CRITICALITY SAFETY EVALUATION OF THE DIABLO CANYON NEW FUEL VAULT WITH FUEL OF 5% ENRICHMENT

Prepared for the

PACIFIC GAS AND ELECTRIC COMPANY

by

Stanley E. Turner, PhD, PE

Rev. 1 April 1995

Holtec Project 30514

Holtec Report HI-931075

230 Normandy Circle
Palm Harbor, FL 34683

2060 Fairfax Ave.
Cherry Hill, NJ 08003

TABLE OF CONTENTS

List of Tables

List of Figures

1.0 INTRODUCTION

The present study is part of an evaluation of the fuel storage facilities at the Diablo Canyon Power Plant in order to qualify the facilities for fuel of 5% average initial enrichment. This report addresses the new-fuel storage vault while companion reports evaluate the spent fuel storage pools (HI-931076 for Region 1 and HI-931077 for Region 2).

The new fuel storage vault is intended for the receipt and storage of fresh fuel under normally dry conditions where the reactivity is very low (k-effective of about 0.4). To assure the criticality safety under accident conditions and to conform to the requirements of General Design Criterion 62, "Prevention of Criticality in Fuel Storage and Handling", two separate criteria must be satisfied as defined in the USNRC Standard Review Plan NUREG-0800, Section 9.1.1, "New Fuel Storage"(1). These accident criteria are as follows:

- When fully loaded with fuel of the highest anticipated reactivity and flooded with clean unborated water, the maximum reactivity, including uncertainties, shall not exceed a k_{eff} of 0.95.
- With fuel of the highest anticipated reactivity in place and assuming the optimum hypothetical low density moderation, (i.e., fog or foam), the maximum reactivity shall not exceed a k_{eff} of 0.98.

2.0 SUMMARY AND CONCLUSIONS

The new-fuel storage vault at the Diablo Canyon Power Station contains two 5 x 7 arrays of storage locations, with each array providing 35 cells arranged on a 22-inch lattice spacing. The new fuel storage vaults have previously been qualified for fuel of 4.5% enrichment[(2)] with a substantial margin remaining below the regulatory limits. Criticality safety analyses and accident evaluations have now been made with fuel of 5.0% enrichment, based upon USNRC criteria as described above (Standard Review Plan Section 9.1.1). These calculations, summarized in Table 1, confirm that, with respect to criticality safety, the new fuel storage vaults of Units 1 and 2 can safely receive and store fuel of 5.0% enrichment within the limits of the USNRC guidelines.

Calculations determined that the Westinghouse OFA fuel is limiting in the flooded condition, while the standard fuel exhibits the higher reactivity under low-density optimum moderation conditions. In the flooded condition, the maximum k_{eff} for OFA fuel was calculated to be 0.945 for 5.0% enriched fuel, including all known uncertainties, which is below the regulatory limit of 0.95. For the hypothetical low-density "optimum" moderation, the maximum k_{eff} of 0.900 for standard fuel occurs at a moderator density of 8%, as illustrated in Figure 1. Because of neutron leakage and absorption of neutrons in materials of construction, the maximum low-density reactivity is less than that for the flooded case. Any burnable poison that may be present in the fuel assemblies (i.e., IFBA rods) will result in lower and more conservative reactivities.

The design criteria define the principal accident conditions. Under other postulated accident conditions the double contingency principle precludes the consideration of multiple accidents occurring simultaneously. Under normal storage conditions in the dry condition, the calculated k_{eff} is 0.420. For seismic conditions, postulated to disrupt the racks allowing the fuel assemblies to

spill out and accumulate in a close-packed array, the calculated k_{eff} will be a maximum of 0.808 for the bounding condition with all steel conservatively assumed to be lost.

Based upon these calculations (and the data in Figure 1), it is concluded that the new fuel vault will safely accommodate 5.0% enriched fuel assemblies of either the Westinghouse standard or OFA designs with assurance that the maximum reactivities conform to the acceptance criteria of SRP 9.1.1.

3.0 CRITICALITY SAFETY ANALYSES

3.1 Storage Vault Design

The new fuel storage vault normally provides two banks of storage racks, each consisting of 5 x 7 arrays of storage locations arranged on a 22 inch lattice spacing. The two banks of storage locations are located in a concrete vault, separated from each other by about 27½ inches, as illustrated in Figure 2. Stainless steel angles, 2-inch x 2-inch x ¼-inch thick, define the storage locations and support the contained fuel assemblies. Steel cross-bracing exists along the outer boundary but is conservatively neglected in the criticality evaluation.

