April 25, 2005

Mr. Christopher M. Crane, President
and Chief Nuclear Officer
Exelon Generation Company, LLC
4300 Winfield Road
Warrenville, IL 60555

SUBJECT: BRAIDWOOD STATION, UNITS 1 AND 2 - ISSUANCE OF EXIGENT AMENDMENTS RE: REVISION OF SCOPE OF STEAM GENERATOR INSPECTIONS FOR UNIT 2 REFUELING OUTAGE 11 - (TAC NOS. MC6686 AND MC6687)

Dear Mr. Crane:

The U.S. Nuclear Regulatory Commission (Commission) has issued the enclosed Amendment No. 135 to Facility Operating License No. NPF-72 and Amendment No. 135 to Facility Operating License No. NPF-77 for the Braidwood Station, Units 1 and 2, respectively. The amendments are in response to Exelon Generation Company, LLC application dated April 11, 2005, as supplemented by letter dated April 14, 2005.

The amendments revise Technical Specification (TS) 5.5.9, "Steam Generator (SG) Tube Surveillance Program," to incorporate changes in the SG inspection scope for Braidwood Station, Unit 2 only, during refueling outage 11. Specifically, the amendments modify the inspection requirements for portions of the SG tubes within the hot leg tubesheet region of the SGs. The license for Braidwood Station, Unit 1, is affected only because Units 1and 2 have common TSs.

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/

George F. Dick, Senior Project Manager, Section 2
Project Directorate III
Division of Licensing Project Management
Office of Nuclear Reactor Regulation

Docket Nos.: STN 50-456 and STN 50-457

Enclosures: 1. Amendment No. 135 to NPF-72
2. Amendment No. 135 to NPF-77
3. Safety Evaluation

cc w/encls: See next page

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EXELON GENERATION COMPANY, LLC

DOCKET NO. STN 50-456

BRAIDWOOD STATION, UNIT NO. 1

AMENDMENT TO FACILITY OPERATING LICENSE

Amendment No. 135
License No. NPF-72

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

   A. The application for amendment by Exelon Generation Company, LLC (the licensee) dated April 11, 2005, as supplemented by letter dated April 14, 2005, 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, 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-72 is hereby amended to read as follows:

(2) Technical Specifications

The Technical Specifications contained in Appendix A as revised through Amendment No. 135 and the Environmental Protection Plan contained in Appendix B, both of which are attached hereto, are hereby incorporated into this license. The licensee shall operate the facility in accordance with the Technical Specifications and the Environmental Protection Plan.

3. This license amendment is effective as of the date of its issuance and shall be implemented within 30 days of the date of issuance.

FOR THE NUCLEAR REGULATORY COMMISSION
/RA/

Gene Y. Suh, Chief, Section 2
Project Directorate III
Division of Licensing Project Management
Office of Nuclear Reactor Regulation

Attachment: Changes to the
Technical Specifications

Date of Issuance: April 25, 2005

EXELON GENERATION COMPANY, LLC

DOCKET NO. STN 50-457

BRAIDWOOD STATION, UNIT NO. 2

AMENDMENT TO FACILITY OPERATING LICENSE

Amendment No. 135
License No. NPF-77

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

   A. The application for amendment by Exelon Generation Company, LLC (the licensee) dated April 11, 2005, as supplemented by letter dated April 14, 2005, 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, 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-77 is hereby amended to read as follows:

(2) Technical Specifications

The Technical Specifications contained in Appendix A as revised through Amendment No. 135 and the Environmental Protection Plan contained in Appendix B, both of which were attached to License No. NPF-72, dated July 2, 1987, are hereby incorporated into this license. The licensee shall operate the facility in accordance with the Technical Specifications and the Environmental Protection Plan.

3. This license amendment is effective as of the date of its issuance and shall be implemented within 30 days of the date of issuance.

FOR THE NUCLEAR REGULATORY COMMISSION
/RA/

Gene Y. Suh, Chief, Section 2
Project Directorate III
Division of Licensing Project Management
Office of Nuclear Reactor Regulation

Attachment: Changes to the
Technical Specifications

Date of Issuance: April 25, 2005

ATTACHMENT TO LICENSE AMENDMENT NOS. 135 AND 135

FACILITY OPERATING LICENSE NOS NPF-72 AND NPF-77

DOCKET NOS. STN 50-456 AND STN 50-457

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. Pages marked with an asterisk are provided for convenience.

Remove Pages	Insert Pages
5.5-9	5.5-9
5.5-12	5.5-12
5.5-13	5.5-13
5.5-14	5.5-14

SAFETY EVALUATION BY THE OFFICE OF NUCLEAR REACTOR REGULATION

RELATED TO AMENDMENT NO. 135 TO FACILITY OPERATING LICENSE NO. NPF-72

AND AMENDMENT NO. 135 TO FACILITY OPERATING LICENSE NO. NPF-77

EXELON GENERATION COMPANY, LLC

BRAIDWOOD STATION, UNIT NOS. 1 AND 2

DOCKET NOS. STN 50-456 AND STN 50-457

1.0 INTRODUCTION

By application dated April 11, 2005, as supplemented by letter dated April 14, 2005, Exelon Generation Company, LLC (the licensee) requested changes to the Technical Specifications (TSs) for Braidwood Station, Units 1 and 2. The supplement dated April 14, 2005, provided additional information that clarified the application, did not expand the scope of the application as originally noticed and did not change the U.S. Nuclear Regulatory Commission (NRC) staff's original proposed no significant hazards consideration determination. Because there was a short time interval between identification of the need for a TS change and the actual performance of the TS requirement, the licensee requested that the amendment request be considered under exigent circumstances. The staff published a public notice in two local newspapers, the Joliet News Herald (April 15, and 18, 2005) and the Morris Daily Herald (April 19, 2005).

