Appendix B Channel Bow

B.1 Introduction

The purpose of this appendix is to describe the approach to account for channel bow in the RODEX4 statistical methodology. It is important to account for the impact of channel bow on the mechanical criteria evaluated with the RODEX4 statistical methodology because the impact of channel bow on the fuel rod power can be quite large, up to 10% on a nodal rod power basis.

The size of the water gaps between adjacent fuel channels is altered by the fuel channel bow. When the channel bow results in an enlargement of the local water gap, the neutron thermal flux is increased locally. The power in the neighboring fuel rods will therefore be higher than in the non-bowed condition. The reverse is true when the local water gaps are reduced.

A channel bow correlation was developed and implemented into the MICROBURN-B2 core simulator for the purpose of accounting for channel bow effects on the realistic power histories used in the RODEX4 statistical methodology. [

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The channel bow model uncertainty is determined [

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B.2 Methodology Modification for the Channel Bow

The process for accounting for the impact of channel bow on the criteria evaluated with the RODEX4 statistical methodology is described below. The process is described first and then the development of the individual components are described in later sections of this appendix.

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B.3 Channel Bow Model Uncertainty Implementation in FROSTY

The channel bow related power uncertainty is added to the other power uncertainties as described in step "d" above. The process is as follows.

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B.4 Channel Bow Model

The main cause of the bow in the fuel channel is the differential irradiation growth between the two opposing sides. The fuel channel accommodates this differential axial growth by bending such that the convex side is the longer side. Neglecting the elastic stresses and strains, the bending is assumed to be a fully permanent deformation; a model for this bending is described below.

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B.5 Channel Irradiation Growth Correlation

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B.6 Implementation into MICROBURN-B2

The MICROBURN-B2 core simulator computes the maximum channel bow magnitude for each assembly consistent with Equations B.6 and B.7. The assembly maximum bow is then used to determine the axial bow profile as a quadratic function with its peak at the axial mid–plane and with the zero function values at the top and the bottom of the channel.

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B.7 Uncertainty of the channel bow model

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B.8 AOO Fast Transient Methodology

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B.9 Sample Problems, Steady State

In Section 6.0, sample applications were presented for a C-lattice BWR-6 plant and for a D-lattice BWR-4 plant. The equilibrium cycles evaluated in these two applications have been repeated with the channel bow methodology presented above in order to illustrate the impact of channel bow effect on the results with respect to the criteria.

The results for the BWR-6 application example are presented in Tables B.3 and B.4, for the nominal power case and the 10% power uprate case, respectively. Due to the changes in RODEX4 and FROSTY since the submittal in 2004, the original, non-bowed case has been re-calculated. The results are consistent but not identical with those previously presented in Section 6.

The first column of Table B.3 shows the results for the reference case without the effects of channel bow (a repeat of the original calculation) while the second column shows the results including the effects of the channel bow methodology presented in this appendix. [

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B.10 Sample Problem, AOO Fast Transient

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Table B.1 - Input Parameters for Bow Calculation

	A32	A30
Active channel length (inch)	149.45	144.24
BOL nominal channel length (inch)	166.906	162.156
BOL nominal channel width (inch)	5.438	5.478

Table B.2 - Channel Bow Bias and Standard Deviation

Table B.3 - BWR 6 Equilibrium Cycle Results Comparison

Table B.4 - BWR 6 Equilibrium Cycle, 110% Power, Results Comparison

Table B.5 - BWR 4 Equilibrium Cycle Results Comparison

Table B.6 - Summary of the BWR-4 Sample Feedwater Controller Failure Analysis with and without Channel Bow

Figure B.1 - Illustration of Simplified Channel Bow Geometry

Figure B.2 - Calculated and Measured Channel Bows

Figure B.3 - Channel Bow with Enhanced Uncertainty Bands

Figure B.4 - BWR-6 Equilibrium Batch – maximum Rod Internal Pressure with and without Channel Bow

Figure B.5 - BWR-4 Equilibrium Batch – maximum Rod Internal Pressure with and without Channel Bow

Figure B.6 - Statistical Measure Of The Global Relative Nodal Power Variation Due To Channel Bow

Figure B.7 - Maximum Nodal Power Variation Due to Channel Bow

References

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