

February 7, 2008

Mr. Charles Pardee
Chief Nuclear Officer
and Senior Vice President
Exelon Generation Company, LLC
4300 Winfield Road
Warrenville, IL 60555

SUBJECT: BYRON STATION, UNIT NO. 2 - RELAXATION OF THE FIRST REVISED
ORDER EA-03-009 (TAC NO. MD6638)

Dear Mr. Pardee:

By letter dated August 30, 2007 (Agencywide Documents Access and Management System (ADAMS) Accession No. ML072430688), Exelon Generation Company, LLC (Exelon, the licensee), requested relaxation from certain inspection requirements of the First Revised Order EA-03-009 (Order), dated February 20, 2004 (ADAMS Accession No. ML040220181). The licensee clarified that this submittal did not contain proprietary information by letter dated January 31, 2008 (ADAMS Accession No. ML080310560).

Exelon has requested relaxation from the Order for the inspection at Byron Station (Byron), Unit No. 2, to implement an alternative to the requirements of Section IV.C.(5)(b) of the Order. Specifically, the proposed alternative would revise the minimum volumetric inspection coverage requirement below the J-groove weld for sixteen reactor pressure vessel (RPV) penetration nozzles, whose inspection is constrained by nozzle end geometry, at Byron, Unit No. 2, to the lowest elevation that can be practically inspected.

The NRC staff has reviewed and evaluated 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, and further, that 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, pursuant to Section IV.F, of the Order, the NRC staff authorizes the proposed alternative inspection for the RPV at Byron, Unit No. 2, until the First Revised NRC Order EA-03-009 is replaced or rescinded, subject to the condition stated in the August 30, 2007, application.

The NRC staff's review is provided in the enclosed Safety Evaluation. If you have any questions, please contact Meghan Thorpe-Kavanaugh at (301) 415-5735.

Sincerely,
/RA/

Russell Gibbs, Chief
Plant Licensing Branch III-2
Division of Operating Reactor Licensing
Office of Nuclear Reactor Regulation

Docket No. STN 50-455

Enclosure: As stated

cc w/encl: See next page

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SAFETY EVALUATION BY THE OFFICE OF NUCLEAR REACTOR REGULATION

FIRST REVISED ORDER EA-03-009 RELAXATION REQUEST,

ALTERNATE EXAMINATION COVERAGE FOR

REACTOR PRESSURE VESSEL HEAD PENETRATION NOZZLES

EXELON GENERATION COMPANY, LLC

BYRON STATION, UNIT NO. 2

DOCKET NO. STN 50-455

1.0 INTRODUCTION

The First Revised Nuclear Regulatory Commission (NRC) Order EA-03-009 (Order), issued on February 20, 2004 (Agencywide Documents Access and Management System (ADAMS) Accession No. ML040220181), requires specific examinations of the reactor pressure vessel (RPV) head and vessel head penetration nozzles of all pressurized water reactor plants. Section IV.F of the Order states that requests for relaxation of the Order 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 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 First Revised 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 (Byron), Unit No. 2, which had been 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 prior to the outage, the following inspection was 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 NDE [nondestructive examination] in accordance with either (i), (ii), or (iii):
 - (i) Ultrasonic testing 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 1.0-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 two inches [see Figure IV-3]); OR from two inches above the highest point of the root of the J-groove weld (on a horizontal plane perpendicular to the nozzle axis) to 1.0-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 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 August 30, 2007 (ADAMS Accession No. ML072430688), Exelon Generation Company, LLC. (the licensee) 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, Unit No. 2. The licensee clarified that this submittal did not contain proprietary information by letter dated January 31, 2008 (ADAMS Accession No. ML080310560).

2.0 FIRST REVISED NRC ORDER EA-03-009 RELAXATION REQUEST FOR EXAMINATION COVERAGE FOR REACTOR PRESSURE VESSEL HEAD PENETRATION NOZZLES

2.1 First Revised Order Requirements for Which Relaxation is Requested

Section IV.C of the Order dated February 20, 2004, 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, Unit No. 2's susceptibility status prior to the plant's spring 2007 outage.

The licensee 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

The licensee seeks relaxation from the Order, to revise the minimum volumetric inspection coverage requirement below the J-groove weld for 16 penetration nozzles at Byron, Unit No. 2, to the lowest elevation that can be practically inspected. The licensee states that during the previous refueling outage for Byron, Unit No. 2, it performed volumetric examinations to the maximum extent practical to meet all requirements of the Order. The inspection distance below the J-groove weld for 16 total penetration tubes did not meet the full requirements of the Order. The specific coverage obtained for these penetration nozzles is provided in Table 1.

Table 1: Byron, Unit No. 2, Spring 2007 (B2R13) Refueling Outage Volumetric/Surface Inspection Coverage Below the Toe of the J-groove Weld	
Nozzle Number	B2R13 Inspection Coverage (Inches Below the J-groove Weld)
33	0.92
34	0.88
39	0.80
42	0.88
44	0.84
45	0.80
51	0.96
52	0.88
53	0.88
55	0.92
56	0.64
58	0.84
63	0.76
68	0.80
69	0.80
71	0.96

2.3 Licensee's Basis for Proposed Alternative

The licensee's relaxation request would allow performance of the volumetric examination required by the Order to the lowest elevation that can be practically inspected for 16 penetration nozzles identified in Table 1. The licensee states that it utilized inspection option (b)(i) and achieved volumetric and surface coverage 2 inches above the J-groove weld down to the lowest elevation that could be practicably inspected on each of these penetration nozzles, with a minimum distance below the J-groove weld for sixteen penetration nozzles as stated in Table 1.

The licensee 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. These items present physical restraints to full effective coverage of the Order-required volumetric inspection area with ultrasonic examination probes.