The amendment requests involves a one time change to TS 5.5.9, "Steam Generator (SG) Tube Surveillance Program," regarding the required SG inspection scope for Braidwood Station, Unit 2, during Refueling Outage (RFO) 11 and the subsequent operating cycle. The proposed changes modify the inspection requirements for portions of the SG tubes within the hot leg tubesheet region of the SGs. The license for Braidwood Station, Unit 1 is affected only due to the fact that Unit 1 and Unit 2 use common TSs. Specifically, the proposed changes would modify:

1.1 TS 5.5.9.b, SG Tube Sample Selection and Inspection

A new requirement has been added to state:

> For Unit 2 during Refueling Outage 11, a 20% minimum sample of all inservice tubes from the top of the hot leg tubesheet to 17 inches below the top of the tubesheet shall be inspected by rotating probe. This sample shall included a 20% minimum sample of the total population of bulges and overexpansions within the SG from the top of the hot leg tubesheet to 17 inches below the top of the tubesheet.

1.2 TS 5.5.9.e.6, Plugging or Repair Limit

Two new paragraphs have been added to state:

> For Unit 2 during Refueling Outage 11 and the subsequent operating cycle, this definition doe not apply to degradation identified in the portion of the tube below 17 inches from the top of the hot leg tubesheet. Degradation found in the portion of the tube below 17 inches from the top of the of the hot leg tubesheet does not require plugging or repair.
>
> For Unit 2 during Refueling Outage 11 and the subsequent operating cycle, degradation identified in the portion of the tube from the top of the hot leg tubesheet to 17 inches below the top of the tubesheet shall be plugged or repaired upon detection.

1.3 TS 5.5.9.e.8, Tube Inspection

A new paragraph has been added to state:

> For Unit 2 during Refueling Outage 11 and the subsequent operating cycle, the portion of the tube below 17 inches from the top of the hot leg tubesheet is excluded.

1.4 TS 5.5.9.e, Acceptance Criteria

TS 5.5.9.e.12 has been added to define "bulge" and "overexpansion."

> For Unit 2 during Refueling Outage 11 and the subsequent operating cycle:
>
> Bulge refers to a tube diameter deviation within the tubesheet of 18 volts or greater as measured by bobbin coil probe: and
>
> Overexpansion refers to a tube diameter deviation within the tubesheet or 1.5 mils or greater as measured by bobbin coil probe.

2.0 BACKGROUND

Braidwood Station, Unit 2 has four model D5 steam generators designed and fabricated by Westinghouse. The thermally treated Alloy 600 steam generator tubes have an outside diameter of 0.75-inch and a nominal wall thickness of 0.043-inch. The tubes are hydraulically expanded for the full depth of the tubesheet at each end and are welded to the tubesheet at the bottom of each expansion. Braidwood Station, Unit 2 operates with a hot-leg temperature of 611-degrees Fahrenheit (611 EF) and will have operated for approximately 14.2 effective full power years (EFPY) at the start of RFO 11.

The licensee has been using bobbin probes for inspecting the length of tubing within the tubesheet. However, the bobbin probe is not capable of reliably detecting stress corrosion cracks (SCC) in the tubesheet region should such cracks be present. For this reason, the licensee has been supplementing the bobbin probe inspections with rotating coil probes in a

region extending from 3-inches above the top of the tubesheet (TTS) to 3-inches below the TTS. This zone includes the tube expansion transition zone located at the TTS. The expansion transition contains significant residual stress and was considered a likely location for SCC should it ever develop. Until the Fall of 2004, there had not been any reported instances of SCC affecting the tubesheet region of thermally treated Alloy 600 tubing, either at Braidwood Station, Unit 2 or elsewhere in the U.S.

In the Fall of 2004, crack-like indications were found in tubes in the tubesheet region of Catawba Unit 2, which is of similar design to Braidwood Station, Unit 2 (i.e., model D5 SGs with thermally treated Alloy 600 tubing) and which has accumulated a comparable operating time 14.7 EFPY at a comparable operating temperature. These crack-like indications were found in bulges (or over-expansions) in the tubesheet region, in the tack roll region, and in the tube-to-tubesheet weld. (The tack expansion is an initial 0.7-inch long expansion at each tube end and formed prior to the hydraulic expansion over the full tubesheet depth. Its purpose was to facilitate performing the tube to tubesheet weld.) Crack-like indications were found in a bulge in one tube and in the tack expansion in nine tubes. Approximately 6 of the 196 tube-to-tubesheet weld indications extended into the parent tube.

