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SUBJECT: Forwards nonproprietary responses to RAI on TR DPC-NE-2005, "Thermal/Hydraulic Statistical Core Design Methodology," including revised pages for TR DPC-NE-2005P.

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DUKE POWER

June 1, 1994

U. S. Nuclear Regulatory Commission
Washington, D. C. 20555

Attention: Document Control Desk

Subject: Duke Power Company
Oconee Nuclear Station
Docket Numbers 50-269, -270, and -287
McGuire Nuclear Station
Docket Numbers 50-369 and -370
Catawba Nuclear Station
Docket Numbers 50-413 and 50-414
Topical Report DPC-NE-2005; "Thermal/Hydraulic Statistical Core Design Methodology"; Non-proprietary Version of Responses to RAI

By letter dated September 23, 1993, responses were provided to the NRC staff's request for additional information regarding the subject topical report. These responses contained information that Duke considers proprietary, and therefore it was requested that the information be withheld from public disclosure pursuant to 10 CFR 2.790. In accordance with the provisions of ¶ 2.790, attached please find a non-proprietary version of the responses provided by the September 23, 1993, 1994 letter.

If there are any questions, please call Scott Gewehr at (704) 382-7581.

Very truly yours,

M. S. Tuckman

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A001

Request for Additional Information and Responses To Topical Report DPC-NE-2005P

The questions are shown in italics and the responses immediately follow.

1. *Explain DPC's intent for this topical report. Does DPC seek its review with respect to its plants or generic PWR application? How does DPC plan to deal with the restrictions and requirements imposed by the VIPRE-01 code SER?*

The intent of this submittal is to outline a statistical Departure from Nucleate Boiling methodology. In DPC-NE-2005, DPC has outlined a statistical analysis method that is based on inherent behavior of the DNBR phenomena in pressurized water reactors. The numerical value of the Statistical Design Limit (SDL) will vary, depending on the CHF correlation used and parameter uncertainties assumed. However, direct use of the VIPRE-01 thermal hydraulic code (rather than the RSM) to calculate the phenomenological statistical variance of DNBR insures the direct applicability of this method to many varying fuel designs and parameter conditions.

DPC seeks the following approval from the NRC regarding this report:

1) Review and approval of the methodology and the stated statistical DNB limits for use at Oconee, McGuire, and Catawba based on the information in the body of the report and the site specific information in the Appendices.
2) Review and approval of the use of the methodology for future analyses of non-DPC reactors consistent with the commitments made in Section 1.3 and 2.5 of the report. This involves development or justification of the models and uncertainties used for any other site. If DPC were to extend this method to another PWR facility, a separate submittal will be made detailing the intent and justification for specific modeling assumptions, choice of flow models and correlations, and plant specific input data, as well as the resulting statistical DNB limits. The form of this submittal would be an additional Appendix to this report. This meets item (3) of Section 3 of the VIPRE-01 SER. The SDL would be calculated using the methodology outlined in the body of the report.

2. *DPC previously submitted two sets of DNB models for each type of plant. One was approved for use in steady-state type calculations and the other for use in transient type calculations. Since there are differences between these models on the basic level of model/input selection, discuss the impact of these differences on SDL determined. The SCD is developed based upon a series of steady state calculations. Explain how the SDL is used for transient analysis.*

Both models used by DPC were included in the statistical propagations detailed in the report. This is explained on page 14 of the report. Statepoints 37 and 38 in Appendix B are identical in fluid and peaking conditions. Statepoint 37 was propagated with the eight channel M/C model from Reference 5 and Statepoint 38 used the fourteen channel model from Reference 6. Table 6 of the report (page 27) shows the results of this comparison. The difference in Statistical DNBR's is negligible.

The determination of whether the SCD limit can be used for a transient is based on the fluid conditions at the point of minimum DNBR (MDNBR) during the transient. If the power, pressure, temperature, and flow rate of this statepoint fall within the parameter range listed in Table 4 of the appropriate Appendix, the SDL can be used. All the statepoint statistical propagations are made from a single set of fluid and peaking conditions.

