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"Evaluation of Fort Calhoun Fuel Alignment Plate Fluence for MRP-227-A"

(Non-Proprietary)

PRESSURIZED WATER REACTOR OWNERS GROUP

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WESTINGHOUSE NON-PROPRIETARY CLASS 3

Evaluation of Fort Calhoun Fuel Alignment Plate Fluence for MRP-227-A

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1 BACKGROUND:

This report is generated in response to part 2 of NRC request for additional information (RAI) 2 (Reference 1), which requests applicants to demonstrate that MRP-227-A is applicable to the unit in question. The initial response to these RAIs is provided in PWROG-14082-P (Reference 2). However, Section 1.1.2 of PWROG-14082-P indicates that further plants-specific analysis is required to demonstrate that the fluence above the fuel alignment plate (FAP) does not exceed the irradiation embrittlement screening threshold.

For Combustion Engineering plants, MRP-227 guidelines MRP 2013-025 (Reference 3) suggests that the combination of

- core power density less than 110 W/cm^3 and
- distance from the top of the active fuel to the bottom of the fuel alignment plate (FAP) greater than 12.4 inches

allows for no further evaluation of core internals above the fuel alignment plate.

Per References 2 and 4, Fort Calhoun Station (FCS) does not meet the screening criteria for cycles 24 to 27[1].

Additionally, further discussions with Omaha Public Power District (OPPD) and document reviews within Westinghouse suggest that the screening criteria were likely not met in some earlier fuel cycles.

The purpose of this report is to evaluate the compensating impact on fluence of a relatively higher active core against a relatively lower power density.

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[1] Unless the current fuel design is altered, FCS is unlikely to meet the screening criteria in future cycles. Future operations are beyond the scope of this discussion.

2 SUMMARY OF INPUT DATA

The fuel-FAP gap distance is provided in Table 5-4 of Reference 4. However, a review of Westinghouse drawings, particularly References 8 and 9, and additional clarification on the contents of Reference 6 suggest that earlier fuel cycles likely did not meet the screening criteria. Specifically:

- Fuel assembly drawings for the first five operating cycles (References 9 through 13) indicate that the minimum fuel-FAP gap is found in the first batch of fuel and is equal to [ ]^{a,c} inches.
- The batch M drawings (Reference 14) indicate that the Fort Calhoun bottom nozzle height had continued to decrease. This suggests that the limiting fuel-FAP gap is limited by the earlier fuel batches in that period. This is calculated based on the batch G drawings (Reference 13) as [ ]^{a,c} inches.
- Based on a comparison of References 14 and 15, later Westinghouse fuel assembly designs maintain a roughly constant bottom nozzle height. The fuel-FAP gap distance is calculated for cycles 11 to 19 based on the batch M distance of [ ]^{a,c} inches.
- The fuel-FAP distances from cycles 20 through 27 are based on the data transmitted in Reference 6.

The correlation between fuel batches and reactor operating cycles is approximate and based on drawing dates and FCS operating history data.

3 DISCUSSION OF FORT CALHOUN DATA

Combining the Westinghouse and AREVA fuel designs yields four fuel-FAP gap distances: [ ]a,c, [ ]a,c, [ ]a,c, and [ ]a,c inches. Note that this average distance changed as fuel assembly design, particularly the bottom nozzle, evolved over time. These changes are not explicitly considered here for two reasons. First, a representative sample of Combustion Engineering and Westinghouse fuel assemblies is provided. Second, the increase in the active fuel height by [ ]a,c inches starting in cycle 24 makes those later cycles the limiting configuration.

According to Table 5-1 of Reference 4, Fort Calhoun has operated at three different core power densities: 76.1, 80.4, and 79.5 W/cm^3.

The probable combinations of these key variables are summarized in Table 1.

Table 1: Summary of MRP-227 Upward Streaming Screening Criteria

Cycle	Fuel-FAP Gap [in]	Power Density [W/cm^3]
1 – 5	[ ]a,c	76.1
6 – 10	[ ]a,c	80.4
11 – 19	[ ]a,c	80.4
20 – 23	[ ]a,c	80.4
24 - 27	[ ]a,c	79.5

For the first, second, third and fifth combinations, the FCS core would not meet the MRP-227 screening criteria for the distance between the active fuel and the fuel alignment plate. However, there is a significant amount of margin in the power density.