As a result of the Catawba findings, the licensee plans expand to the scope of previous rotating coil inspections to address the potential for cracks within the thickness of the tubesheet down to 17-inches below the TTS. However, the licensee believes that any flaws located below 17-inches below the TTS (i.e., in the bottom four inches of the tubesheet region, including the tack expansion region and the tubing in the vicinity of the welds) have no potential to impair tube integrity and, thus, do not pose a safety concern. To avoid the unnecessary plugging or repair of tubes as would be required by the TS should inspection reveal cracks in this region, the licensee is proposing on a one time basis to revise the TS such that tubes found to contain flaws found in the lower 4-inches of the tubesheet region need not be plugged or repaired and that the lower 4-inch region be excluded from current inspection requirements. In addition, the licensee proposed new requirements defining the minimum inspection scope with rotating coils for the upper 17-inch of the tubesheet region and requiring that tubes with indications in this region be plugged or repaired on detection.

3.0 REGULATORY EVALUATION

SG tubes function as an integral part of the reactor coolant pressure boundary (RCPB) and, in addition, serve to isolate radiological fission products in the primary coolant from the secondary coolant and the environment. For the purposes of this safety evaluation, tube integrity means that the tubes are capable of performing these functions in accordance with the plant design and licensing basis.

Title 10 of the *Code of Federal Regulations* (10 CFR) establishes the fundamental regulatory requirements with respect to the integrity of the SG tubing. Specifically, the General Design Criteria (GDC) in Appendix A to 10 CFR Part 50 state that the RCPB shall have “an extremely low probability of abnormal leakage ... and gross rupture" (GDC 14), "shall be designed with sufficient margin" (GDC 15 and 31), shall be of "the highest quality standards possible" (GDC 30), and shall be designed to permit "periodic inspection and testing ... to assess ... structural and leak tight integrity" (GDC 32). To this end, 10 CFR 50.55a specifies that components which are part of the RCPB must meet the requirements for Class 1 components in Section III of the American Society of Mechanical Engineers (ASME) *Boiler and Pressure*

Vessel Code (Code). Section 50.55a further requires, in part, that throughout the service life of a pressurized-water reactor(PWR) facility, ASME Code Class 1 components meet the requirements, except design and access provisions and pre-service examination requirements, in Section XI, "Rules for Inservice Inspection [ISI] of Nuclear Power Plant Components," of the ASME Code, to the extent practical. This requirement includes the inspection and repair criteria of Section XI of the ASME Code. Section XI requirements pertaining to ISI of SG tubing are augmented by additional SG tube surveillance requirements in the TS.

As part of the plant licensing basis, applicants for PWR licenses are required to analyze the consequences of postulated design-basis accidents (DBAs) such as an SG tube rupture (SGTR) and main steamline break (MSLB). These analyses consider the primary-to-secondary leakage through the tubing which may occur during these events and must show that the offsite radiological consequences do not exceed the applicable limits of the 10 CFR 100 guidelines for offsite doses, GDC-19 criteria for control room operator doses, or some fraction thereof as appropriate to the accident, or the NRC-approved licensing basis (e.g., a small fraction of these limits).

Under the plant TS SG surveillance program requirements, the licensee is required to monitor the condition of the SG tubing and to plug or repair tubes as necessary. Specifically, the licensee is required to perform periodic inspections of and to repair or remove from service by plugging all tubes found to contain flaws with sizes exceeding the acceptance limit, termed "plugging limit." The tube plugging limits were developed with the intent of ensuring that degraded tubes (1) maintain factors of safety against gross rupture consistent with the plant design basis (i.e., consistent with the stress limits of the ASME Code, Section III) and (2) maintain leakage integrity consistent with the plant licensing basis while, at the same time, allowing for potential flaw size measurement error and flaw growth between SG inspections. The required frequency and scope of tubing examinations and the tube plugging limits are specified in TS 5.5.9, "Steam Generator (SG) Tube Surveillance Requirements."

The subject TS amendment request concerns the portions of the tubing that are subject to the TS SG tube surveillance requirements, including any necessary plugging or repairs, and the inspection methods to be employed. TS 5.5.9 defines a tube inspection as 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. This includes the full length of tubing within the thickness of the tubesheet on the hot leg side.

The proposed license amendment would limit the required inspections, plugging and repairs in the 21-inch thick tubesheet region to the upper 17-inches of the tubesheet region and is conceptually similar to permanent amendments approved by the NRC staff for a number of plants. Examples include the F* criteria approved for Westinghouse SGs where the tubes were hard roll expanded inside the tubesheet and the W* criteria approved for plants where the tubes were explosively expanded against the tubesheet. In the case of the F* criteria, the required inspection zone was limited to approximately the upper 1.5-inch zone below the TTS. The W* criteria required an inspection zone extending 4 to 6-inches below the TTS. The larger required inspection zone for W* relative to F* is that the explosively expanded joints do not exhibit as much residual interference fit as do hard rolled joints. The proposed license amendment for Braidwood would be the first to exclude a portion of tubing in the tubesheet from TS SG inspection and plugging and repair requirements for plants where the tubes are hydraulically

expanded against the tubesheet. (A previously submitted license amendment request dated October 3, 2002 for Callaway, which has hydraulically expanded tubing, was withdrawn by the licensee.)

