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August 25, 1982

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

Dear Mr. Berggren:

Enclosed are 25 copies of B&W's response to NRC questions on Topical Report BAW-10145P- "Statistical Core Design Applied to Babcock 205 Core." These responses address questions sent to us in an NRC letter, "Request No. 1 for Additional Information on BAW-10145," 9/23/81.

This topical report applies to all 205 FA B&W plants and will be first referenced by TVA for the Bellefonte 1 & 2 plants.

Also attached is one set of microfiche records of computer runs as referenced in the attached responses to questions 7, 9, 10, 12, 36, 37, and 39. The information contained in response to Question 20 and the enclosed microfiche is considered proprietary as sworn in my affidavit presented with our Dec. 10, 1980 submittal of the topical report and should be treated as such.

Since the silver halide microfiche are produced directly from computer runs provision could not be made to mark each fiche header with a proprietary notation as requested by NUREG-390. However each separate microfiche envelope contains a sheet marked proprietary. We trust this will be satisfactory.

Very truly yours

J. H. Taylor

J. H. Taylor
Manager, Licensing

JHT/fw
cc: R. B. Borsum - B&W Bethesda Office

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To: John Berggren

QUESTION 1.

Section 1.2. The objectives section includes discussion on SCD methodology and results. Does the last paragraph in the section describe the result of applying the SCD methodology or objectives that are to be met? It would be more appropriate to describe the methodology and refer to Figure 1-1 as part of methodology section.

RESPONSE

The overall objective of BAW 10145P was to quantify the thermal-hydraulic design margin. The method chosen for this was a sensitivity analysis. The last paragraph in Section 1.2 gives the results of applying SCD methodology. Figure 1-1 illustrates the results. Please see the response to Question 16 for a detailed explanation of Figure 1-1.

QUESTION 2.

Section 1.3 Does the statistical core design methodology depend on using a response surface model (RSM) and a Monte Carlo simulation or are these components just B&W's choice? Isn't the key issue the propagation of errors through a complex computer code? Since this methodology is applied to a generic 205 core, will the RSM estimate apply without change to all specific analyses or will the RSM be re-estimated in each case? If it is intended to apply to all, how will it be justified in each case?

RESPONSE

The SCD methodology depends on a Response Surface Model (RSM) only to the point of making the analyses feasible. The output DNBR uncertainties could have been obtained via direct Monte Carlo runs with the LYNX1/2 code. To carry out 2000 - 3000 of these would be prohibitively expensive.

The objective of propagating input uncertainties, not errors, through a complex computer code was therefore considered feasible with the RSM technique only.

The questions to be answered were the following:

Suppose that a DNBR prediction is made with the LYNX1/2 code, under a set of assumed core conditions. By what amount could this LYNX1/2 value of DNBR vary as a result of uncertainties in the actual value of: channel flow area, due to pin pitch and rod diameter (F_A); fuel pin heat output, due to stack diameter and enrichment (F_Q); bypass flow (W_B); spacing between bundles (A_B); radial peaking (R_{unc}) and the correlation in critical heat flux (CHF_{unc}). The uncertainty due to modeling is treated through the $Code_{unc}$.

The LYNX1/2 prediction for a core condition is considered to be the conditional mean value of a distribution with the total DNBR uncertainty evaluated as outlined above, equaling the standard deviation of that distribution. The RSM is used only to obtain an estimate of σ (DNBR), at a specific core condition, not for replacing a LYNX1/2 prediction.

In developing the RSM, the ranges of the input parameters were carefully chosen so as to bracket the operating parameters of all currently existing 205 plant designs. It is expected that for each plant the input uncertainty distributions will be reviewed for applicability and compatability to the results of BAW 10145P.

QUESTION 3.

Page 1-3. Why were 3000 Monte Carlo runs selected as the appropriate sample size? On page 3-6 as sample size is increased the upper limit on the standard deviation converges to the Monte Carlo estimated standard deviation.

