BW

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February 6, 1995

Charles J. Haughney, Chief
Transportation Branch
Division of Safeguards
and Transportation, NMSS
Division of Industrial and Medical
Nuclear Safety, NMSS
United States Nuclear Regulatory
Commission
Washington D.C., 20555

Dear Mr. Haughney:

REFERENCE: Docket 71-6206, USA/6206/AF

On November 23, 1994, B&W Fuel Company (BWFC) requested to amend the above referenced container certificate to include two new pellets designs for the MkB 15x15 fuel assembly. As noted in the correspondence, KENOIV with 123 Group XSDRN Cross Sections of Cable processed by NITAWL was used to perform the analysis. As mentioned in the request, BWFC was evaluating the reliability of the 123 Cross Section Group and indicated that we would inform you of the results. The review is complete and the results of the evaluation are a supplement to the amendment request and are provided as Attachment I.

As required, six copies of the evaluation are included. I will be on maternity leave from until February 27, 1995. During this time period, please contact Larry Hassler for questions regarding criticality at (804) 832-3205, Andy Shumaker for mechanical engineering questions at (804) 832-5093 or Gerald Lindsey for licensing questions at (804) 832-5021. Thank you.

Sincerely,

B&W FUEL COMPANY
Commercial Nuclear Fuel Plant

Kathryn S Knapp

Kathryn S. Knapp
Manager, Safety & Licensing

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ATTACHMENT I

Purpose

Assess impact of Preliminary Safety Concern relative to the 123 group Cable cross section set on the Model B, Mk B10 and B11 amendment analysis and on the analysis for the current license.

Summary

An error has been noted in the use of the 123 group Cable cross section set for highly enriched systems. An evaluation of this anomaly was made with the 27 group SCALE4.2 cross section set for the Model B shipping container analyses that support both the current license and the Mk B10/B11 amendment request. The evaluation indicates the following: for the Mk BW 15x15 assembly, the bounding assembly for the current license, a decrease in reactivity of about 0.1% was noted; a similar result was found for the Mk-B11 assembly, the bounding assembly for the amendment analysis. Thus, the evaluation shows that the previous analyses remain valid and provide conservative results.

Background

In November of 1994, BWFC was notified by NNFD of a possible error related to the use of the 123 group Cable cross section set. The anomaly was noted during a British review of the NNFD 5x22 shipping container license (Docket No. 71-9250) requested by GA. The NNFD 5x22 container was designed to ship highly enriched ^{235}U. The review showed that the licensing analysis under predicted the container reactivity by up to 3% Δk. Subsequent reviews by GA and the NRC supported the British results and linked the anomaly to the 123 group cross section set. Since BWFC has used this set for all past shipping container criticality analyses, BWFC made an evaluation of the impact of this anomaly on these analyses. As a result of this evaluation, BWFC believes that the anomaly is due to the fixed resonance treatment of ^{235}U in the 123 group set which has been replaced by an explicit treatment in the 27 group SCALE4.2 set. This significantly affects systems containing highly enriched uranium but has only minor effects on low enriched LWR fuel. The results of the BWFC evaluation relative to the Model B shipping container are described below.

Evaluation Of The Analysis For The Current Model B License

The analysis for the current license identified the Mk BW 15x15 assembly as the most reactive of any BWFC assemblies that are to be shipped in the container. The results of this analysis using the 123 group cross section set with the Mk BW 15x15 assembly are as follows:

Configuration	$k_{eff} \pm \sigma$	K_{MAX}
Two 4.6 Wt% Assemblies	0.91538 ± 0.00101	0.936
One 5.1 Wt% Assembly	0.90739 ± 0.00107	0.917

K_{MAX} is obtained from the following equation:

$$\begin{aligned} K_{MAX} &= k_{eff} + 0.01529 + \sqrt{(1.763\sigma)^2 + 0.00529^2} \quad \textit{for 2 assemblies} \\ &= k_{eff} + 0.00500 + \sqrt{(1.763\sigma)^2 + 0.00376^2} \quad \textit{for 1 assembly} \end{aligned}$$

where 0.01529 ± 0.00529 (1.736σ) is the KENO bias associated with the spacing between the two fuel assemblies in the container and 0.005 ± 0.00376 is the bias associated with a single assembly.

