CONTENTS

Contents ..... **i**

List of Figures ..... **ii**

List of Tables ..... **iii**

4 REACTOR **4-1**

4.0 Reactor 4-1

4.1 Introduction 4-1

4.2 Summary of Application 4-1

4.3 Regulatory Basis 4-2

4.4 Technical Evaluation 4-2

4.5 Post Combined License Activities Nuclear Design 4-4

4.6 Conclusions 4-4

LIST OF FIGURES

No figures were included in the chapter.

LIST OF TABLES

No tables were included in the chapter.

4 REACTOR

4.0 Reactor

4.1 Introduction

This chapter describes the design of the BBNPP reactor and reactor core, including the reactor internals, control rod drive and core support structural materials, fuel system design (fuel rods and fuel assemblies), the nuclear design, the thermal-hydraulic design, and reactivity control systems functional design. This chapter also specifies the principal design criteria with which the mechanical design, the physical arrangement of the reactor components, and the capabilities of reactor control, protection, and emergency cooling systems (when applicable) must comply.

4.2 Summary of Application

Bell Bend Nuclear Power Plant (BBNPP) combined license (COL) Final Safety Analysis Report (FSAR) Chapter 4 incorporates by reference U.S. EPR FSAR Tier 2, Chapter 4.

In addition, in BBNPP COL FSAR Chapter 4, the BBNPP COL applicant provided the following supplemental information:

U.S. EPR COL Information Item

- U.S. EPR COL Information Item 5.3-4

The BBNPP applicant provided additional information to address U.S. EPR COL Information Item 5.3-4, which states:

> A COL applicant that references the U.S. EPR design certification will provide plant-specific surveillance data to benchmark BAW-2241P-A and demonstrate applicability to the specific plant.

PPL Bell Bend, LLC Exemption Request

Pursuant to Title 10 of the *Code of Federal Regulations* (10 CFR) 52.7 and 10 CFR 52.93, PPL Bell Bend, LLC has 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, Emergency Core Cooling System (ECCS) Evaluation Models, Paragraph I.A.5, regarding the use of Zircaloy or ZIRLO as fuel cladding material.

Inspections, Tests, Analyses, and Acceptance Criteria

The staff reviewed BBNPP COL Application (COLA) Part 10, “Inspections, Tests, Analyses, and Acceptance Criteria (ITAAC) and ITAAC Closure” to determine the acceptability of ITAAC associated with BBNPP COL FSAR Chapter 4.

4.3 Regulatory Basis

The regulatory basis of the information incorporated by reference is addressed in U.S. EPR Safety Evaluation Report (SER) Section 4.3, "Nuclear Design." The issue of simultaneously reviewing the application for design certification of the U.S. EPR and the BBNPP COL application is addressed in Chapter 1 of this report.

4.4 Technical Evaluation

The staff reviewed BBNPP COL FSAR Chapter 4 and reviewed the U.S. EPR FSAR (the reference design certification) to ensure that the combination of the reference design certification and the COL application represents the complete scope of information relating to this review topic. The staff confirmed that the information contained in the COL application and incorporated by reference addresses the required information relating to the reactor internals, control rod drive and core support structural materials, fuel system design (fuel rods and fuel assemblies), the nuclear design, the thermal-hydraulic design and reactivity control systems functional design. The results of the staff's evaluation of the information incorporated by reference in the COL application are documented in Chapter 4 of the U.S. EPR SER.

Section 1.2.3, "Overview of the Design-Centered Review Approach," of this report provides a discussion of the strategy used by the staff to perform one technical review for each standard issue outside the scope of the design certification and to use this review in evaluating subsequent COL applications. To ensure that the staff's findings on standard content that were documented in the FSER for the reference COL application (Calvert Cliffs Nuclear Power Plant Unit 3 (CCNPP3)) were equally applicable to the BBNPP COL application, the staff undertook the following reviews:

- The staff compared the BBNPP COL FSAR to the CCNPP3 COL FSAR. In performing this comparison, the staff considered changes made to the BBNPP COL FSAR (and other parts of the COL application, as applicable) resulting from requests for additional information (RAIs).

