SS-161

CRITICALITY SAFETY ANALYSIS
OF
THE NEW-FUEL STORAGE VAULT
IN THE DIABLO CANYON POWER PLANT
WITH FUEL OF 4.5% ENRICHMENT

Prepared for the

PACIFIC GAS and ELECTRIC Co.

SAN FRANCISCO, CALIFORNIA

DIABLO CANYON Units 1 and 2

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1 INTRODUCTION

A criticality safety analysis of the Diablo Canyon spent fuel storage racks has previously been prepared* for the purpose of qualifying the spent fuel storage racks to safely accommodate fuel enriched to 4.5% U-235. The evaluation reported here is intended to supplement that analysis and to qualify the new-fuel storage facility to receive fuel of the same 4.5% enrichment.

To assure the criticality safety of the new-fuel storage vault 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 NUREG-0800, Standard Review Plan, Section 9.1.1, "New Fuel Storage." These 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.

Results of the present evaluation confirm that, with assemblies of up to 4.5% enrichment, the new-fuel storage vault at the Diablo Canyon power plant satisfies both criteria cited above.

*Re-racking of Spent Fuel Pools, Diablo Canyon Units 1 & 2 submitted to the USNRC in September 1985 (Dockets 50-275 and 50-323).

2 SUMMARY

The new-fuel storage vault at the Diablo Canyon power plant contains two 5 x 7 arrays of storage locations, with each array providing 35 cells arranged on a 22-inch-square lattice spacing. Results of the criticality safety analysis of this storage vault, with fuel of 4.5% enrichment, are summarized in Table 1 for the two design criteria cases. In both cases, the maximum reactivity (k_{eff}), including all known uncertainties, is less than the corresponding reactivity limit, confirming that the new-fuel storage vault can safely accommodate fuel assemblies of 4.5% enrichment.

In the case of flooding with clean unborated water, and fully loaded with fuel of 4.5% enrichment, the maximum reactivity, including all known uncertainties, is 0.933 (actually k_{∞}, since an infinite array was assumed in the analysis). This maximum reactivity is less than the limiting value of 0.95.

With a hypothetical low density moderator, the maximum k_{eff} occurs at a water density of ~7.5-8%. Figure 1 shows the variation in calculated reactivity (k_{eff}) at various water densities and clearly reveals the peak in reactivity at a low moderator density (~0.0773 g/cc). Because of neutron leakage and inherent absorption in the materials of rack construction; the maximum low density reactivity is less than that for the flooded case. With all locations filled with fuel of 4.5% enrichment, the maximum reactivity at optimum moderation is 0.880, including uncertainties, which is well below the limiting value of 0.98.

Table 1

CRITICALITY SAFETY ANALYSIS OF THE NEW-FUEL STORAGE VAULT WITH FUEL OF 4.5% ENRICHMENT

		Flooded	Optimum Moderation
1.	Moderator density, %	100	7.5-8
2.	Analytical methodology	123 Gp. AMPX-KENO	123 Gp. AMPX-KENO
3.	Nominal k_{eff}	0.9206	0.8657
4.	Calculational bias, Δk	0.0000	0.0024
5.	Uncertainty in bias, Δk	0.0030	0.0030
6.	Statistical variation, Δk	0.0119	0.0078
7.	Mechanical tolerances	N/A	0.0078
8.	Fuel enrichment & density, Δk	0.0031	0.0031
9.	Total	0.9206 ± 0.0127(1)	0.8681 ± 0.0118(1)
10.	Maximum k_{eff} (95%/95%)	0.9333	0.8799
11.	Reactivity limit	0.95	0.98

(1) Includes statistical combination of Items 5, 6, 7, and 8.

