September 11, 2006

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

SUBJECT: BYRON STATION, UNIT NO. 1, AND BRAIDWOOD STATION, UNIT NO. 2 - RELAXATION OF THE FIRST REVISED ORDER EA-03-009 (TAC NOS. MD1159 AND MD1160)

Dear Mr. Crane:

By letter to the Nuclear Regulator Commission (NRC) dated March 31, 2006, Exelon Generation Company, LLC (Exelon) requested relaxation from certain inspection requirements of First Revised Order EA-03-009 (Order), dated February 20, 2004. Exelon requested relaxation from the Order for the inspection of certain reactor pressure vessel (RPV) penetration nozzles that are limited by inaccessible areas for Byron Station, Unit No. 1 (Byron) and Braidwood Station, Unit No. 2 (Braidwood).

The NRC staff has reviewed the information provided by Exelon in support of this request and concludes that Exelon's proposed alternative examination of the RPV penetration nozzles provides reasonable assurance of the structural integrity of the RPV. Further inspection of the RPV in accordance with Section IV.C. of the Order would result in hardship without a compensating increase in the level of quality and safety. Therefore, Exelon has demonstrated good cause for relaxation, and pursuant to Section IV.F. of the Order, the NRC staff authorizes the proposed alternative inspection for the RPV at Byron and Braidwood for the time period for which the Order is in effect.

The NRC staff's review is provided in the enclosed Safety Evaluation. If you have any questions, please contact Robert F. Kuntz at (301) 415-3733.

Sincerely,

/RA/

Timothy J. McGinty, Deputy Director
Division of Operating Reactor Licensing
Office of Nuclear Reactor Regulation

Docket Nos. STN 50-454 and STN 50-457

Enclosure:
Safety Evaluation

cc w/encl: See next page

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Byron/Braidwood Stations

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SAFETY EVALUATION BY THE OFFICE OF NUCLEAR REACTOR REGULATION

FIRST REVISED NRC ORDER (EA-03-009) RELAXATION REQUEST

ALTERNATE EXAMINATION COVERAGE

FOR REACTOR PRESSURE VESSEL HEAD

BYRON STATION, UNIT NO. 1 AND BRAIDWOOD STATION, UNIT NO. 2

EXELON GENERATION COMPANY, LLC

DOCKET NOS. STN 50-454 AND STN 50-457

1.0 INTRODUCTION

The First Revised Order EA-03-009 (Order), issued by the Nuclear Regulatory Commission on February 20, 2004, requires specific examinations of the reactor pressure vessel (RPV) head and vessel head penetration (VHP) nozzles of all pressurized-water reactor plants. Section IV.F of the Order states that requests for relaxation associated with specific penetration nozzles will be evaluated by the NRC staff using the procedure for evaluating proposed alternatives to the *American Society of Mechanical Engineers (*ASME*) Boiler and Pressure Vessel Code* (Code) in accordance with Title 10 of the *Code of Federal Regulations* (10 CFR) Section 50.55a(a)(3). Section IV.F of the Order states that a request for relaxation regarding inspection of specific nozzles shall address the following criteria: (1) the proposed alternative(s) for inspection of specific nozzles will provide an acceptable level of quality and safety, or (2) compliance with this Order for specific nozzles would result in hardship or unusual difficulty without a compensating increase in the level of quality and safety.

For Byron Station, Unit No. 1 (Byron), and Braidwood Station, Unit No. 2 (Braidwood), and similar plants determined to have a low susceptibility to primary water stress-corrosion cracking (PWSCC) in accordance with Sections IV.A, IV.B, and IV.C.(3) of the Order, the following inspection is required to be performed by February 11, 2008, in accordance with Section IV.C.(5)(b) of the Order:

> (b) For each penetration, perform a nonvisual nondestructive examination (NDE) in accordance with either (i), (ii), or (iii):
>
> (i) Ultrasonic testing (UT) of the RPV head penetration nozzle volume (i.e., nozzle base material) from 2 inches above the highest point of the root of the J-groove weld (on a horizontal plane perpendicular to the nozzle axis) to 2 inches below the lowest point at the toe of the J-groove weld on a

horizontal plane perpendicular to the nozzle axis (or the bottom of the nozzle if less than 2 inches [see Figure IV-1]); OR from 2 inches above the highest point of the root of the J-groove weld (on a horizontal plane perpendicular to the nozzle axis) to 1 inch below the lowest point at the toe of the J-groove weld (on a horizontal plane perpendicular to the nozzle axis) and including all RPV head penetration nozzle surfaces below the J-groove weld that have an operating stress level (including all residual and normal operation stresses) of 20 ksi tension and greater (see Figure IV-2). In addition, an assessment shall be made to determine if leakage has occurred into the annulus between the RPV head penetration nozzle and the RPV head low-alloy steel.