The analysis was repeated with a 27 group SCALE4.2 cross section set generated with the CSASN sequence. This set was then used in KENOIV to obtain the k_{eff} for two 4.6 wt% assemblies in the container. Due to the relatively low k_{eff} of the single 5.1 wt% assembly, it was not judged necessary to repeat that analysis. The result for two assemblies is

Configuration	$k_{eff} \pm \sigma$	K_{MAX}
Two 4.6 Wt% Assemblies	0.90879 ± 0.00102	0.924

K_{MAX} is obtained from the following equation:

$$K_{MAX} = k_{eff} + 0.01159 + \sqrt{(1.763\sigma)^2 + 0.00347^2}$$

where 0.01159 ± 0.00347 (1.736σ) is the KENO bias for either one or two fuel assemblies in the container. This bias is discussed in Attachment II and is independent of spacing between assemblies.

A comparison of the 123 and 27 group results shows that the 0.95 criticality safety limit is preserved in both calculations and that the 123 group results are conservative relative to those of the 27 group set.

<u>Evaluation Of The Analysis For The Mk B10/B11 Model B License Amendment</u>

The analysis for the license amendment for the Mk B10 and B11 assemblies identified the Mk B11 assembly as the most reactive of any BWFC assemblies that are to be shipped in the container and it is used for this evaluation. The results of this analysis using the 123 group cross section set with the Mk B11 15x15 assembly are as follows:

Configuration	$k_{eff} \pm \sigma$	K_{MAX}
Two 4.6 Wt% Assemblies	0.92609 ± 0.00107	0.947
One 5.1 Wt% Assembly	0.91733 ± 0.00109	0.927

K_{MAX} is obtained from the following equation:

$$K_{MAX} = k_{eff} + 0.01529 + \sqrt{(1.763\sigma)^2 + 0.00529^2} \quad \textit{for 2 assemblies}$$
$$= k_{eff} + 0.00500 + \sqrt{(1.763\sigma)^2 + 0.00376^2} \quad \textit{for 1 assembly}$$

where 0.01529 ± 0.00529 (1.736σ) is the KENO bias associated with the spacing between the two fuel assemblies in the container and 0.005 ± 0.00376 is the bias associated with a single assembly.

The B-11 analysis was repeated with a 27 group SCALE4.2 cross section set generated with the CSASN sequence. This set was then used in KENOIV to obtain the k_{eff} for two 4.6 wt% B-11 assemblies in the container. Due to the relatively low k_{eff} of the single 5.1 wt% B-11 assembly, it was not judged necessary to repeat that analysis. The result for two assemblies is

Configuration	$k_{eff} \pm \sigma$	K_{MAX}
Two 4.6 Wt% Assemblies	0.92221 ± 0.00100	0.937

K_{MAX} is obtained from the following equation:

$$K_{MAX} = k_{eff} + 0.01159 + \sqrt{(1.763\sigma)^2 + 0.00347^2}$$

where 0.01159 ± 0.00347 (1.736σ) is the KENO bias associated for either one or two fuel assemblies in the container as discussed in Attachment II.

A comparison of the 123 and 27 group results shows that the 0.95 criticality safety limit is preserved in both calculations and that the 123 group results are conservative relative to those of the 27 group set.

Attachment II. SCALE4.2 27 Group Bias Determination

The 21 critical LRC benchmark calculations were rerun using the 27 group SCALE 4.2 cross-section library. The KENOIV calculations in Table A.1 were performed with 625 neutrons per generation and 600 generations with the first 102 generations skipped i.e a total of 311,250 neutrons. These results indicate a maximum bias that is largely independent of spacing and is approximately -0.01429 $\pm$0.00148. This differs from the 123 group cross-section set, see Table A.4, that indicates an increased bias with increased water spacing.

An evaluation was made to test the adequacy of the neutron density per generation. The evaluation indicated that larger neutron densities and generations are required to obtain meaningful results and statistics with the 27 group set as opposed to the 123 group set. Therefore, the limiting cases in Table A.1 were rerun with the number of generations increased to 850 with 2000 neutrons per generation to reduce statistical deviations. Table A.2 shows the calculated bias for the limiting core configurations identified in Table A.1. The maximum calculated bias was -0.01335±0.00197 for core XVI and represents a core with a water gap of 1.288 inches with borated aluminum isolation sheets in the water gap region. With the exception of core I and IX the other cases contained B_4C pins or borated aluminum isolation sheets. There is no apparent trend of the bias with separation distance or intervening materials. Therefore, it is recommended to use the same 27 group bias and uncertainty for all problem types represented by these critical configurations.