4.0 TECHNICAL EVALUATION

The tube-to-tubesheet joint consists of the tube, which is hydraulically expanded against the bore of the tubesheet, the tube-to-tubesheet weld located at the tube end, and the tubesheet. The joint was designed as a welded joint in accordance with the ASME Code, Section III, not as a friction or expansion joint. The weld itself was designed as a pressure boundary element in accordance the ASME Code, Section III. 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 hydraulically expanded tube and the tubesheet. In addition, the weld serves to make the joint leaktight.

The licensee, in effect, is proposing on a one time basis to exempt the lower 4-inches of the 21-inch deep tubesheet region from a tube inspection (see proposed change to TS 5.5.9.e.8, "Tube Inspection") and to exempt tubes with flaw indications in the lower 4-inch zone from the need to plug or repair (see the first of two proposed new paragraphs for TS 5.5.9.e.6, "Plugging or Repair Limit"). The latter part of this proposal (i.e., to exempt tubes from plugging or repair) is needed as a practical matter since although rotating coil probe inspections will not be performed in this region, the bobbin probe will necessarily be recording any signals produced in this zone. This proposal, in effect, redefines the pressure boundary at the tube-to-tubesheet joint as consisting of a friction or expansion joint with the tube assumed to be hydraulically expanded against tubesheet over the top 17-inches of the tubesheet region. Under this proposal, no credit is taken for the lower 4-inches of the tube or the tube-to-tubesheet weld in contributing to the structural or leakage integrity of the joint. The lower 4-inches of the tube and weld are assumed not to exist.

The regulatory standard by which the NRC staff has evaluated the subject license amendment is that the amended technical specifications should continue to ensure that tube integrity will be maintained. This includes maintaining structural safety margins consistent with the plant design basis as embodied in the stress limit criteria of the ASME Code, Section III as is discussed in Section 4.1 below. In addition, this includes limiting the potential for accident induced primary to secondary leakage to values not exceeding those assumed in the licensing basis accident analyses. Maintaining tube integrity in this manner ensures that the amended TS are in compliance with all applicable regulations. The NRC staff's evaluation of joint structural integrity and leakage integrity is discussed in Sections 4.1 and 4.2 of this safety evaluation, respectively.

The licensee has also proposed on a one time basis to add a specific requirement to perform a rotating coil examination of a 20 percent sample of tubes in the upper 17-inch span of the tubesheet region, including a 20 percent sample of the bulges and over-expansions within this 17-inch zone (see proposed addition to TS 5.5.9.b, "SG Tube Sample Selection and Inspection".) The NRC staff has no objection to this new requirement since the 20 percent sample size (which is based on industry guidelines) exceeds current TS minimum sample size requirements (i.e., 3 percent) and, thus, is more conservative than the currently applicable requirement. Should these inspections identify flaw indications, additional inspection samples may be required as defined in the current TS (industry guidelines contain more conservative sample expansion criteria).

To clarify the above proposed requirement, the licensee has proposed adding definitions of "bulge" and "over-expansion" as discussed in Section 3 of this safety evaluation. The licensee states that the definition of "bulge" (i.e., tube diameter variation producing an 18 volt bobbin response) is approximately equivalent to the voltage response of a 1-mil over-expansion and is just above the lowest voltage that can be reasonably differentiated from noise. The definition of "over-expansion" (i.e., tube diameter deviation of 1.5 mils or greater) is intended to ensure that tube diameter deviations of this magnitude are inspected, irrespective of voltage amplitude. The NRC staff notes that the main value of these definitions is that they clarify exactly how the proposed rotating coil sampling plan for bulges and over-expansions is to be implemented. Thus, the NRC staff finds the proposed definitions to be acceptable.

The licensee is also proposing on a one time basis to plug or repair on detection any flaw indication found in the upper 17-inch region of the tubesheet region of the tubes, irrespective of whether the flaw exceeds the TS 40 percent plugging limit (see proposed second new paragraph for TS 5.5.9.e.6, "Plugging or Repair Limit".) The NRC staff finds this acceptable since it is more conservative than current TS 40 percent plugging limit and will provide added assurance that the length of tubing along the entire proposed 17-inch inspection zone will be effective in resisting tube pull out under tube end cap pressure loads and in resisting primary to secondary leakage between the tube and tubesheet.

The current TS permit sleeving repairs in lieu of removing tubes from service by plugging. However, the integrity of the sleeve joints depends on the subject tube being found to be free of detectable flaws at the location of the sleeve joints. Because the existence of flaws in the lower 4-inches of the tubesheet region cannot be precluded, the licensee made a regulatory commitment in its April 11, 2005 letter as follows: "During Refueling Outage 11 and the subsequent operating cycle, no SG tube sleeves that have a connecting joint below 17-inches below from the top of the hot leg tubesheet will be installed."