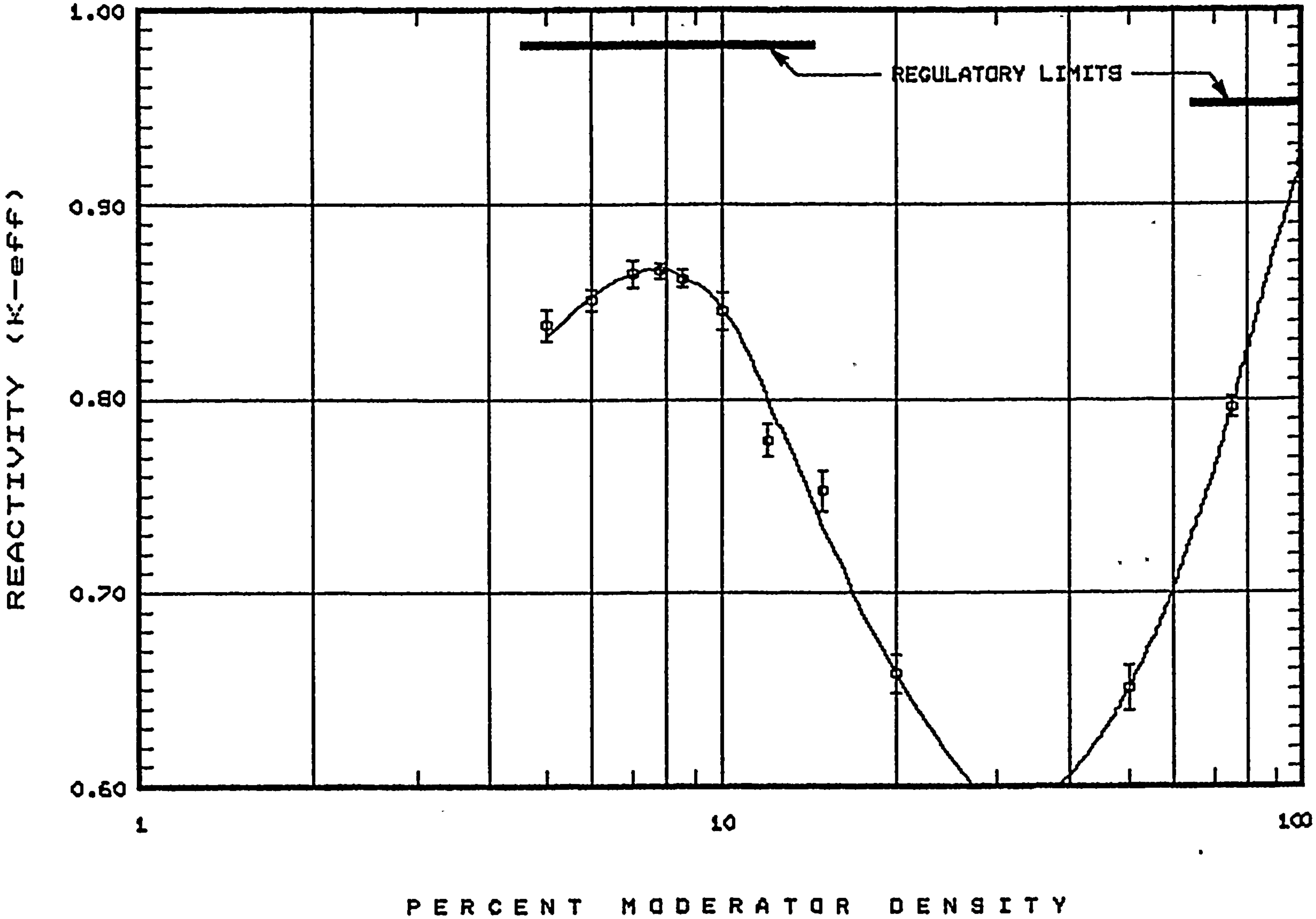

Fig. 1 Variation of new-fuel storage vault reactivity (k_{eff}) with water density ($\rho_{100\%}$ = 0.998).

3 CRITICALITY ANALYSES

3.1 Reference Fuel Assembly

The reference design fuel assembly is a standard Westinghouse 17 x 17 array of fuel rods, with 25 rods replaced by 24 control rod guide tubes and one instrument thimble. Table 2 summarizes the fuel assembly design specifications and expected range of significant tolerances.

3.2 Reference Storage Rack Array

The new-fuel storage vault includes two arrays of storage cells, with each array accommodating 35 fuel assemblies. The fuel assemblies are positioned on a 22-inch center-to-center spacing by stainless steel "L's" on the four corners of each storage location. The entire vault can accommodate up to 70 fuel assemblies.

Figure 2 illustrates the geometric arrangement of storage cells in the Diablo Canyon new-fuel storage vault. To assure conservatism in the criticality analysis, the concrete walls of the vault were assumed to be five-feet-thick (essentially an infinite reflector).