What justification can be given for the validity of using the RSM to propagate the LYNX model input uncertainties? Why isn't it necessary to include an uncertainty due to approximating the LYNX code with the RSM model?

RESPONSE

a) A value of N = 3000 is a reasonable choice for estimating a middle percentile value of a distribution. A larger value of N would have reduced the value of $\hat{\sigma}^{95}$ obtained in equation 3-4. In keeping with the SCD methodology, conservatism was applied to the output rather than the individual inputs. While the Monte Carlo estimated standard deviation alone would have been sufficient, implementation of the upper limit gives confidence in the conservatism of the results.

b) Several justifications can be given for substituting the RSM for the LYNX code in order to propagate input uncertainties.

   1. It is an accepted technique (PRA methods guide).

   2. It is based on 56 combinations of the input parameters, which bracket a spectrum of core conditions.

   3. Over the 56 cases selected the RSM performs well. (Standard error, σ_ε = .073 with a minimum deviation of 4×10^{-4} to a maximum of 0.12 DNBR).

      The σ_ε value is based on a comparison of the RSM predictions with the LYNX predictions at the same 56 inputs.

   4. The RSM is applied only to estimate a σ DNBR.

c) The uncertainty due to approximating the LYNX code with the RSM is included as $Code_{unc.}$ However, only the uncertainty due to variability needs to be included. For the prediction uncertainty, a factor would only be needed if instead of the LYNX predictions the RSM predictions would be substituted overall. They are not. Actually because of this, no credit is taken for the fact that at the only core condition where σ DNBR is finally applied, the 112% FOP case, the RSM is 8 DNBR points too conservative.

QUESTION 4.

Page 2-10. Why were two or three pin DNBR values averaged for UC or CR type pins before the RSM was fit? Does this imply that the RSM predictions are for the average of two or three pins? How does this affect the estimation of the probability that a single pin exceeds a DNBR of 1.0? This appears to be a fundamental issue.

RESPONSE

Different pin DNBR values were not averaged for input to the RSM: the adjacent subchannel DNBR's on a single pin were the values so treated. Thus the RSM is representative of an average DNBR value for a given peaking value which is consistent with the physical configuration. A separate DNBR value exists for a pin from a control rod and from a unit cell type, however. There were two RSM's developed.

By establishing a one-to-one correspondence between peaking and the DNBR on a given pin, the probability of exceeding a DNBR of 1.0 on a pin is a feasible calculation. Please see the Response to Question 24 for a further discussion of the use of multiple subchannel DNBR's on a single pin.

QUESTION 5.

Page 2-21. This table is not self-explanatory. What are the percents for Q and W based on? Are these limits the absolute end points for which the RSM may be used? Since only a small fraction of a possible combinations of the nine input variables were used in developing the RSM model, how well does the model predict for other combinations, both extreme points and other interior points? The fact that the RSM did not fit all original LYNX predictions may imply that the model does not fit in other regions. How can this be checked?

RESPONSE

Q is based on a percentage of the rated core thermal power (3800 MWt), while W is based on a percentage of the primary system design coolant flow (434,000 GPM).

The table represents the recommended limit for the efficient utilization of the RSM. See also the Response to Question 46.

There were 56 combinations of the 9 input variables selected in order to develop a representative and useful RSM. While it may well be said that this number (56) is a "small fraction of possible combinations", nevertheless they are in a boundary of an expected operating surface. They are expected to envelope the operating parameter combinations and do bracket a range of DNBR values from 0.5 to 3.0. The RSM is valid over the interior points as outlined in Table 2-9, page 2-21 or any combination of these levels. Several check cases have been made as verification. However, it must be stressed once more that the purpose of the RSM was to establish sensitivities of DNBR to certain input uncertainties and not of substituting it for the LYNX code.

The validation of the RSM at the end points was done with additional LYNX runs. The results from these check cases are available from Table 2-10.

QUESTION 6.

