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UNITED STATES OF AMERICA

NRC-2009-0198

NUCLEAR REGULATORY COMMISSION

EXELON GENERATION COMPANY, LLC

BYRON STATION, UNIT NO. 2

DOCKET NO. 50-455

EXEMPTION

1.0 BACKGROUND

Exelon Generation Company, LLC (Exelon, the licensee) is the holder of Facility Operating License No. NPF-66 which authorizes operation of the Byron Station, Unit No. 2 (Byron 2). The license provides, among other things, that the facility is subject to all rules, regulations, and orders of the Nuclear Regulatory Commission (NRC, the Commission) now or hereafter in effect.

The facility is one unit of a two-unit pressurized-water reactor station located in Ogle County, Illinois.

2.0 REQUEST/ACTION

Pursuant to Title 10 of the *Code of Federal Regulations* (10 CFR), Section 50.12, "Specific exemptions," the licensee has, by letter dated March 24, 2008 (Agencywide Documents Access and Management System (ADAMS) Accession No. ML080850235), requested an exemption from the requirements of 10 CFR 50.46, "Acceptance criteria for emergency core cooling systems for light-water nuclear power reactors," and 10 CFR Part 50, Appendix K, "ECCS Evaluation Models," for one lead test assembly (LTA) using Westinghouse AXIOM™ cladding.

The regulation at 10 CFR 50.46(a)(1)(i) requires that "[e]ach boiling or pressurized light-water nuclear power reactor fueled with uranium oxide pellets within cylindrical zircaloy or

ZIRLO cladding must be provided with an emergency core cooling system (ECCS) that must be designed so that its calculated cooling performance following postulated loss-of-coolant accidents conforms to the criteria set forth in paragraph (b) of this section." The regulation at 10 CFR 50.46(a)(1)(ii) requires that, "[a]lternatively, an ECCS evaluation model may be developed in conformance with the required and acceptable features of appendix K ECCS Evaluation Models." Appendix K of 10 CFR Part 50 requires, in paragraph I.A.5, that "[t]he rate of energy release, hydrogen generation, and cladding oxidation from the metal/water reaction shall be calculated using the Baker-Just equation (Baker, L., Just, L.C., "Studies of Metal Water Reactions at High Temperatures, III. Experimental and Theoretical Studies of the Zirconium-Water Reaction," ANL-6548, page 7, May 1962)." The regulations make no provisions for use of fuel rods clad in a material other than zircaloy or ZIRLO™. The licensee plans to irradiate one LTA using fuel rods clad with AXIOM™ alloy in Byron 2. Because the material specification of the AXIOM™ alloy differs from the specification for zircaloy or ZIRLO™, the licensee requested a plant-specific exemption from the requirements of 10 CFR 50.46 and 10 CFR Part 50, Appendix K, to support the use of the LTA for Byron 2. However, as discussed subsequently in Sections 3.0 and 4.0, the NRC staff determined that a broad exemption from all the requirements of 10 CFR 50.46 and 10 CFR Part 50, Appendix K, is not required in this particular circumstance.

The licensee plans to use one LTA, containing fresh and twice-burned AXIOM™ clad fuel rods, in the Byron 2 Cycle 16 reactor core. The twice-burned AXIOM™ clad fuel rods would continue to be irradiated up to a lead rod average burnup of up to 75,000 megawatt days per metric ton uranium (MWD/MTU).

Previously, by letter dated June 30, 2006 (ADAMS Accession No. ML061380518), the NRC staff approved the irradiation of four LTAs containing AXIOM™ clad fuel rods in the Byron Station, Unit No. 1 (Byron 1), Cycle 15 core. In the same letter, the NRC staff also approved the

re-insertion of two of the four LTAs into the Byron 1 Cycle 16 core and the other two LTAs into the Byron 2 Cycle 15 core. Byron 1 is currently operating in Cycle 16; Byron 2 is currently operating in Cycle 15. Prior to re-insertion of the LTAs into the Cycle 16 and Cycle 15 cores, respectively, for the second cycle of irradiation, the licensee performed post-irradiation examination (PIE) for the LTAs. During the spring 2010, Byron 2 refueling outage, the licensee plans to perform PIE for the two LTAs, then re-insert one LTA into the Byron 2 Cycle 16 core to gain high burnup data. The LTA will consist of fresh fuel rods in AXIOM™ cladding along with up to 16 twice-burned fuel rods in AXIOM™ cladding selected from the irradiated LTAs. During this third cycle, the twice-burned fuel rods will reach a peak rod average burnup of 75,000 MWD/MTU, which exceeds the NRC staff's burnup limit of 62,000 MWD/MTU (ADAMS Accession No. ML061420458), based on the capabilities of the fuel performance and design models for Westinghouse VANTAGE+ fuel, which is used in the Byron 2 reactor core.