(ii) Eddy current testing or dye penetrant testing of the entire wetted surface of the J-groove weld and the wetted surface of the RPV head penetration nozzle base material from at least 2 inches above the highest point of the root of the J-groove weld (on a horizontal plane perpendicular to the nozzle axis) to 2 inches below the lowest point at the toe of the J-groove weld on a horizontal plane perpendicular to the nozzle axis (or the bottom of the nozzle if less than 2 inches [see Figure IV-3]); OR from 2 inches above the highest point of the root of the J-groove weld (on a horizontal plane perpendicular to the nozzle axis) to 1 inch below the lowest point at the toe of the J-groove weld (on a horizontal plane perpendicular to the nozzle axis) and including all RPV head penetration nozzle surfaces below the J-groove weld that have an operating stress level (including all residual and normal operation stresses) of 20 ksi tension and greater (see Figure IV-4).

(iii) A combination of (i) and (ii) to cover equivalent volumes, surfaces, and leak paths of the RPV head penetration nozzle base material and J-groove weld as described in (i) and (ii). Substitution of a portion of a volumetric exam on a nozzle with a surface examination may be performed with the following requirements:

1. On nozzle material below the J-groove weld, both the outside diameter and inside diameter surfaces of the nozzle must be examined.

2. On nozzle material above the J-groove weld, surface examination of the inside diameter surface of the nozzle is permitted provided a surface examination of the J-groove weld is also performed.

By letter dated March 31, 2006, as supplemented by letter dated August 28, 2006, Exelon requested relaxation to implement an alternative to the requirements of Section IV.C.(5)(b) of the Order for RPV head penetration nozzles at Byron and Braidwood.

2.0 First Revised Order EA-03-009 Relaxation Request for Examination Coverage for Reactor Pressure Vessel Head Penetration Nozzles

2.1 First Revised Order Requirement for Which Relaxation is Requested

Section IV.C of the Order, requires, in part, that inspections of Section IV.C.(5)(b) of the Order be performed by February 11, 2008, for low susceptibility plants similar to Byron and Braidwood.

Exelon has requested relaxation from Section IV.C.(5)(b) of the Order. The specific relaxation requested is identified below.

2.2 Licensee's Proposed Alternative

Exelon seeks relaxation from the Order to revise the minimum volumetric inspection coverage requirement below the J-groove weld for 18 penetration nozzles at Byron and Braidwood, to the lowest elevation that can be practically inspected. During the previous refueling outages for Byron and Braidwood, Exelon performed volumetric examinations to the maximum extent practical to meet all requirements of the Order. The inspection distance below the J-groove weld for 18 total penetration tubes (six from Byron and 12 from Braidwood) did not meet the full requirements of the Order. The specific coverage obtained for these penetration nozzles is provided in Table 1 for Byron and Table 2 for Braidwood.

Table 1: Byron Spring 2005 (B1R13) Refueling Outage Volumetric/Surface Inspection Coverage Below the Toe of the J-groove Weld

Nozzle Number	B1R13 Inspection Coverage (Inches Below the J-groove Weld)
62	0.84
66	0.96
68	0.50
69	0.68
74	0.72
75	0.56

Table 2: Braidwood Spring 2005 (A2R11) Refueling Outage Volumetric/Surface Inspection Coverage Below the Toe of the J-groove Weld		
Nozzle Number	A2R11 Inspection Coverage (Inches Below the J-groove Weld)	
	ID	OD
40	No Relaxation Needed	0.96
46	No Relaxation Needed	0.88
66	No Relaxation Needed	0.92
67	No Relaxation Needed	0.68
68	No Relaxation Needed	0.92
70	No Relaxation Needed	0.64
71	No Relaxation Needed	0.56
73	No Relaxation Needed	0.84
74	0.80	0.80
76	0.92	0.92
77	0.96	0.96
78	0.68	0.68

2.3 Licensee's Basis for Proposed Alternative

Exelon's relaxation request is to perform the volumetric examination required by the Order to the lowest elevation that can be practically inspected for 18 penetration nozzles identified in Table 1 and Table 2. Exelon will utilize inspection option (b)(I) from Section IV.C.(5)(b) of the Order and will achieve volumetric and surface coverage 2 inches above the J-groove weld down to the lowest elevation that can be practically inspected on each of these penetration nozzles, with a minimum distance below the J-groove weld for 18 penetration nozzles as stated in Table 1 and Table 2.

