FINAL SAFETY EVALUATION FOR

TOPICAL REPORT WCAP-16500-P/WCAP-16500-NP, SUPPLEMENT 2,

"EVOLUTIONARY DESIGN CHANGES TO CE 16X16 NEXT GENERATION FUEL AND

METHOD FOR ADDRESSING THE EFFECTS OF END-OF-LIFE PROPERTIES ON SEISMIC

AND LOSS-OF-COOLANT-ACCIDENT ANALYSES"

WESTINGHOUSE ELECTRIC COMPANY

PROJECT NO. 700

1.0 INTRODUCTION AND BACKGROUND

1.1 Introduction

By letter dated November 12, 2014 (Reference 1), Westinghouse Electric Company (Westinghouse) submitted for U.S. Nuclear Regulatory Commission (NRC) staff review of Topical Report (TR) Supplement 2 to WCAP-16500-P/WCAP-16500-NP, "Evolutionary Design Changes to CE 16X16 Next Generation Fuel and Method for Addressing the Effects of End-of-Life Properties on Seismic and Loss of Coolant Accident Analyses" (Reference 2). This TR describes three evolutionary design changes to mid and intermediate flow-mixing (IFM) spacer grids. Upon submittal, this TR also described an approach to address NRC Information Notice (IN) 2012-09, "Irradiation Effects on Fuel Assembly Spacer Grid Crush Strength," (Reference 3). However, by letter LTR-NRC-16-7 dated February 24, 2016 (Reference 4), Westinghouse requested that the approach to address IN 2012-09 be excluded from the regulatory review.

1.2 Background of Combustion Engineering 16x16 Next Generation Fuel

WCAP-16500-P-A/WCAP-16500-NP-A, (Reference 5), describes the Combustion Engineering (CE) 16x16 Next Generation Fuel (NGF) design. Previously licensed reload methodologies and an approved mechanical design methodology were used to demonstrate compliance to NUREG-0800, "Standard Review Plan for the Review of Safety Analysis Reports for Nuclear Power Plants" (SRP) Section 4.2 (Reference 6) and subsequently the applicable General Design Criteria (GDC). The NRC staff's review of WCAP-16500-P and Supplement 1 to WCAP-16500-P-A/WCAP-16500-NP-A was to ensure that the reload and fuel mechanical design methodologies referenced remain applicable to the CE 16x16 NGF design and adequately address the applicable regulatory requirements identified in SRP 4.2. Additionally, based upon lead test assemblies, post-irradiation examinations, mechanical testing, past operating experience of similar designs and materials, and fuel performance model predictions, the NRC staff reviewed expected performance of the CE 16x16 NGF assembly to ensure it satisfied these requirements. Upon completion of the review, the NRC staff found the CE 16x16 NGF assembly design, fuel design criteria, and supporting fuel mechanical and reload design methodology acceptable, subject to the 10 conditions and limitations in the associated safety evaluation (SE).

WCAP-16500-P-A, Supplement 1, Revision 1 (Reference 7) addressed deficiencies in the CE digital set-point methodology and requested removal of the imposed departure from nucleate boiling (DNB) margin penalty in WCAP-16500-P-A/WCAP-16500-NP-A Condition #5. The NRC staff's review of Supplement 1, Revision 1, included an audit of the supporting Westinghouse calculations and concluded that the DNB margin penalty of six percent was no longer necessary.

The topic of this SE, Supplement 2, introduces three evolutionary design changes for spacer grids that can improve grid to rod fretting (GTRF) margin, reduce locally concentrated crud deposition, and improve the spacer grid strap fabrication process. Additionally, an approach to address the concerns outlined in IN 2012-09 was described, but later excluded from the review.

2.0 REGULATORY EVALUATION

Title 10 of the *Code of Federal Regulations* (10 CFR), Part 50, governs the domestic licensing of nuclear production and utilization facilities. Appendix A of 10 CFR Part 50 lists the GDC that must be followed for nuclear power plants. The following is a partial list of GDC applicable to Supplement 2:

2. Structures, systems, and components important to safety shall be designed to withstand the effects of natural phenomena such as earthquakes, tornadoes, hurricanes, floods, tsunami, and seiches without loss of capability to perform their safety functions.

10. The reactor core and associated coolant, control, and protection systems shall be designed with appropriate margin to assure that specified acceptable fuel design limits are not exceeded during any condition of normal operation, including the effects of anticipated operational occurrences.

