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Response to a Request for Additional Information Regarding Addendum 3 to BAW-10199(P) "The BWU Critical Heat Flux Correlation"

Ref. 1: Letter, James F. Mallay (Framatome ANP) to Document Control Desk (NRC), "Request for Review and Approval of Addendum 3 to BAW-10199(P), 'The BWU Critical Heat Flux Correlation'," NRC:04:028, August 17, 2004.

Ref. 2: Letter, Ronnie L. Gardner (Framatome ANP) to Document Control Desk (NRC), "Response to a Request for Additional Information Regarding Addendum 3 to BAW-10199(P), 'The BWU Critical Heat Flux Correlation'," NRC:05:014, March 2, 2005.

Framatome ANP requested the NRC's review and approval of Addendum 3 to the topical report BAW-10199(P), "The BWU Critical Heat Flux Correlations" in Reference 1. A request for additional information was provided by the NRC in an e-mail on February 2, 2005. The response was provided in Reference 2. An additional request for information was provided by the NRC in an e-mail on July 12, 2005. The questions and responses to this request are provided in Attachment A to this letter.

Framatome ANP considers some of the material contained in the attachment to be proprietary. The affidavit submitted with the original topical report satisfies the requirements of 10 CFR 2.390(b) to support withholding of the information from public disclosure.

Sincerely,

Ronnie L. Gardner

Ronnie L. Gardner, Manager
Site Operations and Regulatory Affairs

Enclosures

cc: M. C. Honcharik
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ATTACHMENT A

REQUEST FOR ADDITIONAL INFORMATION
BAW-10199P, ADDENDUM 3
The BWU Critical Heat Flux Correlations

The BWU-B11R CHF Correlation for the Mark-B11 Spacer Grid

Question 1: *There are only three out of range data at 315 psia, and none of data between 315 to 595 psia. How could a proposed new correlation extend a previous approved correlation from 595 - 2425 psia to 315 - 2425 psia because of inclusion of the three out-of-range data?*

Response 1: The CHF test program for the Mark-BW included pressures down to 400 psia. The resulting data was correlated into the BWU-Z CHF correlation in the original of BAW-10199 using a dedicated data base from Mark BW CHF tests. Two other versions of the BWU correlations based on separate data bases were also developed in the original release of BAW-10199 (BWU-I and BWU-N).

In the CHF test program for the Mark-B11 the pressure range was extended down to 315 psia. The Mark-B11 CHF test program was designed to yield a stand alone CHF data base for use with a new version of the BWU CHF correlation. By using a new version of the BWU CHF correlation, the coefficients of the BWU correlation form could be optimized to result in a more accurate representation of the Mark-B11 CHF data base. Unfortunately, because of time constraints at the time of the submittal of Addendum 1, Framatome ANP concluded it would be more efficient to apply the already licensed BWU-Z CHF correlation to the Mark-B11 fuel design with only a simple factor (multiplicative factor, F_{B11}). Since the coefficients of the BWU-Z correlation were not reoptimized with the new Mark-B11 data, only Mark-B11 data within the BWU-Z data base range could be included in the verification. This was done in Addendum 1 and hence the 315 psia data (the only ones outside the Mark-BW data base range) had to be removed.

The development of a new form of the BWU correlation specifically for the Mark-B11 design (BWU-B11R), however, can and should use the entire data base because its coefficients are optimized over that entire data base. Further, the new correlation is a much better representation of the Mark B11 performance as evidenced by the reduced spread of the data.

Question 2: *A previous approved correlation which is excluded three outliers by criterion of M/P value (i.e., M/P CHF ratio deviates more than four standard deviations from the mean). How could a proposed new correlation include the three outliers?*

Response 2: This is related to the optimization of the correlation its the true data base (Mark-B11) rather than a simple comparison with a correlation developed on a different (foreign) data base (the Mark-BW data base). The dedicated Mark-B11 (BWU-B11R) correlation is a much better fit (to its own data) and thus only one data needed to be rejected. The table below shows that BWU is a much better fit to 29051 and 29059 and that it predicts 29064 as a true outlier (almost 9 standard deviations from the mean).

Data Point	M/P in Addendum 1	# Std. Devs. From Mean Addendum 1	Reject in Addendum 1?	M/P in Addendum 3	# Std. Devs. From Mean Addendum 3	Reject in Addendum 3?
29051	[ ]	4.1	Yes	[ ]	1.5	No
29059	[ ]	4.9	Yes	[ ]	0.1	No
29064	[ ]	7.0	Yes	[ ]	8.6	Yes

Question 3: *In DNBR Design Limits calculation, degrees of freedom are n-1-14 in BAW-10199-P-A, and n-1 in both BAW-10199-P-A, Addendum 1 and BAW-10199-P-A, Addendum 2. The proposed Addendum 3 is similar to Addendum 1, but degrees of freedom is n-1-14. This difference should be clarified.*

Response 3: When coefficients of a correlation (equation) are optimized (using their dedicated data bases) the number of degrees of freedom (DF) must be reduced by the number of undetermined coefficients. For the three original correlations (BWU-Z, BWU-I and BWU-N) the reduced DF (n-1-14) was used since the coefficients were optimized from their respective data bases. In Addendum 1 and 2 the coefficients were not reoptimized and thus the unreduced DF was used (n-1). In the present application (BWU-B11R) the coefficients are again optimized using the dedicated Mark-B11 data base and so the reduced DF (n-1-14) must be used. Note that using the reduced DF increases the standard deviation used in calculating the design limit and thus is conservative (i.e., the design limit increases) with respect to using the unreduced DF.

Question 4: *The database should be consistent with an approved methodology. Therefore, number of data should be adjusted corresponding to concerns raised in questions 1 and 2, and a final DNBR Design Limits should also adjusted.*

Response 4: In consideration of questions 1 through 3 above, the entire data base is the applicable one. The new version of the correlation was developed from a dedicated data base and is the way CHF correlation should be done in the first place.

However, in reviewing the two lower pressure data sets (below 1000 psia – see Figure I-1 page I-4) it is acknowledged that there is a slight downward trend from the M/P = 1.0 line. Also, the reviewer commented above (question 1) that there were only three data for the lower pressure group (315 psia). It is further acknowledged that this is true and was only because of possible damage to the electrically heated test section in the Columbia facility that more data were not taken for this group. Future test programs (at Framatome's Karlstein CHF facility) will gather significantly more data at the lower pressure conditions.

The statistics for the 14 data between 315 and 1000 psia (the 600 psia group) show a mean M/P CHF of 0.9962 with a standard deviation of 0.0609. The 95/95 Owen's multiplier (Reference 4 of Addendum 3) is 2.614. From these figures an increased Design Limit of 1.195 is calculated (1/(0.9962 – 2.614*0.0609)).

The statistics for the 3 data at 315 psia show a mean M/P CHF of 0.9828 with a standard deviation of 0.0561. The 95/95 Owen's multiplier is 7.656. From these figures an increased Design Limit of 1.807 is calculated (1/(0.9828 – 7.656*0.0561)).

Framatome thus proposes the following CHF Design Limits for the BWU-B11R CHF Correlation.

Pressure Range, psia	CHF Design Limit
315 to 594	1.81
595 to 999	1.20
1000 to 2425	1.145

It was also noted by the reviewer that there is an inconsistency in the numbering of the coefficients: in the original topical the coefficients are numbered from A0 to A13 while in Addendum 3 they are numbered from A1 to A14. This is a typographical error and will be corrected when the final version of the topical is released.