ENCLOSURE

SAFETY EVALUATION
OF THE
BABCOCK & W..COX
TOPICAL REPORT - BAW-10145P (Proprietary)
(TACS 43323)

STATISTICAL CORE DESIGN APPLIED TO THE
BABCOCK - 205 CORE

JUNE, 1985
CORE PERFORMANCE BRANCH

INTRODUCTION

The subject report describes the statistical analysis of the thermal-hydraulic margin of a 3800-MWt, 205-fuel assembly core. Included are the basis for the statistical core design (SCD) analysis, the basis for the DNBR design analysis, the derivation of the methodology, and sample applications.

The objective of using SCD was to statistically combine uncertainties, rather than compounding them, to recognize additional margin to thermal-hydraulic (DNBR) limits during design overpower and anticipated transient conditions.

Traditional analysis methods provided such a large, conservative margin to DNB for the power-limiting fuel pin that the rest of the core was also intuitively protected. On the other hand, SCD analysis evaluates the level of protection of the whole core statistically, thereby eliminating the need to "overprotect" the power-limiting pin. The quantitative criteria that were chosen for SCD are listed below; the SCD limit was chosen so that these criteria would be met with 95% confidence.

- The expected number of pins in DNB at the design overpower condition is less than one.

- The probability that no pin is in DNB at the design overpower condition exceeds 0.95.

- The probability that the power-limiting pin is not in DNB at the design overpower condition exceeds 0.99999.

- The expected number of pins in DNB with the power-limiting pin at the SCD DNBR limit is less than 0.1% of the total number of pins in the core.

- The probability that the power-limiting pin avoids DNB when at the SCD DNBR limit exceeds 0.95.

The overall approach to SCD development was to build a fast-running computer model, run a large number of cases using the model, and derive the statistical limits from the results of these runs. Data generated with the thermal-hydraulic computer codes and the BWC CHF correlation were used to generate an efficient response surface model (RSM) in the area of interest; the uncertainty distributions for the input parameters were propagated through the RSM using Monte Carlo techniques. Based on these data, the statistical DNBR limit, or SDL, was determined to be 1.30; that is, if the calculated DNBR for the most power-limiting pin remains above 1.30 during the transient/accident being analyzed, the protection criteria listed above will be met with 95% confidence. B&W proposes to use a thermal design limit of 1.35 as opposed 1.30 to provide margin for additional uncertainties.

SUMMARY OF REPORT

The traditional thermal-hydraulic design of pressurized water reactors has maintained core thermal protection during normal operations and incidents of moderate frequency by avoiding departure from nucleate boiling (DNB) during these conditions. The minimum DNB ratio (MDNBR) for each condition or transient was calculated with the core parameters all held at conservative levels assuming that worst-case conditions were experienced during the event. This MDNBR was then compared to the DNBR limit associated with the critical heat flux correlation being used. These comparisons were made on the most power-limiting pin only.

B&W's proposed statistical core design (SCD) retains the transitional criteria that core protection should be provided by designing to avoid DNB but changes the treatment of the uncertainties present in the DNBR calculation. It combines some of these uncertainties statistically while leaving others at conservative levels. SCD uses the DNBR calculated for the most power-limiting pin to quantify the protection afforded to the entire core. This quantification is based on best estimates with uncertainties of these estimates taken into consideration. Comparisons are made to the point of inception of DNB (DNBR = 1.0) rather than

the correlation limit (1.14), since the critical heat flux correlation uncertainty has been included in the statistical treatment.

The overall objective of SCD is to quantify the thermal-hydraulic design margin and to remove any excessive conservatism from the DNBR calculations.

The calculated DNBR for a given plant condition is higher when calculated by the SCD technique since various uncertainties present in the traditional analysis have been removed from this calculation. Likewise, the DNBR limit (TDL) is higher since it now incorporates those uncertainties previously in the calculated DNBR. However, because these uncertainties had been linearly combined in the calculated DNBR and are now statistically combined in the TDL, the margin between the two has increased.

STAFF EVALUATION

The principal review of BAW-10145P was performed by Battelle Pacific Northwest Laboratory and their findings were reported to the NRC in Reference 1. The staff has reviewed this document as well as BAW-10145P and has reached the following conclusions.

1. The statistical methods and techniques used in BAW-10145P are acceptable.

2. The following restrictions are placed on the use of SCD limits.

RESTRICTIONS ON USE OF THE SCD LIMITS

a) Four of the random uncertainty values have been identified as requiring review for applicability on a plant-specific basis. The review must be done prior to the implementation of the SCD limits for each plant. The uncertainties are:

- spacing between bundles, AB
- hot channel factor, F_Q
- axial power peak, F_A
- bypass flow, W_B.

T-H analysis codes and a CHF correlation are used in developing the SCD thermal design limit. Replacement of these codes or correlation, if proposed, must be justified by B&W and be reviewed and approved by the staff.

b) The approved codes and correlation are:

- LYNX-1 code
- LYNX-2 code
- LYNXT-code
- BWC DNB correlation.

c) Moreover, the BWC DNB correlation was developed with models of the B&W geometry rod bundles. The application of SCD to other geometries, if proposed, must be justified by B&W and be reviewed and approved by the staff.

These conclusions are identical to the recommendations made by Battelle except that Battelle did not include the LYNXT code and Battelle recommended a model uncertainty arising from the LYNX/RSM difference and from the model of adjusted DNBR be included in the estimate of total DNBR uncertainty. The LYNXT code was added to the list of acceptable codes since LYNXT and LYNX1/LYNX2 have been found by the staff to produce equivalent DNBR's. As a result of the Battelle recommendations concerning additional model uncertainties, the staff questioned B&W further on their treatment of fitting errors in the response surface mode and the adjusted DNBR model. B&W responded to these questions in Reference 2.

The B&W response showed that a substantial "fitting" error, when propagated over a large range in a detrimentally offset RSM resulted in a small propagation error. Also reasons were given to illustrate why this example propagation error would, in actual application, be even smaller. An assumed (conservatively high) propagation error was then combined with the adjusted DNBR model fitting error and pin failure calculations were performed. In this calculation it was shown that B&W's practice of using a conservative upper tolerance limit on the design σ_{DNBR} more than adequately compensates for any slight additional propagation as fitting errors. Thus, with the B&W methodology as proposed, no additional components of variance are necessary.

SUMMARY

The staff has concluded that the methods and analyses of BAW-10145P are acceptable for use in licensing calculations subject to the following restrictions.

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References:

1. G. M. Hesson, et al, "Review of Report BAW-10145P Statistical Core Design Applied to the BABCOCK-205 Core," Battelle Pacific Northwest Laboratory, October 1983, FATE-83-132.

2. Letter, J. H. Taylor (B&W) to C. O. Thomas (NRC), "Statistical Core Design Model Fitting Errors," May 13, 1985.