Exelon states that the bottom of each RPV upper head penetration nozzle includes a threaded region approximately 1 inch long on the outside diameter along with a chamfered area at the inside diameter which extends approximately 0.76 inches from the bottom of the penetration nozzle. The chamfered surface is machined at a 20 degree angle. In addition to the presence of the threaded and chamfered regions on all penetration nozzles, five penetration nozzles also have a threaded guide cone attached to the bottom of the penetration nozzle via the threaded connection along with a welded set screw and two tack welds. Each of these items invoke

physical restraints to full effective coverage of the Order required volumetric inspection area with ultrasonic examination probes.

Exelon notes that while the Order allows provisions for dye penetrant inspection, it would require extensive work under and around the RPV upper head. Exelon estimates the general area radiation level under the Byron RPV upper head at 5.6 rad per hour (R/hr) and for Braidwood RPV upper head at 4.8 R/hr. In addition, the threaded region of the penetration nozzles would make a dye penetrant inspection impractical. Therefore, Exelon concludes, that additional manual inspection of the uninspected regions of each penetration nozzle for which full Order coverage could not be met would result in significant radiation exposure to personnel without a compensating increase in the level or quality or safety.

Exelon further states that testing of portions of the nozzle significantly below the J-groove weld is not significant to the phenomena of concern. The phenomena that are of concern are leakage through the J-groove weld and circumferential cracking in the nozzle above the J-groove weld. The nozzle is essentially an open-ended tube, and the nozzle wall below the J-groove weld is not part of the reactor coolant system (RCS) pressure boundary. Exelon believes the proposed inspection coverage does not preclude full UT examination coverage of the portions of these nozzles that are of primary interest.

Exelon contracted a structural integrity evaluation for Byron and Braidwood RPV upper head penetration nozzles. A series of crack-growth calculations were performed presuming a flaw where the lower extremity of this initial through-wall flaw is conservatively postulated to be located on the penetration nozzle where either the inside or outside surface hoop stress drops below 0 ksi. The calculation was preformed to demonstrate that more time in effective full power years (EFPY) of operation would elapse before a postulated flaw in the unexamined area of the penetration nozzle would propagate into the pressure boundary formed by the J-groove weld. Both Byron and Braidwood units are in the low susceptibility category, therefore, nonvisual NDE will be performed once every four refueling outages or within 7 calendar years whichever is less. Both Byron and Braidwood units are on 18-month operating cycles, therefore four refueling outages will limit non-visual NDE inspection to every 6 calender years. Further, each refueling outage is conservatively projected by Exelon to accumulate 1.45 EFPY of operational time. A conservatively predicted maximum of 5.8 EFPY would be produced in 6 calendar years of operation at Byron and Braidwood.

The methodology and the technical basis of the crack-growth calculation, which was based on the hoop stress distribution and the PWSCC crack-growth rate recommended in Electric Power Research Institute Topical Report “Materials Reliability Program (MRP) Crack Growth Rates for Evaluating Primary Water Stress Corrosion Cracking (PWSCC) of Thick Wall Alloy 600 Material (MRP-55) Revision 1,” were provided in WCAP-1 6349-P, Revision 0, “Structural Integrity Evaluation of Reactor Vessel Upper Head Penetrations to Support Continued Operation: Byron and Braidwood Units 1 and 2.” The calculation demonstrates that the minium time for a flaw to propagate from the distances below the J-groove weld listed in Table 1 and Table 2 for the limiting RPV upper head penetration nozzles to the bottom of the J-groove weld would be at least 5.9 EFPY. The results of the conservative flaw propagation calculation indicate that, even if a flaw were to occur in the region of the penetration nozzle not being inspected, there would be adequate opportunity for detection prior to the crack reaching the RCS pressure boundary. The results demonstrate that the extent of the proposed inspection coverage would provide

reasonable assurance of the structural integrity of Byron and Braidwood RPV head penetration nozzles and the J-groove welds.