3. *Discuss how "appropriate compensatory measures" will be applied to ensure the allowable DNB behavior for the statepoint is conservatively bounded.*

Please refer to the Definitions page (Page V) of the report for the following definitions:

Design DNBR Limit, DDL
Statistical Design Limit, SDL
Statistical DNBR

The term statistical DNBR applies to a specific statepoint, the SDL is the licensed limit, and the DDL is the MDNBR value used in steady-state and transient DNB analyses.

As stated in the report, new statepoints or revised uncertainties can be evaluated directly with this method. As long as the statistical DNBR value is less than the SDL, the statepoint is conservatively bounded by the SDL. If, however, the statistical DNBR value is larger than the SDL, actions can be taken to ensure that DNB predictions for the condition meet the required 95/95 acceptance criteria. These compensatory measures include either

1) Increasing the design DNBR limit for the statepoint.
2) Using available margin present between the statistical and design DNB limits (between the SDL and the DDL).

Increasing the design DNBR limit (DDL) will increase the minimum DNBR that is allowed in the analysis of the statepoint This requires another key transient analysis input (such as maximum allowable peaking) to be reduced. Penalizing a statepoint in this manner will ensure the required DNBR protection is maintained.

Another equally valid method is to apply any unused margin already available between the statistical (SDL) and design DNBR limit (DDL). This margin is inherently retained in all analyses by using the DDL in design calculations which includes margin above the SDL. A portion of this margin is currently used to account for such things as reactor vessel flow anomalies, instrumentation biases that cannot be statistically compensated for, and physical changes to the fuel assembly not accounted for in standard models (such as rod bow). The margin remaining after all of the DNBR penalties are accounted for can be used to compensate for the increase in SDL required for a particular statepoint. Either of these methods will conservatively adjust the MDNBR limit that must be met in the analysis to ensure adequate protection is maintained.

4. *Explain why RCS flow is varied only between 100 and 106.5% and not below 100% (see Table A-1 on p. A-3) even for low flow cases.*

The percent flow listed for the low flow cases in Table A-2 is in error. The flow rate used for all the statepoints identified as Low Flow in the Comments column was [ ] Additionally, the Minimum flow value listed on Table A-4 for percent design RCS flow should be [ ] The corrected pages are included with this response. Additionally, the flow chart in Figure 2 also contains a typo. The Propagate Uncertainties box should have the words (Monte Carlo - VIPRE) underneath. The RSM is not used at all in the revised method described by the report. A corrected page 30 is also included.

5. *Explain thoroughly how ranges of uncertainties and their associated standard deviations are determined.*

The numerical range of each uncertainty is selected to bound the value calculated for the parameter. This ensures that conservative statistical behavior is calculated and allows for changes in the uncertainty value without requiring re-analysis of the SDL.

(a) *Explain how uncertainties in instrumentation are accounted for. What is meant by the term "random uncertainty" (see Table A-2)? Explain how it is related to instrument error uncertainty.*

The term "random uncertainty" used in Table A-2 of the report means the instrument uncertainties such as sensor calibration accuracy, rack drift, sensor drift, etc., that are combined by the SRSS method. The term was used because the biases which are constant in sign (either positive or negative) are not included in the propagation of an uncertainty and must be accounted for by another means, such as a DNB penalty.

(b) *Identify the sources of the quantitative ranges of uncertainties and their associated standard deviations (for both types of plants).*

The source of the quantitative ranges and the standard deviations are provided on Table 1 of this response for each plant. The statistical propagations for each normally distributed parameter are based on the standard deviation numerical values. Uniform uncertainty propagations are based on the uncertainty numerical magnitude.

