FINAL SAFETY EVALUATION BY THE OFFICE OF NUCLEAR REACTOR REGULATION RELATED

TO AREVA TOPICAL REPORT BAW-10179P, REVISION 9

"SAFETY CRITERIA AND METHODOLOGY FOR ACCEPTABLE CYCLE RELOAD ANALYSES"

PROJECT NO. 728

CAC NO. MF8167

1.0 INTRODUCTION

AREVA Inc. (AREVA) submitted Topical Report (TR) BAW-10179P, Revision 9, "Safety Criteria and Methodology for Acceptable Cycle Reload Analyses," to the U.S, Nuclear Regulatory Commission (NRC) for staff review and approval by letter dated April 15, 2016 (Reference 1). This TR revision provides an update to the methodology that is used to determine plant-specific and cycle-specific parameter operating limits in accordance with NRC Generic Letter (GL) 1988-16, "Removal of Cycle-Specific Parameter Limits from Technical Specifications," specifically for Babcock and Wilcox (B&W) designed 177-Fuel Assembly (FA) nuclear power plants (Reference 2)[1]. In its review, the NRC staff issued a request for additional information (RAI) letter, to which AREVA responded by letter dated March 23, 2017 (Reference 3).

This revision to the TR is a complete, stand-alone revision, similar to the effort undertaken in Revision 7 (Reference 4). Other revisions, including Revision 8, served to append additional material to the TR (Reference 5). In Reference 1, the additional material is incorporated directly into the body of the TR and no appendices exist.

The specific changes made are summarized succinctly on Pages i – ii of the TR. Primarily, the changes are limited to updates that bring the TR more in line with current AREVA editorial style guidance and to correct or update cross-references and inadvertent omissions and inaccuracies. The most substantial change, however, updates the discussion relating to loss-of-coolant accident (LOCA) analysis methods, to incorporate BAW-10192P-A, Revision 0, Supplement 1P, Revision 0 (Reference 6). This report supplement was developed to provide a means to account for the degradation of thermal conductivity in nuclear fuel that occurs as a function of burnup. This phenomenon is not modeled accurately in the TACO3 and GDTACO fuel performance codes, which provide fuel stored energy data used to initialize the emergency core cooling system performance evaluation. The NRC staff issued a final safety evaluation (SE) determining that BAW-10192P-A, Revision 0, Supplement 1P, Revision 0, was approved for use by the NRC by letter to AREVA dated November 2, 2017 (Reference 7).

[1] The TR and the SEs approving prior revisions note that the scope of BAW-10179 has been expanded beyond that originally envisioned in GL 1988-16. However, the principal purpose of the document remains to describe the methods used to generate cycle-specific parameters that have some relevance to plant safety, and thus, some level of regulatory significance that warrants control under the plant Technical Specifications. The present revision does not propose to expand the scope of the document any further.

2.0 REGULATORY BASIS AND REVIEW APPROACH

Generally, Reference 1 is a compendium of NRC-approved methods that are used to determine the plant-specific and cycle-specific parameter operating limits (i.e., reload licensing) for B&W-designed 177-FA nuclear power plants. As such, the TR is largely administrative in nature. Meanwhile, the technical details of each analytic method used in reload licensing are contained in the supporting TRs referenced therein. In addition, the NRC staff positions, including the technical and regulatory bases for determining each referenced TR is acceptable, are contained in the NRC staff SEs approving each of the respective TRs. This consideration reduces the NRC staff review scope of Reference 1 so that the review establishes that all proposed edits reflect mere clarifications, or are otherwise supported by an NRC staff-approved or accepted document.

3.0 TECHNICAL EVALUATION

This evaluation is structured consistently with the content on Pages i – ii of the TR (hereafter, the Change List). The NRC staff review also included an effort to verify, using Revisions 7 and 8 of BAW-10179, that all changes were described in the change listing (References 4 and 5). The NRC staff did not identify any additional changes other than those listed. The NRC staff review identified a general issue, which formed the basis for RAI 1.