Westinghouse performed generic calculations for Combustion Engineering plants in Reference 5. The results presented in Table 2-2 (Fast Neutron Fluence Exposure at 60 EFPY) of Reference 5 are used to estimate the flux increase as the distance to the FAP is decreased. The dimensions in Table 4-7 (2" elevated) of Reference 5 correspond to a [ ]a,c inch gap between the fuel and the FAP. Thus the *Two_Inch* results are used as the base case for MRP-227 screening. The *Four_Inch* results are used when the active fuel to FAP distance is decreased by 2 inches.

Table 2: Interpolated 60 EFPY Fast Neutron Fluence (E > 1.0 MeV) [n/cm^2]

Cycle	Active Fuel to FAP [in]	Fast Fluence[1]	% Increase
	[ ]^{a,c}	1.61E+21	
11 – 19	[ ]^{a,c}	1.82E+21	13%
1 – 10	[ ]^{a,c}	2.05E+21	27%
24 - 27	[ ]^{a,c}	2.23E+21	39%
	[ ]^{a,c}	2.70E+21	

The percentage increase in flux should then be compared to the percentage decrease in the power density:

Table 3: Actual Operating Power Density [W/cm^3]

FCS Power Density	MRP-227 Power Density	% Decrease
76.1	110.0	45%
80.4	110.0	37%
79.5	110.0	38%

Calculating the product of the flux increase (due to the decreased distance) and the flux decrease (due to decreased power density) for the four cases of interest:

Cycles 1-5: $\frac{2.05E+21}{1.61E+21} * \frac{76.1}{110.0} = 0.88 \quad \rightarrow OK$

Cycles 6-10: $\frac{2.05E+21}{1.61E+21} * \frac{80.4}{110.0} = 0.93 \quad \rightarrow OK$

Cycles 11-19: $\frac{1.82E+21}{1.61E+21} * \frac{80.4}{110.0} = 0.82 \quad \rightarrow OK$

Cycles 24-27: $\frac{2.23E+21}{1.61E+21} * \frac{79.5}{110.0} = 1.00 \quad \rightarrow OK$

[1] The fluence values at [ ]^{a,c}, [ ]^{a,c}, and [ ]^{a,c} inches are calculated using linear interpolation. Examination of the data suggests that an exponential fit would be more accurate but that a linear fit is conservative.

The ratio comparison is used to avoid adjusting the fluence results from Reference 5 to account for changes in axial leakage between the generic cases and the actual fuel assembly design at Fort Calhoun. However, the trends in neutron attenuation in the space between the top of the active fuel and the fuel alignment plate should be similar. This comparison shows that the increase in fast neutron fluence at the FAP is more than offset by the reduced power density for approximately the first 23 operating cycles at Fort Calhoun. For the current fuel assembly design, these two factors offset with no margin.

Note that the fluence data for the top of the fuel alignment plate (also taken from Reference 5) were reviewed and similar results are observed in the four cases of interest.

4 SUMMARY OF RESULTS:

A review of the first 27 fuel cycles suggests that, when correcting for the FAP to active fuel distance and average core power density, the applicability of MRP-227-A is preserved at Fort Calhoun at the expected end of plant life (48 EFPY) for Austenitic Stainless Steel materials.

The following RAI response is proposed to supplement the text provided in Reference 2.

Fort Calhoun Station (FCS) has not utilized atypical design or fuel management, including power changes/uprates, which are non-representative of the assumptions of MRP-227-A.

To support this conclusion, the assumptions of MRP-227-A, along with the additional guidance provided by the MRP 2013-025, were evaluated. The assumptions of MRP-227-A were evaluated against fuel design changes, core designs, and plant operation. The FCS calculated reactor core power density remains well below the screening criterion of 110.0 W/cm^3. However, the screening criterion of a 12.4 inch distance between the active fuel and the fuel alignment plate was not met for multiple fuel cycles.

For fuel cycles prior to fuel cycle 20 the distance between the active fuel and the fuel alignment plate was slightly less than the assumed 12.4 inches (the gap varied from [ ]^{a,c} to [ ]^{a,c}). Fuel cycles from cycle 24 to present also do not meet the screening criterion with an gap of [ ]^{a,c}.

Even though these screening criteria were not met, FCS is still bounded by the MRP 2013-025 analysis because the screening criteria used a fuel power density that was between 37% and 45% higher than FCS's fuel power density during the fuel cycles where the screening criterion was not met. This margin more than offsets the increased fluence due to the active fuel being closer to the alignment plate.

Therefore, even with the active fuel slightly closer to the upper alignment plate than analyzed for MRP 2013-025, FCS reactor vessel upper internals would have received less fluence than analyzed in MRP 2013-025.

5 REFERENCES:

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