As the crack-growth rate formula used in the structural integrity evaluation for Byron and Braidwood is the same as the PWSCC crack-growth rate recommended in MRP-55, Revision 1, Exelon stated the following in its August 28, 2006, submittal:

> If the NRC finds that the crack-growth formula in industry report MRP-55 is unacceptable, then EGC [Exelon] will revise its analysis that justifies relaxation of the Order within 30 days after the NRC notifies EGC [Exelon] by written correspondence of an NRC-approved crack-growth formula. If the EGC [Exelon] revised analysis for Braidwood Station Unit 2 and Byron Station Unit 1 shows that the crack-growth acceptance criteria are exceeded prior to the end of the current operating cycle, the relaxation request will be rescinded and the EGC [Exelon] will, within 72 hours, submit to the NRC written justification for continued operation.
>
> If the revised analysis shows that the crack-growth acceptance criteria are exceeded during the subsequent operating cycle, EGC [Exelon] will, within 30 days, submit the revised analysis for NRC review. If the revised analysis shows that the crack-growth acceptance criteria are not exceeded during either the current operating cycle or the subsequent operating cycle, EGC [Exelon] will, within 30 days, submit a letter to the NRC confirming that its analysis has been revised. Any future crack-growth analyses performed for this and future cycles for RPV head penetrations must be based on an acceptable crack-growth rate formula.

3.0 STAFF EVALUATION

The NRC staff's review of this request was based on criterion (2) of Section IV.F of the Order, which states:

> compliance with this Order for specific nozzles would result in hardship or unusual difficulty without a compensating increase in the level of quality and safety.

Full inspection coverage is not achievable at Byron and Braidwood for all RPV upper head penetration nozzles, because of nozzle-end geometry. Specifically, the bottom end of these nozzles are externally threaded, internally tapered, or both. Thus, the geometry of the nozzle ends makes inspection in accordance with the Order difficult and would involve a hardship including increased personnel radiation dose due to possible surface examination options. This evaluation focuses on the issue of whether there is a compensating increase in the level of quality and safety such that these nozzles should be inspected in accordance with the Order despite this hardship.

The alternative inspection proposed by Exelon for 18 RPV upper head penetration nozzles is to volumetrically examine each nozzle from 2 inches above the weld down to the maximum extent practical with a minimum required inspection distance below the J-groove weld as shown in Table 1 and Table 2. Previous Order inspections at Byron and Braidwood, including bare metal visual inspections above the RPV head and non-visual NDE below the RPV upper head,

indicate no evidence of head material wastage, leaking penetrations or reportable indications in the penetration nozzles. The NRC staff reviewed evaluations and analyses performed by Exelon in support of this request, as described below.

Stress profiles, based on the finite element analysis provided in WCAP-16394-P of RPV upper head penetration nozzles at Byron and Braidwood, show that most residual stresses decrease significantly at short distances, less than ½ inch, below the J-groove weld. Since the stress level at the unexamined area is low, initiation of a crack is very unlikely. Operating experience also indicates that locations with this low stress level have been much less susceptible to cracking. In addition, if examination of the high stress locations of these nozzles (i.e., nozzle locations adjacent to the J-groove weld and associated heat affected zone areas) finds no cracks, then cracking at the low stress locations is unlikely.

Exelon's analysis used the methodology described in Footnote 1 of the Order and conservative criteria to set the necessary height of the examination. The analysis postulated a through-wall crack in the unexamined area and showed that it would take the crack more than 5.9 EFPY to reach the J-groove weld. The NRC staff's assessment of Exelon's conclusion is based on data analysis of the supporting figures of the crack-growth predictions for various nozzle angles, as provided in WCAP-16394-P. The NRC staff performed an independent crack-growth calculation, the results of which support Exelon's analysis. Therefore, the NRC staff concurs with Exelon's conclusion, that a crack located beyond a minimum distance below the J-groove weld as provided in Table 1 and Table 2 would take more than 5.9 EFPY to reach the J-groove weld.

As Byron and Braidwood are in the low susceptibility category, nonvisual NDE will be performed every four refueling outages or 7 calender years whichever is less. The NRC staff finds Exelon's estimate of a maximum of 5.8 EFPY of operation in-between Order-required examination periods is conservative. Therefore, an inspection frequency based on Exelon's crack-growth assessment above provides a reasonable basis for the proposed alternative inspection.

