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

SAFETY EVALUATION BY THE OFFICE OF NUCLEAR REACTOR REGULATION

RELATED TO AMENDMENT NO. 83 TO FACILITY OPERATING LICENSE NO. NPF-37,

AMENDMENT NO. 83 TO FACILITY OPERATING LICENSE NO. NPF-66,

AMENDMENT NO. 75 TO FACILITY OPERATING LICENSE NO. NPF-72,

AND AMENDMENT NO. 75 TO FACILITY OPERATING LICENSE NO. NPF-77

COMMONWEALTH EDISON COMPANY

BYRON STATION, UNITS 1 AND 2

BRAIDWOOD STATION, UNITS 1 AND 2

DOCKET NOS. STN 50-454, STN 50-455, STN 50-456 AND STN 50-457

1.0 INTRODUCTION

By letter dated May 17, 1995, as supplemented by letters dated January 17, March 8, March 18, April 4 and April 9, 1996, Commonwealth Edison Company (ComEd, the licensee), submitted a request to modify the operating licenses and the Technical Specifications (TS) for Byron and Braidwood Stations, Units 1 and 2. The proposal was to permit the use of two types of leak tight steam generator tube sleeves designed by ABB-Combustion Engineering, Inc. (CE). Additionally, the licensee proposed deletion of existing references allowing use of Babcock and Wilcox kinetically expanded steam generator tube sleeves because such sleeves are no longer available from the vendor and none are installed at either Byron or Braidwood plants. The additional submittals provided information that did not change the initial proposed no significant hazards consideration determination.

The two proposed CE sleeve types are a tube sheet sleeve and a tube support plate sleeve. A tube sheet sleeve is designed to restore the portion of a tube in the vicinity of the top of the steam generator tube sheet. A tube support sleeve spans the section of a steam generator tube that passes through a tube support plate. A single tube may contain a tube sheet sleeve and two tube support sleeves, if desired. The sleeve material is nickel alloy 690, an American Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel Code (Code) approved material (ASME SB-163), incorporated in ASME Code Case N-20.

The tube sheet sleeve is installed by means of two different joint types: a rolled joint in the tube sheet end and an autogenous gas-tungsten arc weld (GTAW) at the free span end, above any sludge pile accumulation that may exist at the time of a particular sleeve installation. The tube support sleeves are

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welded (autogenous GTAW) to the SG tube in the free span near each end of the sleeve.

Extensive analysis and testing were performed on the CE sleeves and sleeve-to-tube joints to demonstrate that Regulatory and Code design criteria were satisfied under normal operating and postulated accident conditions. The details of the sleeve qualifications are discussed in the following proprietary CE reports: CEN-621-P, Revision 00, "Commonwealth Edison Byron and Braidwood Unit 1 & 2 Steam Generator Tube Repair Using Leak Tight Sleeves", dated April 1995; CEN-627-P, Revision 00-P, "Verification of the Installation Process and Operating Performance of the ABB CENO Steam Generator Tube Sleeve for use at Byron and Braidwood Units 1 & 2," dated January 1996; and CEN-628-P, Revision 00-P, "Verification of the Structural Integrity of the ABB CENO Steam Generator Welded Sleeve," dated March 1996.

The staff has previously reviewed similar CE documents supporting requests for changes to the TS at other plants. The majority of the technical and regulatory issues for the present request are identical to those reviewed in previous Safety Evaluations (SE's) concerning the use of CE leak tight sleeves. This SE will discuss in detail only those issues that warrant revision, amplification, or inclusion based upon the accumulated installation and operating experience with previously installed sleeves at other facilities. A summary of the principal technical issues regarding the design and installation of CE leak tight sleeves follows. Some prior staff evaluations of CE sleeves are detailed in SE's attached to TS Amendments issued for Arkansas Nuclear One, Unit #2, dated January 26, 1993, Maine Yankee Atomic Power Station, dated April 14, 1995, and Waterford Steam Electric Station, Unit #3, dated October 5, 1995.

