



FRAMATOME ANP, INC.

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Document Control Desk
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555-0001

Request for Approval of Appendix A to BAW-10241(P), Revision 1, "Extension of the BHTP CHF Correlation Ranges"

Ref. 1: Letter, Herbert N. Berkow (NRC) to Jerald S. Holm (Framatome ANP), "Final Safety Evaluation for Framatome ANP Appendix A to Topical Report EMF-92-153(P)(A), 'HTP: Departure from Nucleate Boiling Correlation for High Thermal Performance Fuel,' (TAC No. MC3223)," January 6, 2005.

Framatome ANP requests the NRC's review and approval for referencing in licensing actions a revision to topical report BAW-10241(P)(A), "BHTP DNB Correlation Applied with LYNXT." The revision consists of an appendix to the NRC-approved topical report in order to extend the range of applicability of the independent variables in the correlation. The extended range of applicability of the correlation is required because the currently approved ranges will be exceeded in future plant specific analyses, specifically Entergy's Arkansas Unit 1.

The contents of this report are consistent with the appendix to topical report EMF-92-153, "HTP Departure from Nucleate Boiling Correlation for High Thermal Performance Fuel," which was approved for referencing in licensing actions on January 6, 2005 (Reference 1). Framatome ANP requests that the safety evaluation report for Appendix A to topical report BAW-10241, Revision 1, be issued by August 1, 2005 in order to support Entergy's ANO-1 next reload. Because of the review schedule and for efficiency purposes, Framatome ANP requests that the NRC consider assigning the same NRC reviewer to Appendix A of BAW-10241, Revision 1 as was assigned to the review of the appendix to EMF-92-153.

The proprietary version of Appendix A to BAW-10241, Revision 1, is provided in the attachment to this letter. Attachment B is the non-proprietary version.

Framatome ANP considers some of the information contained in the enclosed report to be proprietary. As required by 10CFR2.390(b), an affidavit is enclosed to support the withholding of this information from public disclosure.

Sincerely,


Jerald S. Holm, Director
Regulatory Affairs

1007

Enclosures

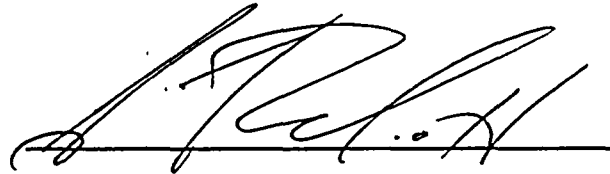
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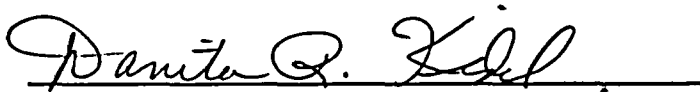
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9. The foregoing statements are true and correct to the best of my knowledge, information, and belief.

A handwritten signature in black ink, appearing to be 'D. Kidd', written over a horizontal line.

SUBSCRIBED before me this 11
day of March, 2005.

A handwritten signature in black ink, 'Danita R. Kidd', written over a horizontal line.

Danita R. Kidd
NOTARY PUBLIC, COMMONWEALTH OF VIRGINIA
MY COMMISSION EXPIRES: 12/31/08



Danita R. Kidd
NOTARY PUBLIC
Commonwealth of VA
Comm. Expires: 12-31-08

Appendix A

Extension of the BHTP CHF Correlation Ranges

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March 2005

A.1 Introduction and Summary

This Appendix represents Revision 1 to the original version of the topical report BAW-10241(P)(A) (Reference 1) which forms the main body of the report. The purpose of this revision is to extend the range of applicability of the correlation in terms of its independent variables. The need to extend the range of applicability of the independent variables exists because conditions are generated in plant specific analyses which are outside of the original range. The extensions discussed in this appendix are consistent with the extensions granted in Reference 3 for the HTP correlation.

The BHTP CHF correlation is based on [] data from [] separate CHF tests at the Columbia University Heat Transfer Research Facility (HTRF). These tests were conducted in the late 1980s to early 1990s time frame. The HTRF was officially closed by the university on December 31, 2003.

The BHTP CHF correlation is []. This type of correlation is termed a [] correlation. Its major independent variables, in addition to quality, are system pressure and local mass velocity. The CHF calculated from these local thermal hydraulic conditions is modified by a [

]. All of these terms are applied multiplicatively as shown in Section 2 of the main body of this report.

