Nuclear Fuel and Components Manufacturing / Fuel Engineering and Safety Analysis

Extended Range Departure from Nucleate Boiling Correlations

Background

The Extended Range Departure from Nucleate Boiling (DNB) correlations, also known as W-3 Alternative (W-3A) correlations, are used to supplement the primary DNB correlation (e.g., WRB-1, WRB-2 or WRB-2M) for those safety analyses where the local coolant conditions or fuel characteristics are outside the ranges of applicability of the primary DNB correlation.

Description

The W-3A extended range DNB correlations consist of the ABB-NV correlation and the WLOP correlation. The ABB-NV correlation is qualified and licensed for all Westinghouse pressurized water reactor (PWR) fuel applications for the fuel region below the first mixing vane grid. The WLOP correlation is a modification of the ABB-NV correlation that was developed for DNB ratio (DNBR) calculations at low-pressure and low-flow conditions.

Benefits

- Provides safety analysis margin for avoidance of unnecessary reactor trip. With the increased DNBR margin of the ABB-NV correlation, the need to have more restrictive constant axial offset control or relaxed axial offset control (RAOC) bands or more restrictive trip setpoints for addressing adverse bottom-skewed axial power distributions is reduced, which improves operating margin and, therefore, decreases the probability of a trip.
- Supports better fuel reload and shutdown margin requirements in DNB analysis of the hot zero power steamline break event. The WLOP correlation removes several limitations of the W-3 correlation such as the applicable pressure range to enable a more optimal loading pattern that meets the DNB design criterion.
- Provides improved margin for the analysis of the fuel region below the first mixing vane grid, which is extremely valuable for the analysis of plants that have the lower plenum flow anomaly.
- Addresses the lessons learned from the following recent Institute of Nuclear Power Operations Operational Experience (OE) reports:

OE 33560 - Unexpected Onset of Reactor Coolant System Lower Plenum Flow Anomaly

Lesson Learned: “Plants susceptible to lower plenum flow anomaly should consider having … adequate DNB margin available in the reload safety analysis to accommodate this potential condition.”

OE 35734 - Advancements in Departure from Nucleate Boiling Correlations May Necessitate the Evaluation of the Assumptions of the Non-Limiting Nature of Bottom-Skewed Power Shapes in the Verification of the Adequacy of Reactor Trip Protection Functions

Lesson Learned: “Bottom-skewed power shapes evaluated … with the W-3 critical heat flux correlation may be more limiting than previously understood relative to power shapes evaluated statistically above the first MVG.”

Experience

Based on Westinghouse DNB correlation experience:

- When the supplemental DNB correlation is not explicitly mentioned in the Technical Specifications, no submittal to the U.S. Nuclear Regulatory Commission is required to change from the W-3 correlation to the W-3 Alternative correlations, meaning that the 10 CFR 50.59 process can be applied during the reload analysis or stand-alone implementation.

Westinghouse

- One of the Safety Evaluation Report requirements for the implementation of the W-3A correlations for Westinghouse PWR applications is that they must be used in conjunction with VIPRE-W. A THINC-IV-based plant can be upgraded to VIPRE-W to support the implementation of the W-3A correlations.

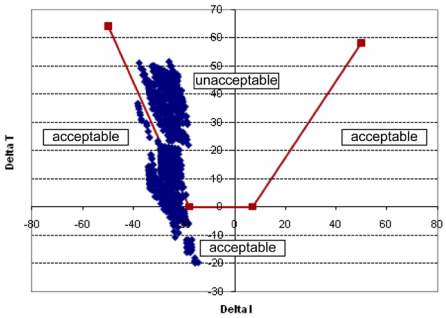
Example of the Benefit from Switching to the ABB-NV Correlation

During the RAOC power shape analysis for a 15 percent uprating, the W-3 correlation did not provide sufficient margin for the bottom-skewed shapes. If the W-3 correlation had been retained, the available options were:

- Reduce the negative side of RAOC band to try to eliminate the violating shapes.
- Make the negative f(ΔI) reset more restrictive by changing the breakpoint and slope, which could make a reactor trip more likely.

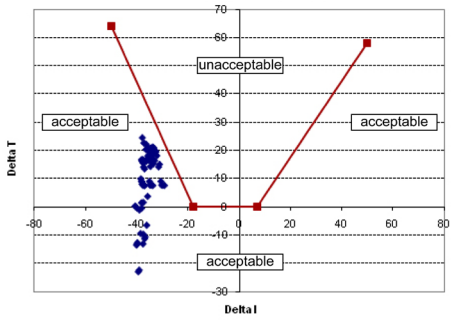
Implementation of the ABB-NV correlation provided margin to address the bottom-skewed shapes without operational restrictions.

The W-3 results, which included 11 percent margin to cover DNBR penalties such as rod bow, showed numerous violations:



RAOC accident power shapes
W-3 analysis with ~11 percent margin

The analysis of the same set of shapes with the ABB-NV correlation yielded acceptable results without having to change the RAOC band or the f(ΔI) function. In addition, the amount of margin retained in the ABB-NV limit was able to be increased to more than 16 percent:

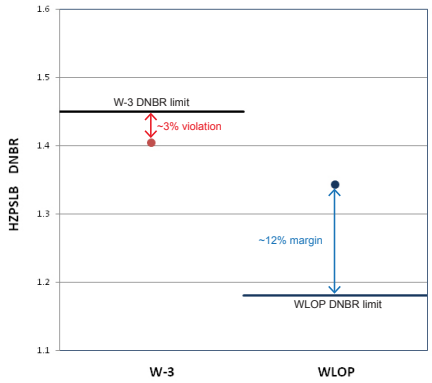


RAOC accident power shapes
ABB-NV analysis with >16 percent margin

Example of the Benefit from Switching to the WLOP Correlation

The DNB analysis of new HZPSLB statepoints did not meet the DNB design criterion using the W-3 correlation.

While the absolute DNBR calculated with the WLOP is lower than the value calculated with the W-3, the DNB criterion can be met with the WLOP correlation because of the improved 95/95 correlation DNBR limit for the WLOP correlation:



Comparison of DNBR results for hot zero power steamline break

Additional example of the Benefit from Switching to the WLOP Correlation

Issues with steam flow prevented attaining full-power operation. To resolve the issue, a change was made to the lag on the high-steam flow engineering safety feature signal, which affected the HZPSLB statepoints. As a result, the pressurizer pressure for the event went below 500 psi, which is below the range of W-3 applicability. Because the plant had implemented WLOP, the statepoints were analyzed and the DNBR limit was met. Use of the W-3 correlation would have resulted in violation of the DNBR limit.

Westinghouse Electric Company
1000 Westinghouse Drive
Cranberry Township, PA 16066

www.westinghousenuclear.com

March 2016 NF-FE-0043