- The staff confirmed that all responses to RAIs identified in the corresponding standard content evaluation were endorsed by the BBNPP COL applicant.

- The staff verified that the site-specific differences were not relevant.

The staff completed its review and finds the evaluation performed for the standard content directly applicable to the BBNPP COL application. This standard content material is identified in this report by use of indented formatting.

U.S. EPR COL Information Item

- U.S. EPR COL Information Item 5.3-4

The following portion of this technical evaluation section is reproduced from CCNPP SER Section 4.6.

> The staff notes that a COL information item has been requested in an open item in Section 4.3 of the SER on the U.S. EPR FSAR Tier 2, Section 4.3, to address plant specific surveillance of the reactor internals in regard to fluence calculation

> methodology. The COL FSAR will need to address this COL information item once it is added to the U.S. EPR FSAR Tier 2, Section 4.3. In a letter dated March 12, 2010, the COL applicant stated that when the COL item is added to the U.S. EPR FSAR, the applicable parts of the COL application for CCNPP Unit 3 would be updated to address this additional requirement. The staff cannot make a final determination on the COL FSAR, Section 4.3, until this issue is addressed. The staff has issued a question requesting that the COL applicant address the requirements of the COL information item resulting from open items in the U.S. EPR FSAR review.

In U.S. EPR FSER, Section 4.3.4.5, the staff noted that the U.S. Nuclear Regulatory Commission (NRC)-approved methodology described in Babcock and Wilcox (BAW)-2241P-A, "Fluence and Uncertainty Methodologies," April 2006, was used by the design certification applicant (AREVA) to estimate the reactor vessel fluence values. The staff concluded that "…the applicant [should] provide a COL information item that addresses a plant-specific fluence methodology benchmark promptly after the first and second surveillance capsule data become available." In a June 17, 2010, letter to the NRC, the CCNPP3 COL applicant stated, "In the AREVA response to U.S. EPR [Request for Additional Information] RAI 344, Question 04.03-27, (ADAMS Accession Number ML101600032), COL Information Item 5.3-4 was added. COL Information Item 5.3-4 states that 'A COL Applicant that references the U.S. EPR design certification will provide plant specific surveillance capsule data to benchmark BAW-2241 P-A and demonstrate applicability to the specific plant.'" The proposed wording of COL Information Item 5.3-4 for CCNPP3 is the same as contained in U.S. EPR COL Information Item 5.3-4.

In a September 21, 2012, letter to the NRC, the BBNPP COL applicant adopted COL Information Item 5.3-4 as proposed by the CCNPP3 COL applicant. The staff review of BBNPP COL FSAR Table 1.8-2, "FSAR Sections that Address COL Items," confirmed that COL Information Item 5.3-4 had been added to the table. Accordingly, the staff considers this issue resolved from a licensing standpoint. The staff notes that COL information Item 5.3-4 involves an activity that can only be completed following issuance of a COL. U.S. EPR RAI 547 states, in part, "…Following the issuance of RAI 533, Question 03.06.01-13, it was identified by the staff that there are a number of similar COL [Information Items] I/Is in FSAR Tier 2 Table 1.8-2 that cannot theoretically be completed by the COL applicant prior to issuance of a COL license." Accordingly, a license condition contained in BBNPP COL application Part 10, Appendix A, requiring implementation of the post-COL program described in COL information Item 5.3-4 is necessary. **Establishment of a License Condition associated with COL information Item 5.3-4 is being tracked as an open item**.

