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U. S. Nuclear Regulatory Commission
Washington, D. C. 20555-0001

ATTENTION: Document Control Desk

Subject: Dynamic Rod Worth Measurement Using CASMO/SIMULATE

McGuire Nuclear Station Units 1 & 2
Docket Nos. 50-369, 50-370

Catawba Nuclear Station Units 1 & 2
Docket Nos. 50-413, 50-414

References: (1) Letter from M. S. Tuckman (Duke) to U.S. NRC Document Control Desk, "Dynamic Rod Worth Measurement Using CASMO/SIMULATE", dated August 16, 1999.

(2) "Westinghouse Dynamic Rod Worth Measurement Technique", WCAP-13360-P-A, Revision 1, October, 1998.

This submittal supplements the Duke Energy Corporation NRC submittal of August 16, 1999, concerning the computational techniques for Dynamic Rod Worth Measurements for McGuire and Catawba Nuclear Stations (Reference 1).

On August 16, 1999, Duke Energy Corporation (Duke) submitted to the NRC a request for NRC approval of the Westinghouse developed Dynamic Rod Worth Measurements (DRWM) using the Duke DRWM calculational method. The proposed Duke DRWM computational method makes use of the CASMO/SIMULATE codes,

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the reactor physics methods currently used by Duke for reload design of McGuire and Catawba cores.

As part of the NRC approval of the Duke topical report DPC-NE-2009, the transient neutronic code S3K was approved for rod ejection accident analysis. S3K is also necessary for the Duke DRWM calculations. Therefore, the purpose of this supplementary submittal is to request NRC approval of the use the S3K code for DRWM applications, as part of the NRC approval of the Duke DRWM calculational methodology for McGuire and Catawba.

To justify the adequacy of the Duke DRWM calculational methodology, extensive benchmarking of the Duke calculated data with measured data and pertinent other calculations was performed. The results show excellent overall agreement.

For the Duke DRWM application also, the review and acceptance criteria for the measured bank worths (individual and total bank worths) will be the same as in Reference 2. The review and acceptance are summarized in Section 3.2 of DPC-NE-2012.

Attachment 1 contains replacement pages for Sections 1, 3, 4, and 5 of the Duke DRWM topical report DPC-NE-2012 (submitted on August 16, 1999) to include some additional discussion and updating of the references. A reprint of DPC-NE-2012 with the replacement pages is included as Attachment 2.

Please address any comments or questions regarding this matter to J. S. Warren at (704) 382-4986 or P. M. Abraham at (704) 382-4520.

Very truly yours,

M. S. Tuckman

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Attachments

xc (w/ Attachments):

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ATTACHMENT 1

Replacement Pages for DPC-NE-2012

Section 1	Page 2
Section 3	Pages 7, 8, 9, 10
Section 4	Pages 11, 13
Section 5	Page 15

five criteria are specifically addressed to demonstrate, from both a technical and programmatic perspective, that Duke Power's methodology for performing DRWM computations is acceptable.

Station personnel received initial training on DRWM procedures, the use of the Advanced Digital Reactivity Computer (ADRC), and application of the ADRC to performing LPPT using DRWM prior to DRWM testing at both Catawba and McGuire. Additional training was also received during each of the six applications of DRWM at Duke. Personnel performing computations to support DRWM were initially trained by Westinghouse in these computations in March 1998 and received procedures on how to perform these computations at that time. This training included the ability to set up input, understand and interpret output results, understand applications and limitations, and to perform analyses in compliance with the procedures provided by Westinghouse.

Duke's DRWM computations make use of the Westinghouse DRWM technique of Reference 1. The steady-state physics calculations to support the Duke DRWM computations are made using the NRC approved CASMO-3/SIMULATE-3P methodology described in Reference 2. To improve DRWM bank worth comparisons, Duke has adopted the Tuttle delayed neutron data from Reference 5 for reactivity measurements.