3.2 Fuel Assembly Specifications

The new fuel storage vaults were evaluated for their ability to accommodate fuel with a 17 x 17 rod array of the Westinghouse standard or optimized (OFA) designs. Table 2 lists the design specifications for the fuel used in the analyses. Calculations were made with the 27-group NITAWL-KENO-5a code package for both the Westinghouse standard fuel assemblies and the OFA fuel assemblies at 5.0% U-235 enrichment. In these calculations, it was found that the standard fuel gave the higher reactivity for the low-density optimum moderation condition while the OFA fuel gave the higher reactivity under the fully flooded accident condition. These results are shown below:

	Standard Fuel	OFA Fuel
8% Moderator Density	0.9002*	0.8961
Fully Flooded	0.9370	0.9449*

* Limiting cases for each condition are summarized in Table 1.

Any boron burnable poison which may be on the surface of pellets in IFBA rods will provide an even greater margin below the limiting k_{eff} values and would therefore be more conservative.

3.3 Analytical Methodology

The primary criticality analyses of the high density spent fuel storage racks were performed with the three-dimensional NITAWL-KENO-5a Monte Carlo code package[3]. NITAWL was used with the 27-group SCALE* cross-section library and the Nordheim integral treatment for U-238 resonance shielding effects. Benchmark calculations, presented in Appendix A, indicate a bias of 0.0103 ± 0.0018 (95%/95%[4]). Verification calculations were also made with the 218-group cross-section library.

In the geometric model used in the calculations with low-density moderation, each fuel rod, each fuel assembly, and the concrete walls of the vault were explicitly described. Beyond the concrete walls of the vault, the neutron flux was assumed to be zero. In the axial direction, a concrete floor was assumed below the fuel and no absorbing material was assumed above the fuel. Each stainless steel angle that supports the assemblies were also explicitly described in the calculational model. For the flooded condition, an infinite radial array of assemblies on a 22-inch lattice spacing was assumed, with each fuel rod and the stainless steel angles explicitly included in the model. The cladding material was assumed to be Zircaloy and alternative clad material with greater absorption cross-section will reduce reactivity.

Monte Carlo (KENO-5a) calculations inherently include a statistical uncertainty due to the random nature of neutron tracking. To minimize the statistical uncertainty of the KENO-calculated reactivity, a minimum of 500,000 neutron histories in 1000 generations of 500 neutrons each, were accumulated in each calculation, generally resulting in a statistical uncertainty of about ± 0.0010 Δk (1σ).

---

* SCALE is an acronym for <u>S</u>tandardized <u>C</u>omputer <u>A</u>nalysis for <u>L</u>icensing <u>E</u>valuation, a standard cross-section set developed by ORNL for the USNRC.

4.0 REFERENCES

1. USNRC Standard Review Plan, NUREG-0800, Section 9.1.1, New Fuel Storage, Rev. 2 - July 1981

2. S. E. Turner, "Criticality Safety Analysis of the New-Fuel Storage Vault in the Diablo Canyon Power Plant with Fuel of 4.5% Enrichment", Southern Science, S-161.

3. R.M. Westfall, et. al., "NITAWL-S: Scale System Module for Performing Resonance Shielding and Working Library Production" in SCALE: A Modular Code System for Performing Standardized Computer Analyses for Licensing Evaluation,, NUREG/CR-0200, 1979.

   L.M. Petrie and N.F. Landers,"KENO 5a. An Improved Monte Carlo Criticality Program with Supergrouping" in Scale: A Modular Code System for Performing Standardized Computer Analyses for Licensing Evaluation, NUREG/V-0200, 1979.

4. M.G. Natrella, Experimental Statistics, National Bureau of Standards, Handbook 91, August 1963.

Table 1

SUMMARY OF CRITICALITY SAFETY ANALYSES
NEW FUEL STORAGE VAULT

	Flooded	Optimum Moderation
Type of Fuel (Westinghouse)	OFA	Standard
Moderator Density	100%	8%
Fuel Enrichment, wt% U-235	5.00	5.00
Reference k_{eff} (KENO-5a)	0.9277	0.8846
Calculational bias,⁽¹⁾	0.0103	0.0103
Uncertainties		
Bias	± 0.0018	± 0.0018
KENO statistics (95%/95%)	± 0.0026	± 0.0026
Lattice Spacing Fuel enrichment Fuel density	± 0.0061	± 0.0042
Statistical combination of uncertainties⁽²⁾	± 0.0069	± 0.0053
Total	0.9380 ± 0.0069	0.8949 ± 0.0053
Maximum Reactivity (k_{eff})	0.9449⁽³⁾	0.9002⁽³⁾

---

(1) Appendix A

(2) Square root of sum of squares.

(3) 218-group check calculations gave maximum k_{eff} values of 0.9401 and 0.8964 for the flooded and optimum moderation cases respectively.

