

April 11, 2006

Mr. J. A. Stall  
Senior Vice President, Nuclear and  
Chief Nuclear Officer  
Florida Power and Light Company  
P.O. Box 14000  
Juno Beach, Florida 33408-0420

SUBJECT: ST. LUCIE PLANT, UNIT NO. 2 - ISSUANCE OF AMENDMENT REGARDING  
DEPTH OF REQUIRED TUBE INSPECTIONS AND PLUGGING CRITERIA  
WITHIN THE TUBESHEET REGION OF THE ORIGINAL STEAM  
GENERATORS (TAC NO. MC5084)

Dear Mr. Stall:

The U.S. Nuclear Regulatory Commission has issued the enclosed Amendment No. 143 to Renewed Facility Operating License No. NPF-16 for the St. Lucie Plant, Unit No. 2. This amendment consists of changes to the Technical Specifications (TSs) in response to your application dated November 8, 2004, as supplemented March 31, 2005, and February 13, 2006.

This amendment revises TS Section 4.4.5.4 to modify the definitions of steam generator tube "Plugging Limit" and "Tube Inspection." The purpose of these modifications is to define the depth of the required tube inspections and to clarify the plugging criteria within the tubesheet region. The amendment also modifies TS Section 4.4.5.5, "Reports," to require a Special Report of indications found in the tubesheet region following each inspection.

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

Sincerely,

*/RA/*

Brendan T. Moroney, Project Manager  
Plant Licensing Branch II-2  
Division of Operating Reactor Licensing  
Office of Nuclear Reactor Regulation

Docket No. 50-389

Enclosures:

1. Amendment No. 143 to NPF-16
2. Safety Evaluation

cc w/enclosures: See next page

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FLORIDA POWER & LIGHT COMPANY

ORLANDO UTILITIES COMMISSION OF

THE CITY OF ORLANDO, FLORIDA

AND

FLORIDA MUNICIPAL POWER AGENCY

DOCKET NO. 50-389

ST. LUCIE PLANT UNIT NO. 2

AMENDMENT TO RENEWED FACILITY OPERATING LICENSE

Amendment No. 143

Renewed License No. NPF-16

1. The Nuclear Regulatory Commission (the Commission) has found that:
  - A. The application for amendment by Florida Power & Light Company, et al. (the licensee), dated November 8, 2004, as supplemented March 31, 2005, and February 13, 2006, complies with the standards and requirements of the Atomic Energy Act of 1954, as amended (the Act) and the Commission's rules and 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, Renewed Facility Operating License No. NPF-16 is amended by changes to the Technical Specifications as indicated in the attachment to this license amendment, and by amending paragraph 3.B to read as follows:

B. Technical Specifications

The Technical Specifications contained in Appendices A and B, as revised through Amendment No. 143, are hereby incorporated in the license. The licensee shall operate the facility in accordance with the Technical Specifications.

3. This license amendment is effective as of its date of issuance and shall be implemented within 60 days of the date of issuance.

FOR THE NUCLEAR REGULATORY COMMISSION

*/RA/*

Michael L. Marshall, Jr., Branch Chief  
Plant Licensing Branch II-2  
Division of Operating Reactor Licensing  
Office of Nuclear Reactor Regulation

Attachment:  
Changes to the Technical  
Specifications

Date of Issuance: April 11, 2006

ATTACHMENT TO LICENSE AMENDMENT NO. 143  
TO RENEWED FACILITY OPERATING LICENSE NO. NPF-16  
DOCKET NO. 50-389

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

Remove Pages

3/4 4-14  
3/4 4-15

Insert Pages

3/4 4-14  
3/4 4-15

SAFETY EVALUATION BY THE OFFICE OF NUCLEAR REACTOR REGULATION

RELATED TO AMENDMENT NO. 143

TO RENEWED FACILITY OPERATING LICENSE NO. NPF-16

FLORIDA POWER AND LIGHT COMPANY, ET AL.

ST. LUCIE PLANT, UNIT NO. 2

DOCKET NO. 50-389

1.0 INTRODUCTION

By letter to the Nuclear Regulatory Commission (NRC) dated November 8, 2004 (ML043150399), as supplemented by letters dated March 31, 2005 (ML050960513), and February 13, 2006 (ML060480061), Florida Power & Light Company (FPL, the licensee) submitted a license amendment request to revise Section 4.4.5 of the St. Lucie Unit 2 Technical Specifications (TSs). The proposed amendment would revise the extent of steam generator (SG) tube inspections in the hot-leg tubesheet region and clarify the plugging limit within this region. This proposed change is only applicable to the currently installed SGs (i.e., the original SGs). The change will eliminate the need to inspect a portion of the tube within the tubesheet region, thereby, allowing any flaws in this region to remain in service.