Other examples of [] correlations are the Westinghouse W-3 correlation (Reference 5) and the Framatome ANP BWC and BWCMV correlations, References 6 and 7, respectively. This type of correlation is generally limited to relatively low qualities at CHF (well below 40%), mass velocities above 0.8 Mlb/hr-sq ft and pressures above about 1400 psia. The specific ranges of the BHTP correlation, as approved in Reference 1, are shown in Table A.1. These are the ranges over which the BHTP correlation was optimized (correlated).

Table A.1 Approved Range of Independent Variables for the BHTP CHF Correlation

Independent Variable	Minimum Value	Maximum Value
System Pressure, psia	1775	2425
Mass Velocity, Mlbm/hr-ft ²	0.897	3.549
Thermodynamic Quality at CHF	-0.130	0.344

The revised range of applicability of the BHTP correlation justified in this Appendix is shown in Table A.2 below along with the specific requirements defined in the notes. The changes in the range of applicability are:

1. A reduction in the lower pressure limit, lower mass velocity limit, and lower quality limit, and
2. An increase in the upper quality limit and flexibility to apply the correlation up to <2600 psia under specific requirements.

Table A.2 Revised Range of Independent Variables for the BHTP CHF Correlation

Independent Variable	As Approved in Reference 1		Extended (see Notes)	
	Minimum Value	Maximum Value	Minimum Value	Maximum Value
Pressure, psia	1775	2425	1385	2425
Mass Velocity, Mlbm/hr-ft ²	0.897	3.549	0.492	3.549
Thermodynamic Quality at CHF	-0.130	0.344	No Lower Limit*	0.512

* because of the increasingly conservative trend of lower quality extrapolation

Notes: Actions for analyzing the operating conditions outside of the approved ranges of the maximum pressure (2425 psia) but less than 2600 psia are as follows.

When pressures greater than the pressure limit of 2425 psia but less than 2600 psia are encountered, all of the local coolant conditions are calculated at the upper pressure limit of 2425 psia using the NRC-approved LYNXT thermal-hydraulic code and then used in the calculation of the BHTP CHF.

Extrapolations below the minimum quality range are performed with no lower limit consistent with Reference 3.

The previously approved range of inlet enthalpy and the fuel design parameters from Tables 1.1 and 1.2, respectively, of Reference 1 will remain applicable.

A.2 Extension of the Correlation

The independent variable ranges are extended using three approaches. First, the existing correlation is applied to an expanded data set and shown to be conservative over the expanded range of data. Second, the conservatism of extrapolating beyond the data base is shown. This second approach is applied to extrapolations to low quality values. Third, a technique to calculate conservative CHF values when outside the range of the data is described. This third approach is used when pressures higher than the upper pressure limit are encountered. Part 1 below presents the first approach and Part 2 below summarizes the second and third approach which was presented in Reference 3.

A.3 Part 1 – Extension of the Correlation Using Data

A.3.1 *Data Base for Justification*

A significant amount of BHTP CHF data were obtained at the Columbia HTRF beyond the approved applicability ranges defined in Table A.1. These additional CHF data were not utilized in the establishment of the BHTP CHF correlation. The additional data were obtained in [] of the [] tests and consisted of [] data overall. The additional data are in pressure groups of 1400, 1000 and 600 psia, mass velocities down to 0.25 Mlb/hr-ft² and thermodynamic qualities at CHF of up to 58 percent.

These [] tests covered the range of physical fuel design parameters in the correlation as defined in Table 1.2 of the body of the report (Reference 1). The data at 600 and 1000 psia were obtained in only 5 of the tests and did not cover a sufficiently wide range of fuel design parameters. Thus, only the 1400 psia data will be used to justify the extension to lower pressure, lower mass velocity and higher quality [()].

In addition, there were only two of the 1400 psia data at low mass velocities (0.25 Mlb/hr-ft²) and one point at high quality (at 58 percent). These three data were removed from the 1400 psia group of data leaving [] data with which to justify the extensions. This [] data base will be referred to as the "New" or "Uncorrelated" data while the original [] data base will be referred to as the "Original" or "Correlated" data.

The test conditions (experimental) for the New data are contained in Table A.3. Table A.4 contains the resulting local conditions and P/M CHF values resulting from the application of the original BHTP CHF correlation with the LYNXT thermal-hydraulic analysis code (Reference 2).