4.1 Joint Structural Integrity

Westinghouse has conducted analysis and testing to establish the engagement (embedment) length of hydraulically expanded tubing inside the tubesheet that is necessary to resist pullout under normal operating and design basis accident conditions. Pullout is the structural failure mode of interest since the tubes are radially constrained against axial fishmouth rupture by the presence of the tubesheet. The axial force that could produce pullout derives from the pressure end cap loads due to the primary to secondary pressure differentials associated with normal operating and design basis accident conditions. The licensee's contractor, Westinghouse, determined the required engagement distance on the basis of maintaining a factor of three against pullout under normal operating conditions and a factor of 1.4 against pullout under accident conditions. Pullout was conservatively treated as tube slippage relative to the tubesheet of 0.25-inches. The NRC staff concurs that these are the appropriate safety factors to apply to demonstrate structural integrity. As documented in detail in a safety evaluation accompanying the NRC staff's approval of new performance based SG TS for Farley Units 1 and 2 (Reference: Letter, Sean Peters, NRC, to L. M. Stinson, Vice President, Southern Nuclear Operating Company, "Joseph M. Farley Nuclear Plant, Units 1 and 2, re: Issuance of Amendments to Facilitate Implementation of Industry Initiative NEI 97-06, Steam Generator Program Guidelines," dated September 10, 2004, ADAMS Accession No. (ML042570427)), the

NRC staff has concluded that these safety factor criteria are consistent with the design basis; namely the stress limit criteria in the ASME Code, Section III.

The resistance to pullout is the axial friction force developed between the expanded tube and the tubesheet over the engagement distance. The friction force is a function of the radial contact pressure between the expanded tube and the tubesheet. The radial contact pressure derives from several contributors including: (1) the contact pressure associated directly with the hydraulic expansion process itself, (2) additional contact pressure due to differential radial thermal expansion between the tube and tubesheet under hot operating conditions, (3) additional contact pressure caused by the primary pressure inside the tube, and (4) additional or reduced contact pressure associated with tubesheet bore dilation (distortion) caused by tubesheet bow (deflection) as a result of the primary to secondary pressure load acting on the tubesheet. Westinghouse employed a combination of pullout tests and analyses, including finite element analyses, to evaluate these contributors. Based on these analyses and tests, Westinghouse concluded that the required engagement distances to ensure the safety factor criteria against pullout are achieved vary from 3 to 8.6 inches depending on the radial location of the tube within the tube bundle, with the largest engagement distances needed toward the center of the bundle.

The NRC staff has not reviewed the Westinghouse analyses in detail and, thus, has not reached a conclusion with respect to whether 3 to 8.6 inches of engagement (termed H* criterion by Westinghouse) is adequate to ensure that the necessary safety margins against pullout are maintained. The licensee, therefore, is proposing on a one time basis to inspect the tubes in the tubesheet region such as to ensure a minimum of 17 inches of effective engagement, well in excess of the 3 to 8.6 inches that the Westinghouse analyses indicate are needed. Based on the following considerations, the NRC staff concludes the proposed 17-inch engagement length is clearly acceptable to ensure the structural integrity of the tubesheet joint.

- Pullout tests demonstrate that the radial contact pressure produced by the hydraulic expansion alone is such as to require an engagement distance of 6-inches to ensure the appropriate safety margins against pullout. This estimate is a mean minus one standard deviation estimate based on nine pullout tests. This estimate ignores the effect on needed engagement distance from differential thermal expansion, internal primary pressure in the tube, and tubesheet bore dilations associated with tubesheet bow.

- Radial differential thermal expansion between the tube and tubesheet under hot operating and accident conditions will act to further tighten the joint (i.e., increase radial contact pressure) and to reduce the necessary engagement distance relative to room temperature conditions. The radial differential thermal expansion arises from the fact that the Alloy 600 tubing has a slightly higher (by 6 percent) coefficient of thermal expansion than does the SA-508 Class 2a tubesheet material and that the tubes are a little hotter than the tubesheet.

- The internal primary pressure inside the tube under normal operating and accident conditions also acts to tighten the joint relative to unpressurized conditions, thus reducing the necessary engagement distance,

- Tubesheet bore dilations caused by tubesheet bow under primary to secondary pressure can increase or decrease contact pressure depending on the tube location

within the bundle and on location along the length of the tube in the tubesheet region. Basically, the tubesheet acts as a flat, circular plate under an upward acting net pressure load. The tubesheet is supported axially around its periphery with a partial restraint against tubesheet rotation provided by the SG shell and channel head. The SG divider plate provides a spring support against upward displacement along a diametral mid-line. Over most of the tubesheet away from the periphery, the bending moment resulting from the applied primary to secondary pressure load can be expected to put the tubesheet into tension at the top and compression at the bottom. Thus, the resulting distortion of the tubesheet bore (tubesheet bore dilation) tends to be such as to loosen the tube to tubesheet joint at the top of the tubesheet and to tighten the joint at the bottom of the tubesheet. The amount of dilation and resulting change in joint contact pressure would be expected to vary in a linear fashion from top to bottom of the tubesheet. Given the neutral axis to be at approximately the axial mid-point of the tubesheet thickness (i.e., 10.5-inches below the to of the tubesheet), tubesheet bore dilation effects would be expected to further tighten the joint from 10-inches below the TTS to 17 inches below the TTS which would be the lower limit of the proposed tubesheet region inspection zone. Combined with the effects of the joint tightening associated with the radial differential thermal expansion and primary pressure inside the tube, contact pressure over at least a 6.5-inch distance should be considerably higher than the contact pressure simulated in the above mentioned pull out tests. A similar logic applied to the periphery of the tubesheet leads the staff to conclude that at the top 10.5 inches of the tubesheet region, contact pressure should be considerably higher than the contact pressure simulated in the above mentioned pull out tests. Thus, the staff concludes that the proposed 17-inch engagement distance (or inspection zone) is acceptable to ensure the structural integrity of the tubesheet joint.

