy 600. This limit was agreed upon by Union Electric Company and included in your amendment application dated October 27, 1998. During the next two operating cycles the staff expects Union Electric Company to complete qualification efforts of the inservice inspection NDE technique, and submit an amendment application requesting the staff to remove the two cycle limitation.

The staff determined that, with the exception of the NDE qualification issue, the amendment application meets the requirements of the Callaway current licensing basis. However, in the course of our review, the staff identified issues with the Electrosleeve steam generator tube repair performance during postulated severe accident conditions. These severe accident conditions are beyond the Callaway Plant, Unit 1 current licensing basis.

In evaluating the risk implications of the amendment request, the staff investigated both the specific Callaway Plant probability of severe accident conditions that may challenge Electrosleeve repaired tubes and the expected performance of the repaired tubes. With regard to the probability of severe accidents that may challenge Electrosleeve repaired tubes, the staff considered Callaway's Standardized Nuclear Unit Power Plant (SNUPPS) design. The staff believes severe accident vulnerabilities are minimized because of the SNUPPS design. In

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considering the robustness of the Callaway Plant SNUPPS design, the staff determined the specific Callaway Plant frequency of severe accident conditions that could challenge Electrosleeve repaired steam generator tubes to be in the low- to mid-10E-6 per year range. With regard to the expected performance of the Electrosleeved repaired tubes during postulated severe accident conditions, the staff recognized that large uncertainties currently exist in characterizing severe accident thermal-hydraulic modeling and expected time-to-failure of Electrosleeved tubes as compared to other reactor coolant system components inside containment. In issuing this amendment, the staff considered the low frequency of severe accidents for Callaway Plant that may challenge Electrosleeves. Although there is some information that may suggest concerns with respect to the comparative time-to-failure of Electrosleeved tubes under severe accident conditions, this information is not sufficiently developed to support imposition of limitations arising from a risk-informed perspective at this time.

In the course of its review, the staff identified policy issues associated with risk-informed regulation that will require further evaluation and guidance development. The staff also identified certain aspects of severe accident phenomena for which further refinement of analysis models is considered necessary for making future risk-informed decisions. The staff intends to pursue both of these areas.

A copy of the Safety Evaluation is also enclosed. The Notice of Issuance will be included in the Commission's next biweekly Federal Register notice.

Sincerely,

/s/
Mel Gray, Project Manager, Section 2
Project Directorate IV & Decommissioning
Division of Licensing Project Management
Office of Nuclear Reactor Regulation

Docket No. 50-483

Enclosures: 1. Amendment No. 132 to NPF-30
2. Safety Evaluation

cc w/encls: See next page

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Non-Concurrence
See conclusions & recommendations in 5/21/99 SER input from DSSA

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Recommend non-concurrence based on May 21 DSSA SER

Recommend NON-CONCURRENCE

considering the robustness of the Callaway Plant SNUPPS design, the staff determined the specific Callaway Plant frequency of severe accident conditions that could challenge Electrosleeve repaired steam generator tubes to be in the low- to mid-10E-6 per year range. With regard to the expected performance of the Electrosleeved repaired tubes during postulated severe accident conditions, the staff recognized that large uncertainties currently exist in characterizing severe accident thermal-hydraulic modeling and expected time-to-failure of Electrosleeved tubes as compared to other reactor coolant system components inside containment. In issuing this amendment, the staff considered the low frequency of severe accidents for Callaway Plant that may challenge Electrosleeves. Although there is some information that may suggest concerns with respect to the comparative time-to-failure of Electrosleeved tubes under severe accident conditions, this information is not sufficiently developed to support imposition of limitations arising from a risk-informed perspective at this time.

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A copy of the Safety Evaluation is also enclosed. The Notice of Issuance will be included in the Commission's next biweekly Federal Register notice.

Sincerely,

Mel Gray

Mel Gray, Project Manager, Section 2
Project Directorate IV & Decommissioning
Division of Licensing Project Management
Office of Nuclear Reactor Regulation

Docket No. 50-483

Enclosures: 1. Amendment No. 132 to NPF-30
2. Safety Evaluation

cc w/encls: See next page

cc w/encl:
Professional Nuclear
Consulting, Inc.
19041 Raines Drive
Derwood, Maryland 20855

John O'Neill, Esq.
Shaw, Pittman, Potts & Trowbridge
2300 N. Street, N.W.
Washington, D.C. 20037

Mr. H. D. Bono
Supervising Engineer
Quality Assurance Regulatory Support
Union Electric Company
Post Office Box 620
Fulton, Missouri 65251

U.S. Nuclear Regulatory Commission
Resident Inspector Office
8201 NRC Road
Steedman, Missouri 65077-1302

Mr. J. V. Laux, Manager
Quality Assurance
Union Electric Company
Post Office Box 620
Fulton, Missouri 65251

Manager - Electric Department
Missouri Public Service Commission
301 W. High
Post Office Box 360
Jefferson City, Missouri 65102

Regional Administrator, Region IV
U.S. Nuclear Regulatory Commission
Harris Tower & Pavilion
611 Ryan Plaza Drive, Suite 400
Arlington, Texas 76011-8064

Mr. Ronald A. Kucera, Deputy Director
Department of Natural Resources
P.O. Box 176
Jefferson City, Missouri 65102

Mr. Otto L. Maynard
President and Chief Executive Officer
Wolf Creek Nuclear Operating Corporation
Post Office Box 411
Burlington, Kansas 66839

Mr. Dan I. Bolef, President
Kay Drey, Representative
Board of Directors Coalition
for the Environment
6267 Delmar Boulevard
University City, Missouri 63130

Mr. Lee Fritz
Presiding Commissioner
Callaway County Court House
10 East Fifth Street
Fulton, Missouri 65151

Mr. Alan C. Passwater, Manager
Licensing and Fuels
Union Electric Company
Post Office Box 66149
St. Louis, Missouri 63166-6149

UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D.C. 20555-0001

UNION ELECTRIC COMPANY

CALLAWAY PLANT, UNIT 1

DOCKET NO. 50-483

AMENDMENT TO FACILITY OPERATING LICENSE

Amendment No. 132
License No. NPF-30

1. The Nuclear Regulatory Commission (the Commission) has found that:

   A. The application for amendment by Union Electric Company (UE, the licensee) dated October 27, 1998, as supplemented by letters in 1999 dated January 11, January 29, February 25, April 7 (two letters), and May 17, complies with the standards and requirements of the Atomic Energy Act of 1954, as amended (the Act) and the Commission's regulations set forth in 10 CFR Chapter I;

   B. The facility will operate in conformity with the application, the provisions of the Act, and the rules and regulations of the Commission;

   C. There is reasonable assurance (i) that the activities authorized by this amendment can be conducted without endangering the health and safety of the public, and (ii) that such activities will be conducted in compliance with the Commission's regulations;

   D. The issuance of this amendment will not be inimical to the common defense and security or to the health and safety of the public; and

   E. The issuance of this amendment is in accordance with 10 CFR Part 51 of the Commission's regulations and all applicable requirements have been satisfied.

2. Accordingly, the license is amended by changes to the Technical Specifications as indicated in the attachment to this license amendment and paragraph 2.C.(2) of Facility Operating License No. NPF-30 is hereby amended to read as follows:

(2) Technical Specifications and Environmental Protection Plan

The Technical Specifications contained in Appendix A, as revised through Amendment No. 132 and the Environmental Protection Plan contained in Appendix B, are hereby incorporated in the license. The licensee shall operate the facility in accordance with the Technical Specifications and the Environmental Protection Plan.

3. This amendment is effective as of its date of issuance to be implemented within 30 days from the date of its issuance.

FOR THE NUCLEAR REGULATORY COMMISSION

Stephen Dembek, Chief, Section 2
Project Directorate IV & Decommissioning
Division of Licensing Project Management
Office of Nuclear Reactor Regulation

Attachment: Changes to the Technical Specifications

Date of Issuance: May 21, 1999

ATTACHMENT TO LICENSE AMENDMENT NO. 132

FACILITY OPERATING LICENSE NO. NPF-30

DOCKET NO. 50-483

Replace the following pages of the Appendix A Technical Specifications with the enclosed pages. The revised pages are identified by amendment number and contain vertical lines indicating the areas of change.