The dynamic calculations to support Duke DRWM computations are made using the SIMULATE-3 Kinetics (S3K) program. S3K is a three-dimensional transient neutronic version of the NRC-approved SIMULATE-3P code and utilizes the same neutron cross section library. It employs a fully implicit time integration of neutron flux and delayed neutron precursors. The NRC has approved S3K for use in the UFSAR Chapter 15 Rod Ejection Analyses (REA) for Catawba and McGuire (Reference 3). The Duke REA benchmark results and results for industry benchmark problems discussed in Section 6.6 of Reference 3 demonstrate that S3K adequately performs transient neutronic calculations with thermal hydraulic feedback. In comparison, the DRWM calculations are simpler since they are isothermal calculations which do not involve thermal hydraulic feedback. For application to DRWM, the extensive benchmark results contained in this report demonstrate that S3K is suitable to generate analytical constants necessary for DRWM.

Application of these codes and procedures, and the Westinghouse DRWM procedure, is controlled by the Duke Power quality assurance program described in Reference 4. This quality assurance program meets the requirements of 10 CFR 50, Appendix B.

near the core interior (assemblies containing banks CC, CA, and SB). Duke typically predicts lower worths for banks SA, CD, SD, and SC than Westinghouse due to differences in the radial power distribution. However, the *measured bank worths* for these six banks generally fall between the Duke and Westinghouse *predicted bank worths,* indicating that this is only a bias between *predicted bank worths.*

The M2C13 and C1C12 *predicted bank worths* differences are larger than the previous cycle comparisons. Although the magnitude of the differences is small and acceptable, both Duke and Westinghouse performed a thorough investigation of the M2C13 predictions, and Duke performed an investigation of the C1C12 predictions. To understand the cause, the model setup, cross-section generation, core shuffling, core depletion, and design information were examined. No deficiencies were identified in either the Duke or Westinghouse nuclear models that explain the larger than expected power distribution and bank worth differences. The reviews concluded that the differences are the result of code and methodology differences between SIMULATE and ANC, and are not attributable to model or calculational errors. Although the investigations did not uncover the exact cause of the larger differences, slightly higher differences in the power distribution comparison were noted for assemblies that operated near the periphery for more than one cycle. Both M2C13 and C1C12 contained more assemblies of these types, located at or near control rod locations, than previous cycles. It is possible that the different spectral history treatments between ANC and SIMULATE are partially responsible for the larger differences in the predicted power distributions.

2) The differences between the Duke and Westinghouse *predicted total bank worths* meet the $\pm$ 2% criterion for all six cores analyzed. The Duke *predicted total bank* worths are consistently lower than Westinghouse *predicted total bank worths* (from -0.1% to –1.9%). As discussed above, the Duke predicted HZP radial power distribution is typically lower in assemblies located near the periphery. Figure 1 shows that more of the control banks are located near the periphery, which tends to over emphasize the contribution of the peripheral assemblies to the calculation of

the total bank worth. The trend of Duke's *predicted total bank worth* being slightly lower than Westinghouse is consistent with the HZP radial power distribution differences.

3) The difference between the *measured bank worths* calculated by Duke and Westinghouse methods meet the ± 2% or ± 25 pcm criterion for all banks. The maximum difference is –10.6 pcm for Bank CB in McGuire 2 Cycle 13. This comparison shows excellent agreement between the Duke and Westinghouse data.

4) The *measured total bank worth* differences between Westinghouse and Duke for the 6 cores range from –1.0 to –0.3%. The measured values from Duke calculations are consistently lower than the values from Westinghouse calculations. Since the extent of this under prediction is small, this deviation is acceptable.

The overall comparison between Westinghouse and Duke results is excellent. The differences shown in Table 1 are well within the expected range for a comparison between two independent core simulator methodologies. The fundamental methodology differences between Duke and Westinghouse are expected to produce differences such as these for predicted bank worths. Other than using the same loading patterns, plant parameters, depletion step information, and the same methodology to calculate the DRWM analytical factors, the Westinghouse and Duke data were produced independently. Westinghouse used the ALPHA/PHOENIX/ANC (APA) and SPNOVA codes, while Duke used the CASMO/SIMULATE/S3K codes. The comparison shows that Duke and Westinghouse produce very consistent results and that the Duke methodology is a suitable substitute for the Westinghouse DRWM methodology. The results also demonstrate that Duke has implemented the DRWM analytical factor methodology consistent with the approved Westinghouse methodology.

