**Babcock & Wilcox**

a McDermott company

Nuclear Power Generation Division

3315 Old Forest Road
P.O. Box 1260
Lynchburg, Virginia 24505
(804) 384-5111

September 8, 1982

Mr. John S. Berggren
Standardization & Special Products Branch
Division of Project Management
Office of Nuclear Reactor Regulation
U. S. Nuclear Regulatory Commission
Washington, DC 20555

Dear Mr. Berggren:

Per discussions between G. A. Schwenk of the NRC staff and G. O. Geissler of my staff I am providing you 25 copies of the attached document titled "Justification For the Retention of the C-6 Bundle Data In the Data Base For the BWC CHF Correlation," September, 1982.

The NRC staff and the contractor reviewing topical report BAW-10143P, Parts 1 and 2 "BWC Correlation of Critifal Heat Flux" August 1981, have been appraised of the information contained in the attached document. This information is being forwarded to you in response to the NRCs verbal request to provide written confirmation for the retention of the C-6 bundle data.

It is anticipated that the receipt of this information will provide the NRC staff the necessary documentation required to release the SER on topical report BAW-10143P.

If you have any questions, please contact Mr. George O. Geissler (804-385-2536) of my staff.

Very truly yours,

J. H. Taylor
Manager, Licensing Services

JHT/fw
cc: G. A. Schwenk - NRC
R. B. Borsum - B&W- Bethesda Office

TO10

Justification for the Retention of the C-6 Bundle Data in the Data Base For the BWC CHF Correlation

September 1982

The data base for the BWC correlation comprises 601 data points. These data were the result of multiple determinations of the Critical Heat Flux (CHF), over the expected range of operation of the independent variables, in seven separate tests. The first test (C-3) was performed in 1973 on an existing 1.8 megawatt heat transfer facility at B&W's Alliance Research Center (ARC). The 1.8 megawatt capacity of this facility was judged by B&W to be insufficient to fully investigate the important parameters of CHF in the development of a new correlation. Consequently, B&W constructed a new 10 megawatt heat transfer facility for further testing.

One of the primary measurements required in CHF testing is that of the electrical current (and thus the heat input) passing through the simulated fuel pins. This electrical current is measured by a current "shunt".

As is true in the construction of any sophisticated testing facility, many of the necessary components had to be obtained from outside sources. The current shunt was one of these components. The specification for the shunt was written for a capacity of 50,000 amps with a specified calibration at 20,000 amps. For consistent readings, the resistance of the shunt must be constant with time and a known (calibrated) function of power. The supplier inadvertently sized the shunt for a maximum of 20,000 amps (not the specified 50,000). The undersizing of the shunt ultimately resulted in a permanent change in its resistance.

As part of the QA program following the completion of the C-6 test, the shunt was recalibrated. This recalibration led to the discovery of the change in resistance. ARC, which was under contract for the testing with the Nuclear Power Generation Division (NPGD) of B&W, determined that this change in resistance was both time dependent (during testing) and also affected the known function of power. Thus a simple invariant correction factor could not be applied to the data. ARC devised a current (power) correction scheme to be applied to the data that was essentially a linear function of testing time and a quadratic function of power level for each data point.

The correction scheme was reviewed and accepted by NPGD. A new shunt was then purchased to the true specification of 50,000 amps maximum current, and the remaining tests (C-7, 8, 9, 11 and 12) were completed.

NPGD then began the process of reducing the data and obtaining the BWC correlation as detailed in BAW-10143P. After final optimization of the correlation coefficients, analysis of variance (ANOVA) tests revealed that the C-6 data did not "fit" in the data base. However, when the C-6 data was deleted, even without reoptimization of the coefficients, all the other tests together and individually passed the ANOVA tests.

From these results, it was clear that either the C-6 data should be deleted from the data base and the coefficients reoptimized, or that it would be necessary to justify retention of the correlation and data base as developed (with the C-6 data) as conservative for CHF protection. Because the correlation had been implemented in design codes and used in preliminary analyses, the latter course was chosen.

