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FRAMATOME ANP, Inc.

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Comments on Draft Safety Evaluation for BAW-10241(P), Revision 0, "BHTP DNB Correlation Applied with LYNXT"

Ref.: 1. Letter, Stephen Dembek (NRC) to James F. Mallay (Framatome ANP), "Draft Safety Evaluation for Topical Report BAW-10241P, Revision 0, 'BHTP Correlation Applied in LYNXT' (TAC No. MB7033)," August 30, 2004.

The NRC issued a draft safety evaluation on BAW-10241(P) and requested that Framatome ANP review the document for proprietary material and for any factual errors (Reference 1). Framatome ANP has reviewed the draft SER provided in Reference 1.

We have determined that the draft safety evaluation contains information that was identified in the topical report as being proprietary information. A marked-up copy of the draft SER is provided in Attachment A omitting the proprietary information and identifying three minor clarifications.

Attachment B provides a summary table of the omitted proprietary information and minor clarifications.

Framatome appreciates this opportunity to offer clarifying comments.

Very truly yours,

James Mallay /rm

James F. Mallay, Director
Regulatory Affairs

Enclosures

cc: M. C. Honcharik
Project 728

T010
Y601

Attachment A

UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D.C. 20555-0001

DRAFT SAFETY EVALUATION BY THE OFFICE OF NUCLEAR REACTOR REGULATION

BAW-10241P, REVISION 0, "BHTP DNB CORRELATION APPLIED WITH LYNXT"

FRAMTOME ANP

PROJECT NO. 728

1.0 INTRODUCTION

By letter dated December 19, 2002 (Reference 1), Framatome ANP (FANP) requested NRC review of topical report (TR) BAW-10241P, "BHTP DNB Correlation Applied with LYNXT." This TR describes a *departure from nucleate boiling* (DNB) *correlation* that has been developed using the LYNXT thermal-hydraulic code (Reference 2) for fuel designs equipped with high thermal performance (HTP) spacer grids. The BHTP DNB correlation is based on the approved HTP DNB correlation (Reference 3). Adjustments have been made in some of the coefficients (A, B, and HTERM) used to describe the performance of this spacer grid design when the LYNXT (Reference 4) code is used. The HTP DNB correlation was developed using the XCOBRA-IIIC thermal-hydraulic code (Reference 5).

The review includes the subject TR and supplemental information provided by FANP in letters dated June 6 and September 3, 2003, and February 11, June 17, and August 9, 2004 (References 6 through 10).

2.0 REGULATORY EVALUATION

The requirement for analyses of this type originates in Title 10 of the *Code of Federal Regulations* Part 50, Appendix A, "General Design Criteria for Nuclear Power Plants." Specifically, Criterion 10, "Reactor Design" applies. Criterion 10 states:

> The reactor core and associated coolant, control, and protection systems shall be designed with appropriate margin to assure that specified acceptable fuel design limits are not exceeded during any condition of normal operation, including the effects of anticipated operational occurrences.

NUREG-0800, "Standard Review Plan for the Review of Safety Analysis Reports for Nuclear Power Plants," Sections 4.2, "Fuel System Design" and 4.4, "Thermal and Hydraulic Design," provide detailed guidance that is acceptable to the staff in meeting the regulatory requirements given above. FANP has applied this guidance in BAW-10241P, Revision 0.

3.0 SUMMARY OF TOPICAL REPORT

BAW-10241P documents the development of the FANP BHTP DNB correlation applied with LYNXT for use in DNB analysis of ~~Mark-~~BHTP fuel design. BHTP represents an extension of the previously approved HTP correlation. The primary difference between the two codes (LYNXT versus XCOBRA-IIIC) associated with critical heat flux (CHF) data reduction is the water properties (Reference 5, ASME property functions versus ASME saturated steam table).