3.0 DISCUSSION

Pursuant to 10 CFR 50.12, the Commission may, upon application by any interested person or upon its own initiative, grant exemptions from the requirements of 10 CFR Part 50, when (1) the exemptions are authorized by law, will not present an undue risk to public health or safety, and are consistent with the common defense and security; and (2) when special circumstances are present. The Commission will not consider granting an exemption unless special circumstances are present.

Authorized by Law

This exemption would allow the licensee to re-insert one LTA containing AXIOM™ fuel rod cladding that is neither Zircaloy nor ZIRLO™, which are the cladding materials contemplated by 10 CFR 50.46(a)(1)(i) and by 10 CFR Part 50, Appendix K, paragraph I.A.5. Selection of a specific cladding material in 10 CFR 50.46(a)(1)(i) and in 10 CFR Part 50, Appendix K, paragraph I.A.5 was at the discretion of the Commission consistent with its statutory authority.

No statute required the NRC to adopt this specification. As stated above, 10 CFR 50.12 allows the Commission to grant exemptions from the requirements of 10 CFR Part 50. The NRC staff has determined that granting of an exemption from 10 CFR 50.46(a)(1)(i) and from 10 CFR Part 50, Appendix K, paragraph I.A.5 related to AXIOM™ fuel rod cladding, which is neither Zircaloy nor ZIRLO™, will not result in a violation of the Atomic Energy Act of 1954, as amended, or the Commission's regulations. Therefore, the exemption is authorized by law. Furthermore, the NRC staff has determined that, because the licensee plans to ensure that the acceptance and analytical criteria of 10 CFR 50.46 and 10 CFR Part 50, Appendix K are met following the insertion of the subject LTA, exemption from the remaining requirements of 10 CFR 50.46 and 10 CFR Part 50, Appendix K is not required.

No Undue Risk to Public Health and Safety

In its March 24, 2008, letter, the licensee provided technical justification to support its conclusion that irradiating one LTA, containing fresh and twice-burned AXIOM™ clad fuel rods, in the Byron 2 Cycle 16 reactor core, up to a lead rod average burnup of up to 75,000 MWD/MTU would result in no undue risk to public health and safety. The licensee's technical justification and the NRC staff's associated conclusions follow.

Fuel Mechanical Design Considerations

Prior to Byron 2 Cycle 16, characterization of the twice-burned AXIOM™ fuel rods will be performed to include an overall visual examination and measurements of cladding oxide, fuel rod growth, and diameter profile. Prior to irradiating the LTA during Byron 2 Cycle 16, the twice-burned AXIOM™ clad fuel rods will be evaluated with current fuel performance methods and codes to ensure that all current design criteria are met for the projected burnup. The licensee stated that if some of the AXIOM™ clad twice-burned rods scheduled for reconstitution exhibit anomalous behavior, have measured characteristics of oxide thickness or rod length that are outside acceptable bounds, or are determined incapable of meeting all current design

requirements, those twice-burned rods will not be used for reconstitution and will be replaced with rods meeting the reload requirements. The licensee also stated that, to ensure that the acceptance criteria of 10 CFR 50.46 and 10 CFR 50, Appendix K, are met, the LTA using AXIOM™ cladding will be evaluated using NRC-approved analytical methods and will address the changes in the cladding material properties and that the reload core containing AXIOM™ cladding will continue to be operated in accordance with the operating limits specified in the Byron Station Technical Specifications (TS). Based upon the limited number of AXIOM™ clad fuel rods, the PIE and characterization which would detect anomalous behavior, the use of NRC-approved models to ensure that all design criteria remain satisfied, and the requirement to operate the Byron Cycle 16 core within TS limits, the NRC staff finds the LTA mechanical design acceptable for Byron 2 Cycle 16.