Page 2-30. There are only 48 points plotted. Where are the remaining?

RESPONSE

There are some input parameter combinations that differ case by case but yield equivalent (or nearly so) DNBR values. This occurred in several cases among the 56 points resulting from the runs shown in Table 2-5. Thus in plotting the 56 LYNX versus RSM predictions the duplications were omitted, resulting in having only 48 points shown in the Figure 2-8. A figure with a more detailed scaling could accommodate the 56 points in total.

QUESTION 7.

Page 2-31. Figure 2-9 shows the MDNBR from the RSM model to systematically overpredict. Is this always the case of the extremes? In general, the reason the RSM does not agree with LYNX is because the RSM is incorrect; there is no random variation. Can you demonstrate that there is no systematic patterns in the residuals?

RESPONSE

Figure 2-9 illustrates the one-at-a-time variations in DNBR, due to Q and separately due to W. Other figures indicate similarly the variation due to each of the other variables. It cannot be said that the RSM overpredicts systematically, not even in Figure 2-9. While the RSM overpredicts with variations in W alone, it underpredicts with variations in Q alone. The amount of model conservatism increases with power.

Note that the effects of Q and W essentially cancel each other or are minimized when applied to actual operating cases in which Q and W move away from nominal (center where the fit is perfect). In addition, the RSM is used only for the assessment of sensitivities, it is applied to a case where Q = 112% and for that case the model yields conservative predictions.

The RSM is not expected to replace LYNX, only to approximate it. The model residuals are spread on both sides of the LYNX observations, without evidence of any systematic pattern. The computer printout microfiche "RSM10VT" is enclosed for inspection.

QUESTION 8.

Page 3-2. Why is code uncertainty treated as multiplicative and correlation uncertainty as additive?

RESPONSE

The code uncertainty accounts for variability in approximating the LYNX code with the RSM. DNBR variability in LYNX increases with increasing absolute DNBR values. Treatment of code uncertainty as multiplicative takes this variation with absolute DNBR level into account.

The correlation uncertainty, on the other hand, is a measure of the precision of the CHF correlation itself about a specified constant DNBR level (1.0 in this case). Treatment of correlation uncertainty must, therefore, be independent of the absolute DNBR level calculated by the RSM and is thus treated as additive.

QUESTION 9.

Where are the details of the least squares analysis for C_1 and C_2? The exact procedure and data used for the analysis is not clear. From Figures 3-4 and 3-5 it appears that data for DNBR range from 2.15 to 3.00, but yet the Monte Carlo results produce DNBR values much lower. Is this a case of extrapolating the model beyond the range of the data?

RESPONSE

The RSM was developed for a "typical" pin using 56 various combinations of the 9 input variables. For these, the DNBR (output) values range from .5 to 3.0, approximately. For each of these results it is feasible to make an adjustment, an increase or decrease in DNBR, as a function of the difference in local peaking only. Assuming that a core condition is kept constant, the amount by which the DNBR is assumed to change, due to local peaking changes alone, is evaluated with the coefficients C_1 and C_2. The details of the computer calculation of the regression analysis for the C_1 value obtained at A_{nom} conditions are enclosed as "RSM1051". C_2 is estimated by the (LYNX-RSM) deviation.

Figures 3-4 and 3-5 show example plots of DNBRs versus local peaking, for a specific set of core conditions. The case shown is for nominal operating conditions whereas the Monte Carlo Analysis was done for the design case (Q = 112%, etc.) shown in Table 3-6 as case 1.

QUESTION 10.

Section 3-2, Page 3-4. What is the function of SAMPLE and what do the input arguments contain? Please explain all variables and constants used.