The data from a high pressure test loop at Columbia University's Heat Transfer Research Facility (Reference 3) were used as a data base for the ~~BTH~~ BHTP correlation development. The BHTP data base (Reference 7) consists of data from [redacted] test sections [redacted] representing the typical Westinghouse HTP designs used for FANP development and [redacted] other vendors' HTP designs in heated lengths, power shapes, presence of spacers and, in some cases, containing intermediate flow mixers (IFMs).

A complete summary of the measured data and the predicted values of relevant variables to the development of the correlation is provided in Reference 7. Dependence of the BHTP correlation on fuel design parameters is also described in the TR. Comparison of correlation predictions to experimental measurements are provided as qualification of its adequacy. The determination of the 95/95 safety limit for BHTP is discussed in the subject submittal (Reference 2).

4.0 TECHNICAL EVALUATION

4.1 BHTP Test Data Base Description

The BHTP correlation data base consists of [redacted] data points from [redacted] tests performed in a high pressure test loop at the Columbia University Heat Transfer Research Facility.

These test section characteristics were varied to represent fuel array design for 14x14 through 17x17 rod arrays using both uniform and non-uniform axial power shape. The radial power distribution was non-uniform for all test assemblies. Rod positions were maintained by HTP spacers. The tests were conducted with assemblies with and without IFMs. Fuel design parameters of the test assemblies varied: from 0.36 to 0.44 inch for the fuel rod diameter; from 0.496 to 0.580 inch for the rod pitch; from 8 to 26.4 inches for the axial spacer span; from 0.457 to 0.533 inch for the lattice subchannel hydraulic diameter; and from 7.9 to 14 feet for heated length. Established coolant conditions (Reference 7) of the tests varied: from 1775 to 2425 psia for pressure; from 0.897 to 3.549 Mlb/h/ft^2 for local mass flux; from 383.9 to 644.3 Btu/lb for inlet enthalpy; and from -0.130 to 0.344 for local quality.

Thermocouples are employed to detect the occurrence of DNB in the tests. They are located at the axial position listed in Table 3.5 of Reference 3. For each set of ~~Mark-~~BHTP spacer grid bundle test data, the LYNXT code was used to predict the local thermal-hydraulic conditions (mass velocity, thermodynamic quality, heat flux, and pressure) axially along the test section heated length. The predicted local conditions at the point of detected burnout are provided in the summary of results for the BHTP data base (Reference 7).

4.2 BHTP DNB Correlation Development

The correlation is an empirically derived function of the local coolant thermodynamic state and mass flux at which DNB is observed to occur in the experiment. The base correlation is developed based on local coolant conditions at the point of DNB predicted from test data for the uniform axial power distribution. The local coolant conditions are calculated with the approved LYNXT computer code (Reference 4). The predicted DNB heat flux is modified by factors which account for the effect of non-uniform axial power distribution and fuel assembly design parameters. This aspect is the same as the formulation used in the approved HTP DNB correlation (Reference 3).

The local conditions data from each CHF test statepoint form the data base for the BHTP CHF correlation. These data (mass velocity, thermal dynamic quality, heat flux, pressure, local thermodynamic quality and axial location) were used to determine the coefficients of the BHTP CHF correlation. The method used for coefficient determination is a least squares fit that minimizes the deviation of predicted CHF to the measured CHF ratio of predicted over measured (P/M) around a mean of 1.0. All the BHTP coefficients were re-optimized with the exception of those in the fuel design factor (FDF) term that includes coefficients b7 through b14. The BHTP correlation optimization is documented in the FANP calculational file supporting TR BAW-10241P.

The BHTP DNB correlation is used in the following steps: (1) local coolant conditions are calculated as a function of radial and axial position within the assembly with a LYNXT subchannel model; (2) the DNB heat flux is calculated at each position within the assembly using the local coolant conditions determined in step 1; and (3) the DNB ratio is calculated as the ratio of predicted DNB heat flux to operating heat flux at each position within the assembly. Minimum DNB ratio (MDNBR) is selected as the least value of the DNB ratio to occur in the assembly. The MDNBR is then used as a measure of the margin to DNB for the operating assembly.