2.0 BACKGROUND

A sleeve is a tube slightly smaller in diameter than a steam generator tube that is inserted into a steam generator tube to bridge a degraded or susceptible section of that steam generator tube. The length of a sleeve is selected according to the individual installation circumstance. Generally, they vary in length between one and four feet. The sleeve becomes the pressure boundary and thereby restores the structural integrity of a degraded or potentially degraded portion of the original steam generator tube.

Tube sleeves have become the preferred method for repairing steam generator tubes over the past decade. Prior to the development of sleeve technology, a defective steam generator tube was removed from service by plugging. However, this reduced the heat transfer area of the steam generator. The reduction in heat transfer (or other thermal-hydraulic operating parameters) could be tolerated up to a limit (referred to as the plugging limit), before other system consequences of the reduced steam generator performance became limiting. Beyond this point, a utility was forced to make operational changes that resulted in reduced electrical generating capacity of the affected unit.

When the major causes of service related tube degradation were identified, it became possible to avert and/or manage them. It was further recognized that much of the service induced degradation was confined to specific areas of a steam generator tube and thus predictable with respect to locations. The locations and consistency of the predominant degradation mechanisms allowed for development of a uniform repair technique. The repair technology, sleeving, was then developed to restore affected tubes.

Because sleeves have minimal effect upon the thermal-hydraulics of a steam generator, their use is essentially unrestricted. This means a licensee may restore degraded sections of steam generator tubes to like new condition without experiencing a penalty with regard to unit generating capacity. This has led to increased use of sleeves versus plugs where practical. Recently, some foreign and domestic plants have installed sleeves in previously unprecedented numbers, up to 100 percent of the steam generator tubes on a single unit.

Over 10 years of operating experience with CE sleeves has shown the technology to be highly reliable. No operationally induced degradation or leakage has occurred in any CE sleeves, with over 6300 installed to date. Three or four instances of installation defects have occurred that resulted in inconsequential leaks which were removed from service.

Since the operational experience has been that installation defects have been the sole cause of leakage in CE designed sleeves, and due to the increased usage of sleeves recently, the staff has reexamined certain aspects of the installation process and procedures to ensure a continued level of high reliability of sleeved tubes even with greatly increased use. Sleeve vendors have revised or adopted improved installation procedures to meet the challenge of installing a large number of sleeves while achieving an extremely low defect rate. This has been accomplished through continuing improvements to installation methods and inspection techniques. This SE will principally examine installation and initial inspection issues.

3.0 SUMMARY OF PREVIOUS REVIEWS

Previous staff evaluations of CE sleeves addressed the technical adequacy of the sleeves in the four principal areas of pressure retaining component design: structural requirements, material of construction, welding, and non-destructive examination. The staff found the analyses and tests that were submitted to address these areas of component design and inspection to be acceptable.

The function of sleeves is to restore the structural integrity of the tube pressure boundary. Consequently, structural analyses were performed for a variety of loadings including design pressure, operating transients, and other parameters selected to envelope loads imposed during normal operating, upset, and accident conditions. Stress analyses of sleeved tube assemblies were performed in accordance with the requirements of the ASME Boiler and Pressure Vessel Code, Section III. These analyses, along with the results of qualification testing and previous plant operating experience were cited to demonstrate that the sleeved tube assembly is capable of restoring steam generator tube structural integrity.

The material of construction of the sleeves is nickel alloy 690, a Code approved material (ASME SB-163), covered by ASME Code Case N-20. As used for tube sleeves, the alloy 690 is thermally treated for enhanced corrosion resistance. The staff has found that the use of alloy 690 sleeves is an improvement over the alloy 600 material used in the original steam generator tubing. Corrosion tests conducted under Electric Power Research Institute (EPRI) sponsorship confirm test results regarding the improved corrosion resistance of alloy 690 over that of alloy 600. Accelerated stress corrosion tests in caustic and chloride aqueous solutions have also indicated that alloy 690 resists general corrosion in aggressive environments. Isothermal tests in high purity water have shown that, at normal stress levels, alloy 690 has high resistance to intergranular stress corrosion cracking in extended high temperature exposure. The NRC has concluded, as a result of these laboratory corrosion tests, that alloy 690 is acceptable for use in nuclear power plants. The NRC endorsed the use of Code Case N-20 in Regulatory Guide 1.85. (Revision 24, July 1986). The NRC staff has approved use of alloy 690 tubing in replacement steam generators as well as sleeving applications.