6. *Explain thoroughly the mechanistic DNB behavior observed in Figures 7A and B.*

Figures 7A and 7B in the report show the sensitivity of DNBR to axial peak location and magnitude. This sensitivity was calculated by holding all other parameters (power, pressure, temperature, flow, and radial peaking) constant. Both the BWC (7A) and BWCMV (7B) CHF correlation results are shown. These graphs show that the response of DNBR varies with axial peak conditions.

(a) *Discuss why the sensitivity to the axial peaks and locations is significantly stronger for Oconee than it is for M/C.*

The evaluations contained in the report indicate that the numerical value of the SDL is dependent on the CHF correlation used in the analysis. Table 5 in the report contained individual parameter sensitivities to DNB for the BWCMV CHF correlation in both axial peak areas defined. Table 2 in this response contains an identical sensitivity evaluation for the BWC and DCHF-1 CHF correlations in both axial peak areas.

For the region of higher statistical behavior, comparison of the BWC and BWCMV sensitivities shows the sensitivity calculated for each key parameter with the BWC correlation has slightly higher sensitivity to DNBR. This results in a higher final calculated SDL. The sensitivity values are more consistent when the same evaluation is made in the lower SDL area and the corresponding statistical DNBR's for the two correlations are almost identical. Correspondingly, the DCHF-1 correlation has lower sensitivities in both areas and has the lowest statistical DNBR in both cases.

Again, Table 2 in this response as well as Table 5 in the report (page 26) shows that the behavior is remarkably consistent between Oconee and McGuire/Catawba and is linked to axial power distribution. There is a difference in the numerical value of the statistical DNBR, and the key to this is the CHF correlation being used. DPC's conclusion is that the general behavior is mechanistic and this is proven by the consistent behavior when the sensitivity is calculated for different fuel types (15x15 non-mixing vane and 17x17 mixing vane), different fuel vendors (Westinghouse and Babcock & Wilcox), and even different CHF correlations (BWC, BWCMV, and DCHF-1).

(b) *DPC's conclusion based upon Figure 6A and B on p. 13 is not clear. Explain further.*

The discussion on page 13 and Figures 4A, 4B, 4C, 5A, 5B, 5C, 6A and 6B of the report show how the statistical DNB behavior is much more dependent on axial peak location than on the fluid parameter values for a particular statepoint, the fuel type, or the CHF correlation. The Figure 4 and 5 series show how the statistical DNB behavior changes with shifts in the axial power distribution. The axial peak location has a large impact on the statistical DNB value. By contrast, Figures 6A and 6B show how little the statistical DNB behavior changes with large changes in the statepoint pressure, temperature, flow rate, and core power variables. This means that if the SDL is determined in either of the axial power distribution areas for one set of fluid conditions, this SDL value would be consistent even if the fluid conditions changed dramatically.

7. *Provide a table which identifies which DNB methodology is used for each transient and explain each such selection.*

The McGuire/Catawba DNB transients currently analyzed using the SCD methodology are listed in Table 3 of this response. No transients are currently analyzed for Oconee with the SCD methodology. All of the transients analyzed with the SCD methodology were selected based on the values of the individual parameters at the point of MDNBR during the transient as explained in the response to Question 2. If these values are within the range for each parameter defined on Table 4 of the appropriate Appendix, the SCD limit can be applied to the transient.

As discussed by the note below Table 4-A and 4-B, this parameter list is subject to change. One of the advantages of the explicit evaluation method describe in the report is the ability to specifically evaluate new conditions for SCD limit applicability. If a new statepoint has a parameter(s) outside the given range, it would be analyzed and if the current SCD limit is conservative, the table would be updated to show the expanded range. The transient that generated the statepoint would then be included on the internal DPC list (Table 3 of this response). This increased parameter range would not be reported directly to NRC.

8. *Explain the last two paragraphs of Section 2.4. Discuss the need to perform statistical DNB analysis in two levels and with two different sample sizes.*

The two different sample sizes were used to minimize the total number of cases propagated for each set of fluid conditions analyzed. The first level of 500 cases per statepoint is used to quickly evaluate the behavior of a statepoint with respect to the two axial peak areas. This shows the statistical DNB behavior and approximate numerical SDL value for the fluid conditions being evaluated.