4.3 Qualification of BHTP DNB Correlation

The approved LYNXT computer code was used to predict DNB heat fluxes to be compared against the measured heat fluxes. The key variables measured at the point of DNB, such as inlet temperature, inlet mass flux, exit pressure and bundle power, were used as boundary conditions in the LYNXT calculations.

Comparison between the predicted location of DNB and the heated rod and thermocouple number at which the primary DNB indication was recorded, indicated the adequacy of the model. The P/M heat fluxes were plotted for all [redacted] tests to indicate the degree of agreement between the prediction using the BHTP correlation and the measured data. The plots showed good agreement in [redacted] tests and for the other [redacted] cases nearly all the data fell within the 95/95 tolerance limit lines. most

The frequency distribution of P/M ratios for the entire data base was used to determine the 95/95 safety limit for the HTP correlation using a distribution free method, the same method which had been used to determine the HTP DNB correlation limit (Reference 2).

4.4 Applicability of BHTP Correlation

The DNB-based safety limit for the first plant to use the Mark-BHTP fuel design will conservatively represent the allowable pressure-temperature conditions for transition core situations (Mark-B10 fuel with Mark-BHTP fuel), as well as the full core situation (all Mark-BHTP fuel) (Reference 6). Operational and safety limits are being set for core power level, axial power imbalance, control rod insertion, and maximum rod relative power to preserve acceptable DNB performance based on the BHTP correlation predictions. In addition, a variable low pressure trip function provides protection to assure the plant does not reach or exceed the DNB-based safety limit of the technical specifications. The DNB-based operational and safety limits established for the plant provide hot pin/hot subchannel protection for acceptable plant operation, based on the local coolant conditions satisfying the correlation range of applicability defined in Table 1.1 of BAW-10241P. In response to the staff concern on the actions to be taken when local conditions fall outside the application ranges for limiting hot rod/hot subchannel, a treatment for qualities below the low quality limit and for pressures above the upper pressure limit was addressed in Reference 9. The staff has reviewed the justification for the approach to treat the out-of-approved range local conditions and has found them acceptable in principle, because the approach will result in a conservative CHF value. However, the staff will impose an allowable extension beyond the approved range for maximum pressure, but not exceeding 2600 psia and there will be no limit below the approved range for minimum quality. It will be subject to plant-specific review if the condition cannot be met. This conclusion is only applied to this review based on the data bases available to support the subject TR.

The BHTP correlation range of applicability, stated in Table 1.1 of BAW-10241P for local coolant conditions, is used in establishing the DNB-based limits associated with the above described operational and safety limits. The BHTP correlation range of applicability, stated in Table 1.2 of BAW-10241P, for fuel design parameters must be verified by the licensee prior to performing any DNB analyses using the BHTP correlation. The staff has reviewed acceptable ranges for both local coolant conditions and fuel design parameters against the BHTP data base in BAW-10241P and the data base in Reference 3. The acceptable ranges are provided in Table 1 and Table 2 attached to this safety evaluation.

5.0 CONCLUSION

The staff has reviewed BAW-10241P and the supplemental information (References 6 through 10) to determine acceptability of the BHTP correlation for use in DNB analysis of the HTP fuels and has concluded as follows:

(1) Based on the data in Reference 3, the BHTP DNB correlation is applicable to fuels whose design characteristics fall within the correlation data base in Table 2 below.

(2) Based on the data in Reference 7, the application of the BHTP correlation for DNB analysis is restricted to the operating conditions given in Table 1, except as noted in Condition 5 below.

(3) The BHTP correlation limit is determined to be as stated in the subject TR (Reference 2).

(4) DNB penalty relative to DNB prediction for a full core of Mark-BHTP fuel during transition core application shall be addressed in the plant-specific application.

(5) Actions for analyzing the operating conditions outside of the approved ranges of the maximum pressure, but less than 2600 psia are acceptable in principle for this application (Reference 9). Extrapolations below the minimum quality range using the process described in the TR are permitted with no lower limit. Any other extrapolation requires a plant-specific review.