In its review, the NRC staff observed that Step 2 of the process delineated on Page 1-5 of Reference 1 appears not to reflect the practice used most recently between the NRC and AREVA in two noteworthy respects. First, the NRC has provided separate SEs approving BAW-10179 revisions and new methodology TRs. In addition, Reference 4 incorporated all material that had previously been included in appendices. Reference 1, presently under review, also incorporates appendices to the main body of the TR. The NRC staff issued RAI 1 to address this issue. In response, AREVA provided revised wording, and committed to include this revised wording in the approved copy of BAW-10179 (Reference 3). The NRC staff reviewed the revised wording and determined that it addresses the issues identified in the RAI. As such, the NRC staff concluded that the response to RAI 1 was acceptable.

3.1 ABSTRACT AND INTRODUCTION

AREVA replaced both the Abstract and the Introduction to reflect the purpose and intent of Reference 1. These updates are administrative in nature and reflect the current revision status; as such, the NRC staff determined that they are acceptable. These changes constitute Items 1 and 2 of the Change List.

3.2 FUEL ASSEMBLY AND FUEL ROD STRESS ANALYSIS CRITERIA

AREVA deleted fuel rods from the stress criteria provided in Section 4.1.2.1, stating that these criteria were covered already in Section 4.2 of the report. The NRC staff confirmed that fuel rods are discussed in this separate section of the TR, and in that respect, the proposed changes are acceptable. This change constitutes Item 3.a of the Change List.

Also in Section 4.1.2.1 of the TR, AREVA added guide tube stress criteria for Conditions III and IV events, stating that such criteria had been inadvertently omitted. AREVA noted that these criteria are contained within Section 3.3 of the main body of BAW-10133PA, “Mark C Fuel Assembly LOCA-Seismic Analyses” (Reference 8). The NRC staff reviewed Section 3.3 of

BAW-10133PA and determined that the discussion in BAW-10179P, Revision 9, is consistent with Section 3.3 of BAW-10133PA in that certain exceptions are provided for guide tubes, which are required to maintain a path for control rod insertion. The NRC staff review concluded that this change is acceptable based on the above consideration. This change constitutes Item 3.b of the Change List.

Stress intensity criteria for Zircaloy components were clarified in Section 4.1.2.1. The NRC staff issued RAI 3 because some language pertaining to allowable stress intensity, contained in Section 4.1.2.1, appeared to introduce less restrictive acceptance criteria specifically for stainless steel and Inconel materials. In the response to RAI 3, AREVA clarified that the specific criteria were applied similarly among Zircaloy, M5, stainless steel, and Inconel. AREVA also proposed revised wording to the TR to reflect this clarification. The NRC staff reviewed the revised pages, which AREVA will include in the NRC-approved copy of the TR, and determined that the concern discussed in RAI 3 was resolved. This change constitutes Item 3.c of the Change list.

Item 3.d is the addition of stress intensity criteria for M5 fuel assembly components. AREVA stated that these are the same criteria as those approved in TR BAW-10227(P)(A), "Evaluation of Advanced Cladding and Structural Material (M5) in PWR Reactor Fuel" (Reference 9). The change specifically identifies the same criteria as being applicable to both Zircaloy and M5. The NRC staff reviewed BAW-10227(P)(A) and determined that while M5 has different correlations to determine minimum yield stress and ultimate stress, the criteria were unchanged from those used for Zircaloy. Thus, the NRC staff confirmed, based on its review, that these stress intensity criteria are applicable to M5. Based on this consideration, the NRC staff determined that this proposed change was acceptable.