REMOVE	INSERT
3/4 4-14	3/4 4-14
3/4 4-15	3/4 4-15
3/4 4-17a	3/4 4-17a
B 3/4 4-4	B 3/4 4-4

SURVEILLANCE REQUIREMENTS (Continued)

4.4.5.4 Acceptance Criteria

a. As used in this specification:

1) Imperfection means an exception to the dimensions, finish or contour of a tube from that required by fabrication drawings or specifications. Eddy-current testing indications below 20% of the nominal tube 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 containing 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 removed from service by plugging or repaired by sleeving and is equal to 40% of the nominal tube wall thickness. The plugging limit for laser welded sleeves is equal to 39% of the nominal sleeve wall thickness. The plugging limit for Electrosleeves is equal to 20% of the nominal sleeve wall thickness;

7) Unserviceable describes the condition of a tube 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 Specification 4.4.5.3c., 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 repaired by sleeving, the tube inspection shall include the sleeved portion of the tube;

9) 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 prior to initial POWER OPERATION using the equipment and techniques expected to be used during subsequent inservice inspections;

10) Tube Repair refers to a process that reestablishes tube serviceability. Acceptable tube repairs will be performed by the following processes:

a) Laser welded sleeving as described in Westinghouse Technical Report WCAP-14596-P, "Laser Welded Elevated Tube Sheet Sleeves for Westinghouse Model F Steam Generators." March 1996 (W Proprietary)

b) Electrosleeving as described in Framatome Technical Report BAW-10219P, Revision 3, 10/98, "Electrosleeving Qualification for PWR Recirculating Steam Generator Tube Repair." The plugging or repair limit for the pressure boundary portion of Electrosleeves is determined to be 20% through wall of the nominal sleeve wall thickness (as determined by NDE). The 20% plugging repair limit will apply to inner diameter pits in Regions B and C.

All steam generator tubes containing an Electrosleeve will be removed from service within 2 cycles following installation of the first Electrosleeve; and

11) Degraded Sleeve means a sleeve containing imperfections greater than 0% but less than 20% of the nominal wall thickness caused by degradation.

b. The steam generator shall be determined OPERABLE after completing the corresponding actions (plug or repair by sleeving all tubes exceeding the plugging or repair limit and all tubes containing through-wall cracks) required by Tables 4.4-2 and 4.4-3.

4.4.5.5 Reports

a. Within 15 days following the completion of each inservice inspection of steam generator tubes, the number of tubes plugged or repaired in each steam generator shall be reported to the Commission in a Special Report pursuant to Specification 6.9.2;

b. The complete results of the steam generator tube inservice inspection shall be submitted to the Commission in a Special Report pursuant to Specification 6.9.2 within 12 months following the completion of the inspection. This Special Report shall include:

1) Number and extent of tubes and sleeves inspected,

2) Location and percent of wall-thickness penetration for each indication of an imperfection, and

3) Identification of tubes plugged or repaired.

c. Results of steam generator tube inspections, which fall into Category C-3, shall be reported in a Special Report to the Commission pursuant to Specification 6.9.2 within 30 days and prior to resumption of plant operation. This report shall provide a description of investigations conducted to determine cause of the tube degradation and corrective measures taken to prevent recurrence.

TABLE 4.4-3

STEAM GENERATOR REPAIRED TUBE INSPECTION

1ST SAMPLE INSPECTION			2ND SAMPLE INSPECTION	
Sample Size	Result	Action Required	Result	Action Required
A minimum of 20% of repaired tubes (1) (2)	C-1	None	N.A.	N.A.
	C-2	Plug defective repaired tubes and inspect 100% of the repaired tubes in this S.G.	C-1	None
			C-2	Plug defective repaired tubes
			C-3	Perform action for C-3 result of first sample
	C-3	Inspect all repaired tubes in this S.G., plug defective tubes and inspect 20% of the repaired tubes in each other S.G. Notification to NRC pursuant to §50.72 (b)(2) of 10 CFR Part 50	All other S.G.s are C-1	None
			Some S.G.s C-2 but no additional S.G are C-3	Perform action for C-2 result of first sample
			Additional S.G. is C-3	Inspect all repaired tubes in each S.G. and plug defective tubes. Notification to NRC pursuant to §50.72 (b)(2) of 10 CFR Part 50

(1) Each repair method is considered a separate population for determination of initial inservice inspection and scope expansion.
(2) The inspection of repaired tubes may be performed on tubes from 1 to 4 steam generators based on outage plans.

STEAM GENERATORS (Continued)

The plugging or repair limit for the pressure boundary portion of laser welded sleeves is determined to be 39% through-wall (by NDE). The laser welded sleeve repair limit applicable to the pressure boundary portion of the sleeve is established in WCAP-14596. Appropriate NDE techniques are also discussed in WCAP-14596.

The plugging or repair limit for the pressure boundary portion of Electrosleeves is determined to be 20% through wall of the nominal sleeve wall thickness (as determined by NDE).

Whenever the results of any steam generator tubing inservice inspection fall into Category C-3, these results will be reported to the Commission pursuant to Specification 6.9.2 prior to resumption of plant operation. Such cases will be considered by the Commission on a case-by-case basis and may result in a requirement for analysis, laboratory examinations, tests, additional eddy-current inspection, and revision of the Technical Specifications, if necessary.

3/4.4.6 REACTOR COOLANT SYSTEM LEAKAGE

3/4.4.6.1 LEAKAGE DETECTION SYSTEMS

The RCS Leakage Detection Systems required by this specification are provided to monitor and detect leakage from the reactor coolant pressure boundary. These Detection Systems are consistent with the recommendations of Regulatory Guide 1.45, "Reactor Coolant Pressure Boundary Leakage Detection Systems," May 1973.

3/4.4.6.2 OPERATIONAL LEAKAGE

PRESSURE BOUNDARY LEAKAGE of any magnitude is unacceptable since it may be indicative of an impending gross failure of the pressure boundary. Therefore, the presence of any PRESSURE BOUNDARY LEAKAGE requires the unit to be promptly placed in COLD SHUTDOWN.

Industry experience has shown that while a limited amount of leakage is expected from the RCS, the unidentified portion of this leakage can be reduced to a threshold value of less than 1 gpm. This threshold value is sufficiently low to ensure early detection of additional leakage.

The total steam generator tube leakage limit of 600 gpd for all steam generators not isolated from the RCS ensures that the dosage contribution from the tube leakage will be limited to a small fraction of 10 CFR Part 100 dose guideline values in the event of either a steam generator tube rupture or steam line break. The 600 gpd limit is conservative compared to the assumptions used in the analysis of these accidents. The 150 gpd leakage limit per steam generator ensures that steam generator tube integrity is maintained in the event of a main steam line rupture or under LOCA conditions.

The 10 gpm IDENTIFIED LEAKAGE limitation provides allowance for a limited amount of leakage from known sources whose presence will not interfere with the detection of UNIDENTIFIED LEAKAGE by the Leakage Detection Systems.

The CONTROLLED LEAKAGE limitation restricts operation when the total flow from the reactor coolant pump seals exceeds 8 gpm per RC pump at a nominal RCS pressure of 2235 psig. This limitation ensures adequate performance of the RC pump seals.

UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D.C. 20555-0001

SAFETY EVALUATION BY THE OFFICE OF NUCLEAR REACTOR REGULATION

RELATED TO AMENDMENT NO. 132 TO FACILITY OPERATING LICENSE NO. NPF-30

UNION ELECTRIC COMPANY

CALLAWAY PLANT, UNIT 1

DOCKET NO. 50-483

1.0 INTRODUCTION

By letter dated October 27, 1998, as supplemented by letters in 1999 dated January 11, January 29, February 25, April 7 (two letters), and May 17, Union Electric Company (UE or the licensee), requested changes to the Technical Specifications (Appendix A to Facility Operating License No. NPF-30) for the Callaway Plant, Unit 1. The proposed changes would revise TS 4.4.5.4, Table 4.4-3, and the associated Bases to allow Callaway Plant, Unit 1 steam generator tubes to be repaired with Electrosleeves. As discussed in this safety evaluation, this amendment includes a two cycle operating limit that requires all steam generator tubes repaired with Electrosleeves to be removed from service at the end of two operating cycles following installation of the first Electrosleeve in the Callaway Plant, Unit 1 steam generators. This limit was agreed upon by the licensee and included in the amendment application dated October 27, 1998.

The supplemental letters in 1999 dated January 11, January 29, February 25, April 7 (two letters), and May 17, provided additional clarifying information and did not change the staff's original no significant hazards consideration determination or expand the scope of the original Federal Register notice published on December 2, 1998 (63 FR 66604).

2.0 BACKGROUND

2.1 Amendment Application

The licensee's amendment application dated October 27, 1998, requested changes to the Callaway Plant, Unit 1 technical specifications (TSs) to allow the use of a new technology for the repair of degraded steam generator (SG) tubes. The method is called Electrosleeve, a structural nickel plating applied to the inside of a degraded tube to form a tube sleeve. Electrosleeve is the trade mark name for the proprietary nickel plating technique for tube sleeving developed by Ontario Hydro Technologies (OHT). It is marketed for commercial use in the United States by Framatome Technologies, Inc. (FTI). The intent of the repair is to install sleeves that would remain in service for the remaining life of the steam generators.