RESPONSE

The statements of the "SAMPLE" program are listed on Page 3-15 in Table 3-5. The input arguments from case 1 Table 3-6 are: Q = 112%, P = 2205, T = 567.7, A = 1.67, Z = 0.5. They can be read in line number 14 of Table 3-5 in the equivalent, coded, units. The coded values are computed with the aid of Table 2-6. The input "X" refers to the number of randomized variables which is seven in this case, "C" is a feature which is not used in the run. The constants are the coefficients of the RSM obtained from Table 2-8. Other inputs are: number of cases, N = 3000, as well as the means, standard deviations or other needed parameters for the randomized variables from Table 3-4. The form of the distribution (Normal, etc.) is also an input. An actual computer run Microfiche is attached (ID: SAMPL 9Z) to aid in explaining.

The line No. 23 contains the constant (.062435) which is from equation B-2 of Page B-3 and represents the sensitivity of DNBR to interbundle area changes.

The constant of line No. 29 is (-.0453456) which is the value obtained from equation 3-1 adjusting the RSM to the MPLP.

$\Delta\ell$ = 1.038164 (MPLP) - 1.02737 (pin peak of RSM cases) =

= .010794 and

C_1 = - 4.201 from Table 3-3. Thus substituting into equation 3-1

$\Delta\ell . C_1 = \Delta DNBR = .010794\ (-\ 4.201) = -.0453456$.

The value of C_3 (equation 3-1) is 1.0 in this case and the value of C_2 of the equation was not used because at 112% FOP the model was found to be 8 DNBR points too conservative (lower than LYNX) and it was decided not to take credit for this factor.

QUESTION 11.

Page 3-8. Is ϕ the cumulative normal distribution? Can the assumption of independence of all pins in the core be justified?

RESPONSE

In the nomenclature, ϕ is defined as the Normal distribution. Precisely, when a variable $X \sim N(\mu,\sigma)$ then $Z = \frac{X - \mu}{\sigma}$ and $Pr(Z \leq k) = \phi(o,1):k$ or $Pr(Z \leq k) = \int_{-\infty}^{k} e^{-\frac{1}{2}Z^2} dZ$.

The assumption is made that the pins have equal variations about their mean for a fixed core condition, and that the means are conditional on that core condition. These means are estimated from the LYNX1/2 Code for given assumed core conditions.

The equations of Section 3.4 are applied at a fixed core condition: case 1 of Table 3-6.

QUESTION 12.

Page 3-10. The calculations for the estimates on this page should be explicitly given as they form the final estimates.

RESPONSE

With the most limiting pin at the SCD limit of 1.30, the following estimates are made:

a) The expected number of pins in DNB is less than 0.1% of the core (54 pins = 0.1%).

   i.e., using equation 3-13 and the values of Table 3-8 (4th column bottom half).

$$E_C = 5.5897 \times 3.8769 + 2.6462 + 1.7767 +$$

$$+ 2(1.1734) + 45.25\ (.7621)$$

$$= 13.8895 + 2.3468 + 34.485 = 50.7213$$

b) The probability that the most power limiting pin avoids DNB is 0.976.

   i.e., Figure 3-7 and equation on the Figure show that

$$Pr\ Z \geq \left[\frac{1. - 1.30}{.146}\right] = Pr\left[Z \geq -2.0548\right] = .976$$

The values from Table 3-8 can be found in the computer run "RELAOAM" which is attached as a Microfiche.

QUESTION 12-2.

Part II:

With the core at the design overpower conditions, the following estimates are made:

a) Less than one pin is expected to be in DNB.

i.e., calculations of equation 3-13, from Table 3-8 (4th column top half):

$$E_C = \left[.0005867 + .7166 \times 10^{-6} + .13247 \times 10^{-6} + \right.$$

$$\left. + .02278 \times 10^{-6}\right] + 2\,(.00919 \times 10^{-6}) + 45.25\,(.00142 \times 10^{-6}) =$$

$$5.875719 \times 10^{-4} + 1.838 \times 10^{-8} + 6.4255 \times 10^{-8}$$

$$= 5.8765 \times 10^{-4}$$

b) The probability that no pins will be in DNB is .999412.

i.e., calculations of equation 3-10, from Table 3-8 last column:

$$P_C = (.999413)\,(.99999928)\,(.99999987)\,(.999999977)$$

$$(.999999991)^2 \times (.9^8858)^{45.25} =$$

$$= (.9994121095)\,(.9999999321) = .9994120417$$

c) The probability that the most power limiting pin avoids DNB is .9999972.

i.e., $Pr \quad Z \geq \left[\frac{1 - 1.72}{.146}\right] = Pr\ (\ Z \geq -\ 4.9315) = .9999972$

QUESTION 13.