3.3 Analytical Methodology

3.3.1 Computer Codes

The criticality analyses were performed with the AMPX[1]-KENO[2] computer package (Monte Carlo) using the 123-group GAM-THERMOS cross-section library and the NITAWL routine for U-238 resonance shielding (Nordheim integral treatment). This method of analysis has been validated[3] against critical experiments and found to have a bias of 0.000 ± 0.003 (95% probability at a 95% confidence level) plus a small correction for the water gap between fuel assemblies (+0.0024 Δk at 7.5-8% density). Although no critical experiments are available for the hypothetical low density moderator, Napolitano et al.[4] have compared the 123-group AMPX-KENO model with continuous-energy SAM-CE calculations with good agreement. These results provide additional confidence in the calculated k_{eff} value for the new-fuel storage vault.

Table 2

FUEL ASSEMBLY DESIGN SPECIFICATIONS

Fuel Rod Data	
Outside diameter, in.	0.374
Cladding thickness, in.	0.0225
Cladding material	Zircaloy-4
Pellet diameter, in.	0.3225
UO_2 pellet density, % TD	95 ± 2
UO_2 stack density, g/cm^3	10.286 ± 0.217
Enrichment, wt.% U-235	4.5 ± 0.02
Fuel Assembly Data	
Number of fuel rods	264 (17 x 17 array)
Fuel rod pitch, in.	0.496
Control rod guide tube	
Number	24
Outside diameter, in.	0.482
Thickness, in.	0.016
Material	Zircaloy-4
Instrument thimble	
Number	1
Outside diameter, in.	0.482
Thickness, in.	0.016
Material	Zircaloy-4
U-235 Loading (@ 4.5% enrichment)	
Grams/axial centimeter of assembly	56.77 ± 1.19