4.2 Joint Leakage Integrity

If no credit is to be taken for the presence of the tube-to-tubesheet weld, a potential leak path between the primary to secondary is introduced between the hydraulically expanded tubing and the tubesheet. In addition, not inspecting the tubing in the lower 4 inches of the tubesheet region may lead to an increased potential for 100 percent throughwall flaws in this zone and the potential for leakage of primary coolant through the crack and up between the hydraulically expanded tubes and tubesheet to the secondary system. Operational leakage integrity is assured by monitoring primary to secondary leakage relative to the applicable TS limiting condition for operation (LCO) limits. However, it must also be demonstrated that the proposed TS changes do not create the potential for leakage during design basis accidents that may exceed values assumed in the licensing basis accident analyses. The licensee states that this is ensured by limiting primary to secondary leakage to 0.5 gallons per minute (gpm) in the faulted SG during a MSLB.

To support its H* criterion (discussed above), Westinghouse has developed a detailed leakage prediction model, which considers the resistance to leakage from cracks located within the thickness of the tubesheet. The NRC staff has not reviewed or accepted this model. For the proposed one time 17-inch inspection zone, Westinghouse cited a number of qualitative arguments supporting a conclusion that a minimum 17-inch engagement length ensures that leakage during MSLB will not exceed two times the observed leakage during normal operation. Westinghouse refers to this as the “bellwether approach.” Thus, for an SG leaking at the TS LCO limit (i.e., 150 gallons per day (gpd)) under normal operating conditions, Westinghouse

estimates that leakage would not be expected to exceed 0.21 gpm (300 gpd), significantly less than the 0.5 gpm assumed in the licensing basis accident analyses for MSLB.

The factor of 2 upper bound is based on the Darcy equation for flow through a porous media where leakage rate would be proportional to differential pressure. Westinghouse considered normal operating pressure differentials between 1200 and 1400 psi and accident differential pressures on the order of 2560 to 2650 psi, essentially a factor of 2 difference. The factor of 2 as an upper bound is based on a premise that the flow resistance between the tube and tubesheet remains unchanged. Westinghouse states that the flow resistance varies as a log normal linear function of joint contact pressure. The NRC staff concurs that the factor of 2 upper bound is reasonable, given the stated premise. The NRC staff notes that the assumed linear relationship between leak rate and differential pressure is conservative relative to alternative models such as Bernoulli or orifice models, which assume leak rate to be proportional to the square root of differential pressure.

The NRC staff reviewed the qualitative arguments developed by Westinghouse regarding the conservatism of the aforementioned premise, namely the conservatism of assuming that flow resistance between the expanded tubing and the tubesheet does not decrease under the most limiting accident relative to normal operating conditions. Most of the Westinghouse observations are based on insights derived from the finite element analyses performed to assess joint contact pressures and from test data relating leak flow resistance to joint contact pressure, neither of which has been reviewed by the NRC staff in detail. Among the Westinghouse observations is that for all tubes there is at least an eight inch zone in the upper 17 inches of the tubesheet where there is an increase in joint contact pressure due to higher primary pressure inside the tube and changes in tubesheet bore dilation along the length of the tubes. In Section 4.1 above, the NRC staff observed that there is at least a 6.5-inch zone over which changes in tubesheet bore dilations when going from unpressurized to pressured conditions should result in an increase in joint contact pressure. The contact pressure due to changes in tubesheet bore dilation should increase further over this 6.5-inch zone under the increased pressure loading on the tubesheet during accident conditions. Considering the higher pressure loading in the tube when going from normal operating to accident conditions, the Westinghouse estimate that contact pressures, and, thus, leak flow resistance, always increases over at least an 8-inch distance appears reasonable to the NRC staff.

Although joint contact pressures and leak flow resistance decrease over other portions of the tube length, Westinghouse expects a net increase in total leak flow resistance on the basis of its insights from leakage test data that leak flow resistance is more sensitive to changes in joint contact pressure as contact pressure increases due to the linear log normal nature of the relationship. The NRC staff's depth of review did not permit it to credit this aspect of the Westinghouse assessment. However, it is clear from the above discussion that there should be no significant reduction in leakage flow resistance when going from normal operating to accident conditions.

Finally, the NRC staff has considered that undetected cracks in the lower 4 inches are unlikely to produce leakage rates during normal operation that would approach the TS LCO operational leakage limits during normal operation, thus providing additional confidence that such cracks will not result in leakage in excess of the values assumed in the accident analyses. Any axial cracks will be tightly clamped by the tubesheet against opening of the crack faces. In addition, little of the end cap pressure load should remain in the tube below 17 inches and, thus, any

circumferential cracks would be expected to remain tight. Thus, irrespective of the flow resistance in the upper 17 inches of the tubesheet between the tube and tubesheet, the tightness of the cracks themselves should limit leakage to very small values. Based on the above, the NRC staff concludes that there is reasonable assurance that the proposed one time exclusion of the lower 4 inches of the tubes in the tubesheet region from the tube inspection and plugging and repair requirements will not impair the leakage integrity of the tube-to-tubesheet joint.