To support its amendment request, the licensee submitted proprietary and non-proprietary versions of Westinghouse Commercial Atomic Power Report, WCAP-16208, Revision 0, "NDE [Nondestructive Examination] Inspection Length for CE [Combustion Engineering] Steam Generator Tubesheet Region Explosive Expansions," and the Westinghouse report entitled, "Responses to NRC Requests for Additional Information on WCAP-16208-P, Rev. 0, 'NDE Inspection Length for CE Steam Generator Tubesheet Region Explosive Expansions'."

Currently, the TSs require, in part, an inspection of the entire portion of the SG tube within the hot-leg tubesheet region. The proposed amendment will revise the St. Lucie Unit 2 TSs to change the extent of the inspections and the plugging limit in the SG hot-leg tubesheet region by applying a methodology referred to as C\* (C-star). Specifically, the proposed amendment will revise St. Lucie Unit 2 TS Section 4.4.5.4 to modify the definitions of Plugging Limit and Tube Inspection as contained in Surveillance Requirements 4.4.5.4.a.6 and 4.4.5.4.a.8 to exclude from inspection the bottom portion of the tube within the tubesheet region. That is, the new specification would require only an inspection of the upper portion of the tube within the hot-leg tubesheet region. The length of the tube required to be inspected is referred to as the C\* distance. This amendment also requires plugging any degradation found within the C\* distance (i.e., rather than plugging degradation when it exceeds the plugging limit). In addition, this amendment adds new reporting criteria associated with implementation of the C\* methodology.

The licensee's supplementary submittals dated March 31, 2005, and February 13, 2006, provided clarifying information that did not change the scope of the proposed amendment as described in the original notice of proposed action published in the *Federal Register* and did not change the initial proposed no significant hazards determination.

## 2.0 REGULATORY EVALUATION

SG tubes function as an integral part of the reactor coolant pressure boundary and, in addition, serve to isolate radiological fission products in the primary coolant from the secondary coolant and the environment. Because of the importance of SG tube integrity, the NRC requires the performance of periodic inservice inspections of SG tubes. These inspections detect, in part, degradation in the tubes resulting from interaction with the SG operating environment. Inservice inspections may also provide a means of characterizing the nature and cause of any tube degradation so that corrective measures can be taken. Tubes with degradation that exceeds the tube repair limits specified in a plant's TSs are removed from service by plugging or are repaired by sleeving (if approved by the NRC for use at the plant). The plant TSs provide the acceptance criteria related to the results of SG tube inspections.

The requirements for the inspection of SG tubes are intended to ensure that this portion of the reactor coolant system maintains its integrity. Tube integrity means that the tubes are capable of performing these functions in accordance with the plant design and licensing basis. Tube integrity includes both structural and leakage integrity. Structural integrity refers to maintaining adequate margins against gross failure, rupture, and collapse of the SG tubes. Leakage integrity refers to limiting primary-to-secondary leakage during normal operation, plant transients, and postulated accidents to ensure that the radiological dose consequences are within acceptable limits.

In reviewing requests of this nature, the NRC staff verifies that a methodology exists that maintains the structural and leakage integrity of the tubes consistent with the plant design and licensing basis. This includes verifying that the applicable General Design Criteria (GDC) (e.g., GDC 14 and 32) of Title 10 of the *Code of Federal Regulations* (10 CFR) Part 50, Appendix A are satisfied. The NRC staff's evaluation is based, in part, on ensuring that the structural margins inherent in Regulatory Guide 1.121, "Bases for Plugging Degraded PWR [Pressurized-Water Reactor] SG Tubes" are maintained. The staff's evaluation also includes verifying that a conservative methodology exists for determining the amount of primary-to-secondary leakage that may occur during design basis accidents. The amount of leakage is limited to ensure that offsite and control room dose criteria are met. The radiological dose criteria are specified, in part, in 10 CFR Part 100 and in GDC 19 of Appendix A to 10 CFR Part 50.

The NRC has approved similar, but not identical, proposals to the licensee's submittal. For example, the NRC has approved a methodology, typically referred to as the W\* (W-Star) criteria, which limits the extent of inspection in the tubesheet region in plants with tubes that were expanded into the tubesheet region with the Westinghouse explosive tube expansion (WEXTEX) process. Some of the proposals approved by the NRC also permit flaws to remain in service in the portion of tube that is required to be inspected. The W\* criteria have been approved for Diablo Canyon Units 1 and 2, (NUDOCS Accession Number 9903030010, ADAMS Accession Number ML021200166) for a total of four cycles of operation. In addition, the NRC approved the W\* criteria for one cycle of operation at Beaver Valley Unit 1 (ML042730587), and it permanently approved the W\* criteria for Sequoyah Unit 2 (ML051160012) and Diablo

Canyon Units 1 and 2 (ML052970219). Although each amendment was conceptually similar, there were differences. The two most significant differences involve (1) the methodology for assessing primary-to-secondary leakage under postulated accident conditions and (2) the requirements pertaining to whether degradation in the inspected portion of the tube could remain in service.

