Westinghouse Non-Proprietary Class 3

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Addendum 2
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SVEA-96 Optima2 CPR Correlation (D4): Modified R-factors for Part-Length Rods

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SVEA-96 Optima 2 CPR Correlation (D4): Modified R-factors for Part-Length Rods

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1 INTRODUCTION AND SUMMARY

The SVEA-96 Optima2 Critical Power Ratio (CPR) correlation D4.1.1, together with its corresponding R-factor model, has been reviewed and accepted for use in BWR licensing analysis as described in WCAP-16081-P-A (Reference 1). Addendum 1 to WCAP-16081-P-A (Reference 2) provides additional justification for conservatively extending the mass flux range of the D4.1.1 correlation beyond the currently approved range of [ ]a,c kg/m^2-s. The D4.1.1 CPR correlation with the mass flux range extension described in Reference 2 is referred to as the "D4" CPR correlation. Reference 2 has been submitted for approval and is currently being reviewed by the NRC.

This document is Addendum 2 to WCAP-16081-P-A. The purpose of this report is to identify and justify a necessary revision to the R-factor model described in Reference 1 as it applies to the two-thirds length rods in the SVEA-96 Optima2 assembly. The SVEA-96 Optima2 CPR correlation with the changes described in this document, as well as those separately described in Reference 2, is referred to here as "D4 with modified R-factors for part length rods."

As discussed in Reference 1, the R-factor term accounts for the effects on the dryout sensitivity of local (i.e. fuel rod) power distribution as well as sub-assembly cross section geometry and spacer grid configuration. The traditional R-factor concept, as applied in the D4 CPR correlation, is basically two dimensional assuming that the power distributions within the assembly are separable into an axial and a radial component.

Aware of the challenges imposed by the more sophisticated geometries found in modern BWR fuel designs, Westinghouse has been developing more phenomenological tools for the prediction of critical power to improve, among other things, the ability to model the local contributions to dryout of full- and part-length rods. As part of this development work, the more phenomenological model was tested by application and comparison to the SVEA-96 Optima2 design as a qualification exercise. The results showed that [

]a,c Also, even though it was determined based on the review of current SVEA-96 Optima2 applications that the impact on current plant applications as a result of the shortcomings identified in the R-factor model are minimal, measures were immediately implemented to affect appropriately corrections to the R-factor treatment.

As a result of the re-evaluation of the FRIGG Loop data, it has been confirmed that the R-factor model utilized in Reference 1 could, in cases [

]a,c

This supplement to Reference 1 provides a detailed discussion of the R-factor shortcoming identified [ ]a,c Since the corrective actions involve changes to the R-factor treatment as described in Reference 1, this Addendum 2 to WCAP-16081-P-A is submitted to provide the necessary supporting information for NRC review and approval. It should also be noted that the R-factor model changes presented in this document do not affect the information submitted in Addendum 1 to WCAP-16081-P-A (Reference 2), which is currently under review by the NRC.

2 REVIEW OF THE CURRENT D4.1.1 R-FACTOR MODEL

As noted in Section 1, the R-factor concept in the D4 correlation is basically two dimensional assuming that the fuel rod power distributions can be treated by separable axial and radial components. As discussed in Section 5.2.2 of Reference 1, in each axial node the rod R-factor is the sum of a term dealing with the impact of the radial rod power distribution in the sub-bundle and an additive constant which does not vary axially. The geometry-dependent dryout sensitivities for the individual rods, such as the effect of spacers, are described by the additive constants. The additive constant for each rod is one of the parameters adjusted to fit experimental data.

Also as discussed in Section 5.2.2 of Reference 1, the R-factor for a given rod is established by integrating the nodal R-factors for that rod axially. [

]^{a,c}

Based on the differences observed between the predictions of the more phenomenological models and the D4.1.1 treatment, re-evaluation of the FRIGG Loop data has confirmed that [

]^{a,c}

Furthermore, in all three measurement series (bottom, cosine and top peaked power profiles) [

]^{a,c}

Also, in the absence of a more phenomenological correlation with an alternative R-factor treatment, the additive constants of the [

]a,c

3 IMPROVED R-FACTOR MODEL [ ]a,c

3.1 REVISED ADDITIVE CONSTANT

Because the situation does not represent a realistic condition in a boiling water reactor, the D4 R-factor model [

]a,c

3.2 AXIAL INTEGRATION OF NODAL R-FACTORS AND AXIAL WEIGHTING

Due to the axial weighting procedure, [

]a,c

Because the fuel assembly length is adapted to the specific plant design to achieve mechanical compatibility with the plant and resident fuel, the full length rod active fuel lengths have small variations from plant to plant. The active fuel length of the [

]a,c

The individual R-factor [

]^{a,c}

4 FAST TRANSIENT APPLICATIONS

The D4 CPR correlation described in References 1 and 2 was developed to provide best estimate CPR values for well-established equilibrium thermal and hydraulic conditions. The thermal and hydraulic conditions during a fast transient are rapidly changing and are not in equilibrium. Therefore, the approach followed in Reference 1 was to demonstrate that the application of the D4 correlation to fast transient conditions leads to conservatively bounding dryout predictions. The conclusion in Reference 1 that the D4 correlation as it is formulated in Reference 1 provides sufficiently conservative predictions of transient dryout test data to demonstrate that the D4/Bison-Slave combination will not underestimate the CPR response of operational transients to which it will be applied and will support conservative CPR operating limits continues to be valid. [

]^{a,c}

Consideration of the dynamics of a fast transient supports the conclusion that conservatively bounding dryout predictions continue to be made regardless of whether the current [

]a,c

An additional way of visualizing this effect is to consider the dryout locations during limiting fast transients on full-length rods. For full length rods, the minimum initial CPR (before the transient is initiated) and the final minimum CPR during the transient occur in the same fuel rod. This is also the case for fuel assemblies with part-length rods when the limiting initial minimum CPR is determined by a full-length fuel rod. However, the final dryout location on the full-length rod will be above the end of the two-third length rod active fuel in the SVEA-96 Optima2 assembly. [

]a,c

Therefore, for limiting transients which are terminated by a reactor scram (e.g., pressurization transients of different types), the axial power profile is rapidly shifted upwards when the scram occurs. [

]a,c

[

]a,c

5 Results

The conclusions in Sections 1 through 4 can be summarized as follows:

1. [

2.

]a,c

3. The axial integration of rod nodal R-factors preserves the FRIGG Loop geometry. [

]a,c

6 SVEA-96 OPTIMA2 CORRELATION APPLICATION FOR LICENSING BASIS ANALYSIS

The manner in which the revised D4 SVEA-96 Optima2 dryout correlation with modified R-factors for part length rods will be applied to licensing basis analyses is summarized as follows:

1. [

2.

3.

]^{a,c}

These features have been implemented in the D4 version of the SVEA-96 Optima2 CPR correlation which will be used for licensing analysis CPR predictions for the SVEA-96 Optima2 assembly.

a,c

Figure 2-1 Axial Power Shape for the Five Different Rod Types Used in the Three SVEA-96 Optima2 Measurement Series

Figure 4-1 Qualitative Behavior of Rod-CPR During a Fast Transient

7 REFERENCES

1. WCAP-16081-P-A, "10×10 SVEA Fuel Critical Power Experiments and CPR Correlation: SVEA-96 Optima2," March 2005.

2. Addendum 1 to WCAP-16081-P-A, "SVEA-96 Optima2 CPR Correlation (D4): High and Low Flow Applications," November 2006.