PPL Bell Bend, LLC Exemption Request

The following portion of this technical evaluation section is reproduced from CCNPP3 SER Section 4.4:

> The staff also notes that the COL application for the CCNPP Unit 3, Part 7, Item 1.2.6 includes an exemption on the use of M5™ advanced zirconium alloy fuel rod cladding. The staff issued RAI 226, Question 04.02-1 to track the evaluation of this exemption request, which is currently underway, in the review of the COL application. The staff cannot make a final determination on the COL FSAR, Section 4.2, until this issue is addressed. **RAI 226, Question 04.02-1 is being tracked as an open item.**

In an April 14, 2010, letter to the NRC the CCNPP3 COL applicant stated, "COLA FSAR Section 4.2 is revised to describe the exemption request related to the use of M5™ advanced zirconium alloy fuel rod cladding, consistent with the description in COLA Part 7." In a September 21, 2012, letter to the NRC, the BBNPP COL applicant stated: "In response to CCNPP Unit 3 RAI No. 226, Question 04.02-1 (Reference 1), changes were made to the CCNPP Unit 3 COLA. These changes were also applicable to the BBNPP COLA. The referenced changes were incorporated into the BBNPP COLA Revision 3 and submitted to the U.S. NRC on March 30, 2012 (Reference 2)."

The staff notes that BBNPP COL FSAR Section 4.2, "Fuel System Design," states:

> Pursuant to 10 CFR 52.7 and 10 CFR 52.93, {PPL Bell Bend, LLC} has 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 50, Appendix K, ECCS Evaluation Models, paragraph I.A.5, regarding the use of Zircaloy or ZIRLO as fuel cladding material. The exemption request is consistent with the U.S. EPR design and is related to the proposed use of the M5™ advanced zirconium alloy for the fuel rod cladding and fuel assembly structural material. The exemption request is described in COLA Part 7.

The staff's evaluation of this exemption request is contained in Appendix 4A of this report.

Inspections, Tests, Analyses, and Acceptance Criteria

For COLA, Part 10, Section 2.4, "Site-Specific ITAAC" the staff notes that there were no ITAAC within the scope of BBNPP COL FSAR Chapter 4.

4.5 Post Combined License Activities Nuclear Design

No post COL activities associated with the scope of BBNPP COL FSAR Chapter 4 are contained in the BBNPP COL application.

4.6 Conclusions

The staff reviewed the BBNPP COL application and the referenced U.S. EPR FSAR Tier 2, Chapter 4. The staff confirmed that the BBNPP COL application addressed the required information relating to the reactor internals, control rod drive and core support structural materials, fuel system design (fuel rods and fuel assemblies), the nuclear design, the thermal-hydraulic design, and reactivity control systems functional design and there is no outstanding information expected to be addressed in the BBNPP COL FSAR related to this chapter. The results of the staff's technical evaluation of the information incorporated by reference in the BBNPP COL application, and associated conclusions, are documented in Chapter 4 of the U.S. EPR Design Certification FSER.

In addition, the staff finds the supplemental information presented within the BBNPP COL FSAR acceptable. The staff based its conclusion on the following:

- BBNPP COL Information Item 5.3-4 is acceptable because it is consistent with the U.S. EPR COL Information Item 5.3-4 and provides a plant-specific fluence methodology benchmark to confirm the suitability of the BAW-2241P-A methodology for use at the

BBNPP. **Establishment of a License Condition associated with COL information Item 5.3-4 is being tracked as an open item.**

- The 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, Paragraph I.A.5, regarding the use of Zircaloy or ZIRLO as fuel cladding material is acceptable. The bases for finding the proposed exemption acceptable are contained in Appendix 4A of this report. This conclusion does not relieve the CCNPP3 applicant from the need to address Open Item RAI 226, Question 04.02-1 for the CCNPP3 COL application.

The staff reviewed the information in the U.S EPR FSAR Tier 2, Chapter 4 on Docket No. 52-020. The results of the staff's technical evaluation of the information related to Chapter 4, "Reactor," incorporated by reference in the BBNPP COL FSAR has been documented in the safety evaluation report (SER) on the design certification application for the U.S. EPR. The SER on the U.S. EPR FSAR is not yet complete. Accordingly, **RAI 91, Question 01-3 is being tracked as an open item** as part of this Chapter. The staff will update Chapter 4 of this report to reflect the final disposition of the design certification application.