The NRC has also approved a redefinition of a tube inspection for one cycle at San Onofre Units 2 and 3 (ML021760674). The SGs at San Onofre are a CE design, similar to the St. Lucie Unit 2 SGs. The explosive tube expansion process used in CE SGs is similar, but not identical, to the WEXTEX tube expansion process associated with the W\* amendments referenced above.

### 3.0 TECHNICAL EVALUATION

#### 3.1 Introduction

St. Lucie Unit 2 is a 2-loop, CE design plant with Model 3410 SGs. Each SG contains approximately 8400 mill-annealed Alloy 600 tubes with an outside diameter of 0.75 inches and a wall thickness of 0.048-inches. Each U-tube is secured into the tubesheet by an explosive expansion (expansion) process. The tubesheet is 21.75 inches thick and each tube is expanded for essentially the full thickness of the tubesheet. The SG tubesheets were gun drilled and the resulting surface finish is termed "rough bore." A weld joins the tube end to the cladding on the primary face of the tubesheet. This weld provides a leak tight boundary and provides resistance to tube pullout. The expansion process produces an interference fit between the tube and tubesheet which can also provide resistance to tube pullout. The transition from the expanded portion of the tube to the unexpanded portion of the tube is referred to as the expansion transition.

Each SG contains horizontal supports (eggcrates), diagonal supports (batwings), and vertical supports. All tube support material is carbon steel. The shorter tubes, located in the first 18 rows at the center of the tube bundle, have 180-degree bends (i.e., are bent in the shape of a "U"). Higher row number tubes (Rows 19-147) have double 90-degree bends with a horizontal run between the bends.

The tube-to-tubesheet joint consists of the tube, which is explosively expanded against the bore of the tubesheet, the tube-to-tubesheet weld located at the tube end, and the tubesheet. Typically, plants designed the tube-to-tubesheet joint as a welded joint rather than a friction or expansion joint. That is, the weld itself was designed as a pressure boundary element, and it was designed to transmit the entire end cap pressure load during normal and design-basis accident conditions from the tube to the tubesheet with no credit taken for the friction developed between the explosively expanded tube and the tubesheet. In addition, the weld serves to make the joint leak tight.

The existing inspection requirements in the plant TSs do not take into account the reinforcing effect of the tubesheet on the external surface of the expanded tube. The presence of the tubesheet constrains the tube and complements tube integrity in that region by essentially precluding tube deformation beyond the expanded outside diameter of the tube. The



resistance to both tube rupture and tube collapse is significantly enhanced by the tubesheet reinforcement. In addition, the proximity of the tubesheet to the expanded tube significantly reduces the leakage from any through-wall defect.

Based on these considerations, power reactor licensees have proposed, and the NRC has approved, alternate repair criteria for defects located in the SG tube contained in the lower portion of the tubesheet, when these defects are a specific distance below the expansion transition or the top of the tubesheet (TTS), whichever is lower.

The C\* methodology defines a distance, referred to as the C\* distance, such that any type or combination of tube degradation below this distance (including degradation of the tube-to-tubesheet weld) is considered acceptable. That is, even if inspections below the C\* distance identified degradation, the regulatory requirements pertaining to tube structural and leakage integrity would be met provided there were no significant flaws within the C\* distance. The C\* distance is determined by calculating the amount of undegraded tubing needed to ensure the tube will not pullout out of the tubesheet and that the amount of leakage from flaws below the C\* distance is limited (i.e., within acceptance limits). This C\* distance is measured from the TTS or the bottom of the expansion transition, whichever is lower.

NDE uncertainties are accounted for in determining the C\* distance. These uncertainties include, but are not limited to, the uncertainties in determining the location of the bottom of the expansion transition and the total inspection distance. These uncertainties are based on previous data for a tubesheet inspection methodology for Westinghouse designed plants (W\*) and were reviewed and approved as part of the staff's safety evaluation approving the W\* repair criteria for Diablo Canyon.

The C\* analysis presented in WCAP-16208, Revision 0, uses nonplant-specific values for primary system pressure, secondary pressure, and primary temperature to determine the required C\* inspection length for tubing within the tubesheet. Except for the normal operating differential pressure and temperature (discussed below), the nonplant-specific values used in the C\* analysis bound the operating conditions at St. Lucie Unit 2. The normal operating differential pressure (i.e., the difference between the primary system pressure and the secondary pressure) for St. Lucie Unit 2 could be marginally higher than that used in WCAP-16208 (assuming 30 percent of the tubes are plugged). Although this would increase the inspection length determined from tube pullout (structural integrity) considerations by approximately 0.1-inch, the C\* inspection distance is controlled by limiting the primary-to-secondary leakage during postulated accidents rather than by tube pullout, as discussed below. As a result, this nonconservative assumption has no effect on the C\* distance. The hot-leg temperature at St. Lucie Unit 2 is lower than that assumed in WCAP-16208, Revision 0. Since this lower temperature results in a looser joint, an updated analysis using this lower temperature was provided in the licensee's February 13, 2006, submittal.