The licensee originally requested approval of the Electrosleeve repair method in an amendment application dated April 12, 1996. In the review of this amendment application, the staff identified a number of issues, including qualification of non-destructive examination techniques planned for inservice examination of the Electrosleeves. The staff's concerns were identified in a letter from S. Collins to G. Randolph dated May 20, 1998. In response to this letter, the licensee submitted an amendment application dated October 27, 1998, which superceded the April 12, 1996, amendment application. The October 27, 1998, amendment application included FTI Topical Report, BAW-10219, Revision 3, dated October 1998.

The October 27, 1998, amendment application proposed that Electrosleeves be installed, inspected and plugged based on criteria delineated in previous submittals, but the length of in-service operation would be limited to two cycles. Specifically, all Electrosleeves shall be removed from the SGs two cycles after the outage Electrosleeves are first installed at Callaway Plant, Unit 1. This limit was proposed due to the staff's concern that the nondestructive examination technique does not ensure acceptable structural safety factors are maintained and, therefore, future inservice inspections may not adequately identify structurally significant flaws. In the October 27, 1998, amendment application, the licensee committed to removing from service all tubes with Electrosleeves at the end of two cycles following installation of the first Electrosleeve, unless a subsequent license amendment request had been submitted and approved by the staff without limitations on the in-service length of operation.

2.2 Electrosleeve Description

An Electrosleeve is a formed-in-place tube sleeve. Inflatable dams and an electrode are inserted into the defective tube and positioned at the location of the tube defect. The plating solution is pumped into the zone defined by the inflatable dams and the electroplating is commenced. After sufficient time to build up the required plating thickness, the process is stopped, the plating equipment removed and the deposited sleeve is inspected for acceptance. An Electrosleeve is either four or eight inches in length depending on the type and severity of degradation the sleeve has to span. A single tube may be plated in one or several locations. The plating process is able to span the typical service induced defects found in SG tubes.

The deposited plating is a proprietary nickel alloy, composed of nickel with a small amount of an alloying element. The grain size is much smaller than that of conventional forged nickel alloys, and, due to the extremely small size, the material is referred to as nanocrystalline nickel. The small grain size enhances the materials' mechanical properties and corrosion resistance.

Extensive analyses and testing were performed on the electroformed material and resulting sleeves. These tests were designed to demonstrate that regulatory requirements were satisfied for both the material and the resulting sleeves. The specifics of the Electrosleeve process, along with the engineering design parameters for the sleeves were originally detailed in a proprietary Framatome generic topical report, "Electrosleeving Qualification for PWR Recirculating Steam Generator Tube Repair," BAW-10219P, Revision 1, dated March 1996. Revision 3 of the topical report was submitted to the staff in the amendment application dated October 27, 1998. Repair of SG tubes by structural electroplating is also described in American Society for Mechanical Engineers (ASME) Code Case N-569. This Code case is not presently endorsed by the NRC.

The following methodology and qualification evaluations were used to qualify the Electrosleeve:

- Define the design requirements for the steam generator tube repair,
- Develop the applicable material properties per the requirements of the ASME Code, Section III,
- Evaluate the tube repair to the possibility of corrosion (primary and secondary side environments),
- Prepare a design analysis of the tube repair per the requirements of the ASME Code, Section III,
- Develop nondestructive examination techniques for the tube repair, and
- Evaluate the tube repair to the requirements of the NRC Regulatory Guide 1.121, "Bases for Plugging Degraded PWR Steam Generator Tubes."

Conventional tube sleeving processes involve the insertion of a smaller diameter tube, the sleeve, into the degraded tube. The sleeve is positioned to bridge the defective area of the tube. The sleeve is then rolled or welded to the tube to form the structural joints. This process has been used for years. However, it has a few limitations. One is the impracticality for installing additional tube sleeves above an existing sleeve due to the access problem created by the first sleeve blocking the path for installing a subsequent sleeve. Additionally, the rolling process used to install some sleeves in the past has created new initiation sites for further tube degradation because of the residual stresses resulting from installation. Welded sleeves are potentially susceptible to stress induced degradation also, because of the residual stress caused by welding or heat treating when a tube is axially constrained at the tube support plates.

A plating operation (e.g., Electrosleeve) does not involve any cold work of the substrate or introduce any significant residual stress. Thus, the potential for subsequent stress induced degradation is reduced compared to conventional sleeving processes.

Plating is generally thought of as a barrier coating to protect against corrosion. The structural uses of plating have not been widespread and have been employed generally for wear resistance. The principal difference between the two plating types would be in the properties and thickness of the plating. Changes in the plating material properties are achieved by choice of alloying elements added to the metal salts used in the plating baths. Plating thickness is controlled by the duration of the plating process.

3.0 EVALUATION

3.1 Process Description and Installation Procedures

The licensee developed a Sleeve Procedure Specification (SPS) which defines the generic requirements for field installation of the Electrosleeves. The licensee stated the SPS was prepared following the guidelines of the ASME Code Section XI for SG tube sleeving and helps control essential and non-essential process variables. A summary of the installation process is as follows:

- Pre-installation eddy current inspection which identifies which tubes are to be repaired,
- Surface cleaning/preparation through mechanical cleaning and application of an electrolyte which enhances the electroplate adherence to the tube inner diameter ,
- Electrochemical deposition of the nickel material,
- Post-installation (preservice) nondestructive examination.

The licensee can verify the sleeving process in-situ by simultaneously electroplating a witness tube (a tube located in a test rig outside the steam generator) which can later be sectioned and examined for acceptance. In addition, process controls and on-line monitoring during the electro-deposition process allow operators and quality control personnel to confirm process variables in accordance with ASME Code requirements.

The staff reviewed the general installation process steps and methods of monitoring and verifying the adequacy of the sleeving process, and concluded the Electrosleeve process and monitoring activities are adequate for controlling essential and non-essential process variables in accordance with ASME Code requirements.

3.2 Material Properties

Electro-deposited nickel is not presently a material of construction listed in a staff endorsed ASME Code Edition or Code Case. Consequently, the material was reviewed for compliance with appropriate Code requirements and guidance for qualifying new materials of construction for use in ASME Code Section III, Class 1 pressure boundary service. The licensee performed testing of the sleeve material in accordance with ASME Code Section III methodologies and American Society of Testing and Materials (ASTM) standards to determine the suitability of the material properties of the Electrosleeve and its use as steam generator sleeve material. A summary of the testing performed on the Electrosleeve follows.

The licensee performed tensile tests using ASTM methods at several temperatures to document yield strength, ultimate strength, and elongation of the electrochemically deposited nickel material. The licensee evaluated this data in accordance with the ASME Code Section III to establish design properties for the nanocrystalline nickel material at a range of temperatures, including operating temperatures.

Multiple specimens were tested in accordance with ASTM procedures to determine the modulus of elasticity. The results showed the modulus of elasticity for the electrochemically deposited nickel material is independent of tube size.

Multiple specimens were bend tested by the licensee in accordance with ASTM procedures to verify the ductility and adhesion of the electrochemically deposited nickel material to the parent tube material. The ductility and adhesion characteristics were verified and deemed acceptable.

The licensee performed fatigue testing on multiple specimens in accordance with ASTM procedures. Tests were conducted at room temperature and elevated temperatures. The licensee concluded the material maintains its fatigue resistance in the temperature range tested.

Thermal stability of the Electrosleeve material is important because of its long-term thermal exposure to high temperatures. The licensee's test results demonstrated the Electrosleeve material is fully stable at pressurized water reactor (PWR) design temperatures and at lower operational temperatures. Testing also indicated the Electrosleeve material is not susceptible to strain-induced recrystallization.

A series of constant load creep tests were performed using ASTM procedures to determine the creep behavior of the Electrosleeve material. Tests were performed at multiple temperatures to evaluate the influence of temperature. Based on the creep test results presented in the topical report (BAW-10219, Revision 3), the creep failures were ductile in nature with no evidence of grain boundary cavitation or fracture in the fracture surfaces.

The licensee performed burst testing on multiple Electrosleeve specimens. The results indicate the sleeve material burst pressures can be calculated by classical burst pressure formulas.

The staff reviewed the information provided in the topical report and determined that the Electrosleeve material was appropriately tested in accordance with ASME Code and ASTM standards and concluded the material was acceptably qualified for use in steam generator sleeves.