APPENDIX 4A 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, Paragraph I.A.5, Regarding the use of Zircaloy or ZIRLO as Fuel Cladding Material

4A.1 Introduction

Pursuant to 10 CFR 52.7 and 10 CFR 52.93, PPL Bell Bend, LLC has 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, Paragraph I.A.5, regarding the use of Zircaloy or ZIRLO as fuel cladding material. The exemption request is consistent with the U.S. EPR design and is related to the proposed use of the M5 advanced zirconium alloy for the fuel rod cladding and fuel assembly structural material. The exemption request is described in BBNPP COLA, Part 7.

4A.2 Request for Exemption – Summary of Application

To accommodate the high burnups that are required for fuel management and core designs, AREVA developed the M5 advanced fuel rod cladding and fuel assembly structural material. M5 is an alloy comprised primarily of zirconium (~99 percent) and niobium (~1 percent). The elimination of tin in M5 has resulted in superior corrosion resistance and reduced irradiation-induced growth relative to both standard zircaloy (1.7 percent tin) and low-tin zircaloy (1.2 percent tin). The addition of niobium increases ductility, which is desirable to avoid brittle failures.

The NRC-approved AREVA topical report BAW-10227P-A, "Evaluation of Advanced Cladding and Structural Material (M5) in PWR [pressurized water reactors] Reactor Fuel," February 2000, which describes AREVA M5 fuel designs and provides justification for its use in pressurized-water reactor cores. The staff evaluated the request for exemption of using M5 advanced fuel rod cladding in the Bell Bend combined license application and found that the U.S. EPR has similar neutronic and thermal-hydraulic conditions in the core as that of a typical PWR. Therefore, the staff finds the exemption of using M5 advanced zirconium alloy for the fuel rod cladding acceptable.

4A.3 Regulatory Evaluation

The staff reviewed the BBNPP COL applicant's request for exemption to ensure that operation with M5 clad fuel in the BBNPP core will be within the conditions of operation necessary for application of BAW-10227P-A and that the BBNPP will be operated within its design basis and comply with applicable requirements following implementation of the proposed changes. These include 10 CFR 50.46; General Design Criteria (GDC) 4, GDC 10, GDC 33, GDC 34, and GDC 35; and Standard Review Plan (SRP) Section 4.2.

4A.4 Technical Evaluation

The proposed exemption would allow use of the M5 advanced alloy as a fuel rod cladding and fuel assembly structural material. Specifically, M5 fuel rods with an initial composition of natural or slightly enriched uranium dioxide (UO_2) as fuel material could be used in the BBNPP reactor core.

The approved topical reports BAW-10227P-A, “Evaluation of Advanced Cladding and Structural Material (M5) in PWR Reactor Fuel,” and BAW-10240(P)(A), “Incorporation of M5 Properties in Framatome ANP Approved Methods,” May 5, 2004, evaluates the material properties of the M5 alloy and conclude that M5 properties are similar or better than those of zircaloy-4. BAW-10240(P)(A) listed BAW-10227P-A in the reference and was approved to 62 GWD/MTU in the staff SE.

The BBNPP COL applicant evaluated the performance of the M5 cladding for both LOCA and non-loss-of-coolant accident (LOCA) scenarios. The licensee’s conclusion was that the results with M5 fuel would not be substantially different from the results obtained with only zircaloy in the core. This conclusion is consistent with the conclusions in AREVA topical reports BAW-10227P-A, and BAW-10240(P)(A). Based on the NRC-approved topical reports, the staff concludes that the BBNPP COL applicant may perform analyses to evaluate BBNPP operation with cores containing M5 fuel with its present NRC-approved models adjusted to compensate for the presence of M5 fuel.

4A.5 Post Combined License Activities

There are no post COL activities related to this section.

4A.6 Conclusion

The staff reviewed the BBNPP COL applicant’s request for exemption to permit the use of AREVA’s advanced zirconium-based M5 alloy for fuel design. Based on its evaluation, the staff concludes that the M5 fuel design is acceptable to a peak rod average burnup limit of 62 GWD/MTU in the BBNPP. Based on its evaluation, the staff concludes that the M5 fuel design is acceptable to be used in the U.S. EPR to a peak rod average burnup limit defined in the staff’s safety evaluation report Section 4.2 of the U.S. EPR design certification.