The welding process employed to join the sleeve to the parent tube is automatic autogenous gas-tungsten arc welding (GTAW). The application of this process to the CE sleeve design was specifically qualified and demonstrated during laboratory tests employing full scale sleeve/tube mock-ups. Qualification of the welding procedures and welding equipment operators was performed in accordance with the requirements of the ASME Code, Section IX (Welding).

A post weld heat treatment (PWHT) will be performed after welding. A PWHT reduces the residual stresses that result from welding. Residual stresses from forming operations (such as bending, welding, etc.) are known to be a principal contributor to stress corrosion cracking (SCC) in alloy 600, the parent tube material. Performance of a PWHT greatly reduces the residual stresses from welding thereby enhancing the SCC resistance of the alloy 600 portion of the weld joint. Accelerated corrosion tests of welded joints with and without PWHT have demonstrated the efficacy of the heat treatment in improving the SCC resistance of the alloy 600 parent tube material (the alloy 690 sleeve material is highly resistant to SCC either with or without PWHT). The rolled joints performed within the tube sheet effectively isolate the alloy 600 from the environment and thus are not susceptible to SCC. Stress relief of these joints is unwarranted.

The sleeve assemblies can be inspected by nondestructive techniques in accordance with the recommendations of Regulatory Guide 1.83, "Inservice Inspection of Pressurized Water Reactor Steam Generator Tubes." Nondestructive examination of sleeved tubes is conducted in two primary ways. Initial weld acceptance is performed using (remote camera) visual testing (VT), ultrasonic testing (UT), and eddy current testing (ET). The VT and UT techniques were developed and qualified in accordance with ASME Code requirements. The ET meets the requirements of the ASME Code and the recommendations of Regulatory Guide 1.83.

4.0 DISCUSSION AND EVALUATION

The licensee's proposed TS change incorporates the CE engineering design and installation processes outlined in Section 3.0, above. The overall design aspects remain essentially unchanged from those previously evaluated in the SE's for other installations as outlined in Section 3.0, above. However, some areas of sleeving technology are evolutionary and can experience significant changes between successive installations. Several improvements to installation methods and initial acceptance NDE have recently been incorporated into the CE sleeving process. These changes are a result of service experience with previously installed CE sleeves and ongoing development of NDE probes by the NDE industry. The changes the staff finds relevant to the overall integrity of the CE sleeving process are in the areas of weld preparation and preservice inspection methods.

4.1 Weld Preparation

Prior to performing any weld, the surface of the metal(s) to be welded must be cleaned. Before a tube sleeve is inserted, the inside of the parent tube at the desired weld location is cleaned of service induced oxides by using motorized wire brushes. Recent experiences at another facility using CE sleeves revealed that precleaning of the tube at the weld area was not dependable enough to ensure consistent weld quality. The staff noted that the initial weld inspection reject rate for new sleeve welds was several times higher than the normally encountered 1 percent rejection rate. At the staff's urging, the licensee and CE obtained ex-service and newly fabricated weld mock-ups for evaluation. Weld samples containing defects were studied to determine root cause. Metallurgical examination of the samples confirmed that inadequate surface cleaning would leave an oxide that could result in two well known weld defects: inclusions and, at the edge of the weld, an incomplete fusion and weld shrinkage which creates small volumetric defects (cavities). Additionally, the presence of oxides could, on a much smaller scale, result in inclusions that might result in a very small leak path through an otherwise structurally sound weld. Since the CE sleeving process is designed to be leak tight, any leakage is cause for rejection of that particular sleeve/weld.