3.3 Corrosion Evaluation

The objectives of the licensee's corrosion evaluation were to determine the susceptibility of the Electrosleeve material to known Alloy 600 degradation mechanisms, such as stress corrosion cracking (SCC), and to evaluate the corrosion potential of the material in environments that might exist in an operating SG. The corrosion evaluation was performed by addressing general corrosion first, followed by evaluation of primary and secondary side environments. As discussed in the following sections, the licensee concluded the Electrosleeve material performed very well in that the development of stress corrosion cracking and several other forms of degradation are not anticipated. The topical report described the test environments and, based on experience and knowledge, the staff agrees with this statement. In addition, the licensee concluded the Electrosleeve material performed far better than the current Alloy 600 tube material.

In addition to testing, the licensee performed a literature review of nickel corrosion and found that, in general, both nickel and its alloys effectively resist attack in acid, neutral and alkaline conditions. The presence of highly oxidizing species have been found to decrease this resistance in some chemical environments (e.g., an environment containing sulfur species). The licensee determined a galvanic attack between pure nickel and Alloy 600 will not occur in SG environments due to the low potential difference generated by the formation of a coupling of these two materials.

3.3.1 General Corrosion Properties

The licensee indicated the test environments used to confirm the general corrosion properties of Electrosleeve material were extremely severe and do not exist in steam generators. However, the corrosion mechanisms, for which testing was conducted, are known problems encountered with Alloy 600 material. The corrosion mechanisms tested included intergranular attack (IGA), SCC, pitting, and crevice corrosion. The licensee followed standard ASTM test procedures.

The corrosion tests performed and respective results were as follows:

- Boiling sulfuric acid IGA test which revealed no evidence of IGA,
- Polythionic acid SCC test which revealed no evidence of SCC,
- Magnesium chloride SCC test which revealed no evidence of SCC,
- Sodium chloride SCC test which revealed no evidence of SCC, and
- Ferric chloride pitting and crevice corrosion test which revealed no evidence of pitting and limited crevice corrosion indicating good overall resistance.

3.3.2 Primary Side Corrosion Evaluation

To evaluate corrosion performance of the Electrosleeve material in the primary side environment, the licensee performed testing which addressed full power operating conditions, shutdown conditions and parent tube with primary water stress corrosion cracking (PWSCC) conditions.

To evaluate full power operating conditions, both pure water and primary water chemistry conditions were tested. Highly stressed hard rolled transition zones and highly stressed reverse U-bend specimens were used in the testing. Also, samples were subjected to temperature and pressure cycling in pure water to induce deformations in the nickel layer. The test samples revealed no cracking or other degradation for the pure water and primary water tests.

The main corrosion concern during primary side shutdown conditions is the presence of boric acid. The effect of boric acid, at various temperatures and concentrations, was evaluated on nickel plating. In addition, Electrosleeves were tested at conditions that simulate oxidizing shutdown crud burst conditions. Measurements of the slight general corrosion, where it occurred in two cases, showed a negligible corrosion rate.

The licensee performed two types of tests to evaluate SCC in the parent tube. The objective of the first test was to verify that a nickel plated layer would prevent SCC in the parent tube at highly stressed regions by providing a protective layer. The objective of the second test was to verify that high residual tensile stresses are not induced into the parent tube at the ends of the sleeve. The first test revealed that even if boric acid is trapped in the crevice of an existing primary side tube crack and the Electrosleeve is installed, no further corrosion attack of the parent tube is expected in addition to no corrosion of the sleeve. The second test verified that high residual tensile stresses are not induced into the parent tube at the ends of the sleeve.

3.3.3 Secondary Side Corrosion Evaluation

Based upon the results of the primary side pure water tests and literature searches regarding the performance of nickel when exposed to industry recommended secondary side water chemistries, there were no concerns regarding the ability of the material to withstand the bulk secondary environment. However the Electrosleeve must be able to withstand the environment that locally forms at the tip of Alloy 600 stress corrosion cracks.

The performance of the Electrosleeve in possible secondary side localized environments was evaluated by exposing the sleeve to extreme environments at elevated temperatures. The environments included high concentrations of active species such as chloride and sulphate, in acidic and alkaline media, and high and low redox conditions. The values of acidity and redox potential for these tests were chosen to accelerate the material degradation and are not present in an operating unit.

3.3.3.1 SSC Propagation Tests

Steam generator tubing, containing outer diameter (OD) initiated cracks, was nickel plated and exposed to secondary side conditions in a mockup. Post-test examination showed no crack propagation into the nickel layer, although the crack propagated through the parent tube to the nickel layer interface.

Alloy 600 tubing, with and without an installed Electrosleeve, in the form of highly stressed C-rings, were used to evaluate the ability of the Electrosleeve to arrest a crack propagating from the tube OD. Testing was performed in an environment known to cause SCC in Alloy 600 material. Examination of the samples after the conclusion of the test revealed no evidence of SCC in any of the sleeves even though the Alloy 600 tube had cracked through-wall to the Electrosleeve material. In addition, there was no evidence of either sleeve disbonding or crack propagation along the interface of the tube and sleeve.

3.3.3.2 Capsule Tests

The objective of this test was to characterize the corrosion performance of the Electrosleeve material in confined conditions of extreme bulk water chemistry. A total of 24 different temperature and environmental combinations were tested.

The conclusion from this test was that the Electrosleeve material will be attacked under highly acidic with highly oxidizing environments. However, the sleeve material is resistant to caustic environments and acidic attack in the absence of oxygen, and the highly oxidizing condition that was tested is not reasonably expected to be present in the bulk medium of the secondary side of the steam generator.

3.3.3.3 Heat Transfer Sludge Corrosion Tests

The objective of these corrosion tests was to assess the corrosion performance of an Electrosleeve when a large area is exposed to the extreme chemistry conditions under a sludge pile. Three bulk water environments were selected to address three different operating scenarios of feedwater contamination: condenser cooling water (lake water ingress), sodium hydroxide, and sulfuric acid. The latter species reflect a serious water treatment system malfunction. Considering water chemistry monitoring and specification requirements, in actuality, none of the three conditions is expected to persist for more than a short time.

For the lake water ingress test, very minor general corrosion occurred at the very end of the time-in-testing. The acid ingress test predictably showed that the nickel was subject to general corrosion with some regions of pitting. The test severity was very high due to a high oxygen level. The general attack of the nickel was stopped or substantially mitigated when oxygen levels were reduced close to normal operating plant levels. This verified that the Electrosleeve material would have good resistance to a credible acidic excursion during operation. Post-test examination of the caustic ingress samples showed minimal localized attack of the Electrosleeve material in accordance with the anticipated performance for nickel. This verified that the sleeve material would withstand a credible caustic excursion during operation.

3.3.4 Staff Evaluation of Corrosion Testing

Nanostructured materials are a new class of materials. Nanostructured nickel has never been used as steam generator tube sleeving material in U.S. plants. Therefore, its behavior in U.S. steam generators is mainly postulated based on results from laboratory tests. The licensee has performed an extensive number of laboratory corrosion tests on the nanostructured nickel used to form the sleeve. The material has performed very well and the licensee has postulated the development of stress corrosion cracking and several other forms of degradation are not anticipated. In addition, the licensee concluded the Electrosleeve material performed far better than the current tube material, Alloy 600. But, the intent of laboratory corrosion tests is to mimic, on an accelerated scale, conditions that may be experienced in field applications. Although such tests are valuable tools for screening candidate materials and are reasonable predictors of a material's performance, they cannot anticipate all actual conditions. Therefore, a material's suspected lack of susceptibility to degradation cannot be entirely relied upon for assuring safe conditions for long-term installation. The staff concludes concurrent application of an effective inservice inspection method is necessary to assure safe plant operation.

In Section 3.5 of this safety evaluation (SE), the staff's assessment of the inservice inspection method is discussed. The main conclusion is that the staff believes that the inspection technique does not ensure that acceptable safety factors would be maintained for all flaw types and that structurally significant flaws would not be identified. Therefore, based on the current inspection capability, the staff cannot approve long-term installation. To address this issue, the licensee proposed that Electrosleeves be installed, inspected and plugged based on criteria delineated in BAW-10219P and the length of inservice operation be limited to two cycles. The staff believes that despite the concerns with the capability of the inservice inspection technique, a two-cycle approach is acceptable based on the corrosion test results and expected corrosion resistance of the Electrosleeve relative to Alloy 600 (i.e., the parent tube material).

3.4 Structural Evaluation of Electrosleeves

A steam generator tube sleeve restores a tube to service by effectively replacing the pressure boundary over a defective region of the original tube. Sleeves are designed such that all postulated loadings associated with internal or external pressure, fatigue, thermal, and seismic events should not compromise the integrity of the steam generator tube. Although

Electrosleeves are fundamentally different from previously approved sleeving methods in that the sleeve is chemically bonded to the tube material over an extended length, the design is such that the sleeve should maintain the margins for structural and leakage integrity consistent with the requirements of the parent tubing. Section III of the ASME Code contains the design requirements for the original steam generator tubes. Because Electrosleeves are proposed as a method to replace the steam generator tube pressure boundary over a specified length of degraded tube, these repairs should also satisfy the requirements in Section III.

