ANO-2

FRESH FUEL PIT CRITICALITY ANALYSIS

STORAGE OF 4.1 WEIGHT PERCENT U-235 ASSEMBLIES

by

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October 17, 1984

Abstract

This report documents a criticality analysis of the Arkansas Nuclear One-Unit 2 pit which contains the fresh fuel storage rack. The FSAR shows that it is safe to store fuel assemblies of up to 3.7 weight percent U-235 under conditions of optimum moderation. The purpose of this study is to determine if the multiplication factor of the pit is less than allowed limits when the rack is loaded with 4.1 weight percent U-235 fuel assemblies.

A three-dimensional model of the fuel storage rack and the pit in which the rack is contained was analyzed with Monte Carol (KENO-IV/S) methods to obtain the K-effective for uniform water densities that might exist in the pit. The multiplication factors of both a nominal and an adverse geometry were obtained at various moderator densities using a 123 group neutron cross-section library, and the most reactive condition identified.

It was found that K-effective was less than the NUREG-0800 limit for all moderator densities. From a criticality standpoint, assemblies of 4.1 weight percent U-235 may be safely stored in the fresh fuel storage pit.

1.0 Summary

The FSAR shows that it is safe to store fuel assemblies of up to 3.7 weight percent U-235 under conditions of optimum moderation. This analysis shows that, from a criticality standpoint, assemblies of 4.1 weight percent U-235 may be safely stored in the fresh fuel storage pit. It is shown that K-effective is less than the NUREG-0800 limit of 0.95 for all moderator densities.

2.0 Assumptions

1.) The fresh fuel rack is filled with unirradiated fuel assemblies containing 4.1 weight percent U-235. The uranium dioxide density of the fuel stack is 10.061 grams/cubic centimeter (91.8 %TD).

2.) The pit is moderated by pure water at various uniform densities.

3.) No burnable poison, control element assembly, or other fixed poison is stored with the fuel assembly.

4.) The temperature of all components of the fuel assembly, rack and pit is 20 degrees C.

5.) All pit walls and the pit floor are modeled as two feet of concrete followed by void. The pit is modeled as being uncovered.

6.) No rack structural material is modeled.

7.) The fuel assembly is modeled as being comprised of fuel pins only. No assembly structural material is modeled.

8.) The fuel rack is positioned laterally to maximize the distance to the pit walls, the most reactive position.

3.0 Nuclear Methods

3.1 Computer Codes Used

KENO-IV/S was used for all criticality calculations. A sixteen group pre-mixed neutron cross-section library was used to obtain the approximate density at which optimum moderation of the pit occurred. A 123 group GAM-THERMOS cross-section library which had been processed by NITAWL-S to account for resonance self-shielding was used in the calculation of the multiplication factor. Descriptions of KENO-IV/S, NITAWL-S and both neutron libraries are contained in Reference 1.

3.2 Verification of KENO Methodology

Five critical experiments performed by Babcock and Wilcox were analyzed with KENO using a 123 group GAM-THERMOS library which had been processed by NITAWL to obtain resonance corrected cross-sections. These experiments, details of which may be found in Reference 2, utilized water moderated, aluminum clad, 2.46% U-235 rods in various configurations. The five MSS KENO calculations give a mean K-eff of

0.9964 ±0.0082 which is in good agreement with the twenty one criticals from Reference 2 which yield a mean K-eff of 0.9967 ± 0.0087. Good agreement is also obtained when the MSS results are compared to the 123 group data from the seventy critical experiments in Reference 3 which yield a mean K-eff of 0.9958 ± 0.0087. The distribution of K-effectives of all three calculations was verified to be normal using SAS (Reference 4). The equivalency between the five MSS KENO benchmark cases and the ninety one combined ORNL and B&W KENO analyses was demonstrated using the F, T and Bartlett tests, also with SAS. Therefore, using the mean and standard deviation from the combined data, the KENO reliability factor is calculated as:

$$0.004 + (1.942)^{*}(0.008689) = 0.0208$$

where a one sided tolerance factor of 1.942 has been applied (95% probability at a 95% confidence level for ninety one samples, c.f. Reference 5, Table 1.4.2). The KENO calculations will be corrected as follows for safety analysis:

$$\text{K-eff(safety)} = \text{K-eff(KENO)} + 0.021$$

No specific correction has been made for experimental uncertainties in the critical experiments cited in Reference 2 since they are approximately ten times smaller than the statistical variations in the calculational results. In accordance with Reference 6, no correction due to differences between the conditions at which the benchmark is made and the conditions at which the pit is analyzed is needed.

4.0 Results

ANO-2 fresh fuel is stored in cavities whose internal dimensions are 8.56 inches on a side. Since the outside assembly dimensions are 8.096 inches, there is a ± 0.232 inch pitch-to-boundary uncertainty in the lateral placement of any one assembly in its cavity. Both a nominal and an adverse geometry were modeled. The nominal geometry had all assemblies centered in the storage cavities while in the adverse geometry the assemblies were shifted within the storage cavities to minimize the distance to the center assembly. A scoping study using the nominal geometry and a sixteen group library was used to obtain the approximate water density at which peak reactivity occurred. NITAWL/KENO 123 group analysis of the two geometries at various moderator densities yields a maximum K-effective with the adverse geometry at a water density of 0.06 gm/cc.

The K-eff calculated from 20,000 neutron histories at 0.06 gm/cc using the 123 group neutron library is 0.92619. After applying the KENO safety factors as calculated in Section 3.2, we obtain 0.947 as the maximum K-eff of the pit at the 95/95 confidence level. This is less than the 0.95 calculational limit for possible moderation and well below the 0.98 limit at optimum moderation as required in NUREG-0800. A similar calculation with the KENO result of 0.87172 at 1.0 gm/cc yields a K-eff of 0.893, also well below the calculational limits of NUREG-0800. Figure 1 is a graph of the multiplication factor versus moderator density over the range in which K-eff is greatest calculated with the adverse geometry. The adjusted K-eff, to which calculational and modeling uncertainties have been added, is plotted along with the best estimate K-eff from the KENO computer code. As can be seen, 0.060 gm/cc is indeed the optimum moderator density and 0.98, the allowable calculational limit for the optimum moderation condition, bounds all values.

5.0 Conclusion

This analysis has shown that the ANO-2 fresh fuel pit can, from a criticality standpoint, safely store 4.1 weight percent enriched fuel assemblies. Assurance is provided that K-eff is maintained below the limit of 0.95 for all moderator densities. The design complies with the requirements of NUREG-0800 and ANSI/ANS-57.3-1983.

6.0 References

1. SCALE-2: A Modular Code System for Performing Standardized Computer Analysis for Licensing Evaluation, Oak Ridge National Laboratory, Doc. No. CCC-450, MSS File No. 015-27.

2. N. M. Baldwin et al. Critical Experiments Supporting Close Proximity Water Storage of Power Reactor Fuel, BAW-1487-7 (July 1979).

3. R. M. Westfall, J. R. Knight, "Scale System Cross-Section Validation with shipping-Cask Critical Experiments", Trans. Am. Nucl. Soc., 33, 368 (1979).

4. ANSI N15.15-1974, American National Standard Assessment of the Assumption of Normality (Employing Individual Observed Values).

5. R. E. Oden and D. B. Owen, Tables for Normal Tolerance Limits, Sampling Plans and Screening, Marcel Dekker, Inc., New York, N.Y., 1980.

6. D. G. Napolitano, D. R. Harris, et. al., "Validation of the NITAWL-KENO Methodology in Modeling New-Fuel Storage Criticality", Trans. Am. Nucl. Soc., 44, 291 (1983).

FIGURE 1
K-EFF VS. WATER DENSITY
WITH AND WITHOUT UNCERTAINTY