FRAMATOME TECHNOLOGIES

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U. S. Nuclear Regulatory Commission
ATTN.: Document Control Desk
Washington, D.C. 20555

Subject: Revised Measurement Uncertainty for Westinghouse 193 Plant Control Rod Worth Calculations

References:
1. NEMO - Nodal Expansion Method Optimized, BAW-10180P-A, Rev. 1, B&W Fuel Company, Lynchburg, Virginia, March 1993.
2. Comparisons of Core Physics Calculations with Measurements, BAW-10120P-A, Babcock and Wilcox, Lynchburg, Virginia, July 1979.

Gentlemen:

The attachment to this letter provides the justification for reducing the uncertainty factor that Framatome Cogema Fuels (FCF) currently applies to control rod worth calculations for Westinghouse 193 fuel assembly cores. Background information to support this justification is given below.

When B&W Fuel Company was developing reload methodology for Westinghouse 193 fuel assembly reactors, there was limited Westinghouse plant data available for use in benchmarking design calculations. The value justified in reference 1 for rod worth uncertainty for the Westinghouse plants was the same as for B&W plants. This value was originally based on critical experiment comparisons that were used for benchmarking calculational models. While these comparisons provided reliable results, the physical conditions of the experiments were not indicative of the conditions encountered in-reactor. Consequently, conservative uncertainty factors were chosen to ensure adequate safety margins for key safety parameters, and were verified by the plant data base provided in reference 1.

During the past four years, NEMO[1] has been used to license numerous fuel cycles. As a result, a significant amount of additional plant data is now available for benchmarking and for improving reactor predictions.

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The historic uncertainty used for shutdown margin and other rod worth evaluations is 10%. This value was chosen to ensure conservatism in rod worth applications and was documented in reference 2. The limited data base of reference 1 also confirmed the conservatism of this value. Data provided in the attachment will justify a reduction of this value to 8%. Please note that FCF will continue to use an uncertainty value of 15% for ejected rod worth calculations.

The utilization of the 8% uncertainty will be a cost benefit to the utilities that are using Mark-BW fuel for reload fuel cycles. Shutdown boron concentrations can be reduced as a result of the decreased uncertainty and reductions in time, waste inventories, and man-rem exposure will be realized. The operating limits for control rod insertion which preserve shutdown margin can also be widened to enhance operating flexibility.

FCF will be using the reduced rod worth calculational uncertainty in upcoming reload fuel cycles for Sequoyah Units 1 and 2. In order to meet the needs of our customer, you are requested to provide your approval for the reduced uncertainty by October 31, 1996.

Very truly yours,

J. H. Taylor

J. H. Taylor, Manager
Licensing Services

cc: R. B. Borsum
R. C. Jones, NRC
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Development of Total Rod Worth
Nuclear Reliability Factor
for Westinghouse 193 Plants

The NEMO code (reference 1) has been used for several years in license applications. During this time, FCF has accumulated extensive comparisons of NEMO calculations with measurements. Comparisons of regulating rod worth have been acquired from recent startup physics tests for B&W plants and a revised NEMO nuclear reliability factor (NRF) for total rod worth of 5% for B&W plants had recently been derived (reference 2) and subsequently approved by the NRC (reference 3). Similarly, the following discussion presents the development of a NEMO nuclear reliability factor for total rod worth for Westinghouse 193 fuel assembly plants.

NEMO calculations for several 193 plants have been performed, with emphasis on Sequoyah Units 1 and 2, since these plants are currently being licensed to operate with MkBW fuel. Table 1 shows the percent deviation for rod worth between NEMO calculations and measurements for cycles 1 through 8 for Sequoyah 1 and cycles 1 through 7 for Sequoyah Unit 2, cycle 1 of McGuire 1 and 2, Catawba 1 cycle 1, and Trojan cycles 10 through 14. The rod worths shown in Table 1 represent measurements performed with the boron dilution technique. Each of the rod bank measurements for Cycle 1 of Sequoyah 1 and 2, McGuire 1 and 2, Catawba 1, and Trojan cycles 10 through 14 were performed by boron dilution. For cycles after cycle 1 for Sequoyah 1 and 2, only the reference bank (highest worth bank) was measured by boron dilution (except C and D for Sequoyah 2 cycle 3), the other bank worths were measured with the rod exchange technique. Measured data based on the rod exchange technique were not selected because: 1) rod exchange measurement is slightly less accurate than boron dilution and the decreased accuracy should not be reflected in a calculational NRF, 2) the rod exchange method uses theoretical factors (derived by Westinghouse analytical methods) for inferring the measured test bank worths and so analytical variances can affect the measurement, and 3) any error in the measurement of the reference bank would be reflected in the test bank worths, and hence the total.

