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THE EFFECTS OF A SPECTRAL MODIFIER ON THE CLINCH RIVER BREEDER REACTOR LOW LEVEL FLUX MONITOR EXPERIMENTS CONDUCTED IN ZPPR-5[†]

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Current design of the Clinch River Breeder Reactor (CRBR) calls for the at-power flux monitors to be located outside the reactor vessel some 330 cm from the center of the core. This design uses these same detectors for the monitoring of refueling operations and the subsequent approach to power. Although adequate for at-power operation, these monitors could prove marginal in the shutdown mode (so called low level flux monitors).

A series of calculations[1] were performed at Oak Ridge National Laboratory in early 1974 in order to confirm the use of the ex-vessel monitors as low level flux monitors (LLFM). In addition to confirming the adequacy of the detectors during shutdown, the analysis indicated a low sensitivity to rod positioning but a moderate to high sensitivity to source movement.

In order to confirm the above analysis, a series of experiments are to be performed on the CRBR engineering mockup (ZPPR-5). The matrix design limits the distance from the core center to the detector position to ∿200 cm. Hence, the full 330 cm from the core center to the LLFM can not be mocked up in the ZPPR-5 assembly.

An attempt was made to design a spectral modifier which would result in the same source and absorber detector response as found in the CRBR design. This was accomplished using the source and adjoint fluxes obtained from a

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one-dimensional ANISN[2] calculation. Because of economic reasons, the materials examined were limited to those normally used in critical experiments.

Several spectral modifiers were examined. Of those examined, one containing 15" of stainless steel, 2" of dilute borated polyethylene (∿.17% wt B) and 5" of polyethylene was found to best match the reference CRBR absorber and source response. The dilute borated polyethylene was not readily available and that which was available (∿5% wt B) was found to drastically alter the detector response (∿27%) and furthermore, the presence of such a "black" absorber made convergence of the transport calculation difficult. An alternate design (16" of stainless steel, 3.2" of polyethylene) was deemed the most economical. The percent error for the source position change portion of the experiment varied from 8% for the preferred spectral modifier to 17% for the alternate.

In order to determine the approximate size of the detection efficiency correction for various phases of the experiments, a series of 2-D calculations were made using the transport code DOT III[3]. Axial leakage was determined using a 3-D Monte Carlo code KENO[4] and was then converted to a fictitious cross section for use in the DOT calculations. The effects of control rod changes and source movement on the ZPPR-5 LLFM detection efficiency with and without a spectral modifier were examined.

Two types of comparisons were made and summarized in Tables 1A and 1B, respectively:

1.) Absolute value of LLFM detection efficiency with spectral modifier vs. absolute value of LLFM detection efficiency without a spectral modifier, and

2.) LLFM detection efficiency ratios with spectral modifier vs. LLFM detection efficiency ratios without a spectral modifier.

The first would be used for determining absolute countrate, the latter for use in the Modified Source Multiplication algorithm for determining level of subcriticality.

Table 1A indicates that using the spectral modifier enhances the detection efficiency at the LLFM position by approximately a factor of 18 to 20 for a boron detector and a factor of 8 to 10 for a U-235 fission detector. Thus, with a spectral modifier, statistical confidence in the countrate is greatly increased for either type of detector.

Using Table 1B, detection efficiency ratios with and without spectral modifiers can be compared (i.e., compare 1 to 2, etc.). As shown, the LLFM detection efficiency ratio is less sensitive to spatial effects or source movements with a spectral modifier than without.

Table 1A.

Configuration*	B-10 Detector Efficiency: With Spectral Modifier(s)	B-10 Detector Efficiency: Without Spectral Modifier(t)	Ratio s/t	U-235 Detector Efficiency: With Spectral Modifier(x)	U-235 Detector Efficiency: Without Spectral Modifier(y)	Ratio x/y
A	2.6499-5	1.4039-6	18.88	1.6776-7	1.8099-8	9.27
B	2.6353-5	1.3730-6	19.19	1.6684-7	1.7698-8	9.43
C	2.4199-5	1.2121-6	19.96	1.5320-7	1.6246-8	9.43
D	2.6681-5	1.4278-6	18.69	1.6891-7	1.8991-8	8.89

Table 1B.

Ratio No.	Initial* Configuration	Final* Configuration	Spectral Modifier	Detector Type	(x) Initial Detector Efficiency	(y) Final Detector Efficiency	Ratio x/y
1	A	B	In	B-10	2.6499-5	2.6353-5	1.006
2	A	B	Out	B-10	1.4039-6	1.3730-6	1.023
3	A	B	In	U-235	1.6775-7	1.6683-7	1.006
4	A	B	Out	U-235	1.8099-8	1.7698-8	1.023
5	D	C	In	B-10	2.6681-5	2.4199-5	1.103
6	D	C	Out	B-10	1.4278-6	1.2121-6	1.178
7	D	C	In	U-235	1.6891-7	1.5320-7	1.103
8	D	C	Out	U-235	1.8991-8	1.6246-8	1.169

*Configurations.

Configurations

A - All control rods except center rod inserted - PSR pair (1,244-32) located in inner core region approximately 132 cm from LLFM detector.

B - All control rods except center rod inserted - PSR pair (1,235-45) located in inner core region approximately 220 cm from LLFM detector.

C - All control rods except center rod inserted - All PSR pairs withdrawn - Cf-252 source at position (1,237-33) located approximately 22 cm on a line 180° from core center (this point is approximately 165 cm from LLFM detector).

D - All control rods except center rod inserted - All PSR pairs withdrawn - Cf-252 source at position (1,237-21) located approximately 89 cm on a line 180° from core center (this point is approximately 133 cm from LLFM detector).

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