3.2 Measured to Predicted Evaluation

The previous section focused on evaluating the differences in bank worth due to code methodology differences between Duke and Westinghouse. This section performs an evaluation of the predicted bank worths relative to measured bank worths. This section uses the data contained in Table 4 and Table 5 to summarize measured to predicted results for each of the six benchmark cycles. For this evaluation, the appropriate review and acceptance criteria are those used in LPPT to assess the accuracy of the measured results. The review and acceptance criteria from Reference 1 are:

DRWM *Review* Criteria for Low Power Physics Testing (LPPT)

Parameter	Criteria
Individual Bank Worths	Measured worths ± 15% or ± 100 pcm of their predicted worths, whichever is greater
Total Worth of All Banks	Sum of measured worths ±8% of the sum of predicted worths

DRWM *Acceptance* Criteria for Low Power Physics Testing (LPPT)

Parameter	Criteria
Total Worth of All Banks	Sum of measured worths ≥90% of the sum of predicted worths

For the ± 15% or ± 100 pcm criterion, all bank worths less than 667 pcm (=100/0.15) are compared to the 100 pcm criterion, and banks with predicted worths greater than 667 ppm are compared to the 15% criterion.

Table 2 presents the Westinghouse DRWM results for each of the benchmark cycles. The maximum bank worth differences shown in Table 2 were chosen by comparing each bank worth difference to the appropriate limit; low worth banks (< 667 pcm) were compared to 100 pcm, and high worth banks were compared to 0.15*(predicted bank worth). The banks with the minimum margin to the criterion were selected for inclusion in Table 2.

Table 2
Westinghouse Measured to Predicted DRWM Results

Cycle	Bank	Westinghouse Maximum Bank Worth Difference			Total Bank Worth Difference
		Predicted Worth (pcm)	(M-P) pcm	%(M-P)/P	%(M-P)/P
C1C11	CD	631	63.8	10.1	1.7
M2C12	CA	337	-42.9	-12.7	0.2
M1C13	CB	645	25.1	3.9	0.3
C2C10	SB	916	88.3	9.6	2.8
C1C12	CB	697	22.7	3.3	1.1
M2C13	CB	643	47.1	7.3	2.9

M = Measured (using Westinghouse analytical factors)
P = Predicted

Table 3 presents the Duke DRWM results for each of the benchmark cycles. The maximum bank worth differences were chosen similar to Table 2.

Table 3
Duke Measured to Predicted DRWM Results

Cycle	Bank	Duke Maximum Bank Worth Difference			Total Bank Worth Difference
		Predicted Worth (pcm)	(M-P) pcm	%(M-P)/P	%(M-P)/P
C1C11	CD	612.9	74.8	12.2	2.5
M2C12	CA	323.8	-30.9	-9.5	0.6
M1C13	CC	740.8	-32.2	-4.3	-0.3
C2C10	CB	543.7	52.4	9.6	4.0
C1C12	CB	667.7	47.6	7.1	2.8
M2C13	CB	630.0	49.8	7.9	3.4

M = Measured (using Duke analytical factors)
P = Predicted

The results in Table 2 and Table 3 show that both Westinghouse and Duke meet the ± 15% or ± 100 pcm LPPT review criterion for individual banks, and the ±8% total bank worth review criterion. In addition, the acceptance criterion of ≥ 90% of the sum of the predicted worths is met for all cycles.

Overall, the Duke measured to predicted comparison is very consistent with the Westinghouse results.

4. COMPLIANCE WITH FIVE DRWM CRITERIA

Appendix A contains the five criteria that have been approved by the NRC in Reference 1 to assess the ability of a utility to perform DRWM computations. This section specifically addresses each criterion.