3.3 HOLD-DOWN ANALYSIS CRITERIA

AREVA proposes to modify the hold-down analysis criteria for consistency with the response to RAI 6 associated with the BAW-10179, Revision 0, review (Reference 10). The only change is to broaden a design requirement, formerly applicable to Condition I events, so that it now applies to both Condition I and II events. Specifically, the TR now requires that the hold-down spring system shall be capable of maintaining fuel assembly contact with the lower support plate during Condition I and II events. Condition II events, more commonly considered as anticipated operational occurrences, are more severe than Condition I events, such that this change is more restrictive. The NRC staff understands, however, that in practice AREVA performs hold-down analyses consistent with the RAI 6 for Revision 0 of BAW-10179, such that this change is editorial. Based on these considerations, the NRC staff determined that the modification to the hold-down analysis criteria was acceptable. This constitutes Item 4 on the Change List.

3.4 LOSS-OF-COOLANT ACCIDENT ANALYSIS METHOD

AREVA revised the grid strength definition provided in Section 4.1.9.2 of the TR. In its review, the NRC staff observed that the proposed changes appeared to delete an existing requirement, and issued RAI 4 to obtain clarifying information. In its response, AREVA clarified that existing language in prior revisions of BAW-10179 could have been misinterpreted relative to what is defined in the source TR (BAW-10133PA, Revision 1) and that the modified language improves consistency with existing NRC-approved grid strength definitions (Reference 8). Based on AREVA's confirmation that the intent of the TR is to reference the BAW-10133PA without

alteration, the NRC staff determined that the concern expressed in RAI 4 was resolved and that the modified wording is acceptable. This change constitutes Item 5 on the Change List.

3.5 FUEL ROD STRESS ANALYSIS CRITERIA

AREVA made further changes to the Fuel Rod Stress Analysis Criteria contained in Section 4.2.5.1. AREVA separated Conditions I & II and Conditions III & IV stress criteria for fuel rod cladding and revised the Conditions III & IV stress criteria, citing Section 4.7 of the SE approving BAW-10227P-A (Reference 9). These changes constitute Items 6.a, and 6.b of the Change List. The NRC staff was unable to determine that these changes are acceptable as set forth in the Change List. RAI 2 was issued to address these changes.

The NRC staff identified an issue, in that some proposed revisions to the Stress Analysis Criteria discussed in Section 4.2.5.1 of the TR appeared inconsistent with the NRC approval of prior methodologies, and with the event classification scheme provided in American National Standards Institute/American Nuclear Society 57.5, "Light Water Reactors Fuel Assembly Mechanical Design and Evaluation," which is referenced in Section 2 of the TR. In the response to RAI 2, AREVA proposed to modify the revised text to provide consistency with previously approved AREVA TRs. AREVA provided references to the specific NRC approvals, and revised pages of Reference 1, which will be included in the NRC-approved version of the TR. The NRC staff reviewed the cited NRC approvals and revised TR pages and determined that the apparent inconsistency identified by the NRC staff had been resolved. Based on this consideration, the NRC staff concluded that the response to RAI 2 was acceptable, as are the proposed changes to Items 6.a and 6.b of the Change List.

3.6 FUEL ROD STRAIN ANALYSIS METHOD

AREVA proposed to revise Section 4.2.6.2 of the TR to reflect that TACO3, GDTACO, and COPERNIC have different cladding strain definitions (References 11, 12, 13). The NRC staff reviewed the proposed change and determined that it does not alter any computational methods, and merely introduces information already contained in NRC-approved TRs. Therefore, the NRC staff determined that the change is acceptable. This change constitutes Item 7 on the Change List.

3.7 FUEL ROD PRESSURE

AREVA revised Section 4.2.8.2 to clarify the different burnup limits that apply when using either TACO3 and GDTACO, or COPERNIC. This change introduces the burnup limits applicable for the COPERNIC code, which were previously not mentioned in the TR. The NRC staff determined that this revision is appropriate since it clarifies burnup limits appropriate for the COPERNIC code, which are different from those established for TACO3 and GDTACO. This constitutes Item 8 on the Change List.

