FINAL SAFETY EVALUATION BY THE OFFICE OF NUCLEAR REACTOR REGULATION

WCAP-10965-P, ADDENDUM 2/WCAP-10966-A, ADDENDUM 2, "QUALIFICATION OF THE NEW PIN POWER RECOVERY METHODOLOGY"

WESTINGHOUSE ELECTRIC COMPANY

PROJECT NO. 700

1.0 INTRODUCTION AND BACKGROUND

By letter dated June 1, 2009, the Westinghouse Electric Company (Westinghouse) submitted Topical Report (TR) WCAP-10965-P-A, Addendum 2/WCAP-10966-A, Addendum 2, "Qualification of the New Pin Power Recovery Methodology" (Reference 1), to the U.S. Nuclear Regulatory Commission (NRC) for review and approval. The objective of the TR is to provide the necessary information that will allow the use of the Westinghouse Advanced Nodal Computer Code (ANC) to perform three-dimensional explicit pin-by-pin calculations that will account for history effects associated with control rod motion (References 2 and 3). Traditional pressurized-water reactors (PWRs) operate without significant insertion of control rod banks. The advent of new PWR core designs, wherein some control rod insertion is a typical mode of operation, has presented the likelihood of introducing significant heterogeneities, the cumulative effect of which will not be captured in fuel pin powers using conventional pin power methodology. To remedy these deficiencies of the conventional methodology of pin power reconstruction in ANC, the new methodology is introduced that follows the history of each individual fuel pin in ANC, and computes the fuel pin macroscopic cross-sections based on the fuel pin history and the local spectrum.

The efficacy of the new methodology for pin power recovery with the ANC code is critically dependent on the capabilities and results of the codes PARAGON (Reference 4) and NEXUS (Reference 5). The former is a Westinghouse lattice code; a stand-alone neutron transport code whose solution algorithm is based on the collision probability method. In addition to serving as a stand-alone lattice physics code, it is also, as in the case of the new methodology for pin power recovery in ANC, a cross section generation tool. The latter code NEXUS parameterizes cross sections calculated by the lattice code for input to ANC. It is this capability that is a key to the new methodology for pin power reconstruction.

2.0 REGULATORY EVALUATION

Section 50.34 of Title 10 of the *Code of Federal Regulations* requires applicants to provide safety analysis reports to the NRC detailing the performance of structures, systems, and components provided for the prevention or mitigation of potential accidents. Westinghouse is seeking a review and approval of the WCAP-10965-P, Addendum 2/WCAP-10966-A, Addendum 2, TR in order to replace the existing methodology of pin power reconstruction in ANC with the new pin power recovery methodology.

3.0 TECHNICAL EVALUATION

3.1 Summary of the WCAP-10965-P, Addendum 2/WCAP-10966-A, Addendum 2, "Qualification of the New Pin Power Recovery Methodology" Topical Report

The conventional methodology for reconstruction of the k-th pin power consists of the summation over energy groups of the product of three terms: the energy release per fission times the macroscopic fission cross section for the g-th energy group homogenized over the fuel assembly; the value of the g-th group flux at the k-th pin location of the smooth assembly flux; and a g-th group pin factor that captures the heterogeneity of the individual pins and is based on pre-calculated fine-mesh PARAGON assembly calculations. Due to the assembly-wide homogenization of the cross sections, this methodology is limited in predicting the depletion history of the individual fuel pin, especially in strongly heterogeneous compositions associated with the repeated insertion of control rods.

To overcome some of these shortcomings of the conventional methodology, the new methodology **[**

] The NRC staff requested the analytic expressions for computing **[** **]** based on the values of PARAGON lattice calculations and the NEXUS cross section parameterization as RAIs in Reference 6. Westinghouse responded by describing the **[**

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3.2 Qualification of the New Pin Power Recovery Methodology

The qualification of the new pin power reconstruction methodology, as implemented in ANC, has been demonstrated by comparing pin powers computed for a single assembly to those of higher-order calculations with the pin-by-pin transport theory lattice code PARAGON at identical operating conditions. These conditions encompass a wide range of control rod insertion and withdrawal scenarios that envelope anticipated core operating histories. For these calculations the 17X17 Westinghouse fuel assembly with 4.95 w/o ^{235}U is assumed, and burnups to a fuel rod average of 62 GWD/MTU.

In addition to these single assembly calculations, a comparison is made of computed pin powers for unrodded full-core PWR simulations using ANC with the conventional and the new pin power recovery methodologies.