Traditionally, the NRC staff had two criteria for LTA programs: (1) the number of LTAs should be limited, and (2) the core locations of LTAs should be non-limiting (i.e., not in the highest power regions). In 2003, the NRC staff endorsed the concept of locating LTAs next to the highest power or high-duty regions for simulating typical reactor operations. By letters dated January 8 and August 29, 2003 (ADAMS Accession Nos. ML030070476 and ML032410054, respectively), the NRC staff approved Westinghouse Topical Report WCAP-15604-NP, Revision 1, “Limited Scope High Burnup Lead Test Assemblies,” which provides the basis and guidelines for the operation of a limited number of LTAs for a high burnup irradiation program. Based on the licensee’s planned LTA program, the NRC staff considers that the burnup extension is consistent with the approved report. Based on the approved report, acceptable PIEs for the Byron LTAs prior to the second cycle of irradiation, and the licensee’s plans for PIE and characterization of the twice-burned fuel rods prior to the third cycle of irradiation, the NRC staff concludes that it is acceptable to extend the LTA burnup limit to a peak rod average of 75,000 MWD/MTU for Byron Unit 2.

The Byron 2 reactor core contains a total of 193 fuel assemblies; each fuel assembly contains 264 fuel rods. As mentioned previously, the Byron 2 Cycle 16 LTA, which is the subject of the licensee's exemption request, will consist of up to 16 twice-burned fuel rods in AXIOM™ cladding with the remainder (and the majority) being fresh fuel rods in AXIOM™ cladding, and will be placed in the Cycle 16 reactor core in a non-limiting core location. The licensee stated that setting the number of AXIOM™ clad rods at this level restricts the portion of such rods to a value of 0.52 percent, which, even if failed, is well within the postulated core damage in the Byron Station's current licensing basis. The licensee also stated that, even though there have been no AXIOM™ clad fuel rod failures in the industry to date, if a failure were to occur, the effects would be well within the TS limits for doses and core coolable geometry would be maintained. Based upon the limited number of AXIOM™ clad fuel rods placed in non-limiting core locations, the use of approved models and methods, and the acceptable performance to date of the AXIOM™ cladding, the NRC staff finds that the irradiation of the subject LTA in the Byron 2 Cycle 16 core will not result in unsafe operation nor violation of specified acceptable fuel design limits. Furthermore, in the event of a design-basis accident, these LTAs will not promote consequences beyond those currently analyzed, as discussed next.

Dose Analyses Considerations for Extended Burnup

The licensee stated in its March 24, 2008, letter, that the assessment contained in Westinghouse Topical Report WCAP-12610-P-A, "VANTAGE + Fuel Assembly Reference Core Report," April 1995, concluded that the fuel-handling accident (FHA) total effective dose equivalent doses are not adversely affected by extended burnup up to 75,000 MWD/MTU. However, the licensee recognized that there is uncertainty in fission product gap inventory, due to the limited fission gas release measurements on high burnup fuel, and provided a discussion of the conservatisms in the Byron FHA dose calculation. These included use of the alternative

source term (AST) methodology, the relative power for this particular LTA in Cycle 16, offloading time, containment isolation, and mechanical fuel damage due to impact.

AST Methodology

The NRC approved the use of an AST methodology for Byron Station in License Amendment No. 147, dated September 8, 2006 (ADAMS Accession No. ML062340420). The analyses provided by the licensee in support of the amendment and approved by the NRC staff used gap release fractions for accidents other than the loss-of-coolant accident (LOCA), which are two times the values in Table 3 of Regulatory Guide (RG) 1.183, “Alternative Radiological Source Terms for Evaluating Design Basis Accidents at Nuclear Power Reactors,” July 2000. The factor of two was used to offset the fact that some fuel assemblies would exceed the rod power/burnup criteria in RG 1.183. For the FHA, all of the fuel rods in the limiting assembly were assumed to fail, releasing their fuel/clad gap fission product inventory. The NRC staff has previously found this approach acceptable in the safety evaluation accompanying the above-cited amendment.