The Electrosleeve qualification program combined analysis and mechanical testing to ensure that installed sleeves would be qualified for all recirculating SG designs and their operating conditions. Laboratory testing of the sleeve design was conducted using tubes with a range of diameters applicable to SGs installed in U.S. plants. Different test types were conducted to verify that all postulated loads experienced in service were within the structural capabilities of the sleeves. The structural capabilities for degraded Electrosleeves discussed in the following subsections refer to the flaw sizes that do not incorporate additional allowances for flaw growth and nondestructive evaluation (NDE) uncertainty. The structural limit corresponds to the maximum allowable flaw size that can be tolerated while still maintaining necessary margins of safety. The following summarizes the staff's evaluation of the design requirements and flaw specific structural limits for Electrosleeve repairs.

3.4.1 Assessment of Locked Tube Conditions

SG tube support plates were designed to prevent the lateral movement of all tubes. However, service induced corrosion of SG components and the buildup of corrosion products on the secondary side of the tubing may lead to a condition where tubes cannot freely translate axially through tube support structures within a SG. Tubes, in essence, become locked at tube support plate locations. Such conditions have been detected in SGs that are inservice by measuring the forces associated with removing sections of tubes during plant outages. Differential thermal expansion between a tube and other SG components during normal operating and postulated accident loadings may introduce loads on a tube that would not be realized if it were in an unlocked condition. This is a consequence of the tube support plate support structure expanding (i.e., axial translation) at a different rate than the Alloy 600 tubing under transient thermal conditions. These different rates of expansion give rise to stresses in the tube.

Stresses in locked tubes may also be introduced during the Electrosleeve installation process. Although the Electrosleeving installation method is a relatively low temperature operation, small differences in the thermal expansion coefficients between the parent tube and the Electrosleeve material will produce residual stresses within the Electrosleeve repair. Localized residual stresses in the sleeved region may result in stresses outside of the repaired region in order to maintain equilibrium. Testing was performed to measure the loads introduced into a locked parent tube as a result of the sleeving process. This test was conducted to quantify the additional loads that result from repairing locked tubes with the Electrosleeving repair method.

Testing was performed on different diameter tubes that were rolled and welded into a rigid mockup of a tubesheet and tube support plate. The tubes were instrumented with strain gauges and thermocouples and sleeved in the tubesheet and freespan region. The licensee concluded based on the test results that the residual stresses resulting from the sleeving process are low and not considered significant. The staff has reviewed the results from this testing and confirmed the magnitude of the measured loads through an analytical approach. Based on the results of this assessment, the staff concludes that residual stresses from the Electrosleeving process are low and not a concern for the long-term integrity of either the parent tube or sleeve.

During plant transients (e.g., startup, shutdown), changes in the temperature difference between the SG wrapper or other secondary support structures and the tubes, can lead to elevated axial stresses in locked tubes adjacent to support locations. For example, a locked tube on the periphery of the tube bundle near a tube support plate vertical support may experience an axial load when the tube cools more rapidly than the SG wrapper. The magnitude of the thermal load introduced into a tube is a function of the tube's position with respect to the secondary support structures, the flexibility of the support plate, and the number of other tubes that are locked into the support plate. The licensee completed an evaluation to quantify the locked tube loads applicable to the Callaway SGs. Based on the staff's evaluation of the stress limits and the margin to failure considering the criteria in NRC Regulatory Guide (RG) 1.121, "Bases for Plugging Degraded PWR Steam Generator Tubes," locked tube loads represent the bounding condition applicable to Electrosleeve repairs. Because these loads act in the axial direction along a tube, circumferentially-oriented cracking and uniform thinning of the tube are the primary modes of degradation affected under locked tube conditions. The staff's evaluation of the structural limit of Electrosleeve repairs relative to these loads is provided in Section 3.4.4 of this SE.

3.4.2 Electrosleeve Capabilities to Withstand Cyclic Loading

A table of design transients was developed for the each of the various SG types. The licensee stated that cyclic load test parameters were developed in accordance with Appendix II of Section III of the ASME Code. Three types of specimens were considered in this phase of the design verification testing: (1) unnotched, "minimum bond specimens", (2) samples containing a one inch long notch extending 30 percent through the thickness of the sleeve, and (3) circumferentially notched (360 degree) specimens with a 30 percent throughwall notch. The testing exposed the specimens to pressure, thermal, and/or axial loads as appropriate to simulate conditions representative of service loadings.

The first phase of the testing used "minimum bond specimens". These specimens consist of a sleeve/tube sample that has all of the parent tube (i.e., Alloy 600) machined away except for a small bond length at each end of the sleeve. The samples were subjected to axial cyclic loads, thermal cycling, and pressure cycling. At the conclusion of these tests, specimens were visually and ultrasonically tested (UT) for bond or sleeve failure. The licensee stated that all specimens were acceptable, with no evidence of degradation.

A series of cyclic load tests were performed on notched sleeves in order to verify an Electrosleeve's resistance to crack propagation with respect to the proposed plugging criteria. Samples with one inch axial or full circumferential notches machined 30 percent into the sleeve wall were tested. The sleeves with axial defects were cyclically tested by internal pressure. The sleeves with circumferential defects were tested with axial loads. The vendor assumed life cycle loads under locked conditions because this represented the bounding condition for Electrosleeve repairs.

Prior to testing, the number of transients expected to occur during normal operation including anticipated transients such as startup and shutdown loadings and reactor trips were determined. Numerous other transients were assumed and accounted for in the analysis. Test loads were developed to allow testing to proceed in steps, with each step representing two years of operating life. The test steps were repeated until the specimens failed or until 40 years of service life was reached. In most cases the specimens reached the equivalent of 40 years of life without failing. The shortest service life anticipated based on the test results was concluded to be in excess of 25 years. The interval between inspections (each refueling outage for degraded sleeves) is far shorter than this conservative estimate of the expected service life. Therefore, the licensee concluded that no fatigue related failures (e.g., leaks) would be expected in service.

The licensee stated that the cyclic load testing of unnotched Electrosleeves was completed in accordance with Appendix II to Section III of the ASME Code. The staff has evaluated the licensee's test program with the requirements specified by the ASME Code for experimental stress analysis. Based on the staff's review of the information presented in BAW-10219P, Revision 3, the testing completed by the vendor does not appear to satisfy the requirements in Appendix II for cyclic testing. In order to properly assess a material's resistance to fatigue damage, it is necessary to construct design fatigue curves similar to those in Appendix I of Section III. Based on the information provided by the licensee, only a limited number of smooth Electrosleeves were subjected to cyclic load testing. The number of tests was insufficient to generate a design fatigue curve for this material. Although the testing may not have been in strict accordance with the requirements of the ASME Code, the staff has determined that fatigue related damage to this material in SG tube applications is not the principal concern that limits its service life. The basis for this conclusion is that the cyclic load test results provide sufficient information to allow the staff to assess an Electrosleeve's resistance to fatigue damage.

Testing of degraded (i.e., notched) Electrosleeved tube specimens under limiting cyclic loading conditions demonstrated that the sleeve material is adequately resistant to the initiation and growth of fatigue cracking. Inspections of the tube specimens representative of sleeve repairs applicable to Callaway after completion of the testing showed no signs of fatigue related failure. These results indicate that Electrosleeves have considerable resistance to cyclic loads that enable them to resist potential fatigue related damage that could develop between extended inspection intervals. Therefore, the staff concludes that Electrosleeves have sufficient resistance to cyclic loading damage for steam generator tube sleeving applications. The requirement to perform periodic sleeve examinations at each inspection will also facilitate the detection of damage due to cyclic loading, if such degradation should appear in the future.

3.4.3 Assessment of Electrosleeve Burst Pressure Margins

Regulatory Guide (RG) 1.121, "Bases for Plugging Degraded PWR Steam Generator Tubes," indicates that SG tube (and sleeve) repair limits, less allowances for NDE uncertainty and flaw growth should, in part, maintain a margin to burst of 3 under normal operating pressures and 1.4 under postulated accident conditions. In order to demonstrate that a degraded Electrosleeve would retain such margins under the proposed repair limits for axially-oriented, linear defects, the vendor developed a model relating the burst pressure of axially cracked SG tubes to the length and depth of the flaw and completed burst testing of simulated flaws in

Electrosleeves. The empirical model incorporated available burst pressure data from previous studies completed by the Electric Power Research Institute, Babcock & Wilcox, and the NRC via Battelle Labs. The vendor augmented the data set for model development with the burst pressure test data of Electrosleeved tube specimens.

