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BHTP DNB Correlation Applied with LYNXT

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U.S. Nuclear Regulatory Commission
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Nature of Changes

Item	Page	Description and Justification
1.	All	This is a new document.

Contents

Tables

Figures

Nomenclature

Acronym	Definition
AOO	Anticipated Operational Occurrence
BHTP	Designation for the principal correlation described in this report
DHYD	[ ] equivalent diameter
DNB	Departure from Nucleate Boiling
[	]
[	]
[	]
HTP	The Framatome ANP pressurized water reactor fuel assembly design for which the BHTP DNB correlation is developed.
IFM	Intermediate Flow Mixer
[	]
[	]
LYNXT	Computer code for performing core DNBR analysis
[	]
PWR	Pressurized Water Reactor
[	]
[	]
XCOBRA-IIIC	Computer code for performing core DNBR analysis
[	]

1.0 Introduction and Summary

This document describes the Framatome ANP, Inc., Departure from Nucleate Boiling (DNB) correlation, HTP (Reference 1), and its proposed use with the LYNXT computer code (Reference 2). The HTP correlation has been used for the HTP fuel designs since 1994. The HTP correlation was reviewed and approved by the Nuclear Regulatory Commission (Reference 1). The HTP correlation is presently used with the XCOBRA-IIIC computer code (Reference 3).

The database for the HTP correlation was obtained in a high pressure test loop at Columbia University's Heat Transfer Research Facility. [ ] The HTP DNB data base is fully described in Reference 1.

The HTP correlation is an empirically derived function of the local coolant thermodynamic state and mass flux at which DNB is observed to occur in experiment. The heat flux at which DNB occurs is predicted using local coolant quality, local mass flux, and [ ] pressure. A minor [ ] dependence is also present. The HTP correlation contains factors to account for the effects of [ ]

DNB correlations are applied with a specified computer code in order to obtain local conditions. [ ]

The correlation predictions of the measured data are summarized in the following sub-sections. The BHTP correlation is described in detail in Section 2.0 of this document. The qualification of the correlation against the experimental database is discussed in Section 3.0. The statistical characterization of the correlation is presented in Section 4.0.

1.1 *Range of Applicability*

The BHTP correlation application range of coolant conditions are provided in Table 1.1. The coolant conditions commonly encountered during steady-state operation and Anticipated Operational Occurrences (AOO) in PWRs are also within this range. The range of fuel design parameters are provided in Table 1.2. These are unchanged from Reference 1. [ ]

1.2 *Comparison of BHTP Correlation Predictions to Experimental Measurements*

The BHTP correlation is used to predict the DNB heat flux for each test point in the database. The distribution is characterized [ ] A statistical summary of the P/M ratios for the individual test sections is provided in .

A comparison of predicted DNB heat flux to measured DNB heat flux for the entire database is given in Figure 1.1. Upper and lower dashed lines on this plot enclose a band [ ] about the measured value.

The frequency distribution of the P/M ratios for the entire database is depicted in Figure 1.2. The 95/95 safety limit for the BHTP correlation is 1.132, derived using a [ ] as discussed in Section 4.0.

Table 1.1 BHTP Correlation Range of Applicability: Coolant Conditions

Variable	Minimum Value	Maximum Value
Pressure (psia)	1775	2425
Local Mass Flux (Mlb/h/ft^2)	0.897	3.549
Inlet Enthalpy (Btu/lb)	383.9	644.3
Local Quality	-0.130	0.344

Table 1.2 BHTP Correlation Range of Applicability: Fuel Design Parameters

Parameter	Value
Fuel Rod Diameter, in	0.360 – 0.440
Fuel Rod Pitch, in	0.496 – 0.580
Axial Spacer Span, in	10.5 – 26.2
Hydraulic Diameter, in	0.4571 – 0.5334
Heated Length, ft.	9.8 – 14.0

2.0 The BHTP DNB Correlation

The BHTP correlation is based on the HTP correlation that was approved in Reference 1. [

]

2.1 *Base Correlation*

The BHTP correlation is a [ ] function of [

]

Q_{base} is the predicted DNB heat flux ($MBtu/h/ft^2$) prior to application of the [
] factors and the [ ] factor.

[

]

[

]

2.2 *Fuel Design Factor*

The predicted DNB heat flux obtained from Equation (2.1) is modified by terms which account for the effects of the [ ]

[

]

The DNB heat flux including [ ] effects, Q_{pred}, is obtained from Equation (2.1) and the factor FDF defined above: [

]

2.3 ***Non-Uniform Axial Power Distribution Correction Factor***

The predicted DNB heat flux obtained from the base correlation is modified as follows for [

]

3.0 Qualification of the BHTP DNB Correlation

The **[** **]** data points supporting the BHTP DNB correlation are obtained from **[** **]** programs performed at the Columbia University Heat Transfer Research Facility. The test data and test sections are fully described in Reference 1. The correlation comparison to data and the thermal hydraulic models employed in the LYNXT (Reference 2) simulations of the tests are presented in this section.

3.1 *Thermal Hydraulic Models of Test Assemblies*

The local coolant conditions for each statepoint in the DNB data base are computed with the approved LYNXT computer code (Reference 2). The LYNXT simulation includes a specification of the test assembly geometry and power peaking, single phase friction and component loss coefficient correlations, two-phase flow correlations, a turbulent mixing correlation, and appropriate calculation control parameters. The standard LYNXT models (Reference 2, Appendix B) are used with the BHTP correlation.

3.2 *Calculation Results and Analysis of Residuals*

[

]

4.0 Statistical Characterization of the BHTP DNB Correlation

The BHTP DNB correlation safety limit is derived using the ratio of the [ ] DNB heat flux to the [ ] DNB heat flux [ ]. The correlation safety limit is the value of the [ ] ratio [ ] which, with 95% confidence, 95% of the population of P/M values fall. The correlation safety limit is derived using a [ ]

To evaluate the safety limit, the data sample is sorted in descending order of [ ] ratio. There are [ ] data points in the sample. [ ] defines the degree of confidence, g, associated with the fractional probability, P, that [ ] values chosen [ ] This degree of confidence, g, is defined in terms of [

] 1.132. Hence, the value of the correlation safety limit is 1.132. With 95% confidence, at least 95% of the population of [ ] ratios will be [ ] than this value.

5.0 References

1. EMF-92-153(P)(A) and EMF-92-153(P)(A) Supplement 1, *HTP: Departure From Nucleate Boiling Correlation for High Thermal Performance Fuel*, Siemens Power Corporation, March 1994.

2. BAW-10156-A Revision 1, *LYNXT – Core Transient Thermal-Hydraulic Program*, B&W Fuel Company, August 1993.

3. XN-NF-75-21(P) (A) Revision 2, *XCOBRA-IIIC: A Computer Code to Determine the Distribution of Coolant During Steady State and Transient Operation*, Exxon Nuclear Company, January 1986.

4. [ ]

5. [ ]

Distribution

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