3.8 FCT LIMIT ANALYSIS CRITERIA

This section of the TR was revised to distinguish between melt temperatures of uranium oxide (UO_2) and gadolinia. Previously, the criteria stated simply that maximum fuel temperature must be less than the melting temperature of UO_2. Including the allowance for gadolinia is appropriate, because gadolinia has a different melting temperature than UO_2. This constitutes Item 9 on the Change List.

3.9 FCT LIMIT ANALYSIS METHOD

The analysis method was revised to incorporate COPERNIC-specific burnup limits, and to allow for the calculation of **[ ]**. Previously, the TR had stated that the **[ ]**. In response to RAI 5, AREVA clarified that the changed language reflects a more modern understanding of fuel cycle behavior, yet remains consistent with the original approval of Reference 10. Based on this clarification, the NRC staff determined that the RAI response was acceptable, as was the proposed change to Section 4.2.9.2 of the TR. This constitutes Item 10 on the Change List.

3.10 CORE THERMAL HYDRAULIC DESIGN CRITERIA

AREVA revised the second paragraph of Section 6.1, regarding the hold-down criterion for core thermal hydraulic design. Previously, the hold-down capability of the fuel assembly was characterized using the term “gravity” but is now characterized using the term “weight”. In addition, the prior capability requirement related to normal operation, which AREVA has clarified to mean during Condition I and II events. These changes are both editorial. In particular, the change to Condition I and II events has the effect of clarifying that conditions of normal operation *include anticipated operational occurrences*, which is phrasing common for the NRC’s general design criteria. The change is also consistent with the response to RAI 6, associated with the review of Reference 10. In that RAI response, AREVA provided similar clarifying information. Based on the clarifying nature of these changes, the NRC staff determined that they were acceptable. This constitutes Item 11 on the Change List.

3.11 LOSS-OF-COOLANT ACCIDENT EVALUATION

AREVA revised Chapter 9 of the TR, which describes the LOCA evaluation. Changes to this section were made to incorporate a new supplement to BWNT LOCA (BAW-10192P-A, Revision 0, Supplement 1P, Revision 0). The new supplement describes updated methods that are used to account for nuclear fuel thermal conductivity degradation as a function of fuel burnup. The NRC staff approved the supplement by letter dated November 2, 2017 (Reference 7). Since the supplement is approved for use by the NRC, the NRC staff determined that its inclusion in Reference 1 is acceptable. This constitutes Item 12 on the Change List.

3.12 RECONSTITUTED FUEL ASSEMBLIES

During the NRC staff review of Reference 1, AREVA submitted a letter to the NRC staff requesting clarification of the NRC staff interpretation of its approval of BAW-2149A, “Evaluation of Replacement Rods in BWFC [Babcock and Wilcox Fuels Company] Fuel Assemblies” (References 14 and 15). Specifically, AREVA requested that the NRC clarify whether its approval of BAW-2149A applied to fresh fuel assemblies containing stainless steel replacement rods. The NRC issued a letter to AREVA dated February 1, 2017, indicating that the NRC staff approval of BAW-2149 applies to fresh fuel assemblies (Reference 16). The RAI response letter included changes to Reference 1 to reflect the clarified NRC staff position and incorporate references to the NRC staff letter. Based on the consistency of these revisions with Reference 16, the NRC staff determined that these changes are acceptable.

4.0 CONCLUSION

Based on the review described above, the NRC staff determined that Reference 1 is acceptable. Revision 9 of BAW-10179P is approved for referencing by the NRC.

5.0 REFERENCES

1. AREVA Inc., BAW-10179P, Revision 9, "Safety Criteria and Methodology for Acceptable Cycle Reload Analyses," April 15, 2016 (Agencywide Documents Access and Management System (ADAMS) Accession No. ML16106A285).

2. NRC Generic Letter 1988-16, "Removal of Cycle-Specific Parameter Limits from Technical Specifications," October 4, 1988 (ADAMS Accession No. ML031200485).