Burst pressure testing involves applying an increasing internal pressure to a test specimen until the sleeve fails by rupture. The vendor conducted burst testing of Electrosleeve samples with the parent tube machined away to leave only the sleeve material for test. This was done to demonstrate acceptable margins for Electrosleeve structural integrity without the parent tube providing reinforcement to the installed sleeve. The objective of these tests were to verify that degraded sleeves would have sufficient structural integrity to withstand a differential pressure of three times normal operating pressure in accordance with the criteria specified in RG 1.121. A margin of three on normal operating pressures is the limiting structural case for tube burst applicable to the Callaway SG tubes. Test specimens were fabricated with two types of defects in the sleeve; axial and pitting flaws. The flaws extended 30 percent to 50 percent into the sleeve wall. Testing was conducted at several temperatures. The licensee reported that the failure pressure of each test specimen exceeded the criteria specified in RG 1.121.

The results of these tests indicate that there is greater than a margin of three for burst between the differential tube pressure associated with normal operation and the measured burst pressure for Electrosleeves. This margin is in excess of the burst pressure margins specified for degraded tubes in RG 1.121. In addition, the calculated burst pressure of degraded Electrosleeves, using the model proposed by the licensee, yields results that are consistent with the guidance for tube integrity margins in RG 1.121. The staff has reviewed the proposed burst pressure model and concluded that it provides an adequately conservative estimation of the Electrosleeve burst pressure. In addition, the staff concludes on the basis of analytical results from the model and testing completed by the licensee that Electrosleeve repairs will maintain adequate margins for burst due to internal pressure loading.

3.4.4 Stress Analyses

Design pressures and nominal sleeve dimensions were used in the determination of a tentative pressure thickness for the sleeve wall. In addition, ASME Code Section III stress limits associated with Service Level A through D are satisfied by the proposed design. The results of the analytical assessments of the stress limits during normal operating and postulated accident conditions indicate that the Electrosleeve design meets the applicable design requirements of Section III of the ASME Code. The staff independently evaluated the stress limits of Electrosleeves and concluded that their design meets all the noncyclic loading requirements of Section III of the ASME Code.

Degraded Electrosleeve minimum thickness requirements were developed in accordance with the guidance provided in RG 1.121. RG 1.121 specifies by reference that the structural capability of degraded SG tubes shall meet the limits included in Section III of the ASME Code. The licensee determined a minimum allowable wall thickness associated with each of the stress limits necessary to ensure adequate margins for tube structural integrity. The limiting load that yielded this structural limit was from stresses associated with tubes locked into tube support plates.

The burst pressure model developed to assess the structural margins for Electrosleeves containing axial cracking could not be utilized to estimate the structural margins of circumferentially flawed sleeves. To address this mode of cracking, the licensee completed an analysis using empirically derived limit load expressions. The staff has assessed the methodology employed by the licensee in the analysis of circumferential flaws by performing its own estimations of the Electrosleeve circumferential flaw structural limits using alternative limit load and failure theories. The results of the staff's evaluation indicate that the structural limit calculated for degraded Electrosleeve tubes is conservative with respect to the limiting circumferential flaw subject to internal pressure loads and axial tensile loads due to tube locking.

The staff notes that the peak thermal expansion loads that form the basis for the structural limit for Electrosleeves are experienced by tubes in the immediate vicinity where the tube support plates are fastened to the SG wrapper. Therefore, only a limited number of tubes may be affected by the high thermal loads. As the distance of a tube increases from rigid secondary support connections to the bundle wrapper, the thermally-induced loads on the tube decrease. Therefore, the majority of the tubes in the Callaway SGs should not experience the locked tube loads considered herein.

3.4.5 Staff Evaluation of Electrosleeve Structural Margins

The Electrosleeve design was evaluated both analytically and experimentally to demonstrate that this repair method will restore the condition of the tube to meet the requirements of the ASME Code. The staff verified that the proposed Electrosleeve design applicable to the Callaway SGs was consistent with the noncyclic stress limits of Section III of the ASME Code. The cyclic load testing described in BAW-10219P, Revision 3, does not appear to satisfy the Code requirements for fatigue testing. However, as stated in Section 3.4.2 an Electrosleeve's resistance to cyclic loading is acceptable for steam generator tube repairs.

The staff also reviewed the licensee's calculations and test results to develop the structural limit for degraded Electrosleeves. The minimum structural limit for all flaw morphologies is used in conjunction with nondestructive testing uncertainties and postulated degradation growth rates to establish a sleeve plugging limit (Section 3.7). An independent assessment of the structural integrity margins associated with degraded Electrosleeves by the staff indicates that the limiting structural limit included in Table 8.5.1 of BAW-10219P, Revision 3, was derived in accordance with regulatory guidance to establish SG tube repair limits. Therefore, the staff concludes that the Electrosleeve repair method is acceptable on the basis that it will provide structural integrity margins consistent with other approved SG tube repairs.

3.5 Non-Destructive Examination (NDE)

The NDE of Electrosleeves is conducted using UT techniques. UT is performed after application of the sleeve (preservice inspection) and during inservice inspections. The purpose of the preservice inspection UT is to examine the sleeved area to determine proper installation. Preservice inspection UT will be performed on all sleeves. The purpose of the inservice inspections is to determine whether service related degradation of the sleeve and pressure boundary portions of the tube behind the sleeve has occurred. Inservice inspection scopes and expansion criteria will be in accordance with the plant's TSs.

The UT examination system, acceptance criteria, qualification efforts and the staff's evaluation of the NDE technique will be discussed in the following sections.

3.5.1 Ultrasonic Testing Examination System

The nondestructive examination of Electrosleeves is conducted using UT techniques. Although eddy current testing is currently a more commonly used method for examining steam generator tubes and sleeves, the licensee found there are significant problems with the use of eddy current techniques for examination of the Electrosleeve repair. The primary difficulty is that the electromagnetic properties of the material limit the ability to discriminate sleeve geometry from degradation, accurately depth size crack-like flaws, and detect less significant degradation using commercially available technology.

The ultrasonic testing system consists of UT data acquisition equipment including a UT probe head, probe motor unit, probe driver, water system, NDE integrated control box and a computer station. The UT probe head contains several transducers for normal beam and axial and circumferential shear wave testing. This combination of transducers enables the analysts to assess the sleeve and applicable parts of the tube for process defects and in-service degradation. Once UT data is collected, it is processed and displayed at the computer station in several different modes for interpretation. Flaw detection, characterization and sizing are performed using C-scans, D-scans, A-scans and profilometry displays.

Normal beam data is used to perform time-of-flight measurements to determine pit depth, tube-to-sleeve disbond and thickness. Shear wave examination data is used to detect and size defects such as SCC. The analysis of shear wave data uses three basic methods to estimate the depth of a crack. The methods are tip sizing, multiple skip method and target motion time-of-flight (TOF). Detection of a crack tip signal is rare in a steam generator tube examination, therefore, the tip sizing method is rarely used. The multiple skip method relies on corner reflectors (i.e., the intersection of flaws with inner diameter [ID] and OD surfaces) for analysis. Before sleeving, a deep OD initiated flaw produces both an OD and ID corner reflector. The addition of ID sleeve material to a tube containing this deep OD initiated flaw eliminates the ID corner reflector. Therefore, after sleeve installation, the multiple skip method is not used to size cracks in the parent tubing. The target motion TOF method is most frequently used for sizing cracks. Combinations of these methods were used for the UT qualification efforts discussed in Section 3.5.3 of this SE.

The licensee is developing two additional techniques to supplement and improve the accuracy of the three shear wave analysis techniques discussed above. The development and qualification of these techniques is still in the preliminary stages and these techniques were not used in the UT qualification efforts discussed in Section 3.5.3 of this SE. Therefore, the NRC staff has not reviewed these techniques in detail. The licensee has verbally stated that these techniques may address concerns the staff has with the current techniques (discussed in Section 3.5.4 of this SE).

3.5.2 Ultrasonic Testing Acceptance Criteria

The UT examinations consist of preservice inspection and inservice inspection acceptance criteria, depending on the purpose of the examination.

The preservice inspection data is analyzed to: verify correct sleeve positioning, thickness and size; ensure adequate sleeve-to-tube bonding by identifying disbonds greater than the maximum allowable; ensure significant sleeve installation defects (e.g., nodules or pits) do not exist; and gather baseline data for future comparisons.