The licensee notes that while the Order allows provisions for dye penetrant inspection, it would require extensive work under and around the RPV upper head. The licensee estimates the general area radiation level under the upper head near the nozzles at 6.3 rem per hour. In addition, the threaded region of the penetration nozzles would make a dye penetrant inspection impractical. Therefore, the licensee 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 of quality or safety.

The licensee 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. The licensee believes the proposed inspection coverage does not preclude full ultrasonic testing (UT) examination coverage of the portions of these nozzles that are of primary interest.

The licensee contracted for a structural integrity evaluation for the Byron, Unit No. 2, RPV upper head penetration nozzles. A series of crack growth calculations was 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 performed to demonstrate that more time in effective full power years 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. Byron, Unit No. 2, is now in the High susceptibility category; therefore, nonvisual NDE will be performed once every refueling outage. Byron, Unit No. 2, has an 18-month operating cycle.

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 the Electric Power Research Institute (EPRI) Report, "Material 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-16394-P. According to the licensee, the calculation demonstrates that the minimum time for a flaw to propagate from the distances below the J-groove weld listed in Table 1 for the limiting RPV upper head penetration

nozzles to the bottom of the J-groove weld would be greater than 6 years of operation. The licensee states that 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 licensee concludes that the results demonstrate that the extent of the proposed inspection coverage would provide reasonable assurance of the structural integrity of Byron, Unit No. 2, RPV head penetration nozzles and the J-groove welds.

As the crack growth rate formula used in the structural integrity evaluation for Braidwood Station, Units 1 and 2 and Byron, Unit No. 2, is the same as the PWSCC crack growth rate recommended in MRP-55, Revision 1, the licensee states the following:

If the NRC finds that the crack-growth formula in industry report MRP-55 is unacceptable, then the licensee will revise its analysis that justifies relaxation of the Order within 30 days after the NRC informs the licensee of an NRC-approved crack-growth formula. If the licensee's revised analysis for Byron Station, Unit 2, shows that the crack-growth acceptance criteria are exceeded prior to the end of the current operating cycle, this relaxation request will be rescinded and the licensee 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, the licensee 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, the licensee 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, Unit No. 2, for all RPV upper head penetration nozzles, because of nozzle end geometry. Specifically, the bottom end of these nozzles are externally threaded, or 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 the licensee for 16 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. The NRC staff reviewed evaluations and analyses performed by the licensee 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, Unit No. 2, show that most residual stresses decrease significantly at short distances, less than one half 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., inspected 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.

The licensee'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 6 years to reach the J-groove weld. The NRC staff's assessment of the licensee'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. NRC staff performed an independent crack growth calculation, the results of which support the licensee's analysis. Therefore, NRC staff agrees with the licensee's conclusion that a crack located beyond a minimum distance below the J-groove weld as provided in Table 1 would take more than 6 years to reach the J-groove weld.

Due to the identification of a PWSCC flaw in one penetration nozzle at Byron, Unit No. 2, during the plant's spring 2007 outage, the RPV head has been reclassified as being within the High susceptibility category in accordance with Paragraph IV.B of the Order. As the current Byron, Unit No. 2, RPV head is now in the High susceptibility category, nonvisual NDE will be performed every refueling outage. The NRC staff finds that the licensee's estimate of a maximum of 18 months of operation between Order-required examination periods is representative. Therefore, the inspection frequency, given the licensee's crack growth assessment above, provides a conservative basis to ensure structural integrity for the licensee's proposed alternative inspection area.

However, this analysis incorporates a crack growth formula as provided in the EPRI Report, "Material Reliability Program (MRP) Crack Growth Rates for Evaluating Primary Water Stress Corrosion Cracking (PWSCC) of Thick Wall Alloy 600 Material (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 the licensee in its August 30, 2007, letter to the NRC, and is as follows:

If the NRC staff finds that the crack-growth formula in industry report MRP-55 is unacceptable, then the licensee will revise its analysis that justifies relaxation of the Order within 30 days after the NRC informs the licensee of an NRC-approved crack-growth formula. If the licensee's revised analysis for Byron Station, Unit 2, shows that the crack-growth acceptance criteria are exceeded prior to the end of the current operating cycle, this relaxation request will be rescinded and the licensee 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, the licensee 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, the licensee 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. The licensee's proposed alternative inspection, to perform the UT examination below the J-groove weld for sixteen penetration nozzles to the maximum extent practical with a minimum inspection distance below the J-groove weld as defined by Table 1 and subject to the condition above, provides reasonable assurance that these safety issues are addressed at Byron, Unit No. 2.

The licensee has noted that surface examination could be performed to increase the inspection coverage for each nozzle, but that 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 the licensee'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, the licensee has demonstrated good cause for relaxation from the requirements of the Order.

4.0 CONCLUSION

The NRC staff concludes that the licensee's proposed alternative inspection, to perform the ultrasonic testing of 16 penetration nozzles at Byron, Unit No. 2, to the maximum extent practical below the J-groove weld, with a minimum inspection distance as defined in Table 1 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, the licensee 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, Unit No. 2, until the Order is replaced or rescinded, subject to the following condition as agreed to by the licensee:

If the NRC finds that the crack-growth formula in industry report MRP-55 is unacceptable, then the licensee will revise its analysis that justifies relaxation of the Order within 30 days after the NRC informs the licensee of an NRC-approved crack-growth formula. If the licensee's revised analysis for Byron Station, Unit No. 2, shows that the crack-growth acceptance criteria are exceeded prior to the end of the current operating cycle, this relaxation request will be rescinded and the licensee 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, the licensee 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

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Principal Contributor: J. Collins, NRR

Date: February 7, 2008