Page 8-3. Why is such a simplified approach as sensitivity used for the effect of AB in equation (B-2)?

RESPONSE

It is apparent from several questions that some confusion exists concerning the various components and treatment of the pin peaking. The following discussion is included to clarify the responses to this and subsequent questions relating to pin peaking.

The DNBR on any pin is the result of (among other things) the specific power output of that pin. The specific pin power of any pin in the core is calculated using several different variables:

1) The average rated power of a pin in the core ($\bar{q}$) and the corresponding core power (Q).

2) The normalized (within core) radial peak (R) for the bundle which contains that pin.

3) The normalized (within bundle) local peak (L) for the pin. The local peak is a function of both the position of the pin in the bundle (ΔL) and the local peaking gradient within that bundle (ΔA). The local peaking gradient is primarily a function of bundle spacing (AB).

4) The hot channel factor on pin power due to manufacturing tolerances (F_Q).

Thus

$$q_{Pin} = \bar{q} \times Q \times R \times L \times F_Q$$

The RSMs were developed for a specific pin location in a specific bundle. Thus, for each input point (to the RSM), Q, R, and F_Q were determined by the experimental design of the RSM. A fixed value of L corresponded to the RSM base location within the bundle. Then, for any combination of input variables, a DNBR on the RSM pin can be evaluated with the RSM. In order to determine DNBR values for pins in that bundle other than the RSM pin, an adjustment based on the local peaking value of the specific pin must be implemented. This is the ΔL adjustment of section 3.1. It is not an uncertainty. Thus by inputting Q, R, ΔL, F_Q, and the other non-peaking related variables into the RSM, the DNBR on any pin can be evaluated.

Next we must consider uncertainty propagation through the RSM. No uncertainty on Q is considered. Q is held at its conservative value in the analyses (and thus is completely deterministic). R is a deterministic variable in the analyses, but its uncertainty R_{unc} is treated as a random variable. F_Q is a random variable in itself (its mean, or deterministic value being 1.0). This leaves the local peaking variable, L. It is deterministically treated as discussed above using ΔL (i.e., each pin in the bundle has a specified L differing by some ΔL from the base pin on which the RSM was developed). Its uncertainty, arising from bundle area uncertainty (ΔA), is treated as the random variable AB.

In answer to the specific question concerning equation B-2, a simple linear sensitivity was used to maximize the effects of AB on the Statistical Design Limit. This maximization was deemed to be appropriate since the AB uncertainty is important in determining corewide protection.

QUESTION 14.

Page B-4. How is the normal distribution conservative compared to the uniform?

RESPONSE

The conservatism of the normal distribution is evidenced by the fact, that for identical core conditions the normal yields larger σ values of DNBR than for the uniform. An example was performed for case 1 of Table 3-6, where the uncertainty of AB was assumed to be uniformly distributed. The resultant σ (DNBR) was .13949, a smaller value than .1424 which was obtained under the normality assumption.

QUESTION 15.

Page 1-2, Paragraph 2. Much is said about the difference between the most power limiting pin (MPLP) and the hot pin. There is nothing in the report to indicate that the SCD actually determines the hot pin instead of using the MPLP. When would this distinction be important and what are the implications of using the SCD rather than the traditional design methods in this regard?