The C\* analysis considered the forces acting to pull the tube out of the tubesheet (i.e., from the internal pressure in the tube) and the forces acting to keep the tube in place. These latter forces are a result of friction and the forces arising from (1) the residual preload from the expansion process, (2) the differential thermal expansion between the tube and the tubesheet, and (3) internal pressure in the tube within the tubesheet. In addition, the effects of tubesheet bow, due to pressure and thermal differentials across the tubesheet, were considered since this bow causes dilation of the tubesheet holes from the secondary face to approximately the

midpoint of the tubesheet and reduces the ability of the tube to resist pullout. The amount of tubesheet bow varies as a function of radial position with locations near the periphery and near the stay cylinder experiencing less bow. The effects of tubesheet hole dilation were analyzed using the worst case hole (location) in the tubesheet.

### 3.2 St. Lucie Unit 2 Proposal

The licensee's basis for eliminating the requirement to inspect the tube below the C\* distance is documented in its submittals. St. Lucie Unit 2 will conservatively apply the greatest C\* length calculated for any tube to all tubes in the SG. The resulting C\* amendment will allow the licensee to exclude from inspection the tube portion located from 10.3 inches below the TTS or the bottom of the hot-leg transition, whichever is lower, to the hot-leg tube end. Any tube degradation occurring within the tubesheet below the C\* length is acceptable. Any degradation within the tubesheet located above the C\* distance will be plugged on detection.

The following sections summarize the staff's evaluation of the proposed St. Lucie Unit 2 C\* proposal in terms of maintaining SG structural and leakage integrity.

### 3.3 Tube Structural Integrity

The proposed amendment will permit tubes with defects to remain in service; therefore, the licensee must demonstrate that the tubes returned to service using the C\* methodology will maintain adequate structural integrity for the period of time between inspections. Tube rupture and the pullout of a tube from the tubesheet are two potential modes of structural failure considered for tubes returned to service under the C\* methodology.

In order for a tube to rupture as a result of implementing the C\* criteria, a flaw would need to grow above the tubesheet's secondary face. If the entire flaw remains within the tubesheet, the reinforcement provided by the tubesheet will prevent tube rupture. The C\* methodology proposed for St. Lucie Unit 2 requires an inspection of the C\* distance and the repair of any service related degradation in the C\* distance. Therefore, any known flaws remaining in service following the rotating probe examinations will be located a minimum of 10.3 inches below the TTS. Industry operating experience shows flaw growth rates within the tubesheet are well below that necessary to propagate a flaw from 10 inches below the TTS to outside the tubesheet. Therefore, it's not likely that any of these flaws will grow in an axial direction and extend outside the tubesheet during one operating cycle. Thus, tube burst is precluded for these flaws due to the reinforcement provided by the surrounding tubesheet.

In the event that undetected flaws are present in the C\* distance or new flaws initiate in the C\* distance in the operating cycle following an inspection, the licensee indicated it would assess the effects of these flaws on the structural and leakage integrity of the SG. Based on past operating experience, no challenge to structural or leakage integrity is expected from these flaws (i.e., undetected flaws or flaws that may initiate within the C\* distance).

The other postulated structural failure mode for tubes remaining in service using the C\* methodology is pullout of the tube from the tubesheet due to axial loading on the tube. Differential pressures from the primary side to the secondary side of the SG impart axial loads into each tube that are reacted at the tube-to-tubesheet interface. Axial tube loading during normal operating conditions can be significant. The peak postulated loading, however, occurs

during events involving a depressurization of the secondary side of the SG (e.g., main steam line break (MSLB)). The presence of degradation within a SG tube decreases the load bearing capability of the affected tube. If a tube becomes sufficiently degraded, these loads could lead to an axial separation of the tube.

Resistance to tube pullout is provided by the interference fit created during the expansion process. In addition, the differential thermal expansion between the tube and the tubesheet and the internal pressure of the tube creates a tighter interference fit between the tube and the tubesheet to further resist tube pullout. Resistance to tube pullout, however, is reduced by tubesheet bow which causes the tubesheet holes to dilate near the TTS.

The analysis supporting the licensee's proposed modifications to the tube inspection requirements addressed the limiting conditions necessary to maintain adequate structural integrity of the tube-to-tubesheet joint. Specifically, the tube must not experience excessive displacement relative to the tubesheet under bounding loading conditions with appropriate factors of safety considered. For C\*, the most limiting condition for structural integrity is maintaining a margin of three against the axial loads experienced during normal operation.