3. AREVA Inc., "Response to Request for Additional Information Regarding BAW-10179P Revision 9, 'Safety Criteria and Methodology for Acceptable Cycle Reload Analyses,'" March 23, 2017 (ADAMS Accession No. ML17088A723).

4. AREVA Inc., BAW-10179P-A, Revision 7, "Safety Criteria and Methodology for Acceptable Cycle Reload Analyses," May 13, 2008 (ADAMS Accession No. ML081430520).

5. AREVA Inc., BAW-10179P-A, Revision 8, "Safety Criteria and Methodology for Acceptable Cycle Reload Analyses," August 6, 2010 (ADAMS Accession No. ML102210446).

6. AREVA Inc., BAW-10192PA-00, Supplement 1P, Revision 0, "BWNT LOCA: BWNT Loss-of-Coolant Accident Evaluation Model for Once-Through Steam Generator Plants," November 25, 2015 (ADAMS Accession No. ML15337A257).

7. Final Safety Evaluation for Topical Report BAW-10192PA-00, Supplement 1, Revision 0, "BWNT LOCA – BWNT Loss-of-Coolant Accident Evaluation Model for Once-Through Steam Generator Plants," November 2, 2017 (ADAMS Accession No. ML17264B086).

8. Babcock and Wilcox, A McDermott Company, BAW-10133PA, Revision 1, "Mark C Fuel Assembly LOCA-Seismic Analyses," June 1986. Proprietary document is not located in ADAMS.

9. Framatome Cogema Fuels, BAW-10227(P)(A), Revision 1, "Evaluation of Advanced Cladding and Structural Material (M5) in PWR Reactor Fuel," April 19, 2004, (ADAMS Accession No. ML15162B043) ADAMS package does not contain a publicly available copy of the report.

10. Babcock and Wilcox Fuel Company, BAW-10179P-A, Revision 0, "Safety Criteria and Methodology for Acceptable Cycle Reload Analyses," August 1993. Proprietary document is not located in ADAMS.

11. Babcock and Wilcox Nuclear Technologies, BAW-10162P-A, "TACO3 – Fuel Pin Thermal Analysis Computer Code," December 13, 1989 (ADAMS Accession No. ML15040A369). Complete document and publicly available version were not found in ADAMS.

12. Babcock and Wilcox Nuclear Technologies, BAW-10184P-A, "GDTACO – Urania Gadolinia Fuel Pin Thermal Analysis Code," February 1995, (ADAMS Accession No. ML15028A446) (Proprietary report; no non-proprietary version available).

13. Framatome ANP, Inc., BAW-10231(P)(A), Revision 1, "COPERNIC Fuel Rod Design Computer Code," September 30, 2004 (ADAMS Accession No. ML042930233).

14. Peters, Gary, AREVA, Inc., letter to U.S. NRC, "Request for NRC Concurrence Regarding the Applicability of Topical Report BAW-2149A 'Evaluation of Replacement Rods in BWFC Fuel Assemblies' to Cores Containing Fresh Fuel Assemblies With Stainless Steel Rods," July 7, 2016 (ADAMS Accession No. ML16193A060).

15. Babcock and Wilcox Owners Group, BAW-2149A, "Evaluation of Replacement Rods in BWFC Fuel Assemblies," October 22, 1993 (ADAMS Accession No. ML16252A435). Publicly available version was not located in ADAMS.

16. Kevin Hsueh, U.S. NRC, letter to Gary Peters, AREVA, Inc., "Request for U. S. Nuclear Regulatory Commission Concurrence Regarding the Applicability of Topical Report BAW-2149A, 'Evaluation of Replacement Rods in BWFC Fuel Assemblies', to Cores Containing Fresh Fuel Assemblies with Stainless Steel Rods," February 1, 2017 (ADAMS Accession No. ML16357A669).

Attachment: Resolution of Comments

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