LTA Relative Power

The licensee stated that, due to its high burnup, the LTA's relative power will not approach the 1.7 peaking limit assumed in the Updated Final Safety Analysis Report (UFSAR). The Byron 2 Cycle 16 reactor core will be designed such that the LTA will remain in a non-limiting location. Therefore, with more appropriate relative assembly powers credited for both the LTA and other potentially-impacted assemblies, the calculated dose would decrease. Although relative assembly powers are not generally credited in design-basis accident (DBA) radiological consequences analyses, the NRC staff finds that the specific situation described above does show that conservatism exists in the current licensing basis FHA analysis when compared to the expected impact of dropping the extended burnup LTA.

Offloading Time

The licensee stated that, although the FHA calculation assumes that core offload begins no sooner than 48 hours after shutdown, in practice, core offload typically commences much later than 48 hours after entry into Mode 3. However, because the licensee did not provide supporting documentation on how it would assure the expected >48 hours to start core offload (i.e., TS, physical constraints, procedures, etc.), the NRC staff finds that this conservatism cannot be credited as a conservatism related to this exemption request for the subject LTA. However, the NRC staff notes that other conservatisms in the FHA, discussed previously and below, more than offset this non-credited core offload time.

Containment Isolation

In accordance with Byron Station TS 3.9.4, the movement of recently irradiated fuel (i.e., fuel that has occupied part of a critical reactor core within the previous 48 hours) requires that containment integrity be in effect. Fuel with additional decay can be moved without containment integrity or exhaust filtration. Compensatory measures to close any openings and ensure exhaust is in the proper direction within 1 hour after a FHA are required procedurally as defense-in-depth measures; however, they are not credited in the analysis in accordance with RG 1.183. The NRC staff, in its review of the licensee's AST methodology, has previously found this approach acceptable and would, therefore, apply to movement of the LTA.

Mechanical Fuel Damage Due to Impact

The Byron Station UFSAR analysis assumes all rods of the dropped assembly fail. The licensee stated that this is a very conservative assumption given the broad spectrum of loads considered and the resulting high structural strength of the fuel assembly and other core components. The licensee also stated that irradiated fuel assembly drop events (e.g., Fort Calhoun in 2003, North Anna in 2001, and Haddam Neck in 1986) have also yielded no increase in local area dose rates. The NRC staff concludes that the amount of assumed fuel

damage in the current licensing basis is conservative based on fuel mechanical design and actual industry experience, even if the FHA were to involve the subject LTA.

The NRC staff finds that the conservatisms associated with the AST analysis, LTA relative power, compensatory measures during irradiated fuel movement, and FHA fuel damage assumptions compensate for the uncertainties in the gap fractions. Therefore, the fission product gap inventory assumed in the current licensing basis FHA radiological assessment remains bounding for the extended burnup LTA.

For other DBAs, even though extended burnup to 75,000 MWD/MTU for the one LTA would cause a variation in the core inventory compared to the current fuel, there are no significant increases to isotopes that are major contributors to accident doses. Therefore, the NRC staff finds that current licensing basis DBA results remain bounding for estimated offsite and control room operator doses and the radiation dose limitations of 10 CFR 50.67, “Accident Source term,” and 10 CFR Part 50, Appendix A, GDC-19, “Control Room,” will not be exceeded. The NRC staff finds that the licensee used assumptions, inputs, and methods that are consistent with the conservative regulatory requirements and guidance identified above. Based on the Byron Station current licensing bases and the acceptable conservatisms discussed above, the NRC staff finds with reasonable assurance that the licensee’s estimates of the exclusion area boundary, low-population zone, and control room doses will continue to comply with the applicable regulatory criteria. Therefore, the proposed extension of the fuel rod average burnup limit for one LTA is acceptable with regard to the radiological consequences of postulated DBAs.

Conclusion

Based upon the limited number and anticipated performance of the AXIOM™ clad fuel rods, the use of PIE and characterization to detect anomalous behavior to preclude further irradiation damage, and the use of NRC-approved models to ensure that all design criteria

remain satisfied, the NRC staff finds the use of the subject LTA up to 75,000 MWD/MTU in the Byron 2 Cycle 16 reactor core to be acceptable.