A total of 23 measurements or samples are shown in Table 1. The mean was 1.82 with a standard deviation of 2.70%. Comparison of these results to the MkB results in reference 2 (20 samples) showed that the mean (or bias) was different (-1.52 versus 1.82) but the standard deviation was very similar (2.67 versus 2.70).

These data support that NEMO is consistently predicting the rod worths in all plants except that the bias is different. Statistical tests were performed that confirmed the conclusion that the standard deviations of the two data bases were similar and that the biases of the two databases were different.

To conservatively determine the NRF, the bias for the Westinghouse 193 database is used. The data for both the Westinghouse 193 plants and the B&W 177 plants are pooled to determine the standard deviation. Since the data bases passed the normality test, the pooled standard deviation (STD_p) was calculated as follows:

$$S_p^2 = [(n_{193} - 1)*S_{193}^2 + (n_{M\&B} - 1)*S_{M\&B}^2]/(n_{193} + n_{M\&B} - 2)$$

$$= (22*2.70^2 + 19*2.67^2) / 41 = 7.2153$$

and

$$STD_p = SQRT(S_p^2) = 2.6861$$

Next a combined K factor was obtained since the bias (Westinghouse plant data only) is represented by a different number of points than the standard deviation (B&W and Westinghouse plant data). The combined K factor is 2.1916, representing 23 data points for the bias and 41 degrees of freedom (43-2 degrees of freedom) for the standard deviation. The final reliability factor was:

NRF = 1.82 + 2.1916*2.6861 = 7.71%

A conservative 8% NRF will be used for total rod worth uncertainty for future NEMO calculations in support of Westinghouse 193 plant reload licensing. Note that a 15% uncertainty will still be applied to single rod banks and individual control rods.

References

1. BAW-10180-A, Rev. 1, "NEMO - Nodal Expansion Method Optimized," B&W Fuel Company, Lynchburg, Virginia, March 1993.
2. J.H. Taylor to Nuclear Regulatory Commission, Revised Measurement Uncertainty for Control Rod Worth Calculations, JHT/95-124, December 20, 1995.
3. R. C. Jones to J. H. Taylor, Acceptance of Revised Measurement Uncertainty for Control Rod Worth Calculations, January 26, 1996.

Table 1. Rod Worth Statistics, 193 Plants

No.	Plant/Cycle (Banks)	NEMO (pcm)	Measured (pcm)	Deviation (%)
1	S1C1 (D-SC)	5995.0	6038.9	-0.73
2	S2C1 (D-A)	3994.9	4055.7	-1.50
3	S1C2 (D)	859.5	871.i	-1.33
4	S1C3 (D)	900.1	871.4	3.29
5	S1C4 (D)	972.5	963.0	0.98
6	S1C5 (D)	916.8	886.4	3.43
7	S1C6 (D)	994.9	964.5	3.15
8	S1C7 (D)	1393.5	1380.0	0.98
9	S1C8 (D)	1251.1	1249.5	0.13
10	S2C2 (D)	922.4	903.3	2.12
11	S2C3 (D,C)	1643.0	1666.2	-1.39
12	S2C4 (D)	1088.3	1037.5	4.89
13	S2C5 (D)	1131.4	1102.7	2.60
14	S2C6 (D)	1247.5	1242.8	0.38
15	S2C7 (D)	1147.8	1134.3	1.19
16	M1C1 (D-SC)	6226.0	6216.0	0.16
17	TRJC10 (D-A)	3833.0	3511.0	9.17
18	TRJC11 (D-A)	4008.0	3803.0	5.39
19	TRJC12 (D-A)	4219.0	4123.0	2.33
20	TRJC13 (D-A)	4018.0	3870.0	3.82
21	TRJC14 (D-A)	3977.0	3794.0	4.82
22	M2C1 (D-SC)	6308.8	6380.0	-1.12
23	C1C1 (D-SC)	5980.5	6042.0	-1.02

Mean	1.82
StdDev	2.70
Count	23
K factor	2.328
NRF	8.11