27. The reactivity control systems shall be designed to have a combined capability, in conjunction with poison addition by the emergency core cooling system, of reliably controlling reactivity changes to assure that under postulated accident conditions and with appropriate margin for stuck rods the capability to cool the core is maintained.

35. A system to provide abundant emergency core cooling shall be provided. The system safety function shall be to transfer heat from the reactor core following any loss of reactor coolant at a rate such that (1) fuel and clad damage that could interfere with continued effective core cooling is prevented and (2) clad metal-water reaction is limited to negligible amounts. …

Regulatory guidance for the review of fuel system designs and adherence to applicable GDCs is provided in SRP, Section 4.2, "Fuel System Design." In accordance with SRP Section 4.2, the objectives of the fuel system safety review are to provide assurance that:

a. The fuel system is not damaged as a result of normal operation and anticipated operational occurrences.

b. Fuel system damage is never so severe as to prevent control rod insertion when it is required.

c. The number of fuel rod failures is not underestimated for postulated accidents, and

d. Coolability is always maintained.

3.0 TECHNICAL EVALUATION

The following NRC staff review focusses on the topics presented by WCAP-16500-P/NP, Supplement 2, and the associated request for additional information (RAI) responses (Reference 8). The NRC staff's objectives for review of Supplement 2 to WCAP-16500-P/WCAP-16500-NP, have been established based on the topics presented in the supplement and the regulatory evaluation in Section 2.0 of this SE. They are summarized below:

- Verify that proposed changes to CE 16x16 NGF spacer grid designs do not adversely affect their ability to satisfy the acceptance criteria identified in SRP Section 4.2.
- Verify that any changes to previously approved methodologies are acceptable and justified.

3.1 Design Changes to CE 16x16 NGF Spacer Grids

Three evolutionary design changes to mid and IFM spacer grids are presented in the Supplement 2 to WCAP-16500-P/WCAP-16500-NP. These changes consist of modified outer straps (MOS), additional outer strap tabs (OST), and **[ ]**

3.1.1 Modified Outer Straps

Post-irradiation examination (PIE) of the current CE 16x16 NGF design performed by Westinghouse has shown that outer strap dimples are the limiting feature with respect to GTRF margin. The current mid grid design alternates springs and dimples on the outer strap for each fuel rod. The proposed design change replaces the dimples on the outer strap with springs. Consequently, to maintain a spring-opposing-dimple configuration, the outermost inner grid strap must also be modified for the affected cells. Replacing the springs of these cells with dimples creates "double-dimple" cells in these locations.

PIE of test assemblies for the original CE 16x16 NGF design demonstrates superior GTRF performance of the outer strap springs which were incorporated at all locations on the outer strap of the MOS design. However, the effects of the modifications to the outermost inner grid straps on GTRF performance required additional testing. Therefore, Westinghouse performed an experiment in their Vibration Investigation and Pressure-drop Experimental Research (VIPER) loop to examine the effects of double dimple cells on GTRF margin in those areas. Westinghouse concluded that double dimple cells do not reduce GTRF margin, and overall GTRF margin for the MOS design change is improved.

An RAI was issued regarding the methods and results of the VIPER loop tests to verify the conclusion that GTRF margin is not reduced in the areas surrounding double dimple cells since the testing procedure and results were not explained in detail in the TR. The staff concern was that two adjacent fuel pins may be more rigidly held against the same section of grid strap via dimples. Vibration or oscillation at different rates or in different directions of the fuel pins could potentially cause damage to one or both due to interaction across the more rigid connection (the double dimples).

In response to the RAI, Westinghouse explained the consistency between the relative wear from the VIPER tests and that from designs with reactor experience. Based on these similarities, the NRC staff expects that the VIPER loop demonstrates GTRF effects adequately for use in this investigation of double dimple effects. It was stated that wear depth for a given spacer grid depends on the contact surface geometry and that double dimple cells maintain the same combination of contact points between the grids and the rods. Westinghouse confirmed that the wear observed in the outermost inner grid strap locations for the new design was largely similar to the wear seen for the original design in these locations. Therefore, the NRC staff agrees with the determination made by Westinghouse that the GTRF margin is not reduced in the areas surrounding the double dimple cells.

An RAI was issued regarding changes in grid loss coefficients, pressure drop, and flow distribution as a result of the MOS change. In response, Westinghouse indicated that mechanical and thermal hydraulic (TH) effects of the MOS changes are minimal and are accounted for explicitly in the licensed methodologies. They indicated that **[**

] Additionally, the inlet geometry is unchanged and, therefore, no impact on inlet flow distribution is observed.