A.3.2 Extension of the Upper Quality Limit

The New data range in thermodynamic quality from -0.026 to 0.512 . The Original and New data are plotted against quality (using the original BHTP CHF correlation) in Figures A.1 and A.2, respectively. Both data sets are combined and shown in Figure A.3. The New data is generally conservative with respect to the Original data, P/M values below 1.0 are conservative in that the Measured (M) CHF obtained in the test are greater than the value Predicted (P) by the BHTP correlation. The New data is about 24 percent conservative overall with an average P/M of 0.7413 versus the Original average P/M of 0.994.

The upper limit in thermodynamic quality at CHF can be extended to 0.512 (51.2 percent) based on these data and analysis with the original BHTP correlation,.

A.3.3 Extension of the Lower Mass Velocity Limit

The New data range in mass velocity from 0.492 to 3.513 Mlb/hr-ft². The Original and New data are plotted against mass velocity (using the original BHTP CHF correlation) in Figures A.4 and A.5. The data sets are combined and shown in Figure A.6. All of the New data is conservative with respect to the Original data as shown in Figures A.5 and A.6.

The data below one million lb/hr-ft² is the most important data for the extension of the lower mass velocity limit. In this subgroup of [] data the mean P/M is 0.730 (27 percent conservative) with all of the data having a P/M less than 1.0. The combined scatterplot (Figure A.6) shows this conservatism.

The lower limit in mass velocity can be extended to 0.492 Mlb/hr-ft² based on these data and analysis with the original BHTP correlation.

A.3.4 Extension of the Lower Pressure Limit

The New data is comprised of the 1400 psia data group (1385 to 1430 psia). The 1400 psia data is conservative by about 24 percent overall with all P/M values below a value of 1.0. The conservatism of the data is shown in Figure A.7.

The lower limit in pressure can be extended to 1385 psia based on these data and analysis with the original BHTP correlation,

A.3.5 Effect of Different Geometries on the Extended Data

The extension of the BHTP correlation was examined to verify that the extension of the BHTP correlation is conservative for each approved assembly geometry. The examination was performed for each test section since each test section represents a single geometry.

The Average P/M CHF values are shown for each test section in Figure A.8. The test section averages for the original data are represented by the open bars. The shaded bars (which overlay the open bars) represent the average of the extended data only.

Note that there is extended data for [] tests: only tests 62, 63 and 66 through 68 lacked extended data. Further note that in each test section that had extended data, the average of the extended data is conservative with respect to the original data (the extended data P/M is lower than the original data P/M in all cases).

This comparison indicates that in no case does the differing geometry produce a non-conservative trend when the BHTP correlation is applied to the extended data. Therefore, it is concluded that the entire set of the [] extended data can be used to conservatively extend the range of independent variables of the BHTP correlation.



**Figure A.1 P/M CHF versus Thermodynamic Quality at CHF
Original BHTP Data Base with BHTP Correlation**



**Figure A.2 P/M CHF versus Thermodynamic Quality at CHF
New (Uncorrelated) BHTP Data with BHTP Correlation**

**Figure A.3 P/M CHF versus Thermodynamic Quality at CHF
 Original and New (Uncorrelated) BHTP Data with BHTP Correlation**

**Range of Independent Variables for the BHTP CHF Correlation with the Extension of the
 Upper Quality Limit**

Independent Variable	As Approved		Extended	
	Minimum Value	Maximum Value	Minimum Value	Maximum Value
System Pressure, psia	1775	2425	1775	2425
Mass Velocity, Mlbm/hr-ft ²	0.897	3.549	0.897	3.549
Thermodynamic Quality at CHF	-0.130	0.344	-0.130	0.512



**Figure A.4 P/M CHF versus Local Mass Velocity
Original BHTP Data Base with BHTP Correlation**

**Figure A.5 P/M CHF versus Local Mass Velocity
New (Uncorrelated) BHTP Data with BHTP Correlation**

**Figure A.6 P/M CHF versus Local Mass Velocity
Original and New (Uncorrelated) BHTP Data with BHTP Correlation**

**Range of Independent Variables for the BHTP CHF Correlation with the Extension the
Upper Quality and Lower Mass Velocity Limits**

Independent Variable	As Approved		Extended	
	Minimum Value	Maximum Value	Minimum Value	Maximum Value
System Pressure, psia	1775	2425	1775	2425
Mass Velocity, Mlbm/hr-ft ²	0.897	3.549	0.492	3.549
Thermodynamic Quality at CHF	-0.130	0.344	-0.130	0.515