To justify the acceptability of any type or combination of tube degradation below the C\* distance from a structural integrity standpoint, the licensee completed an assessment using analytical calculations and laboratory experiments. The laboratory experiments included tests of prototypical SG tube-to-tubesheet joints to evaluate the length of sound tubing necessary to maintain structural integrity (i.e., to ensure the tube would not pull out of the tubesheet under axial loading conditions). The most limiting regulatory condition from a structural integrity standpoint was determined to be that the tube must resist pullout from the tubesheet during normal operation with a factor of safety of three. Laboratory data from two sources were used in performing this assessment. These include data obtained under CE Owners Group (CEOG) Task 1154 and data obtained during the development of WCAP-16208. This latter data are referred to as pullout screening tests since they were performed simply to confirm that the joint length would satisfy the limiting load condition (i.e., three times the normal operating load) rather than determining the axial load resistance provided by the joint. On the other hand, the Task 1154 samples were tested to determine the axial load resistance of various joint lengths. The Task 1154 data are from the following sources:

- C An 8-inch thick, seven tube-to-tubesheet joint mockup built for Ringhals
- C A portion of the as-built SG tubesheet from a cancelled Boston Edison contract
- C Tube-to-tubesheet mockups fabricated for CEOG Task 1154 tube pullout and leakage tests

Results from pullout testing of the Task 1154 prototypical SG tube-to-tubesheet joints provided the basis for determining the length of sound tubing necessary to maintain the appropriate structural margins for tubes that may be severed from degradation within the tubesheet. The test specimens were subjected to axial loadings in order to demonstrate acceptable structural capabilities. The axial resistance provided by these specimens was evaluated using the load required to move the tube within the tubesheet (maximum load). To determine the axial load resistance provided by just the expansion process, only the tests performed under ambient pressure and room temperature conditions were evaluated. Adjustments were made to the data to account for testing differences and differences in the tube wall thickness. A 95-percent lower bound curve to the adjusted data was used in evaluating the axial load resistance

provided by the expansion process. The pullout screening tests discussed above confirmed the adequacy of the pullout forces measured under the Task 1154 program.

In addition to the resistance from pullout provided by the expansion process, the following were also considered in determining the appropriate inspection distance from a structural integrity (tube pullout) standpoint: (1) resistance to tube pullout from the differential thermal expansion between the tube and the tubesheet, (2) resistance to tube pullout from the internal pressure in the tube within the tubesheet, (3) uncertainty in determining the amount of tube inspected, and (4) reduction in the resistance to tube pullout from the bowing of the tubesheet.

Consideration of the effects of pressure and temperature were based on analytical calculations (rather than test results). Although the increase in joint tightness (i.e., increase in the axial load resistance of the tube-to-tubesheet joint) as a result of internal pressure and differential thermal expansion between the tube and tubesheet was addressed analytically, the pullout tests performed at operating pressure and/or temperature were reviewed to verify that the results from these tests supported the analytical adjustments made to account for these effects.

Consideration of the uncertainty in determining the amount of tube inspected was based on testing as discussed in WCAP-16208. The uncertainties used in determining the appropriate C\* inspection distance were based on data obtained during the development of the W\* inspection distance since both involve inspection of tubes explosively expanded into the tubesheet.

Consideration of the effects of tubesheet bow were based on analytical (finite element) calculations as discussed in WCAP-16208. Since the analytical model considered the point of maximum tubesheet deflection, it will result in the most dilation and the greatest reduction in axial load carrying capability of the tube-to-tubesheet joint.

The above factors were combined and it was determined that an inspection distance of approximately 3 inches was required to prevent tube pullout, which is significantly less than the C\* inspection distance of 10.3 inches proposed by the licensee. This is because the C\* inspection distance is governed by leakage integrity considerations rather than structural integrity considerations.

With respect to the licensee's assessment of tube pullout, the staff notes that instead of considering a lower 95 percent bound of the tube pullout data (of maximum load), it considered the most limiting pullout data since all tubes should resist pullout from the tubesheet. In addition, the staff considered the load associated with the first movement of the joint since movement of this joint was not considered (to the staff's knowledge) in the original design of the tube-to-tubesheet joint. These considerations would only increase the inspection distance for ensuring structural integrity by a minor amount. As a result, the structural integrity inspection distance is still significantly less than the proposed inspection distance of 10.3 inches (even accounting for the nonconservative assumption regarding the differential pressure loads discussed above) and is considered acceptable. In addition, the staff notes that it did not review the scaling procedures that the licensee applied to the tube pullout data in detail; however, the adjustments made appeared reasonable and even if no adjustments were made to the data it would not have significantly affected the structural integrity inspection distance.

With respect to the finite element model, the NRC staff reviewed the input assumptions and the

results of the model. As a result of this review, the staff concludes that the input assumptions were conservatively chosen and that the results of the analysis are comparable to other analyses reviewed and approved by the staff given the design configuration of the CE SGs (e.g., stay cylinder, explosive expansions).