Based upon these findings, CE revised the cleaning method to assure optimum removal of service induced oxides. The revised cleaning procedure entailed some equipment changes. More significantly, from the quality assurance standpoint, a 100 percent VT of the cleaning results was instituted. Prior VT inspections were performed on a sampling basis. The VT is performed using a remote fiber optic camera system. CE advises that the 100 percent VT is an interim step until enough field experience is gained to consider adoption of a statistical sampling plan in the future. For Byron and Braidwood, the licensee has committed (in its letter of March 8, 1996) to do a 100 percent VT until such time that additional evidence is available to support a change to this commitment. At that time, the staff will be notified.

4.2 Weld Acceptance Inspections

For compliance with the Code and Regulatory requirements, initial and periodic examinations of steam generator tubes and sleeves are performed. Sleeve welds can be initially inspected for acceptance by VT and UT. ET has traditionally been used for an initial baseline inspection for comparison with later required periodic inspections. Some licensees have recently extended the baseline ET examination as a secondary initial weld acceptance inspection. Thus the welds are initially inspected by three methods: VT, UT, and ET. The recent event at another facility involving inadequately cleaned tubes suggested that the initial acceptance examinations used at that time (VT and UT) may not have been sufficient in those limited circumstances. As a result of this event, ComEd committed (in its letter of March 8, 1996) to the following installation NDE processes to check for proper cleaning and to ensure detection of the types of defects found in the sleeved tubes removed from this facility, should they occur.

* A visual examination will be performed on the I.D. surface of all tubes to be sleeved prior to sleeve installation to ensure proper cleaning until further testing/experience is obtained to justify the reduction of the inspection frequency.

* 100 percent of all sleeve welds will be visually inspected.

* UT inspection after welding will be performed using analysis guidelines developed for an enhanced UT inspection system that will be used which is capable of detecting lack of fusion in welds made in tubes with inadequate cleaning.

* ET inspection of the sleeve welds will be performed using analysis guidelines developed for the Plus Point probe examination of the welded sleeve. The Plus Point ET probe is qualified for sleeve weld inspection per the requirements of EPRI Appendix H.

For future examinations, the licensee has committed to employing improved NDE techniques qualified in accordance with EPRI guidelines (licensee's letter of April 4, 1996).

For the purposes of sleeve campaigns at Byron or Braidwood, the licensee has committed (licensee's letter of April 4, 1996) to plug upon detection of any indications of weld inclusions, volumetric defects, or linear indications until such time that a qualified inspection method is developed that is capable of reliably sizing the defect and locating it with respect to the pressure boundary. The staff understands that such artifacts that appear above an upper weld joint, and are confined to the sleeve, are not structurally significant and would be acceptable. However, NDE techniques for determining the size or position of these artifacts are not available at this time. The licensee's commitment regarding plugging tubes which have defects in the sleeves or sleeve welds, is acceptable.

Periodic inspection and primary-to-secondary leakage monitoring as incorporated in the TS for Byron and Braidwood will identify any premature degradation that may occur in the sleeved joints. The staff concludes that periodic monitoring and inspections are acceptable.

4.3 <u>Sleeve Length</u>

The staff notes that the submitted TS change request and the supporting CE documents do not address potential changes to the sleeve length from those lengths specified in the controlling CE documents listed in Section 1.0, above. Generally, the desired changes from the specified lengths are for use of shorter lengths due to installation access difficulties. The staff has considered the welding, metallurgical, and inspection issues as they may be affected by shorter length sleeves and finds none of those technical issues are adversely affected. Where a longer length sleeve may be desired, thermal expansion stresses must be reevaluated. The staff finds that the vendor's sleeve design evaluations, done in accordance with the ASME Code, are adequate for addressing these potential changes without prior staff review. Therefore, the licensee, in concert with the vendor, may employ sleeve lengths different from those currently specified in the governing CE documents in order to accommodate installation needs if evaluated in accordance with the methods and criteria in the governing CE documents and found acceptable.