The design criteria and methodologies licensed in CENPD-178-P (Reference 9), WCAP-16500-P-A/WCAP-16500-NP-A, and the associated supporting supplements remain applicable with no modifications necessitated by the MOS change. These facts, combined with the overall improvement in GTRF margin shown through PIE and the VIPER loop tests, ensure that the design is not adversely affected and it continues to satisfy the acceptance criteria for fuel system damage identified in SRP Section 4.2. Therefore, the NRC staff finds the MOS design change acceptable.

3.1.2 Additional Outer Strap Tabs

PIE of the CE 16x16 NGF design also showed that the heaviest crud deposition occurred on the rods adjacent to the locations where lead-in tabs are omitted in the current mid and IFM grid designs. The omitted lead-in tab locations in the current design are in the center, between pins 8 and 9, at the top and bottom edges of the grid outer straps. Computational Fluid Dynamics (CFD) modelling performed by Westinghouse also suggests that TH conditions in these locations promote crud deposition. The proposed design change adds a lead-in tab to each of the missing locations on the top and bottom of the grids. For mid grid applications, a small amount of supporting material for the lead-in tabs must be added to the corresponding center strap to be consistent with the rest of the grid. The center straps of the IFM grids do not require this supporting material since they are already consistent with the other straps throughout the grid.

The OST change introduces certain TH effects that impact some of the design bases addressed in WCAP-16500-P-A/WCAP-16500-NP-A. Specifically, a small increase in grid loss coefficients is seen relative to the original NGF grids, though Westinghouse states that this increase has no impact on the overall grid or fuel assembly pressure drop. Additionally, a small change in flow distribution within the fuel assembly and between fuel assemblies in mixed assembly cores is seen due to the additional outer strap tab (OST) change. These TH effects are explicitly accounted for in the licensed methodologies used to demonstrate compliance with the acceptable design criteria.

The design criteria and methodologies established in CENPD-178-P, WCAP-16500-P-A/WCAP-16500-NP-A and the associated supporting supplements remain applicable with no modifications necessitated by the OST change. Additionally, the GTRF performance is not expected to be affected as a result of the OST change because the rod support features and materials remain unchanged by OST. These facts, combined with the predicted decrease in crud deposition, ensure that the design is not adversely affected and that it continues to satisfy the acceptance criteria for fuel system damage identified in SRP Section 4.2. Therefore, the NRC staff finds the OST design change acceptable.

3.1.3 [ ]

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3.1.4 Conclusion on Spacer Grid Design Changes

The three design changes presented, MOS, OST, and **[ ]** have each been found acceptable by NRC staff on the bases that: (1) any changes or combination of changes will be analyzed and explicitly accounted for according to approved licensed methodologies, (2) the overall design is not expected to be adversely affected and is expected to continue to satisfy the acceptance criteria identified in SRP Section 4.2, and (3) no new methodologies or design criteria are necessary to accommodate the proposed design changes. The only imposed restriction on implementation of the three changes is that **[ ]** may only be used if MOS is concurrently applied, except for application to IFM grids for which the MOS change is not applicable.

3.2 Information Notice 2012-09

IN 2012-09 was issued by NRC staff to inform addressees of operating experience involving evaluations of fuel assembly structural response to external loads and associated issues the NRC staff identified during reviews of fuel designs for design certification applications. Operating experience regarding the effects of in-reactor service on fuel assembly component response to externally applied forces challenged existing NRC staff guidance.

Supplement 2 to WCAP-16500-P/WCAP-16500-NP, detailed an approach to address the issue presented by IN 2012-09. Westinghouse intended to use the seismic, vibration, and mechanical testing procedures currently approved in CENPD-178-P for CE fuel with some modifications to address the issue detailed in IN 2012-09.

Three major modifications and two minor modifications to the approved seismic/LOCA testing and analysis methodology were presented. The major modifications consisted of simulating end of life (EOL) conditions with “gapped” spacers, crediting flowing water damping instead of still water damping, and modifying coolability testing and analyses to use “maximum credible deformation” in place of “maximum hypothetical deformation.” The less significant modifications were related to forced-vibration testing. They consisted of changing the shaker from hydraulic to electro-mechanical and exciting the test section from the center rather than the lower end. A number of RAIs were issued regarding these changes and RAI responses were received.