In summary, the NRC staff concludes that the proposed tube-to-tubesheet joint length (or inspection distance) is acceptable to ensure structural integrity of the tubesheet joint. This conclusion is based on numerous factors including the presence of the tubesheet which precludes tube burst, past inspection results that indicate that flaws are detected early enough to prevent structurally significant flaws from developing within the C\* inspection distance, the conservative assumptions in the tube pullout analysis (e.g., worst case tube dilation, use of limiting pullout data, use of a 95 percent NDE uncertainty adjustment), the confirmation through testing that the analytical adjustments for pressure and temperature are supported, and the restriction to tube pullout provided by the tube bundle upper support structure. The upper support structure design is such that vertical movement of tubes is limited by supports or neighboring tubes for all tubes except those on the periphery of the tube bundle. The proposed inspection distance takes no credit for restriction to tube movement inherent to the SG design.

### 3.4 Tube Leakage Integrity

In assessing leakage integrity of a SG under postulated accident conditions, the leakage from all sources (i.e., all types of flaws at all locations and all nonleak-tight repairs) must be assessed. The combined leakage from all sources is limited to below a plant-specific limit based on radiological dose consequences. The licensee reported this plant-specific limit as 0.15 gallons per minute (gpm). This limit is referred to as the “accident-induced leakage limit.”

As part of the C\* methodology, the licensee restricts the amount of primary-to-secondary leakage from the tube-to-tubesheet joint to a fraction of the accident-induced leakage limit for the most limiting design basis accident conditions (i.e., MSLB). That is, the proposed inspection distance of 10.3 inches was determined based on ensuring that the leakage from flaws within the tubesheet region would contribute only a small fraction of the accident-induced leakage limit.

The licensee’s method for determining the amount of leakage from flaws within the tubesheet region depends on whether the flaws are located within the C\* distance or below the C\* distance. For flaws located within the C\* distance, no leakage is anticipated since the proposed TSs state that all degradation in this region will be plugged on detection. As a result, the only flaws expected within the C\* distance would either be newly initiated or undetected (e.g., below the threshold of detection) flaws. These flaws typically do not grow, in one operating cycle, to the extent that they would leak during post-accident conditions. Although no leakage is expected from flaws within the C\* distance, the licensee is required to assess potential leakage from such flaws as part of their assessments. Since the C\* methodology does not require inspections below the C\* distance (10.3 inches from the TTS or the bottom of the expansion transition, whichever is lower), there is a potential that flaws that could leak will exist below the C\* distance. As a result, the licensee developed a methodology for determining the amount of accident-induced primary-to-secondary leakage from flaws in this region of the tubesheet. This methodology and the NRC staff’s review of this methodology are discussed below.

The amount of leakage from flaws below the inspection distance depends on the number of



flaws, the locations of the flaws, and the severity of the flaws. The methodology developed by the licensee assumes that each in service tube (i.e., currently approximately 6900 tubes per SG) has a 360° circumferential, 100-percent through-wall flaw (i.e., a tube sever) located at the bottom of the C\* inspection distance. Given past accident-induced and industry operating experience, the staff considers the assumption that all tubes contain circumferential, through-wall flaws at the C\* distance to be conservative. Previous tube inspections using bobbin coil eddy current and rotating probe eddy current inspections (to a depth of 8 inches below the top of tubesheet) have identified a total of seven indications within the tubesheet region at St. Lucie Unit 2. The staff also considers only assuming one flaw per tube acceptable since leakage from flaws in the lower half of the tubesheet would not be expected to be a significant contributor to leakage given (1) the length of the tube-to-tubesheet crevice, (2) tubesheet bow in the lower region of the tubesheet tends to increase the resistance to leakage (since tubesheet bow in the lower region of the tubesheet tends to make the holes contract rather than dilate), and (3) the amount of leakage from the portion of the tube within the tubesheet region will predominantly be a function of the flaw nearest the TTS (i.e., at 10.3 inches below the TTS as assumed by the licensee).

Assuming flaws are present below the C\* distance, the licensee's methodology determined the amount of leakage from the flaws left in service with the C\* criteria using a combination of laboratory leak test data and analysis. Leak tests were performed on 0.75-inch outside diameter Alloy 600 mill annealed tube samples expanded into an 8-inch thick carbon steel collar to represent SG tubes explosively expanded into tubesheet holes. Two different carbon steel collar hole finishes were tested to simulate two different CE tubesheet manufacturing techniques. The drilled collar hole specimens were used to represent CE gun-drilled (rough bore) tubesheets, such as at St. Lucie Unit 2, and the drilled and reamed collar hole specimens were used to represent CE tubesheets fabricated with a bore trepanning association process (smooth bore). The tubes were expanded into the full length of the simulated tubesheets (collars) using the standard CE explosive fabrication method. Electronic Discharge Machining (EDM) was subsequently performed on the tubes to produce tube-to-simulated tubesheet engagement lengths ranging from 1 inch to 5.5 inches. Leak rates through a 360-degree EDM-generated tube flaw are expected to be greater than leakage from a service-induced, through-wall, stress corrosion crack. Multiple leak tests were performed on each sample to provide data at various tube-to-tubesheet joint lengths and at different test temperatures.