Table 2

DESIGN BASIS FUEL ASSEMBLY SPECIFICATIONS

FUEL ROD DATA	OFA	STANDARD
Outside diameter, in.	0.360	0.374
Cladding inside diameter, in.	0.315	0.329
Cladding material	Zr-4	
Stack density, g UO_2/cc	10.41 ± 0.20	
Pellet diameter, in.	0.3088	0.3225
Maximum enrichment, wt % U-235	5.00 ± 0.05	
FUEL ASSEMBLY DATA		
Fuel rod array	17x17	
Number of fuel rods	264	
Fuel rod pitch, in.	0.496	
Number of control rod guide and instrument thimbles	25	
Thimble O.D., in. (nominal)	0.474(1)	0.482
Thimble I.D., in. (nominal)	0.442(1)	0.450

---

(1) Alternative Thimble Dimensions are 0.476" OD and 0.440" ID. This difference has a negligible effect on reactivity.

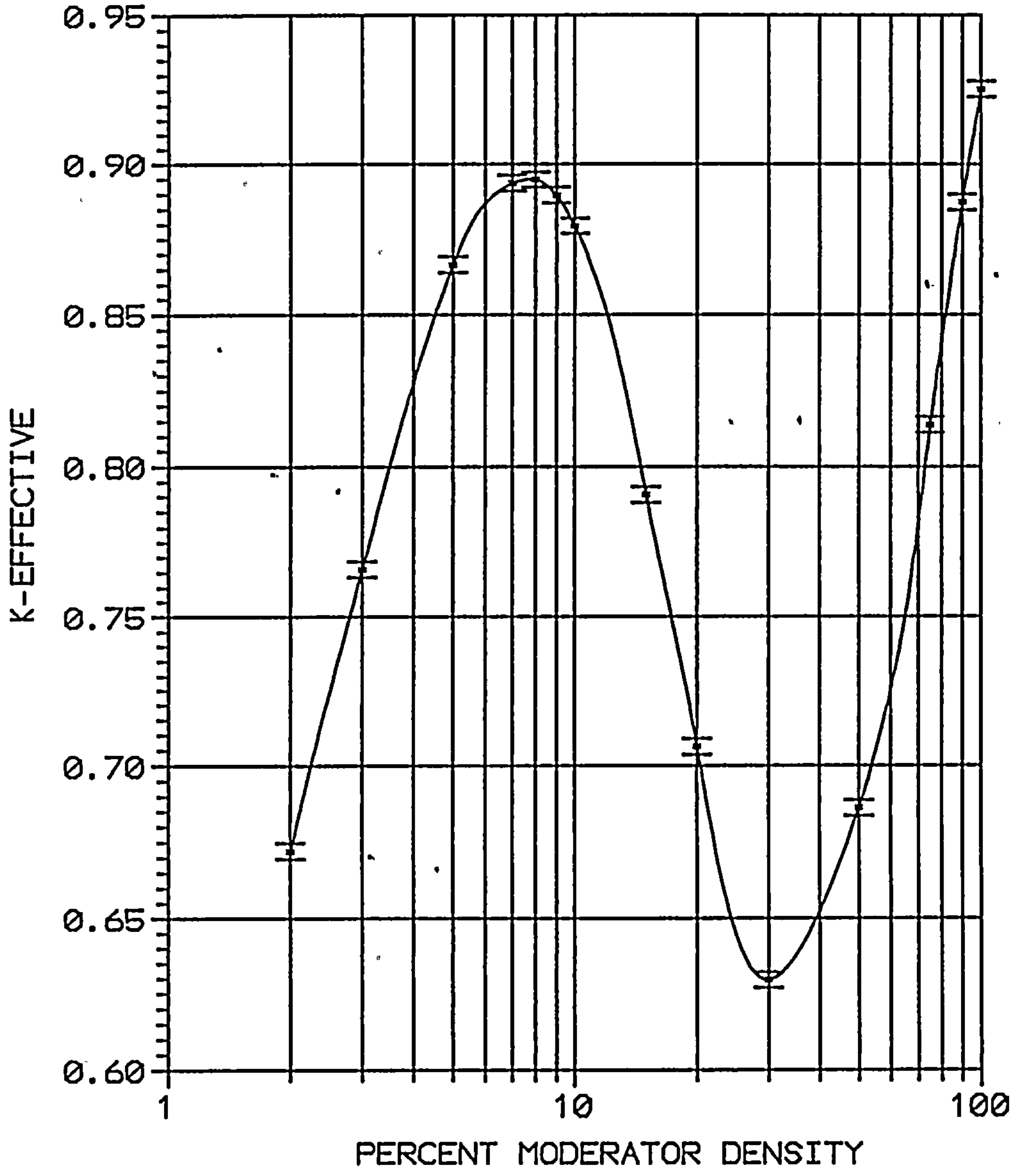

Fig. 1 REACTIVITY VARIATION WITH MODERATOR DENSITY

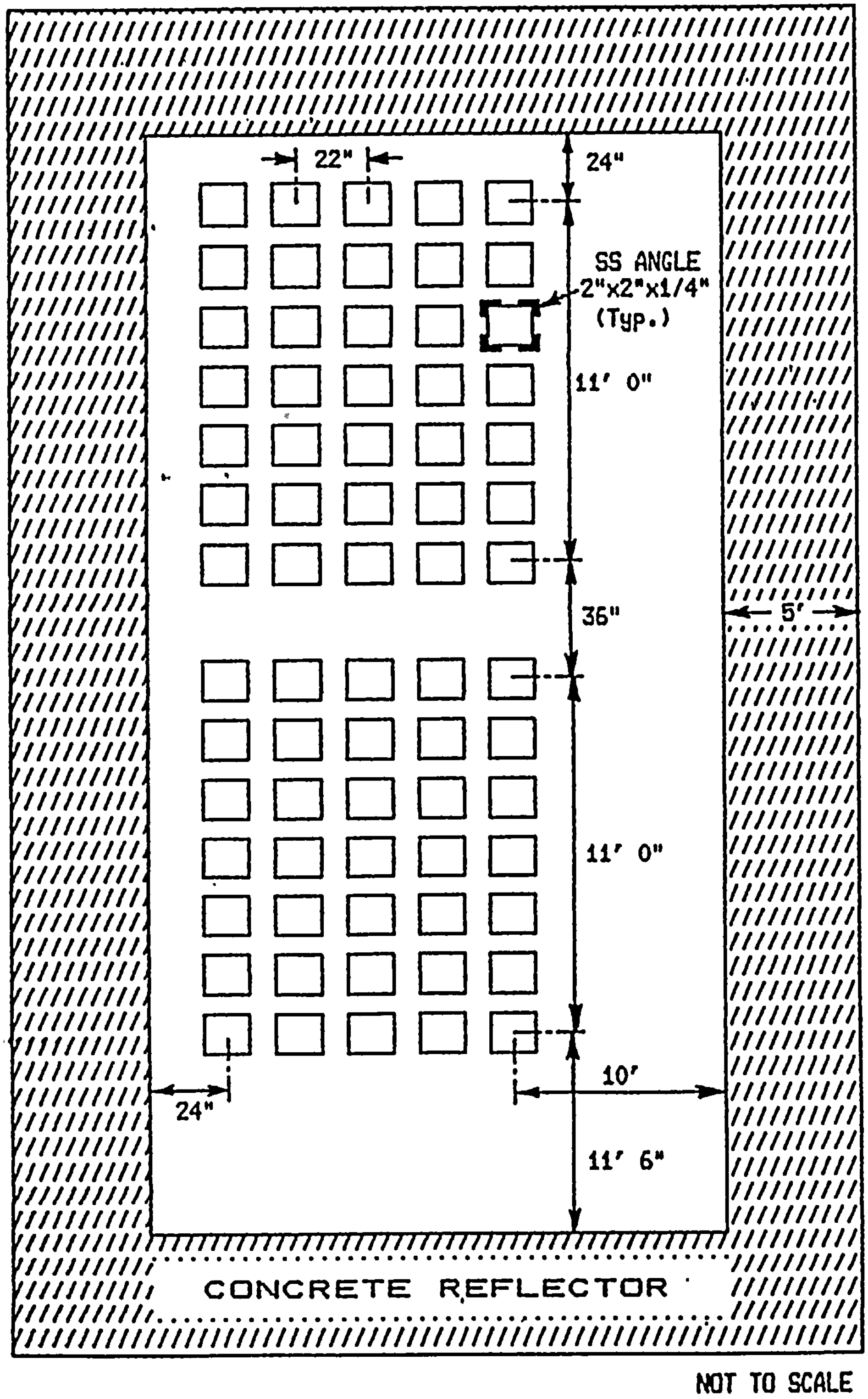

Fig. 2 Geometric arrangement of the Diablo Canyon new-fuel storage vault

ENCLOSURE 2

CORRECTED REVISED ANALYSIS FOR LAR 95-01, ATTACHMENT E, "CRITICALITY SAFETY EVALUATION OF REGION 1 OF THE DIABLO CANYON SPENT FUEL STORAGE RACKS WITH FUEL OF 5.0% ENRICHMENT"

HI-931076 REV. 2