The previous paragraph identified the maximum 27 group bias plus uncertainty from using the worst single core configuration. A more precise understanding of the bias is to view it in a statistical sense. It is possible that any single measured or calculated core configuration could have included larger errors than those that would actually occur if the experiment was carried out more than one time. To state the case another way, is it appropriate to penalize all future criticality results because one of twenty-one core configurations appears to indicate a larger bias which could be the result of random measured error? This type of problem is addressed in statistical analysis by considering the determination of the expected sample mean and is a valid approach to use when groups of calculations are done at different conditions (as is the case for the different core configurations). The sample mean approach would view the core critical experiments as separate entities. If each core configuration experiment (and KENOIV analysis) were repeated a very large number of times, all core configurations would converge on the true sample mean. Furthermore, the true sample mean would be the same for each of the experiments. The true or expected sample mean is defined as:

$$E(x) = \sum_{i=1}^{i=M} w_i x_i / \sum_{i=1}^{i=M} w_i$$

where w_i and x_i are the weighting factors and the core bias values, respectively. E(x) is the expected sample mean. The weighting factors are defined as:

$$w_i = n_i / \sigma_i^2$$

where n_i and σ_i are the number of KENOIV generations (sample size) and the combined measured and KENOIV calculated standard deviation, respectively. The equations above were programmed into an Excel spread sheet and the results are shown in Table A.3. The expected sample mean of the bias was computed to be -0.01159 while the average bias was computed to be -0.01189. Both values are very close. The standard deviation for the expected sample mean method is the maximum standard deviation computed for any individual core. In this case the 1σ value is $\pm$0.00197 from core XVI. The one-sided upper tolerance factor at the 95/95 confidence level is assumed to be the same as for the KENOIV results or 1.763. For the average bias method the standard deviation is computed directly from the 8 core configurations to be $\pm$0.0009093 with a one-sided upper tolerance factor at the 95/95 confidence level of 3.188. Both methods are shown in Table A.3. To summarize; the expected sample mean method results in a bias of -0.01159 $\pm$0.00347 (1.763σ). The average bias method results in a bias of -0.01189 $\pm$0.00290 (3.188σ). It is recommended to use the expected sample mean bias.

The maximum calculated bias using the 27 group SCALE 4.2 library occurred for core XVI with a value of -0.01335 $\pm$0.00197 (1σ). The expected sample mean method results in a bias of -0.01159 $\pm$0.00347 (1.763σ). Since there is no trend of the maximum calculated bias values versus water spacings or intervening materials, either bias may be used but the expected sample mean bias is judged to be more appropriate. Thus, a bias of **-0.01159 $\pm$0.00347 (1.763σ)** will be used for analyses with the 27 group SCALE4.2 cross section set.

Table A.1. KENOIV LRC Critical Results
With the CSASN 27 Group SCALE 4.2 Library
(Neutrons per Generation = 625; Number of Active Generations = 498)

Spacing Between Arrays (in.)/Fiche	Core Number	KENOIV w/ CSASN/27 Gp (1σ Uncertainty)	Measured (1σ Unc)	Calculated Minus Measured (1σ Uncertainty)
None	I	0.98903 (0.00127)	1.0002 (0.0005)	-0.01117 (0.00136)
	II	1.00489 (0.00104)	1.0001 (0.0005)	+0.00479 (0.00115)
0.644	III	1.00438 (0.00099)	1.0000 (0.0006)	+0.00438 (0.00116)
	IV	0.98764 (0.00120)	0.9999 (0.0006)	-0.01226 (0.00134)
	XI	1.00013 (0.00108)	1.0000 (0.0006)	+0.00013 (0.00124)
	XIII	0.99377 (0.00120)	1.0000 (0.0010)	-0.00623 (0.00156)
	XIV	0.99323 (0.00115)	1.0001 (0.0010)	-0.00687 (0.00152)
	XV	0.99266 (0.00106)	0.9998 (0.0016)	-0.00712 (0.00192)
	XVII	0.99619 (0.00113)	1.0000 (0.0010)	-0.00381 (0.00151)
	XIX	1.00027 (0.00099)	1.0002 (0.0010)	+0.00007 (0.00141)
1.288	V	0.98603 (0.00117)	1.0000 (0.0007)	-0.01397 (0.00136)
	VI	0.99602 (0.00109)	1.0097 (0.0012)	-0.01368 (0.00162)
	XII	0.99439 (0.00116)	1.0000 (0.0007)	-0.00561 (0.00135)
	XVI	0.98777 (0.00121)	1.0001 (0.0019)	-0.01233 (0.00225)
	XVIII	0.99390 (0.00112)	1.0002 (0.0011)	-0.00630 (0.00157)
	XX	0.99767 (0.00113)	1.0003 (0.0011)	-0.00263 (0.00157)

1.932	VII	0.98589 (0.00116)	0.9998 (0.0009)	-0.01391 (0.00147)
	VIII	1.01234 (0.00123)	1.0083 (0.0012)	+0.00404 (0.00172)
	X	0.99469 (0.00119)	1.0001 (0.0009)	-0.00541 (0.00149)
	XXI	0.98649 (0.00117)	0.9997 (0.0015)	-0.01321 (0.00190)
2.576	IX	0.98871 (0.00118)	1.0030 (0.0009)	-0.01429 (0.00148