Westinghouse requested that the approach to address IN 2012-09 be excluded from the regulatory review. Therefore, the NRC staff has not reviewed these changes or the associated RAI responses and no determination of acceptability regarding these changes or the associated RAI responses has been made.

4.0 <u>LIMITATIONS AND CONDITIONS</u>

Use of WCAP-16500-P-A/WCAP-16500-NP-A, Supplement 2, for licensing actions is subject to the following conditions and limitations:

1. CE 16x16 NGF spacer grids **[ ]** must also apply the Modified Outer Strap (MOS) design change. Intermediate Flow-Mixing (IFM) grids for which the MOS design change is not applicable may **[ ]** since the **[ ]** do not challenge any safety analyses or design criterion.

2. Any changes or combinations of changes approved in this safety evaluation shall be analyzed and explicitly accounted for according to approved licensed methodologies prior to implementation.

3. Licensees may not reference the proposed approach to address IN 2012-09 detailed in the Supplement 2 to WCAP-16500-P/WCAP-16500-NP submittal as this approach has not been reviewed or approved by the NRC staff.

5.0 CONCLUSION

Based on the review of the material presented in the Supplement 2 to WCAP-16500-P/WCAP-16500-NP, and responses to RAIs, the NRC staff concludes the following:

The NRC staff finds the proposed physical changes to CE 16x16 NGF mid and IFM grids acceptable, provided that the conditions specified in Section 4.0 of this safety evaluation are met. This determination has been made on the bases that: (1) any change or combination of changes will be analyzed and the results explicitly accounted for in the licensed methodologies, (2) the overall design is not expected to be adversely affected and is expected to continue to satisfy the regulatory criteria identified in SRP Section 4.2, and (3) no new methodologies or design criteria are necessary to accommodate the proposed design changes.

By Westinghouse request, the proposed approach to address IN 2012-09 has not been reviewed by NRC staff and no determination regarding its acceptability has been made.

6.0 REFERENCES

1. Letter from J. A. Gresham (W) to U.S. Nuclear Regulatory Commission, “Submittal of WCAP-16500-P, Supplement 2, and WCAP-16500-NP, Supplement 2, "Evolutionary Design Changes to CE 16x16 Next Generation Fuel and Method for Addressing the Effects of End-of-Life Properties on Seismic and Loss of Coolant Accident Analyses," LTR-NRC-14-73, November 12, 2014 (Agencywide Documents Access and Management System (ADAMS) Accession No. ML14324A015).

2. WCAP-16500-P, Supplement 2, “Evolutionary Design Changes to CE 16x16 Next Generation Fuel and Method for Addressing the Effects of End-of-Life Properties on Seismic and Loss of Coolant Accident Analyses,” November 2014 (ADAMS Accession No. ML14324A016).

3. NRC Information Notice 2012-09, "Irradiation Effects on Fuel Assembly Spacer Grid Crush Strength," June 28, 2012 (ADAMS Accession No. ML113470490).

4. LTR-NRC-16-7, “Change to Scope of Review for Topical Report WCAP-16500-P, Supplement 2 and WCAP-16500-NP, Supplement 2,” February 2016 (ADAMS Accession No. ML16057A813).

5. WCAP-16500-P-A, "CE 16x16 Next Generation Fuel Core Reference Report," September 2007 (ADAMS Accession No. ML072500357).

6. NUREG-0800, “Standard Review Plan,” Revision 3, Section 4.2, March 2007 (ADAMS Accession No. ML070740002).

7. WCAP-16500-P-A, Supplement 1, Revision 1, "Application of CE Setpoint Methodology for CE 16x16 Next Generation Fuel (NGF)," December 2010 (ADAMS Accession No. ML103510190).

8. LTR-NRC-15-93, "Responses to the Requests for Additional Information Received on WCAP-16500-P Supplement 2/WCAP-16500-NP, Supplement 2, "Evolutionary Design Changes to CE 16x16 Next Generation Fuel and Method for Addressing the Effects of End-of-Life Properties on Seismic and Loss of coolant Accident Analyses," November 2015 (ADAMS Accession No. ML15316A551).

9. CENPD-178-P, Revision 1-P, "Structural Analysis of Fuel Assemblies for Seismic and Loss of Coolant Accident Loading," August 1981 (ADAMS Accession No. ML14122A087).

Attachment 1: Resolution of Comments

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