4.3 Summary

The NRC staff finds that the proposed one time license amendment ensures that the structural and leakage integrity of the tube-to-tubesheet joint will be maintained with structural safety margins consistent with the design basis, with leakage integrity within assumptions employed in the licensing basis accident analyses and, thus, in accordance with the applicable regulations without undue risk to public health and safety.

4.4 Regulatory Commitments

As noted in Section 4.0, the current TSs permit sleeving repairs in lieu of removing tubes from service by plugging. However, the integrity of the sleeve joints depends on the subject tube being found to be free of detectable flaws at the location of the sleeve joints. Because the existence of flaws in the lower 4 inches of the tubesheet region cannot be precluded, the licensee made a regulatory commitment in its April 11, 2005 letter as follows: "During Refueling Outage 11 and the subsequent operating cycle, no SG tube sleeves that have a connecting joint below 17 inches below from the top of the hot leg tubesheet will be installed." The staff finds that reasonable controls for the implementation and for subsequent evaluation of proposed changes pertaining to the above regulatory commitment are best provided by the licensee's administrative processes, including the commitment management program (see Regulatory Issues Summary 2000-017, "Managing Regulatory Commitments Made by Power Reactor Licensees to the NRC Staff".) The above regulatory commitment does not warrant the creation of regulatory requirements (items requiring prior NRC approval of subsequent changes.)

5.0 EXIGENT CIRCUMSTANCES

The Commission’s regulations, 10 CFR 50.91, contain provisions for issuance of amendments when the usual 30-day public comment period cannot be met. One type of special exception is an exigency. An exigency is a case where the NRC staff and licensee need to act promptly. In this case, there is insufficient time to process the license amendment request within the normal time frame. Pursuant to 10 CFR 50.91(a)(6), the licensee requested the proposed amendment on an exigent basis.

Under such circumstances, the Commission notifies the public in one of two ways: (1) by issuing a *Federal Register* notice providing an opportunity for hearing and allowing at least two weeks for prior public comments, or (2) by issuing a press release discussing the proposed changes, using local media. In this case, the Commission used the second approach and published a public notice in two local newspapers Joliet Herald News (April 15 and 18, 2005) and the Morris Daily Herald (April 19, 2005).

In its submittal, the licensee discussed the need for an exigent review of proposed license amendment. After the industry was informed of the SG tube degradation at Catawba, Unit 2, the licensee included the information into the planning for the Braidwood 2 spring 2005 refueling outage. As noted earlier, Braidwood 2 has the same model SGs as Catawba 2 with comparable operating time. Potential degradation areas were determined to be the top of the tubesheet expansion transition region, tube bulges or overexpansions, tack expansion region and degradation propagating from the tube end weld into the tube. In preparation for inspection of these regions, the licensee initiated development of a method for dispositioning potential indications within the tube end weld. By mid-March 2005, the licensee concluded that degradation contained within the tube end weld could not be properly addressed by ASME Code analysis methods. The licensee also determined that the bottom portion of the tube is not a critical portion of the tube necessary to maintain structural and leakage integrity.

The licensee requested a telephone conference call with the NRC staff to discuss its proposed SG inspection scope for the Braidwood 2 spring outage. During the conference call on April 5, 2005, it was concluded that application of limited tubesheet inspection areas where degradation potential could occur required a change to TS 5.5.9. Additional regulatory guidance was issued in NRC Information Notice (IN) 2005-09, "Thermally Treated Alloy 600 Steam Generator Tubes and Tube-to-Tubesheet Welds," issued on April 7, 2005.

On the basis of the little time available between the conference call with the licensee, the additional guidance contained in IN 2005-09, and the completion of the Braidwood 2 spring outage, there was insufficient time available in which to process a normal license amendment request. Therefore, the NRC staff has determined that a valid need exists for issuance of the license amendment in accordance with the exigent provisions of 10 CFR 50.91(a)(6).

6.0 FINAL NO SIGNIFICANT HAZARDS CONSIDERATION DETERMINATION

The Commission's regulations in 10 CFR 50.92 state that the Commission may make a final determination that a license amendment involves no significant hazards considerations if operation of the facility in accordance with the amendment would not: (1) involve a significant increase in the probability or consequences of an accident previously evaluated; or (2) create the possibility of a new or different kind of accident from any accident previously evaluated; or (3) involve a significant reduction in the margin of safety. Based on its analysis, the NRC staff has concluded that:

> 1. The amendments will not involve a significant increase in the probability or consequences of an accident previously evaluated.
> The previously analyzed accidents are initiated by the failure of plant structures, systems, or components. The proposed changes that alter the SG inspection criteria do not have a detrimental impact on the integrity of any plant structure, system, or component that initiates an analyzed event. The proposed changes will not alter the operation, or otherwise increase the failure probability of any plant equipment that initiates an analyzed accident. Therefore, the proposed change does not involve a significant increase in the probability of an accident previously evaluated.

Of the applicable accidents previously evaluated, the limiting transients with consideration to the proposed changes to the SG tube inspection criteria are the SG tube rupture (SGTR) event and the steam line break (SLB) accident.

During the SGTR event, the required structural integrity margins of the SG tubes will be maintained by the presence of the SG tubesheet. SG tubes are hydraulically expanded in the tubesheet area. Tube rupture in tubes with cracks in the tubesheet is precluded by the constraint provided by the tubesheet. This constraint results from the hydraulic expansion process, thermal expansion mismatch between the tube and tubesheet and from the differential pressure between the primary and secondary side. Based on this design, the structural margins against burst, discussed in Regulatory Guide (RG) 1.121, "Bases for Plugging Degraded PWR SG Tubes," are maintained for both normal and postulated accident conditions.