4.4 <u>Sleeve Life Predictions</u>

Data and discussions were presented by CE that attempted to use the accelerated corrosion test results to predict service life of the sleeve joint. During the development of the PWHT process, CE devised a service life prediction model that was based upon the accelerated corrosion test data. CE welded sleeves, without PWHT, have achieved 10-years of operation without service induced problems. The accelerated corrosion tests demonstrated the PWHT joints to be superior in SCC resistance to the as-welded joints. Using this test data in the predictive model, CE estimated the stress relieved sleeve joints would last longer than the remaining licensed life of the plant. The staff has concluded that accelerated corrosion tests provide a good qualitative assessment of relative service life for various sleeving processes. However, quantitative estimates of service life do not have a high degree of reliability. For this reason, the staff does not accept deterministic life prediction calculations for tube materials.

4.5 <u>Changes to the Licenses</u>

Each of the licenses include a requirement to conduct steam generator sleeving corrosion testing. The licensee proposed eliminating the requirement to conduct testing on kinetically welded joints because kinetically welded sleeves are not installed at either Byron or Braidwood and with the issuance of this amendment the licensee is not permitted to install such sleeves. The staff finds the licensee's proposed revisions to the licenses to be acceptable.

4.6 Changes to the Technical Specifications

The licensee's proposed changes to the TS include the specification of a random sample method for selection of sleeve sample size for inspections and criteria for expansion of the sample size in the event that flaw indications are found (TS 4.4.5.2.e). They also specify the plugging limit for the sleeved tubes (TS 4.4.5.4.a.6). The vendor reports (ABB-CE) describing the sleeving process and its implementation are incorporated into the TS (TS 4.4.5.4.a.10)b)). References to the kinetically welded sleeves are deleted. The changes to the TS adequately reflect the implementation of the CE sleeves and are, therefore, acceptable.

4.7 Changes to the Technical Specification Bases

The licensee has proposed changes to the Bases consistent with the changes to the TS. Specifically, the changes remove references to the Babcock and Wilcox kinetically welded sleeves and incorporate references to the ABB Combustion Engineering sleeves. Additionally, there is an editorial change to the bases for Byron. The staff finds the proposed changes to be acceptable.

5.0 SUMMARY

Based upon the review and evaluation of the information and data presented in the CE proprietary reports and supporting licensee documents listed in Section 1.0, above, the staff finds that the request by the licensee for a proposed amendment to the facility licenses to modify the TS to permit repair of steam generator tubes by installation of CE designed sleeves, is acceptable. Further, the licensee has committed to performing PWHT of welded joints and adopting the expanded NDE program for verification of tube cleaning and initial weld acceptance as detailed in Sections 4.1 and 4.2, above. For future inspections, the licensee has committed to employing advances in EPRI qualified NDE techniques as they become commercially available.

The staff also notes that sleeve length may be altered from those lengths specified in the governing CE documents listed in Section 1.0, above, as this specification of lengths has been found to be overly restrictive and burdensome to licensees without any measurable benefit to safety.

The staff concludes that the proposed sleeving repairs can be accomplished to produce sleeved tubes of acceptable metallurgical properties, structural integrity, leak tightness and corrosion resistance. The staff also finds that the proposed preservice inspection methods for examining the condition of the welds are acceptable.

The request to delete references to the use of the Babcock and Wilcox kinetically expanded steam generator sleeves is acceptable. No sleeves of this type are presently installed at Byron and Braidwood.

6.0 STATE CONSULTATION

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

7.0 ENVIRONMENTAL CONSIDERATION

The amendments change a requirement with respect to the installation or use of a facility component located within the restricted area as defined in 10 CFR Part 20 and change surveillance requirements. The NRC staff has determined that the amendments involve no significant increase in the amounts, and no significant change 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 amendments involve no significant hazards consideration, and there has been no public comment on such finding (60 FR 35064). Accordingly, the amendments meet 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 amendments.

8.0 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 amendments will not be inimical to the common defense and security or to the health and safety of the public.

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Date: April 12, 1996