4.1 Criterion 1: Eligibility of Codes for DRWM Computations

Only lattice physics codes and methods which have received prior NRC review and approval are eligible to be used in determining the physics constants to be used in DRWM. For the Duke application of DRWM, both the CASMO lattice physics code and the SIMULATE three dimensional core simulator code have been approved by the NRC for use by Duke in Reference 2.

The SIMULATE-Kinetics (S3K) code for the dynamic modeling of the DRWM process is a three-dimensional transient neutronic version of SIMULATE-3, and utilizes the same neutron cross section library. As part of the NRC approval of DPC-NE-2009, S3K has been approved for Rod Ejection Accident analysis (NRC letter of September 22, 1999 to G.R. Peterson of Catawba Nuclear Station). As discussed in Section 1, the S3K code is also necessary for the Duke DRWM calculations. The extensive benchmarking of the Duke DRWM calculations, making use of the S3K code, with the measured data and with the Westinghouse calculations show excellent agreement. Therefore, S3K is seen to be suitable for the Duke DRWM calculations. As part of the Duke request for NRC approval of the Duke DRWM methodology, S3K approval for DRWM applications for McGuire and Catawba is also being requested.

4.2 Criterion 2: Application of Procedures to DRWM Computations

This criterion states that "In a manner consistent with the procedures obtained from Westinghouse, the utility analyses shall be performed in conformance with in-house application procedures which ensure that the use of the methods is consistent with the Westinghouse approved application of the DRWM methodology". Duke has incorporated the Westinghouse provided DRWM computational procedures into an internal procedure to ensure consistency with the NRC approved methodology. Future Duke DRWM analyses will be performed according to the Duke DRWM procedure. The Duke QA program described in Reference 4 will be used to perform all DRWM computations. Therefore, Criterion 2 has been met.

In conclusion, considering the entire benchmark database, all of the criteria have been met with the exception of six individual bank worths in two cycles. The cause of the larger *predicted bank worth* differences in the six banks of McGuire 2 Cycle 13 and Catawba 1 Cycle 12 has been identified as being due to differences in the predicted radial power distribution. The magnitude of the deviations for predicted bank worths are small and are considered acceptable. Overall the comparison between Westinghouse and Duke predictions are considered good for comparisons of two independent physics methodologies. The comparisons that exceeded the $\pm$25 pcm criterion have been investigated and the reason for the larger deviations is understood and the magnitudes are not unexpected. Finally, all of the review and acceptance criteria for measured to predicted bank worth comparisons were easily satisfied. Therefore, it is concluded that the intent of Criterion 4 has been met in this evaluation.

4.5 Criterion 5: Quality Assurance and Change Control

The calculations for DRWM will be conducted using engineering calculation procedures which ensure conformance with the Duke QA program described in Reference 4. The Duke procedures have provisions for implementing changes to the methods and procedures being used for DRWM. Processes are available which provide a means by which Duke can directly inform Westinghouse and track any problems or errors discovered while performing the DRWM calculations or procedures. Westinghouse also has a requirement to inform utilities that have taken a technology transfer on DRWM of changes to the process as part of their QA procedures regarding technology transfer. Therefore, Criterion 5 has been met.

6. REFERENCES

1. "Westinghouse Dynamic Rod Worth Measurement Technique", WCAP-13360-P-A, Revision 1, October 1998.

2. "Nuclear Design Methodology Using CASMO-3/SIMULATE-3P", DPC-NE-1004PA, Revision 1, December 1997.

3. "Duke Power Company Westinghouse Fuel Transition Report", DPC-NE-2009P, (NRC letter of September 22, 1999 to G.R. Peterson of Catawba Nuclear Station).

4. "Topical Report Quality Assurance Program", Duke Energy Corporation, DUKE-1-A, Amendment 25, May 31, 1999.

5. "Delayed-Neutron Yields in Nuclear Fission", R. J. Tuttle, Proceedings of the Consultants' Meeting on Delayed Neutron Properties, International Nuclear Data Committee INDC(NDS)-107/G+Special, March 26-30, 1979.

ATTACHMENT 2

Reprint of DPC-NE-2012