The proposed changes do not affect other systems, structures, components or operational features. Therefore, the proposed changes result in no significant increase in the probability of the occurrence of an SGTR accident.

The consequences of an SGTR event are affected by the primary-to-secondary leakage flow during the event. Primary-to-secondary leakage flow through a postulated broken tube is not affected by the proposed change since the tubesheet enhances the tube integrity in the region of the hydraulic expansion by precluding tube deformation beyond its initial hydraulically expanded outside diameter.

The probability of an SLB is unaffected by the potential failure of an SG tube as this failure is not an initiator for an SLB.

The consequences of an SLB are also not significantly affected by the proposed changes. During an SLB accident, the reduction in pressure above the tubesheet on the shell side of the SG creates an axially uniformly distributed load on the tubesheet due to the reactor coolant system pressure on the underside of the tubesheet. The resulting bending action constrains the tubes in the tubesheet thereby restricting primary-to-secondary leakage below the midplane.

Primary-to-secondary leakage from tube degradation in the tubesheet area during the limiting accident (i.e., a steam line break (SLB)) is limited by flow restrictions resulting from the crack and tube-to-tubesheet contact pressures that provide a restricted leakage path above the indications and also limit the degree of potential crack face opening as compared to free span indications. The primary-to-secondary leak rate during postulated SLB accident conditions would be expected to be less than that during normal operation for indications near the bottom of the tubesheet (i.e., including indications in the tube end welds). This conclusion is based on the observation that while the driving pressure causing leakage increases by approximately a factor of two, the flow resistance associated with an increase in the tube-to-tubesheet contact pressure, during an SLB, increases by approximately a factor of 2.5. While such a leakage decrease is logically expected, the postulated accident leak rate could be conservatively

bounded by twice the normal operating leak rate if the increase in contact pressure is ignored. Since normal operating leakage is limited to less than 0.104 gpm (150 gpd) per TS 3.4.13, "RCS Operational Leakage," the associated accident condition leak rate, assuming all leakage to be from lower tubesheet indications, would be bounded by approximately 0.2 gpm. This value is well within the assumed accident leakage rate of 0.5 gpm discussed in Updated Final Safety Analysis Table 15.1-3, "Parameters Used in Steam Line Break Analyses." Hence it is reasonable to omit any consideration of inspection of the tube, tube end weld, bulges/overexpansions or other anomalies below 17 inches from the top of the hot leg tubesheet. Therefore, the consequences of an SLB accident remain unaffected.

2. The proposed amendments will not create the possibility of a new or different kind of accident from any previously analyzed.

The proposed changes do not involve the use or installation of new equipment and the currently installed equipment will not be operated in a new or different manner. No new or different system interactions are created and no new processes are introduced. The proposed changes will not introduce any new failure mechanisms, malfunctions, or accident initiators not already considered in the design and licensing bases.

3. The proposed amendment will not involve a significant reduction in a margin of safety.

The proposed changes maintain the required structural margins of the SG tubes for both normal and accident conditions. Nuclear Energy Institute (NEI) 97-06, "Steam Generator Program Guidelines," Revision 1 and Regulatory Guide (RG) 1.121, "Bases for Plugging Degraded PWR Steam Generator Tubes," are used as the bases in the development of the limited hot leg tubesheet inspection depth methodology for determining that SG tube integrity considerations are maintained within acceptable limits. RG 1.121 describes a method acceptable to the NRC for meeting General Design Criteria (GDC) 14, "Reactor coolant pressure boundary," GDC 15, "Reactor coolant system design," GDC 31, "Fracture prevention of reactor coolant pressure boundary," and GDC 32, "Inspection of reactor coolant pressure boundary," by reducing the probability and consequences of an SGTR. RG 1.121 concludes that by determining the limiting safe conditions for tube wall degradation the probability and consequences of an SGTR are reduced. This RG uses safety factors on loads for tube burst that are consistent with the requirements of Section III of the American Society of Mechanical Engineers (ASME) Code.

For axially oriented cracking located within the tubesheet, tube burst is precluded due to the presence of the tubesheet. For circumferentially oriented cracking, Westinghouse letter LTR-CDME-05-32-P, "Limited Inspection of the Steam Generator Tube Portion Within the Tubesheet at Braidwood Unit 2 and Byron Unit 2," dated April 2005, defines a length of degradation free expanded tubing that provides the necessary resistance to tube pullout due to the pressure induced forces, with applicable safety factors applied. Application of the limited

hot leg tubesheet inspection depth criteria will preclude unacceptable primary-to-secondary leakage during all plant conditions. The methodology for determining leakage provides for large margins between calculated and actual leakage values in the proposed limited hot leg tubesheet inspection depth criteria.

7.0 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.

8.0 ENVIRONMENTAL CONSIDERATION

The amendments change a requirement with respect to installation or use of a facility component located within the restricted area as defined in 10 CFR Part 20. 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 made a final finding that the amendments involve no significant hazards consideration. 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.

9.0 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.

Principal Contributor: E. Murphy

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