Given the laboratory leak rate data obtained at elevated temperatures (i.e., 600 degrees Fahrenheit), the licensee's leakage methodology calculates the necessary C\* inspection length using several relationships developed in WCAP-16208. The inspection length (uncorrected joint length) associated with the minimum detectable leak rate from the leak rate tests was determined using the relationship between tube-to-tubesheet joint length and leak rate developed from the leak rate tests. This "uncorrected" inspection length was then analytically corrected assuming the limiting MSLB conditions, when tubesheet bow and accompanying tubesheet hole dilation effects are maximum. A final (corrected) inspection length was established that accounted for tubesheet hole dilation effects and uncertainty related to NDE probe axial position. This methodology uses the load at first slip (rather than the maximum load or load at first move).

The licensee also discussed its overall approach for addressing normal operating and accident-induced leakage since the limits on normal operating and accident-induced leakage are the same. With the same limits, it may be necessary to keep the actually observed

operating leak rate well below the operational TS leak rate limit to ensure that the accident-induced leakage rate that is assumed in the accident analysis is not exceeded as a result of the higher differential pressure (driving force for leakage) during an accident. The accident-induced leakage rate can increase as a result of either: (1) the higher differential pressure between the primary and secondary coolant systems associated with a design-basis accident (DBA) causing the leak rate from flaws leaking during normal operation to leak at higher rates; or (2) the higher loadings associated with a DBA causing a flaw that was not leaking during normal operation to leak during the accident. The staff did not review this methodology in detail; rather, the staff verified that the licensee's projection of accident-induced leakage associated with postulated indications in the tubesheet region (0.032 gpm) was well below the accident-induced leakage limit.

During its review of the licensee's leakage methodology, the staff noted some inconsistencies in the leak rate data and potential uncertainties introduced into the data. These include:

The leak rate response to increasing differential pressure was not consistent between the room temperature leak rate tests at the Westinghouse Windsor facility and the Westinghouse Science and Technology Division (STD) facility. For example, in some cases the leak rates increase with increasing differential pressure and in other cases the leak rate stayed the same or decreased with increasing differential pressure. The leak rate for the STD data appeared to consistently increase with increasing differential pressure.

Although earlier testing in support of the W\* methodology showed leak rates decreased as temperature increased (from room temperature to operating temperatures), operating temperature leak rates in the C\* tests were greater than the corresponding room temperature leak rates in many cases. Similarly, the W\* tests indicated the leak rate was relatively independent of the differential pressure and the C\* tests indicated that the leak rate increases with differential pressure.

Leak tests in support of the C\* methodology were conducted at two facilities with different test techniques and different leak rate measurement techniques. Since initial tests of samples at the STD facilities yielded leak rates that were significantly less than the last comparable leak rates measured at the Windsor facility, an all volatile water treatment (AVT) was applied to some of the test samples. Leak rate tests performed after the AVT treatment resulted in an increase in the leak rate, suggesting oxides developed either during earlier tests or during post test handling at the first facility (Windsor). No destructive examination was performed to characterize the test samples tube-to-collar crevices during testing or at the completion of testing. Almost all of the room temperature leak rates measured at the Windsor facility are greater than the leak rate measured at STD (for the same specimen).

The leak rate was higher in the heatup phase than in the cooldown phase for some specimens while the opposite trend occurred in other specimens.

The leak rate data were determined to be independent of the tubesheet hole roughness (rough bore or smooth bore) whereas the resistance to tube pullout is dependent on the tubesheet hole roughness (the smoother bore tubesheet holes are less resistant to tube pullout).

Multiple tests were performed on the same specimen. These multiple tests included both room temperature and elevated temperature tests along with tests of various crevice lengths. The initial tests may have introduced deposits into the crevice which could have restricted the leak rate of subsequent tests.

The leak rate decreased with time for the C\* tests. This trend was not always observed in similar tests performed for tubes hydraulically expanded into a tubesheet collar (i.e., H\* tests).

The determination that the EDM process had no effect on obstructing the leak path was based on one specimen (albeit at several locations within that specimen).

The tube and collar temperatures were not monitored during the welding and cutting of the specimens, introducing uncertainty on whether the joint loosened or whether oxides could have formed in the crevice.

The surface finish of the specimens was not measured, introducing uncertainty of whether the surface finish of the specimens is comparable to that in the field.

In addition to the above, the staff notes that, (1) the inspection distance associated with leakage was determined from the correlation of joint length to the load at first slip rather than from a correlation of joint length to the load at first move and (2) the leak rate at 460 degrees Fahrenheit may be greater than that at 600 degrees Fahrenheit.