RESPONSE

In traditional analyses any pin-related uncertainties (such as F_A and F_Q) are applied to the MPLP. In actuality each pin has a certain combination of statistical uncertainties. Thus, for instance, a pin with only slightly less power output than the MPLP could have a more severe level of the pin-related uncertainties at any given time. This could cause that pin to have a lower DNBR than the MPLP -- to become the "hot pin".

SCD, in essence, allows each pin to "see" its individual uncertainties when determining core protection. Then, by considering the integral value of pins that could approach DNB, the degree of core protection is determined. Thus the assumption that the hot pin is always the MPLP is avoided in the SCD approach.

QUESTION 16.

Page 1-4, Figure 1-1 (also Figure 4-5 on page 4-15). These identical figures do not "stand alone" nor are they supported by adequate text. Even a thorough reading of the report does not make clear the relationships between the traditional and the statistical core design. Apparently the use of the SCD permits an increase in the margin for maneuvers from 24 units to 37 units. Is this the "payoff" for use of the SCD? In addition, the relationship between the traditional approach's 22-unit compounded thermal-hydraulic uncertainty and the SCD 12-unit compounded thermal-hydraulic uncertainty penalty needs to be quantified and given explicitly.

RESPONSE

a) Figure 1-1 is, indeed, an illustration of the "payoff" for the use of SCD. It illustrates the difference in techniques by considering a specific design case. The DNBR values to the far right and left of both bars are identical, since they are the best estimate DNBR (2.13 for the case illustrated) and the true limiting DNBR (1.0) respectively. Between these two values are uncertainties, penalties, and margins. This is where the two analyses differ.

   In traditional analyses, we start with a nominal LYNX1/2 model (which unmodified would result in a DNBR of 2.13) and modify it to include radial uncertainty and densification penalty (19 DNBR "points" or "units"), the power variation (29) and all of the compounded thermal-hydraulic uncertainties (22). The resulting minimum DNBR for a traditional analysis is 1.43. Then, starting from the true limit DNBR (1.0), we add the CHF correlation uncertainty (14) and the added thermal-hydraulic penalty (5) to define a lower Thermal Design Limit (1.19). When the 1.43 is compared with the 1.19, we are left with the margin (24 points). For different design cases (such as peaking protection or off-normal core condition cases), some or all of this margin will be used.

   In the SCD analysis we again start with a nominal LYNX1/2 model, but modify it to include only the power variation (29) and part of the compounded thermal-hydraulic uncertainties (12). We get (for the illustration case) a minimum DNBR of 1.72.

At this point five (5) sets of uncertainties are still to be accounted for: the radial uncertainty, the remaining part of the thermal-hydraulic uncertainties, the CHF correlation uncertainties, the code uncertainty, and the added thermal-hydraulic uncertainty. All of these uncertainties (except for the last which is essentially a contingency penalty) are then combined using the SCD techniques resulting in the combined SCD Uncertainty Penalty (30). When added to the 1.0 true DNBR limit, the 1.30 Statistical Design Limit (SDL) results. Finally, we directly apply the added thermal-hydraulic penalty (5) as in the traditional method to arrive at the 1.35 Thermal Design Limit (TDL). When the 1.72 minimum DNBR that resulted from the modified LYNX1/2 analysis is compared to the TDL of 1.35, we obtain the margin for the SCD analysis (37 points).

Thus, the SCD technique has 13 points more margin (37 - 24 = 13) available for different design cases than the traditional technique. All of the separate uncertainties are accounted for in each technique either in obtaining the LYNX1/2 minimum DNBR or in obtaining the Thermal Design Limit. The difference is that, in SCD, some of the uncertainties in the LYNX1/2 minimum DNBR in the traditional analysis have been transferred for use in obtaining the TDL. The margin gain - 13 DNBR points - is the "payoff".

b) The compounded thermal-hydraulic penalty in the traditional analysis consists of seven (7) parts: the pressure uncertainty (P), the temperature uncertainty (T), the inlet flow factor uncertainty (FF), the hot channel factor on pin power (F_Q), the hot channel factor on channel flow area (F_A), the uncertainty on core bypass flow (W_B), and the bundle flow area uncertainty (AB). These seven (7) compounded uncertainties result in the 22 point reduction in DNBR. For the SCD analysis, these uncertainties are divided. P, T, and FF are retained as compounded uncertainties for determining the LYNX1/2 minimum DNBR. F_Q, F_A, W, and AB are statistically treated in determining the Statistical Design Limit.