There are two primary uses of a CHF correlation: 1) the level of CHF for a specific design condition, and 2) the design limit departure from nucleate boiling ratio (DNBR) above which CHF protection is assured. The justification for the retention of the correlation as developed is as follows:

a) CHF Level Table 1 shows all of the CHF tests and their associated statistics. The average measured to predicted ratio (M/P) of the questionable C-6 data set is low (0.9511) in relation to the remainder of the data (1.0079 from Table 2). Recorrelation could be performed without the C-6 data, with the overall data base mean forced back to 1.0 as in the original correlation. This would, then, raise the level of CHF predicted by the new correlation for any given condition. Thus retention of the original correlation results in a lower (more conservative) predicted CHF level.

b) Design Limit DNBR ($DNBR_L$) - The $DNBR_L$ depends on the number of data points, the correlation mean M/P ratio, and the correlation standard deviation, $\sigma_{M/P}$, as detailed in BAW-10143. The current 1.14 $DNBR_L$ is shown on Table 1. If the C-6 data are deleted (but the original correlation used) a 1.12 $DNBR_L$ results (see Table 2). Further, if recorrelation had been performed, the standard deviation would have been smaller resulting in a $DNBR_L$ even lower than the 1.12. Since a higher $DNBR_L$ is conservative for CHF protection, retention of the current 1.14 Design Limit DNBR is conservative.

In conclusion, the justification for possible deletion of the questionable C-6 data (identified by ANOVA tests) is provided by the physical explanation of the defective current shunt. The justification for retention of the C-6 data in the data base is provided by two facts: 1) recorrelation without the C-6 data would result in higher predicted CHF levels and 2) the Design Limit DNBR without the C-6 data would be lower than the current 1.14 limit.

Table 1

BWC WITH C-6 DATA

| Test ID | Data Points, N | Mean, M/P | Std. Dev., $\sigma M/P$ |
|---|---|---|---|
| C-3 | 68 | 1.0104 | .0695 |
| C-6 | 92 | 0.9511 | .0716 |
| C-7 | 95 | 1.0175 | .0690 |
| C-8 | 122 | 0.9944 | .0621 |
| C-9 | 85 | 1.0065 | .0642 |
| C-11 | 30 | 1.0281 | .0739 |
| C-12 | 109 | 1.0086 | .0615 |
| 7 Tests | 601 | 0.9992 | .0697 |

$$DNBR_L = \frac{1}{\overline{M/P} - K_{n,\gamma,p}\sigma^{*}_{M/P}}$$

$$= \frac{1}{0.9992 - 1.759\ (0.0703)} = 1.142$$

$n = 601 - 11 - 1 = 589$ (DF with 11 coefficients)

$\gamma = 0.95$ (confidence)

$p = 0.95$ (population)

$\sigma^{*}_{M/P}$ based on n

Reference: Section 5.2, BAW-10143P

Table 2

BWC WITHOUT C-6 DATA

| Test ID | Data Points | Mean, M/P | Std. Dev. $\sigma M/P$ |
|---|---|---|---|
| C-3 | 68 | 1.0104 | .0695 |
| C-7 | 95 | 1.0175 | .0690 |
| C-8 | 122 | 0.9944 | .0621 |
| C-9 | 85 | 1.0065 | .0642 |
| C-11 | 30 | 1.0281 | .0739 |
| C-12 | 109 | 1.0086 | .0615 |
| 6 Tests | 509 | 1.0079 | .0657 |

$$DNBR_L = \frac{1}{\overline{M/P} - K_{n,\gamma,p}\sigma^*_{M/P}}$$

$$= \frac{1}{1.0079 - 1.763\ (0.0664)} = 1.123$$

$n = 509 - 11 - 1 = 497$

$\gamma = 0.95$

$p = 0.95$

$\sigma^*_{M/P}$ based on n

ANOVA for 6 Tests

F - Ratio = 2.052

DF between = 5

DF within = 503

Not significant at .05 level