Inservice inspections of Electrosleeves are performed to determine whether service related degradation of the sleeve, pressure boundary portions of the tube behind the sleeve and the sleeve-to-tube bond have occurred in excess of TS allowable limits. The licensee has a TS requirement in TS Table 4.4-3, "Steam Generator Repaired Tube Inspections," to inspect at least 20 percent of all installed sleeves. The licensee has proposed to modify Table 4.4-3 to require an inspection of at least 20 percent of each type of installed sleeve. This proposal is consistent with current industry guidance for steam generator sleeve examinations. In addition to the initial inspection scope, Table 4.4-3 requires the inspection results to be classified and, depending on the classification, may require the performance of additional sleeve inspections. Future sleeve inservice inspection scopes and expansion criteria will be in accordance with these TSs.

3.5.3 Ultrasonic Testing Qualification Efforts

The licensee developed multiple data sets to assess the capability of the UT system. Each of these data sets were developed to address a particular inspection parameter or flaw type, such as: parent tube OD pits; sleeve OD pits; sleeve ID pits; disbonds; varied wall thicknesses; axial and circumferential outside diameter stress corrosion cracking (ODSCC) and PWSCC and IGA. The licensee assessed all data sets (i.e., UT data versus destructive examination data) to determine the probability of detection (POD) and UT sizing capabilities. The UT sizing capability was characterized in terms of average error, maximum error, standard deviation, and UT uncertainty (root mean square error). The UT uncertainties were the values considered by the licensee when determining the plugging limit as discussed in Section 3.7 of this SE.

A normal beam UT examination (for flaw detection and sizing) is required to perform the preservice inspections which determine sleeve thickness and size, sleeve-to-tube bonding, and sleeve installation defects (e.g., pits). Normal beam and shear wave UT examinations (detection only) are required to perform the preservice inspection which determines sleeve positioning. The licensee stated that: (1) all data sets had a high POD, and (2) the normal beam UT uncertainties were sufficiently low for all data sets such that they could be accounted for in the margin between the structural limit and plugging limit.

Normal beam and shear wave UT examinations (for flaw detection and sizing) are required to perform the inservice inspections. The licensee stated that: (1) all data sets had a high POD, and (2) the UT uncertainties for all data sets were sufficiently low such that they could be accounted for in the margin between the structural limit and plugging limit.

3.5.4 Staff Evaluation of Non-Destructive Examination Technique

The licensee has chosen UT as the NDE technique to perform preservice and inservice inspections of the Electrosleeve. The UT technique must be able to detect all flaw types (e.g., volumetric and crack-like) and must be able to disposition all flaws in accordance with the TSs.

The licensee developed multiple data sets to assess the capability of the UT system to detect and depth size all tube/sleeve flaw types (i.e., pitting, thinning, stress corrosion cracking, etc.). The staff reviewed the POD determination, UT uncertainties and the data which supports these values. The staff concluded the licensee could adequately perform the examinations necessary for preservice inspections. The POD, UT uncertainties and the data which supports these values were reasonable and will assure that safety significant flaws would be detected, sized and dispositioned in accordance with TS requirements and that structural limits (see Section 3.7 of this report) will be maintained.

The staff reviewed the examination techniques necessary for inservice inspections and identified concerns with the depth sizing capability of the shear wave examination when sizing stress corrosion cracks. The UT under-call errors were significant when assessing the deepest flaws in the data set. The staff determined the shear wave UT technique does not ensure that structural limits are maintained when depth sizing stress corrosion cracks. This conclusion was previously communicated to the licensee. However, the licensee has proposed a limit of two cycles on the length of inservice operation for all Electrosleeves. The staff believes that despite the concerns with the capability of the inservice inspection technique, a two-cycle approach is acceptable based on the Electrosleeve corrosion test results and the expected corrosion resistance of the Electrosleeves relative to Alloy 600 (i.e., the parent tube material).

As discussed in Section 3.5.1 of this SE, the licensee is developing additional UT analysis techniques to supplement and improve the accuracy of the current techniques. This may enable the licensee to address the NDE issues before the end of two operating cycles.

3.6 Flaw Growth

The licensee performed an evaluation of the corrosion resistance properties of the Electrosleeve material through laboratory testing as discussed in Section 3.3 of this SE. The licensee concluded that general corrosion, crevice corrosion, pitting, stress corrosion cracking and IGA are not a concern when exposed to PWR environments. Despite these conclusions, the licensee made what they considered very conservative estimates on the potential growth rate of all degradation mechanisms in order to obtain data to use in determining the plugging limit. These estimates were mainly based on technical assumptions rather than laboratory data since laboratory data indicated degradation would be negligible or nonexistent. Since the flaw growth rate estimates used in developing the plugging limit are conservative with respect to the laboratory corrosion test results, the staff determined the flaw growth rate estimates utilized by the licensee are appropriate.

3.7 Electrosleeve Plugging Limits

The sleeve is made up of three regions which require different evaluations relative to repair or plugging. These regions are the taper region, the bond region and the "sleeve as pressure boundary" region. In each of these regions, the TS plugging limits apply to that which is part of the reactor coolant pressure boundary (e.g., if both the sleeve and parent tube are part of the reactor coolant pressure boundary, the TS plugging limit for both the sleeve and parent tube would apply).

Taper regions are located at both ends of the sleeve and are where the full thickness of the sleeve tapers off. In this region the parent tube is the pressure boundary. The licensee stated that tube degradation in this region would be dispositioned in accordance with the 40 percent throughwall TS criterion if the degradation was volumetric in nature (e.g., pitting, wastage or wear). If any other tube degradation (e.g., cracking) was identified the tube would be plugged or repaired on detection. Sleeve degradation in this region could be left in-service because the sleeve is not part of the pressure boundary.

There is a bond region at each end of the sleeve next to the taper region. In the bond region, the combined thickness of the sleeve and tube constitutes the pressure boundary. The licensee indicated that tube degradation in this region would be dispositioned in accordance with the 40 percent throughwall TS criterion if the degradation was volumetric in nature. If any other tube degradation was identified the tube would be plugged or repaired on detection. Sleeve degradation in this region would be dispositioned in accordance with the 20 percent throughwall TS criterion.

The "sleeve as pressure boundary" region is in the center of the sleeve and spans the defect in the parent tube. In this region, the sleeve is the pressure boundary. Degradation of the sleeve will be dispositioned in accordance with the 20 percent TS criterion. Degradation of the parent tube is acceptable, as long as it does not extend into the sleeve beyond the sleeve's plugging/repair limit.

In conventional sleeving, typical industry practice is to plug/repair a sleeve upon detection of cracking in any region of the sleeve repair. The plug-on-detection philosophy cannot be applied to flaws detected in the "sleeve as pressure boundary" region of the Electrosleeve. This is because the Electrosleeve bonds to the tube along the entire length of the sleeve and the UT inspection detects the original parent tube flaw regardless of whether the parent tube flaw has extended into the sleeve. The licensee chose to address this issue by depth sizing parent tube flaws and dispositioning the sleeve as pluggable/repairable, if the flaw depth indicates the flaw has propagated into the sleeve beyond the sleeve plugging limit.

Table 12.5.2 of BAW-10219P contains a description of the plugging limit for sleeve ID pits in the bond region and "sleeve as pressure boundary" region. This plugging limit conflicts with the proposed TS plugging limit of 20 percent through the sleeve. To address this, the licensee added a statement to proposed TS Section 4.4.5.4.a.10.b) to state that Electrosleeves would be installed in accordance with BAW-10219P, except the 20 percent plugging or repair limit would apply to ID pits in the bond region and "sleeve as pressure boundary" region. This resolves the conflict and is acceptable to the staff.

The proposed Electrosleeve plugging limit was established in accordance with RG 1.121 and should ensure that all tubes repaired by Electrosleeving will retain acceptable margins for tube integrity from degradation in the repaired tube area. The proposed plugging limit for degradation in the sleeve as pressure boundary region was established by determining the structural limit associated with the most limiting stress margin specified in RG 1.121 and includes allowances for degradation growth and NDE uncertainty. The sleeve will maintain the margins for tube integrity through application of the proposed plugging limit consistent with the tube integrity margins specified in RG 1.121. On this basis, the staff concludes that the proposed Electrosleeve plugging limit is acceptable.

3.8 Leakage Integrity

The Electrosleeve design provides a leak-tight seal for primary-to-secondary water. Leak testing was performed at room temperature on Electrosleeved Alloy 600 tubes. The specimens used in this test consisted of "minimum bond specimens." This is a sleeve/tube sample that has all of the parent tube machined away except for a small bond length at each end of the sleeve. The specimens were subjected to a primary side hydro test at 4200 psig and then a leak test at 2500 psig. No visible leakage was observed. These test results are consistent with the design objective of a leak-tight sleeve.