The second group of 3000 case statepoints are selected to calculate the limiting SDL value for the reactor type being analyzed. The increase in number of cases to 3000 provides a more thorough evaluation of the statistical DNB response and improves statistically the Chi Square and K factor multipliers used to conservatively increase the coefficient of variation in the final SDL calculation. The licensed statistical design limit is greater than the largest value calculated in all the 3000 case propagations for each axial peak area.

DPC may increase the number of cases at a particular statepoint for future evaluations to take advantage of the improved effect on the statistical multipliers. This increase in the number of cases is consistent with the methodology as presented and does not in any way reduce the conservatism of the SDL limit calculated. Increasing the number of cases simply reduces the statistical uncertainty associated with calculation of the coefficient of variation.

9. *Explain the rational for and appropriateness of selection of certain sets of statepoints to determine the impact of changes on statistical DNBR behavior (see Table 6).*

The evaluations in Table 6 of the report show how little the statistical DNB behavior is affected by small modifications in the analysis. The first section shows the change for identical conditions and models with a change in one parameter uncertainty distribution (normal versus uniform). Section 2 shows the change if a different VIPRE-01 model is used with the same fluid conditions, peaking conditions, and uncertainty distributions. The last section shows the change with the same VIPRE-01 model, fluid conditions, and uncertainties but with a different fuel design. As discussed in the response to question 6b, Figures 6A and 6B demonstrate the there is very little change in statistical DNB behavior for large changes in the statepoint pressure, temperature, flow rate, or core power variables. Thus, the sensitivity of the SDL to other changes can be evaluated using a single statepoint.

All of these evaluations were included to further demonstrate that the statistical DNB behavior and SDL are more closely related to the CHF correlation and axial power distribution than to small perturbations in individual uncertainties, VIPRE-01 models, or fuel type. This evaluations also provide the basis for the criteria for re-submittal or in-house evaluation detailed on Table 7 (as explained in the response to Question 10).

10. *Explain Table 7.*

Table 7 in the report is intended as a guide for use by DPC in evaluating what action must be taken for anticipated changes (a revised uncertainty, new fuel type, etc.). In all cases, the evaluations will use the methodology detailed in the report. Basically, changes that are anticipated to have a negligible or very small impact on the SDL will require internal DPC evaluation. Only changes that have a significant impact on the calculated SDL number will be submitted to the NRC for approval.

An example of the kind of anticipated events is a change in an uncertainty magnitude. For this instance, limiting SCD statepoints in each axial power distribution area will be evaluated to determine the impact on the SCD limit. If the statistical DNBR value is the same or smaller than the SDL, no additional work is required. If the value is larger, appropriate compensation measures will be used to conservatively compensate for the change (as described in the answer to Question 3). This same approach will be used for different uncertainty distributions, new fluid or peaking condition statepoints, or minor modifications to the fuel assembly design.

For changes that will have a much bigger impact on the statistical DNB behavior, the impact of the change will be evaluated and a new Appendix to this report submitted for NRC approval. This additional Appendix will have the same format and content as the two already included in the report. Examples of when this approach would be used are a completely new fuel assembly design, a new thermal hydraulic code, a new CHF correlation, or DPC analysis of a third party's reactor.

A slight change to Table 7 is also included in the response to this question. The original table required that a modified CHF correlation would require submittal of a new Appendix. This has been changed to require an evaluation only. The term modified means the form of the CHF correlation is the same, just a single factor or multiplier has been changed or added. This change is because a modified correlation will not impact the statistical DNB behavior and will not significantly change the SDL compared to the original correlation. A modified correlation will still require a separate CHF correlation topical submittal to the NRC. Any other changes that affect the correlation form will be considered a new CHF correlation.