6.0 REFERENCES

1. Letter from James F. Mallay, Framatome ANP to USNRC, Issuance of BAW-10241P, "BHTP DNB Correlation Applied with LYNXT," for Review and Acceptance, dated December 19, 2002. (ADAMS Accession No. ML023600367)

2. Topical Report BAW-10241P, Revision 0, "BHTP DNB Correlation Applied with LYNXT," December 2002. (ADAMS Accession Nos. ML023600394; non-proprietary version ML023600376)

3. EMF-92-153(P)(A), Supplement 1, "HTP: Departure from Nuclear Boiling Correlation for High Thermal Performance Fuel," March 1994. (ADAMS Accession Nos. 9403240220 for letter; 943240226 for proprietary version of TR; 9403240222 for non-proprietary version of TR)

4. BAW-10156-A, Revision 1, "LYNXT Core Transient Thermal-Hydraulic Program," August 1993. (ADAMS Accession Nos. 9309130167 for letter; 09130194 for TR)

5. 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," January 1986. (ADAMS Accession No. 8605140222)

6. Letter from James F. Mallay, Framatome ANP to USNRC, "Response to RAI [Request for Additional Information] Regarding BAW-10241(P), Revision 0, 'BHTP DNB Correlation Applied with LYNXT'," dated June 6, 2003. (ADAMS Accession No. ML031710023)

7. Letter from James F. Mallay, Framatome ANP to USNRC, "Response to RAI Regarding BAW-10241(P), Revision 0, 'BHTP DNB Correlation Applied with LYNXT'," dated September 3, 2003. (ADAMS Accession Nos. ML032480676 for letter and non-proprietary version of attachment; ML032480690 for proprietary version of attachment)

8. Letter from James F. Mallay, Framatome ANP to USNRC, "Response to RAI Regarding BAW-10241(P), Revision 0, 'BHTP DNB Correlation Applied with LYNXT'," dated February 11, 2004. (ADAMS Accession Nos. ML040440489 for letter and non-proprietary version of attachment; ML040440491 for proprietary version of attachment)

9. Letter from James F. Mallay, Framatome ANP to USNRC, "Response to RAI Regarding BAW-10241(P), Revision 0, 'BHTP DNB Correlation Applied with LYNXT'," dated June 17, 2004. (ADAMS Accession No. ML041750287)

10. Letter from James F. Mallay, Framatome ANP to USNRC, Additional Information Related to the Review of BAW-10241(P), dated August 9, 2004. (ADAMS Accession No. ML04228252)

Attachment: Table 1: Range of Coolant Conditions for BHTP Correlation
Table 2: Range of Fuel Design Parameters for BHTP Correlation

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Date: August 30, 2004

Table 1: Range of Coolant Conditions for BHTP Correlation

Pressure (psia)	1775 to 2425
Local Mass Flux (Mlb/hr/ft^2)	0.897 to 3.549
Inlet Enthalpy (Btu/lb)	383.9 to 644.3
Local Quality	-0.130 to 0.344

Table 2: Range of Fuel Design Parameters for BHTP Correlation

Fuel Rod Diameter (in)	0.360 to 0.440
Fuel Rod Pitch (in)	0.496 to 0.580
Axial Spacer Span (in)	10.5 to 26.2
Hydraulic Diameter (in)	0.4571 to 0.5334
Heated Length (ft)	9.8 to 14.0

Attachment B

SUMMARY TABLE OF PROPOSED CHANGES

PAGE NO.	LINE(S) NO.	PROPOSED CHANGE AND REASON
2	3	Change “Mark-B” to “the.”
2	8	Change “BTP” to “BHTP.”
2	9 - 11	Omitted proprietary data.
2	21	Omitted proprietary data.
2	34	Omit “Mark-B.”
3	34	Omitted proprietary data.
3	36	Omitted proprietary data; added “...most...”