Table A.2. KENOIV LRC Critical Results For Eight Worst Deviations
With the CSASN 27 Group SCALE 4.2 Library
(Neutrons per Generation = 2000; Number of Active Generations = 847)

Spacing Between Arrays (in.)	Core Number	KENOIV w/ CSASN/27 Gp (1σ Uncertainty)	Measured (1σ Unc)	Calculated Minus Measured (1σ Uncertainty)
None	I	0.98964 (0.00053)	1.0002 (0.0005)	-0.01056 (0.00073)
0.644	IV	0.98892 (0.00052)	0.9999 (0.0006)	-0.01098 (0.00079)
1.288	V VI XVI	0.98797 (0.00052) 0.99715 (0.00049) 0.98675 (0.00051)	1.0000 (0.0007) 1.0097 (0.0012) 1.0001 (0.0019)	-0.01203 (0.00087) -0.01255 (0.00130) -0.01335 (0.00197)
1.932	VII XXI	0.98689 (0.00050) 0.98896 (0.00050)	0.9998 (0.0009) 0.9997 (0.0015)	-0.01291 (0.00103) -0.01074 (0.00158)
2.576	IX	0.99100 (0.00051)	1.0030 (0.0009)	-0.01200 (0.00103)

Table A.3. LRC 27 Group Bias Plus Uncertainty Statistical Analysis
For The Eight Worst Case Bias Cores

BIAS	1Sig Unc	W(I)	Bias x W(I)
-0.01056	0.00073	1.589E+09	-16784237.19
-0.01098	0.00079	1.E+09	-14901554.24
-0.01203	0.00087	1.119E+09	-13462029.33
-0.01255	0.00130	501183432	-6289852.071
-0.01335	0.00197	218248344	-2913615.398
-0.01291	0.00103	798378735	-10307069.47
-0.01074	0.00158	339288576	-3643959.301
-0.01200	0.00103	798378735	-9580544.82
		6.721E+09	

Ave Bias	=	-0.01189
Standard Deviation of Average Bias	=	0.000909255
95/95 One-Sided Tolerance Factor	=	3.188
95/95 One-Sided Uncertainty	=	0.002898703
Mean Bias	=	-0.011587838
Standard Deviation of Mean Bias	=	0.00197
95/95 One-Sided Tolerance Factor	=	1.763
95/95 One-Sided Uncertainty	=	0.0034731

Table A.4. KENOIV LRC Critical Results With the Cable 123 Group Library (From Previous License Submittals)

Spacing Between Arrays inches	Core Configuration	KENOIV Calculated k_{eff}	Measured Critical k_{eff}	Calculated Minus Measured
None	I	1.00447	1.0002	+0.00427
	II	1.00892 (0.00168)	1.0001 (0.0005)	+0.00882
0.644	III	0.99937 (0.00149)	1.0000 (0.0006)	-0.00063
	IV	1.00669 (0.00192)	0.9999 (0.0006)	+0.00679
	XI	1.00242 (0.00168)	1.0000 (0.0006)	+0.00242
	XIII	1.01025 (0.00188)	1.0000 (0.0010)	+0.01025
	XIV	1.00405 (0.00181)	1.0001 (0.0010)	+0.00395
	XV	0.99596 (0.00171)	0.9998 (0.0016)	-0.00384
	XVII	1.00015 (0.00188)	1.0000 (0.0010)	+0.00015
	XIX	1.00150 (0.00176)	1.0002 (0.0010)	+0.00130
1.288	V	1.00189 (0.00186)	1.0000 (0.0007)	+0.00189
	VI	1.00929 (0.00187)	1.0097 (0.0012)	-0.00041
	XII	0.99691 (0.00173)	1.0000 (0.0007)	-0.00309
	XVI	0.99193 (0.00200)	1.0001 (0.0019)	-0.00817
	XVIII	0.99139 (0.00179)	1.0002 (0.0011)	-0.00881
	XX	0.99193 (0.00186)	1.0003 (0.0011)	-0.00837
1.932	VII	0.99190 (0.00192)	0.9998 (0.0009)	-0.00790
	VIII	1.01708 (0.00181)	1.0083 (0.0012)	+0.00878
	X	0.99182 (0.00179)	1.0001 (0.0009)	-0.00828
	XXI	0.98954	0.9997	-0.01016
2.576	IX	0.98847	1.0030	-0.01453

[a] Read as $k_{eff} \pm \sigma$