Consistent with Common Defense and Security

The proposed exemption would allow the use of one LTA with a variant cladding material. This change to the plant core configuration has no impact on security issues. Special nuclear material in the LTA will continue to be handled and controlled in accordance with applicable regulations. Therefore, the common defense and security is not impacted by this exemption.

Special Circumstances

In accordance with 10 CFR 50.12(a)(2)(ii), special circumstances are present whenever application of the regulation in the particular circumstances would not serve the underlying purpose of the rule or is not necessary to achieve the underlying purpose of the rule.

The underlying purpose of 10 CFR 50.46(a)(1)(i) is to establish acceptance criteria for ECCS performance. Previously, on June 30, 2006, the NRC staff approved an exemption for four Byron LTAs that demonstrated the acceptability of the AXIOM™ cladding under LOCA conditions (ADAMS Accession No. ML061380518). The unique features of the LTAs were evaluated for effects on the LOCA analyses. The results showed that the LTAs would not adversely affect ECCS performance. Because the current LTA will be located in a non-limiting core location, the licensee concluded and the NRC staff agrees that the LOCA safety analyses will remain bounding for the Cycle 16 LTA for Byron 2. Therefore, the NRC staff concludes that application of 10 CFR 50.46(a)(1)(i) in this particular circumstance is not necessary for the licensee to achieve the underlying purpose of the rule.

10 CFR Part 50, Appendix K

Paragraph I.A.5 of Appendix K to 10 CFR Part 50 states that “[t]he rate of energy release, hydrogen generation, and cladding oxidation from the metal/water reaction shall be

calculated using the Baker-Just equation." The Baker-Just equation, developed in 1962, presumed the use of zircaloy clad fuel, and thus did not address AXIOM™ clad fuel for determining acceptable fuel performance. The underlying intent of this portion of Appendix K is to ensure that analysis of fuel response to LOCAs is conservatively calculated. Previously, in its June 30, 2006, exemption for four Byron LTAs with AXIOM™ clad fuel rods (ADAMS Accession No. ML061380518), the NRC staff concluded that, based on the material composition of the AXIOM™ alloy, which is similar to other licensed zirconium alloys, the high temperature metal-water reaction rates are expected to be similar. The NRC staff also concluded that, because of the limited number of AXIOM™ clad fuel rods and the similarity in material composition to other advanced cladding materials, the application of the Baker-Just equation in the analysis of the four Byron LTAs with AXIOM™ clad fuel rods was acceptable. Based on the NRC staff's previous conclusions for four LTAs with AXIOM™ clad fuel rods, the NRC staff concludes that an exemption from 10 CFR Part 50, Appendix K, as requested by the licensee, is not necessary for the licensee's request to apply the Baker-Just equation to the one LTA with AXIOM™ clad fuel rods planned for insertion in the Byron 2 Cycle 16 reactor core, because application of the Baker-Just equation in this circumstance will achieve the underlying purpose of the rule.

4.0 CONCLUSION

Accordingly, the Commission has determined that, pursuant to 10 CFR 50.12(a), an exemption from the requirements of 10 CFR 50.46(a)(1)(i) is authorized by law, will not present an undue risk to the public health and safety, and is consistent with the common defense and security. Also, special circumstances are present. Therefore, the Commission hereby grants the licensee an exemption from the requirement of 10 CFR 46(a)(1)(i) related to fuel cladding material to allow one LTA containing AXIOM™ clad fuel rods to be irradiated in Byron 2 during Cycle 16 up to a lead rod average burnup of up to 75,000 MWD/MTU. The remaining requirements of 10 CFR 50.46 remain in effect for the Byron 2 Cycle 16 reactor core.

Furthermore, for the reasons stated in the previous section, the Commission has determined that an exemption from the requirements of 10 CFR Part 50, Appendix K, is not required. Therefore, the Commission is not issuing an exemption from 10 CFR Part 50, Appendix K for the Byron 2 Cycle 16 reactor core.

Pursuant to 10 CFR 51.32, the Commission has determined that the granting of the exemption from 10 CFR 46(a)(1)(i) will not have a significant effect on the quality of the human environment (74 FR 20000; April 30, 2009).

This exemption is effective upon issuance.

Dated at Rockville, Maryland, this 30th day of April 2009.

FOR THE NUCLEAR REGULATORY COMMISSION

/RA/

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