In addition, the licensee already has a restrictive TS limit on primary-to-secondary leakage of 150 gallons per day per SG. This is in accordance with the staff position regarding primary-to-secondary leakage limits for SGs with sleeves.

3.9 Quality Assurance

In the course of reviewing submittals associated with the Electrosleeving license amendment request, the staff identified several examples of inaccurate data being supplied to the staff, two of which were documented in the staff's December 18, 1997, request for additional information. The licensee responded to this concern in a letter February 24, 1998, and amendment application dated October 27, 1998.

The licensee performed an internal review and determined that the cause for the errors was inadequate independent review prior to submittal of licensing documentation to the NRC. In addition to performing an internal review, the licensee performed an independent Quality Surveillance of the Electrosleeve vendor. The licensee determined that the cause for the vendor's errors was also inadequate independent review of licensing documentation. Both parties provided personnel training to reinforce the procedures and management expectations on the expected level of review of licensing documentation. In addition, it was determined that adequate time and resources had to be provided to personnel responsible for reviewing licensing documentation to enable them to adequately process and review licensing submittals to the NRC.

In addition to the procedural issues discussed above, the licensee and vendor implemented a completely independent review of all licensing submittals associated with Electrosleeving which were previously submitted. Three types of common errors were found in the course of the review: typographical errors; errors transcribing data from a source document to a licensing document; and errors associated with mislabeling units (i.e., mils vs. inches). These errors were corrected and incorporated into the revised topical report. The licensee noted that the correction of the documentation errors did not affect the overall technical conclusions previously documented because those conclusions were reached based on information obtained from the source documents which previously had been determined to be accurate.

The internal audits conducted by the licensee and vendor, and the licensee's independent Quality Surveillance of the vendor appear to be thorough. The root cause was identified and subsequent corrective actions appear to be appropriate. The staff did not identify any further errors in their review of subsequent submittals. Therefore, the staff considers this issue to be adequately addressed.

3.10 Future Considerations

The technical evaluation documented in this SE concludes that a limited two-cycle approach to the installation of Electrosleeves is technically supported and, therefore, acceptable. In order for the staff to approve Electrosleeving without limitations in the future, another license amendment request must be submitted, and the remaining issues from the May 20, 1998, NRC letter to Union Electric would have to be addressed. These issues are as follows.

A significant issue to be dealt with is the staff's concern regarding the UT technique's ability to reliably depth size stress corrosion cracks. Despite the relatively reasonable UT uncertainty for the SCC data set, a review of the data supporting the UT uncertainty reveals significant under-call errors when assessing the deepest flaws in the data set. Therefore, the staff cannot conclude the UT technique can reliably depth size stress corrosion cracks and ensure that structural limits are maintained. This issue is further described in Request for Additional Information (RAI) Question #1 of the May 20, 1998, NRC letter to Union Electric Company.

Several more issues, regarding the UT inspection, UT qualification data sets, a tube pull program and the effect of honing on the Electrosleeve, were raised in the May 20, 1998, NRC letter to Union Electric Company. The staff determined it was not necessary for the licensee to address these issues as part of the two-cycle amendment request, but they need to be revisited if a permanent amendment is requested. The issues dealt with UT inspections from one direction (RAI Question #4), a tube pull program (RAI Question #6), inspection of dented intersections (RAI Questions #9 and 10), additional UT data on pits and disbonds (RAI Question #13), the effect of honing on the Electrosleeve (RAI Question #14) and UT procedures and peer review report (RAI Question #15). The depth to which these issues would need to be addressed is dependent on how the licensee addresses the UT depth sizing of the SCC issue described above.

The staff notes that one of the structural acceptance criterion included in Table 8.5.2, "Electrosleeve Structural Limits Level D Conditions," of BAW-10219P is inconsistent with the guidance provided in RG 1.121. Specifically, RG 1.121 states that the margin of safety against tube failure (i.e., burst) under postulated accident conditions should be consistent with margins of safety specified in Section III of the ASME Code. The NRC has generally accepted a margin of 1.4 against tube rupture. The criterion listed in Table 8.5.2 indicates that the structural limits were calculated without consideration of an additional margin for tube burst. Independent calculations by the staff have verified that the stated structural limits for burst under Service Level D conditions appear to be determined without considering the appropriate factor of safety. Although these structural limits appear to be in error, this does not affect the staff's conclusions stated in this safety evaluation regarding the acceptability of the Electrosleeving repair technique. As discussed in Sections 3.4.1 and 3.4.4 of this SE, the limiting structural loads for Electrosleeve repairs result from tubes locked into steam generator tube support structures under Service Level A conditions. Therefore, the structural limit that forms the basis for establishing the proposed repair limit is more limiting than the value determined by considering burst failure under postulated accident conditions while applying appropriate margins of safety. However, if future conditions are such that the burst pressure under Level D service conditions govern the structural limit for Electrosleeves, the licensee would be required to either modify the topical report to reflect the structural limit determined using margins of safety specified in RG 1.121 or provide a technical basis for the acceptance criterion indicated in Table 8.5.2.

3.11 Proposed Technical Specification Changes

In order to incorporate the proposed changes to permit sleeving of the Callaway SGs using Electrosleeves, the licensee has proposed the following changes to the TSs.

a. Proposed changes to TS 4.4.5.4.a.2) and 4.4.5.4.a.4)

   The phrase "or sleeve" is added to the definitions of "Degradation" and " % Degradation" to address degradation of sleeving.

b. Proposed change to TS 4.4.5.4.a.6) "Plugging or Repair Limit"

   The definition of "Plugging or Repair Limit" is modified to specify the plugging/repair limit for the pressure boundary region of the Electrosleeve is 20 percent of the nominal wall thickness.

c. Proposed change to TS 4.4.5.4.a.9) "Preservice Inspection"

   Administrative change. Deletes the word "and."

d. Proposed new TS 4.4.5.4.a.10)b) "Tube Repair"

   The section is added to specify that tube repair using Electrosleeves shall be in accordance with the methods described in Framatome Topical Report BAW-10219P, "Electrosleeving Qualification for PWR Recirculating Steam Generator Tube Repair," Revision 3, dated October 1998. This section also states that the 20 percent TS plugging limit for the sleeve will apply to inner diameter pits in Regions B and C (as defined in the topical report). This clarifies a contradiction between the TS plugging limit for inner diameter pits and the topical report's plugging limit for inner diameter pits. In addition, this proposed new TS section adds a statement that requires all Electrosleeves to be removed from service within two cycles following installation of the first Electrosleeve.

e. Proposed new TS 4.4.5.4.a.11) "Degraded Sleeve"

   The section is added to incorporate the definition of a degraded sleeve to specify that a degraded sleeve is any sleeve containing imperfections greater than zero percent but less than 20 percent of the nominal wall thickness caused by degradation.

f. Proposed change to TS Table 4.4-3 "Steam Generator Repaired Tube Inspection"

   This table is modified to clarify that each repair method is considered a separate population for determination of the initial inservice inspection scope, as well as scope expansion which is already specified.

g. Proposed revision to TS Bases section

The Bases section is modified to include the plugging/repair limit for the pressure boundary portion of Electrosleeves to be 20 percent of the nominal sleeve wall thickness as determined by NDE.

Based on the evaluation contained in this safety evaluation, the NRC staff concludes the proposed technical specification changes, including the two-cycle limitation, are acceptable.

4.0 STATE CONSULTATION

In accordance with the Commission's regulations, the Missouri State official was notified of the proposed issuance of the amendment. The State official had no comments to provide.

5.0 ENVIRONMENTAL CONSIDERATION

The amendment changes a requirement with respect to installation and use of a facility component located within the restricted area as defined in 10 CFR Part 20 and changes surveillance requirements. The NRC staff has determined that the amendment involves no significant increase in the amounts, and no significant changes in the types, of any effluents that may be released offsite, and that there is no significant increase in individual or cumulative occupational radiation exposure. The Commission has previously issued a proposed finding that the amendment involves no significant hazards consideration, and there has been no public comment on such finding (63 FR 66604). Accordingly, the amendment meets the eligibility criteria for categorical exclusion set forth in 10 CFR 51.22(c)(9). Pursuant to 10 CFR 51.22(b) no environmental impact statement or environmental assessment need be prepared in connection with the issuance of the amendment.

6.0 CONCLUSION

The Commission has concluded, based on the considerations discussed above, that (1) there is reasonable assurance that the health and safety of the public will not be endangered by operation in the proposed manner, (2) such activities will be conducted in compliance with the Commission's regulations, and (3) the issuance of the amendment will not be inimical to the common defense and security or to the health and safety of the public.

Principal Contributors: C. Beardslee
G. Hornseth
P. Rush

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