**Figure A.7 P/M CHF versus System Pressure
Original and New (Uncorrelated) BHTP Data with BHTP Correlation**

**Range of Independent Variables for the BHTP CHF Correlation with the Extension of the
Upper Quality and Lower Mass Velocity and Pressure Limits**

Independent Variable	As Approved		Extended	
	Minimum Value	Maximum Value	Minimum Value	Maximum Value
System Pressure, psia	1775	2425	1385	2425
Mass Velocity, Mlbm/hr-ft ²	0.897	3.549	0.492	3.549
Thermodynamic Quality at CHF	-0.130	0.344	-0.130	0.512



**Figure A.8 Histogram of Test Section P/M CHF Averages
For the Original BHTP Data Base and for the New Data**

A.4 Part 2 – Extension of the Correlation Outside the Data Ranges

Reference 3 dealt with the extension of the thermodynamic quality lower limit and the pressure upper limit in great detail. The extensions for the thermodynamic quality lower limit and the pressure upper limit were modified during the review process for Reference 3. The extensions proposed for the BHTP correlation are identical to those finally approved by the NRC in Reference 3. In addition, it has been shown in Part 1 that the application of the BHTP correlation to the new data is much more conservative than the application of the original HTP correlation to this same new data. (The original HTP application was roughly 10 percent conservative. The present BHTP application is about 24 percent conservative.) Therefore, the analytical conclusions observed in Reference 3 for the HTP correlation are appropriate for the correlation extensions in lower quality and higher pressure for the BHTP correlation.

In the SER of Reference 3, the HTP correlation application for the extensions of the lower quality limit and upper pressure limit were approved with the following stipulations.

“Actions for analyzing the operating conditions outside of the approved ranges of the maximum pressure (2425 psia) but less than 2600 psia are stated below. Extrapolations below the minimum quality range using the process described in Reference 1 are permitted with no lower limit. Any other extrapolation requires a plant-specific review.

When pressures greater than the upper pressure limit of 2425 psia but less than 2600 psia are encountered, all of the local coolant conditions are calculated at the upper pressure limit of 2425 psia using the NRC-approved thermal-hydraulic code and then used in the calculation of the HTP CHF.”

Table A.3 Additional BHTP Data – Bundle Conditions

Following are the bundle conditions (test conditions) of the [] additional data. These data are used for justification of the extension of the independent variables beyond the applicability ranges defined by the original BHTP data base in Reference 1.

Units:

ID : LXXYYY where L designates low pressure, XX is the test section number, and YYY is the run number
P : Pressure, psia
T_{in} : Inlet Temperature, F
G : Mass Velocity, Mlb/hr-ft²
Q'' : Average Heat Flux, MBtu/hr-ft²

BHTP: DNB Correlation Applied with LYNXT
Appendix A: Extension of the BHTP CHF Correlation Ranges

BHTP: DNB Correlation Applied with LYNXT
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BHTP: DNB Correlation Applied with LYNXT
Appendix A: Extension of the BHTP CHF Correlation Ranges



Table A.4 Additional BHTP Data – Local Conditions and BHTP Results

Following are the results of applying the original BHTP CHF correlation to the [] additional data. These data are used for the justification of the extension of the independent variables beyond the applicability ranges defined by the original BHTP data base in Reference 1.

Units:

ID : LXXYYY where L designates low pressure, XX is the test section number, and YYY is the run number
P/M CHF : Predicted to Measured CHF Ratio
CHF : Measured CHF, Btu/hr-ft²
P : Pressure, psia
G : Mass Velocity, lb/hr-ft²
Zchf : Location of CHF, inches
F Fact : Non-uniform AFS factor
Hin : Inlet Enthalpy, Btu/lb



BHTP: DNB Correlation Applied with LYNXT
Appendix A: Extension of the BHTP CHF Correlation Ranges



BHTP: DNB Correlation Applied with LYNXT
Appendix A: Extension of the BHTP CHF Correlation Ranges



A.6 References

1. BAW-10241(P)(A), "BHTP DNB Correlation Applied with LYNXT," Framatome ANP, September 2004.
2. BAW-10156-A Revision 1, "LYNXT Core Transient Thermal-Hydraulic Program," August 1993.
3. EMF-92-153(P)(A) Revision 1, "Extension of HTP CHF Correlation Ranges," Framatome ANP, January 2005