Since the leak rate through a flaw in a tube within the tubesheet is a complex function of several factors, it is not totally unexpected that there were some inconsistencies in the data. These factors include the trapping of corrosion products between the tube and tubesheet, the formation of oxides before and during the occurrence of leakage, the deposition of boric acid in the "crevice" after leakage initiates, viscosity of the fluid, contact pressure, the tube and the tubesheet's response to changing temperature conditions (e.g., tube cooling quicker than tubesheet), tubesheet hole asperities, and extrusion of the tube into the asperities during the initial expansion process. As a result, even though the staff noted some inconsistencies and potential uncertainties in the leak rate data, the staff considers the leakage methodology acceptable for the following reasons:

1. The licensee is performing inspections and repairing all service induced degradation to a minimum depth of 10.3 inches below the TTS (or expansion transition).
2. The tubesheet hole dilation model is based on the most dilated hole in the tubesheet. No credit is taken for the significant reduction in total leakage that would be realized by applying less dilation to the other radial positions of the tubesheet, such as near the periphery and near the stay cylinder.
3. The licensee assumes all tubes remaining in service contain a 360-degree circumferential, 100-percent through-wall flaw (i.e., a tube sever) at the bottom of the C\* inspection distance. This assumption is conservative given industry inspection results within the tubesheet region.



4. EDM slits used to simulate circumferential cracks for the leak rate tests produce a larger width flaw with less flow resistance compared to a service related stress corrosion crack. In addition, the accumulation of sludge and corrosion products at the secondary face of the St. Lucie SG tube-to-tubesheet joint is expected to provide a greater restriction to flow relative to the leak test samples.
5. Flaws postulated below the C\* distance are assumed to be leaking although industry operating experience has demonstrated negligible leakage under normal operating conditions, even when cracks are located in the expansion transition zone near the TTS.
6. The SGs that this methodology will be applied to are expected to be replaced in 2007. As a result, implementation of this methodology will be limited to essentially only one cycle.
7. No credit is taken for corrosion in the tubesheet joint which would be expected to lead to blocking of the leak path and significantly reduce the total potential leak rate.

In summary, the NRC staff concludes that the proposed tube-to-tubesheet joint length (or inspection distance) is acceptable to ensure that the amount of accident-induced leakage from undetected flaws below the C\* distance (i.e., the inspection distance) will be limited to a small fraction of the accident-induced leakage limit.

### 3.5 Reporting Requirements

As part of implementation of the C\* methodology, the licensee proposed to modify TS 4.4.5.5.c to require specific information to be submitted to the NRC within 120 days after the reactor coolant system reenters Mode 4 following each inspection. The information to be reported for indications found in the tubesheet region includes the number of indications identified, the location of each indication, orientation of each indication, severity of each indication, and whether the indications initiated from the inside or outside diameter of the tube, the cumulative number of indications detected in the tubesheet region as a function of elevation within the tubesheet region, and the projected end-of-cycle accident-induced leakage from tubesheet indications (e.g., 0.1 gpm from indications below the C\* inspection distance and the amount of leakage from indications within the C\* distance). This leakage will be combined with the postulated end-of-cycle accident-induced leakage from all other sources, and if the preliminary estimated total projected end-of-cycle accident-induced leakage from all sources exceeds the leakage limit the NRC staff shall be notified prior to Unit restart. This report will permit the staff to verify the operating experience continues to be conservative relative to the assumptions made in the amendment and will permit timely notification if the projected leakage at the end-of-cycle is expected to exceed leakage limits. As a result, the staff concludes that the proposed changes to the TSs reporting requirements are acceptable.

### 3.6 Summary

Based on the above evaluation, the NRC staff concludes that the licensee's proposed methodology for assessing structural and leakage integrity for flaws in the tubesheet region is acceptable. Therefore, the staff concludes that the licensee's proposal to limit the extent of tube inspections in the hot-leg tubesheet, to repair all degradation detected in the region of the

tubesheet required to be inspected, and to supplement their reporting requirements is acceptable.

#### 4.0 STATE CONSULTATION

Based upon a letter dated May 2, 2003, from Michael N. Stephens of the Florida Department of Health, Bureau of Radiation Control, to Brenda L. Mozafari, Senior Project Manager, U.S. Nuclear Regulatory Commission, the State of Florida does not desire notification of issuance of license amendments.

#### 5.0 ENVIRONMENTAL CONSIDERATION

This amendment changes a requirement with respect to installation or 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 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. This amendment also relates to changes in record keeping, reporting, or administrative procedures or requirements. 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 (69 FR 68408, dated November 24, 2004). Accordingly, the amendment meets the eligibility criteria for categorical exclusion set forth in 10 CFR 51.22(c)(9) and 10 CFR 51.22(c)(10). 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 Contributor: Kenneth Karwoski

Date: April 11, 2006

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