QUESTION 17.

Page 2-3, Section 2.1.3, Paragraph 1 versus page 2-5, Section 2.2.3, Paragraph 1. Intrabundle local peaking (L) is defined but no uncertainty is associated with this parameter while intrabundle radial peaking is not defined yet an uncertainty is given to it. Is there some relationship between L and F_Q, i.e., L is the factor and F_Q is the corresponding uncertainty?

RESPONSE

The axially-averaged relative power density for a fuel rod is the product of the interbundle radial power peak (bundle radial or R) and the intrabundle local peak (local or L). This product is customarily signified FΔH, but is called the radial-local peak (RL) in BAW 10145P. The practice of dividing the fuel rod radial peak into bundle radial and intrabundle local components is somewhat arbitrary being related to design code input requirements.

The terms intrabundle local peaking and intrabundle radial peaking are synonymous and interchangeable. The factor F_Q represents the uncertainty in fuel rod power associated with certain manufacturing tolerances as described in Section 2.2.3.1. Thus L and F_Q are related in the sense that L is a determinant of fuel rod power and F_Q is the uncertainty in fuel rod power resulting from manufacturing tolerances. The uncertainty on intrabundle local peak is not otherwise directly accounted for, but is represented by the interbundle area variation uncertainty, AB, as discussed on Page 3-2, Paragraph 2.

See also the Response to Question 13.

QUESTION 13.

Page 2-4, Section 2.2.2. How are the uncertainties in the core inlet flow distribution handled in the SCD?

RESPONSE

As stated in Section 2.4, Page 2-8, Paragraph 3, the inlet flow distribution uncertainty remains in the thermal-hydraulic analyses. Hence the treatment of this uncertainty with SCD methods is the same as with traditional methods. The uncertainty is applied to the power limiting bundle to produce an inlet flow which is five percent (5%) less than the core average inlet flow. This reduction in flow on the power limiting bundle is based on the results of flow testing of a one-sixth scale model of the reactor vessel at B&W's Alliance Research Center.

QUESTION 19.

Page 2-5 and 2-6, Section 2.2.4. The discussion on computer code uncertainty given here is not clear nor is the discussion in Appendix B of any assistance. The discussion of F_A and F_q given in Paragraph 2 of Paragraph B-5 requires clarification. The argument given in Paragraph 4 of B-5 that the $code_{unc}$ is treated conservatively requires clarification.

RESPONSE

Perhaps it was misleading to name the term "$Code_{unc}$" when in fact it represents a modelling uncertainty. However, in essence the RSM is just one more "code". The RSM is used to evaluate the σ(DNBR) as explained in the answers to questions 3 and 2 above, among others.

It was necessary, for the sake of the RSM precision, to average DNBR-S on a single pin. However, the uncertainty in DNBR, due to variability among subchannels surrounding a pin, needed to be re-introduced. This was done via equation B-5. This is a standard calculation for "within cell" variation when computing components of total variation in an analysis of variance.

The pins with larger peaks have significantly lower variability in DNBR predictions than the cooler ones with lower peaks. However, both types were averaged into the "$Code_{unc}$" via equation B-5. When this value is then actually applied to the most power limiting pin it effectively overestimates σ (DNBR) for that pin - resulting in conservatism.

The fact that the "$Code_{unc}$" is treated multiplicatively is an added conservatism (see the Response to Question 48). A further discussion of F_A and F_q is given in the Response to Question 49.