3.2.1.1 Single Assembly Model Calculations with Non-Burnable Absorber

The ANC computed pin power based on the new pin power recovery methodology has been qualified in the context of a standard 17X17 Westinghouse fuel assembly without a burnable absorber over a range of fuel enrichments up to 4.95 w/o ^{235}U and burnup histories up to 70 GWD/MTU. Four control rod histories were simulated for the ANC testing, with the new pin power recovery methodology, under severe heterogeneity changes in the fuel assembly. The reconstructed pin-by-pin power ANC results were compared to the PARAGON calculated pin-by-pin power results. Comparisons were made of the corner pin power, of the pin (5,4) power, of the limiting pin power, and the average pin power. The agreement is excellent and typically within **[ ]** and usually within **[ ]** at high burnups.

3.2.1.2 Single Assembly Model Calculations with Burnable Absorber

The ANC computed pin power based on the new pin power recovery methodology has been also qualified with regard to Burnable Absorbers with simulations under several control rod insertion scenarios. These BAs included Integral Fuel Burnable Absorbers, Wet Annular Burnable Absorbers and gadolinia pins. The results again show that the limiting pin discrepancy between the ANC nodal calculations with the new pin power recovery methodology versus PARAGON pin-by-pin power results is within **[ ]** for most of the burnup range, and remains mostly within **[ ]** at high burnups.

3.2.2 Pressurized-Water Reactor Core Power Calculations for Unrodded Cores

A direct comparison of the ANC computed results between the new and the conventional pin power recovery methodologies was made in the context of traditional unrodded PWR core simulations. For this purpose, a model for a traditional 4-loop plant without control rod insertion was generated and the pin powers computed based on the new pin power recovery methodology. These were compared to calculations of the pin powers of the same core model using the conventional pin power recovery methodology. The comparisons showed differences of **[ ]** for core peaking factors F_Q, $F_{\Delta H}$ and F_Z over the cycle, and thereby demonstrated good consistency between the two methodologies. Moreover, the new methodology predicted systematically slightly lower peaks for the peripheral assemblies, as would be expected. This is consistent with the single assembly results that demonstrated the ability of the new pin power recovery methodology to take into account the effect of the pin burnup tilt in the peripheral assemblies.

4.0 LIMITATIONS AND CONDITIONS

Westinghouse has provided a series of simulations to demonstrate the performance of the ANC code with the new pin power recovery methodology for control rod histories that exacerbate heterogeneous environments. These calculations confirm that the new pin power methodology is accurate for both unrodded and rodded pin power predictions. Pin power histories computed with the ANC code, as presented in this safety evaluation, are dependent on the results of the NRC approved codes PARAGON (Reference 4) and NEXUS (Reference 5). Thus, the use of

ANC with the new pin power recovery methodology described in the WCAP-10965-P-A, Addendum 2/WCAP-10966-A, Addendum 2, TR in licensing applications requires the concomitant application of the NRC approved lattice code PARAGON and the NRC approved cross section parameterization and reconstruction methodology of the NEXUS code system.

5.0 CONCLUSION

The NRC staff has reviewed the TR submitted by Westinghouse and determined that WCAP-10965-P, Addendum 2/WCAP-10966-A, Addendum 2, is an adequate enhancement to replace the pin power recovery methodologies of NRC-approved methodologies WCAP-10965-P-A, (Reference 2), and where appropriate of WCAP-10965-P-A, Addendum 1, (Reference 3).

6.0 REFERENCES

1. Letter from Gresham, J. A. (Westinghouse) to U.S. Nuclear Regulatory Commission, “Submittal of WCAP-10965-P-A, Addendum 2/WCAP-10966-A, Addendum 2, ‘Qualification of the New Pin Power Recovery Methodology’,” June 1, 2009. (ADAMS Accession No. ML091560106)

2. WCAP-10965-P-A, “ANC – A Westinghouse Advanced Nodal Computer Code,” Westinghouse Electric Company, September 1986.

3. WCAP-10965-P-A, Addendum 1, “ANC – A Westinghouse Advanced Nodal Computer Code: Enhancements to ANC Rod Power Recovery,” Westinghouse Electric Company, April 1989.

4. WCAP-16045-P-A/WCAP-16045-NP-A, “Qualification of the Two-Dimensional Transport Code PARAGON,” August 2004. (ADAMS Accession No. ML042250311)

5. WCAP-16045-P-A, Addendum 1-A/WCAP-16045-NP-A, Addendum 1-A, “Qualification of the NEXUS Nuclear Data Methodology,” September 2007. (ADAMS Accession No. ML072570325)

6. Letter from U.S. Nuclear Regulatory Commission to J. A. Gresham (Westinghouse), “Request for Additional Information Re: Westinghouse Electric Company Topical Report WCAP-10965-P, Addendum 2, ‘Qualification of the New Pin Power Recovery Method’,” November 9, 2009. (ADAMS Accession No. ML093070458)

7. Letter Gresham, J. A. (Westinghouse) to U.S. Nuclear Regulatory Commission, “Response to the NRC’s Request for Additional Information RE: Westinghouse Electric Company Topical Report WCAP-10965-P, Addendum 2, ‘Qualification of the New Pin Power Recovery Method’,” December 2, 2009.

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