However, this analysis incorporates a crack-growth formula as provided in the MRP-55, Revision 1. The NRC staff has completed a preliminary review of the crack-growth formula, but has not yet made a final assessment regarding the acceptability of the report. Therefore, a condition has been included regarding the approval of the proposed relaxations. The condition was agreed to by Exelon in its August 28, 2006, letter to the NRC, and is as follows:

> If the NRC finds that the crack-growth formula in industry report MRP-55 is unacceptable, then EGC [Exelon] will revise its analysis that justifies relaxation of the Order within 30 days after the NRC notifies EGC [Exelon] by written correspondence of an NRC-approved crack-growth formula. If the EGC [Exelon] revised analysis for Braidwood Station Unit 2 and Byron Station Unit 1 shows that the crack-growth acceptance criteria are exceeded prior to the end of the current operating cycle, the relaxation request will be rescinded and the EGC [Exelon] will, within 72 hours, submit to the NRC written justification for continued operation.
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> If the revised analysis shows that the crack-growth acceptance criteria are exceeded during the subsequent operating cycle, EGC [Exelon] will, within

> 30 days, submit the revised analysis for NRC review. If the revised analysis shows that the crack-growth acceptance criteria are not exceeded during either the current operating cycle or the subsequent operating cycle, EGC [Exelon] will, within 30 days, submit a letter to the NRC confirming that its analysis has been revised. Any future crack-growth analyses performed for this and future cycles for RPV head penetrations must be based on an acceptable crack-growth rate formula.

The safety issues that are addressed by the Order are degradation (corrosion) of the low-alloy steel RPV upper head, reactor coolant pressure boundary integrity and ejection of the RPV upper head penetration nozzle due to circumferential cracking of the nozzle above the J-groove weld. Exelon's proposed alternative inspection, to perform the UT examination below the J-groove weld for 18 penetration nozzles to the maximum extent practical with a minimum inspection distance below the J-groove weld as defined by Table 1 and Table 2 and as conditioned, provides reasonable assurance that these safety issues are addressed at Byron and Braidwood.

Exelon has noted that surface examination could be performed to increase the inspection coverage for each nozzle; however, these additional inspections would require extensive work in very high radiation fields. The NRC staff finds that performing these additional surface examinations would result in hardship through significant radiation exposure without a compensating increase in the level or quality or safety.

Based upon the information above, the NRC staff finds that Exelon's proposed alternative examination is acceptable as it provides reasonable assurance of the structural integrity of the RPV upper head, associated penetration nozzles and J-groove welds. Further inspections to comply with the Order requirements would result in hardship or unusual difficulty without a compensating increase in the level of quality and safety. Therefore, Exelon has demonstrated good cause for relaxation from the requirements of the Order.

4.0 CONCLUSION

The NRC staff concludes that Exelon's proposed alternative inspection, to perform the UT of 18 penetration nozzles at Byron and Braidwood to the maximum extent practical below the J-groove weld, with a minimum inspection distance as defined in Table 1 and Table 2 and as conditioned, provides reasonable assurance of the structural integrity of the RPV upper head, associated penetration nozzles and J-groove welds. Further inspections of these penetration nozzles in accordance with Section IV.C.(5)(b), of the Order would result in hardship without a compensating increase in the level of quality and safety. Therefore, Exelon has demonstrated good cause for relaxation, and pursuant to Section IV.F of the Order, the NRC staff authorizes the proposed alternative inspection as stated above at Byron and Braidwood until the Order is replaced or rescinded, subject to the following condition:

> If the NRC finds that the crack-growth formula in industry report MRP-55 is unacceptable, then EGC [Exelon] will revise its analysis that justifies relaxation of the Order within 30 days after the NRC notifies EGC [Exelon] by written correspondence of an NRC-approved crack-growth formula. If the EGC [Exelon] revised analysis for Braidwood Station Unit 2 and Byron Station Unit 1 shows that the crack-growth acceptance criteria are exceeded prior to the end of the

current operating cycle, the relaxation request will be rescinded and the EGC will, within 72 hours, submit to the NRC written justification for continued operation.

If the revised analysis shows that the crack-growth acceptance criteria are exceeded during the subsequent operating cycle, EGC [Exelon] will, within 30 days, submit the revised analysis for NRC review. If the revised analysis shows that the crack-growth acceptance criteria are not exceeded during either the current operating cycle or the subsequent operating cycle, EGC [Exelon] will, within 30 days, submit a letter to the NRC confirming that its analysis has been revised. Any future crack-growth analyses performed for this and future cycles for RPV head penetrations must be based on an acceptable crack-growth rate formula.

Principal Contributor: J. Collins, NRR

Date: September 11, 2006