11. Provide the SDL if no distinctions are made of axial power distributions.

The results of the entire analysis completed in the report show how mechanistic the statistical DNB response is to axial power distribution. This mechanistic behavior was determined by direct use of the thermal hydraulic codes, models, and correlations used in DNB predictions. This behavior is consistent with different fluid conditions, fuel geometries, and CHF correlations. The one consistent fact is the larger statistical variation for a specific set of axial peaks. The use of two statistical DNB limits to address this behavior is a straight forward application. Use of a single limit would be unnecessarily conservative. However, if the appropriate distinctions are not made for the generic DNB behavior with axial power distributions, the SDL for all cases will be the largest value calculated for all the conditions evaluated. If this restriction were imposed, the SDL would be 1.43 for Oconee and 1.40 for McGuire/Catawba.

TABLE 1

Uncertainty Ranges And Standard Deviations

The following table shows the source of the quantitative range of each uncertainty and its associated standard deviation. Section 1 of the table contains the Oconee information and Section 2 the sources for the McGuire/Catawba values.

SECTION 1 - Oconee

Parameter	Source
Power	Standard deviation of 1.0% based on DPC calculations. Uncertainty value is a 2σ value (2%).
Pressure	Standard deviation of 15 psi based on DPC calculations. Uncertainty value is a 2σ value (30 psi).
Temperature	Standard deviation of 1.0 degrees Fahrenheit based on DPC calculations. Uncertainty value is a 2σ value (2 deg F).
Flow	Standard deviation of 1.0% design flow based on DPC calculations. Uncertainty value is listed as a 2σ value (2%).
$F\Delta H$	Standard deviation of 2.84% calculated based on the nuclear code packages used for core design and analysis. This standard deviation bounds the highest value from the code package combination used for Oconee (Reference 1).
F_Z	Standard deviation of 2.91% calculated based on the nuclear code packages used for core design and analysis. This standard deviation bounds the highest value from the code package combination used for Oconee (Reference 1).
Z	Uncertainty range of +/- 6 inches. Selected based on the noding size of nuclear codes. No standard deviation (uniform uncertainty).
Local Heat Flux HCF	Uncertainty range of [ ] Based on calculated values from the nuclear fuel vendor. Standard deviation is calculated from [ ] uncertainty value [ ]

Rod Power HCF	Uncertainty range of [ ] Based on calculated values from the nuclear fuel vendor. Standard deviation is calculated from [ ] uncertainty value [ ]
Hot Channel Flow Area	Uncertainty range of [ ]. Based on calculated values from the nuclear fuel vendor. No standard deviation (uniform uncertainty).
CHF Correlation	Standard deviation of 8.88% calculated from the BWC CHF test data base (Reference 2).
Thermal Hydraulic Code / Model	Uncertainty range of [.] Value used in Reference 3. Standard deviation is calculated from the [ ] uncertainty value [ ].

SECTION 2 - McGuire/Catawba

Parameter	Source
Power	Uncertainty Range of 2%. Selected from Reference 5. Kept at 2% to bound specific uncertainties calculated for M/C. Standard deviation is calculated from 2% uncertainty value (2/1.64 = 1.22%).
Pressure	Uncertainty Range of 30 psi. Selected from Reference 5. Kept at 30 psi to bound specific uncertainties calculated for M/C. No standard deviation (uniform uncertainty).
Temperature	Uncertainty Range of 4 degrees Fahrenheit. Selected from Reference 5. Kept at 4 degrees to bound specific uncertainties calculated for M/C. No standard deviation (uniform uncertainty).
Flow	Uncertainty Range of 2.2%. Selected from Reference 5. Kept at 2.2% to bound specific uncertainties calculated for M/C. Standard deviation is calculated from 2.2% uncertainty value (2.2/1.64 = 1.34%).
FΔH Measurement	Standard deviation of 1.98% calculated based on the nuclear code packages used for core design and analysis. This standard deviation bounds the highest value from the code package combination used for M/C (Reference 1).

Engineering HCF	Uncertainty range of 3.0%. Selected based on the value in Technical Specifications. Standard deviation is calculated from the 3% uncertainty value (3/1.64 = 1.82%).
Spacing	Uncertainty range of 2.0%. Selected from Reference 5. Standard deviation is calculated from the 2% uncertainty value (2/1.64 = 1.22%).
F_Z	Standard deviation of 2.68% calculated based on the nuclear code packages used for core design and analysis. This standard deviation bounds the highest value from the code package combination used for M/C (Reference 1).
Z	Uncertainty range of +/- 6 inches. Selected based on the noding size of nuclear codes. No standard deviation (uniform uncertainty).
CHF Correlation	Standard deviation of 10.2% calculated from the BWCMV CHF test data base (Reference 4).
Thermal Hydraulic Code / Model	Uncertainty range of [ ] Value used in Reference 5. Standard deviation is calculated from the [ ] uncertainty value [ ].

TABLE 2

Comparison of the DNB Parameter Sensitivity of Different CHF Correlations With Consistent Axial Power Distributions

The following table shows the DNB sensitivity of each key parameter for the BWC CHF correlation (Oconee), the BWCMV CHF correlation (McGuire/Catawba), and the DCHF-1 CHF correlation (McGuire/Catawba). The first comparison is of a statepoint in the higher SDL area and the second is in the lower SDL area. The fluid and radial peaking conditions for each statepoint are given in the Appendices.

CHF Correlation	1.3 Peak @ 0.2 Z	1.3 Peak @ 0.8 Z
BWC	Statepoint 63	Statepoint 75
BWCMV	Statepoint 6	Statepoint 9
DCHF-1	Statepoint 6	Statepoint 9

1.3 Axial Peak, 0.2 Z

Parameter	BWC	BWCMV	DCHF-1
Power (%)			
Pressure (psi)			
Temperature (Deg F)			
Flow (%)			
FΔH (%)			
F_Z (%)			
Z (per 6 inches)			
SDL			

1.3 Axial Peak, 0.8 Z

Parameter	BWC	BWCMV	DCHF-1
Power (% RTP)			
Pressure (psi)			
Temperature (Deg F)			
Flow (%)			
FΔH (%)			
F_Z (%)			
Z (per 6 inches)			
SDL			

All values shown are in terms of % DNB per unit of parameter.

TABLE 3
SCD Transient Limiting Statepoints

The following table shows all the M/C transients currently evaluated with the SCD methodology. The determination of whether the transient uses the SCD approach is the value of all the key parameters (power, pressure, temperature, flow, peaking) at the point of MDNBR during the transient. All values listed are from the MDNBR point of the transient.

Transient	Core Power	Core Inlet Flow (Kgpm)	Core Inlet Temperature	Pressure	$F\Delta H$	F_Z	Z
Feed Line Break							
Partial Loss of RCS flow							
Total Loss of RCS Flow							
Uncontrolled RCCA Withdrawal / Subcritical							
*Uncontrolled RCCA Withdrawal / 100%							
*Uncontrolled RCCA Withdrawal / 100%							
Uncontrolled RCCA Withdrawal / 50%							
*Uncontrolled RCCA Withdrawal / 10%							
*Uncontrolled RCCA Withdrawal / 10%							
Single RCCA Withdrawal							
Statically Misaligned RCCA							
Dropped RCCA							

* This accident was analyzed with two different reactivity insertion rates.

\# This accident was analyzed with a $F\Delta H$ range of [1.547-1.70 and a F_Z range of 1.316-1.335.]

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5) McGuire and Catawba Nuclear Stations Core Thermal-Hydraulic Methodology Using VIPRE-01, DPC-NE-2004P-A, Duke Power Company, Charlotte, North Carolina, December 1991.

6) Thermal-Hydraulic Transient Analysis Methodology, DPC-NE-3000P-A, Revision 1, Duke Power Company, Charlotte, North Carolina, December 1991.