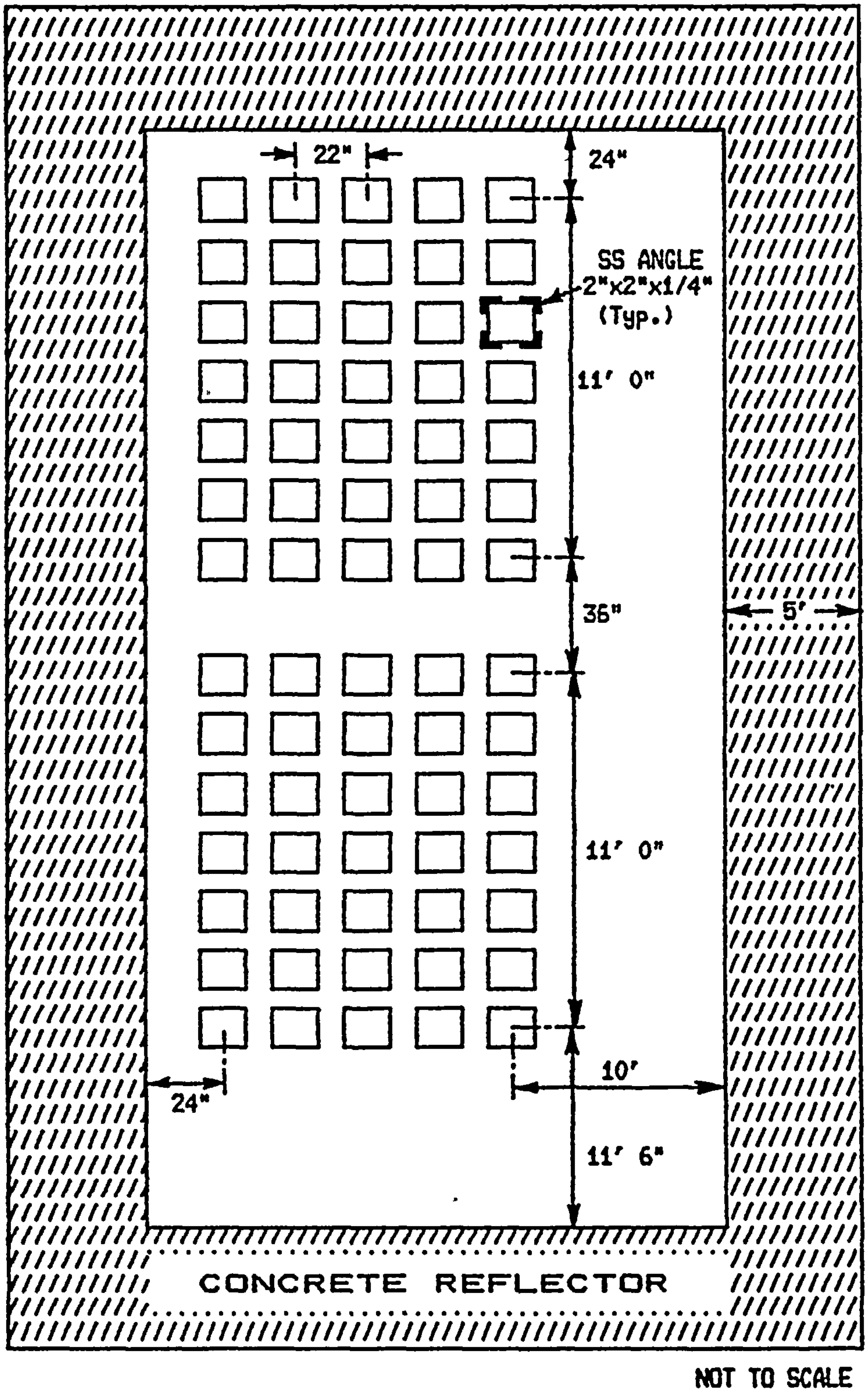

Fig. 2 Geometric arrangement of the Diablo Canyon new-fuel storage vault.

3.3.2 Flooded Condition

The calculations for the flooded condition assumed an infinite array of fuel assemblies separated only by clean unborated water at 20°C. Each fuel pin was explicitly represented in the KENO geometric model. At the 22-inch lattice spacing, the fuel assemblies are effectively isolated from each other by the >13 inches of water separating the assemblies and the reactivity is not sensitive to the mechanical tolerance (± 1/16 inch) in lattice spacing. The assumption of an infinite array conservatively neglects neutron leakage and assures that the true reactivity (k_{eff}) for the flooded condition will always be less than the calculated k_{∞} value. Uncertainty in reactivity due to tolerances on fuel enrichment and density were assumed to be the same as those previously evaluated (± 0.0031 Δk) for the spent fuel storage rack. Independent AMPX-KENO calculations with the 27-group SCALE[6] cross-section library gave a bias-corrected k_{∞}, including all uncertainties of 0.9274 ± 0.0085 (95%/95%) which confirms the reference 123-group calculations.

3.3.3 Low Density Moderation

For the evaluation of low density moderation, 3-dimensional AMPX-KENO calculations were made using homogenized compositions for the fuel region and with U-238 resonance shielding effects calculated in the NITAWL routine of AMPX. (Independent sensitivity studies with KENO showed that k_{eff} values calculated with homogenized compositions and with explicit pin descriptions were indistinguishable at the low moderator densities.) A cross-section of the 3-dimensional geometric model used in the AMPX-KENO calculations of the new-fuel storage vault is illustrated in Fig. 2. For the criticality calculations, a 5-foot-thick concrete reflector was assumed to enclose the four sides and bottom of the vault, with the vault top assumed to be open (zero flux boundary condition imposed at a height of 5 feet above the fuel storage array).

Results of the AMPX-KENO calculations at various moderator densities were presented in Fig. 1. These data show that the optimum moderation (maximum k_{eff}) occurs at ~7.5-8% density (0.0773 g/cc water). In making these calculations, 7,500 neutron histories were used to identify the optimum density,

and 25,000 histories were used for the optimum moderation calculation. At optimum moderation, with fuel of 4.5% enrichment, the calculated k_{eff} is 0.8657 ± 0.0078 (with a one-sided tolerance factor[5] for 95% probability at a 95% confidence level).

Incremental reactivity effects due to tolerances on lattice spacing and on the "L" bracket dimensions cannot be determined by KENO calculations, since the incremental reactivity is sufficiently small to be lost in the normal KENO statistical variation. For conservatism, the uncertainty in mechanical tolerances was assumed equal to the statistical variation of the reference KENO calculation (± 0.0078 Δk) for 95% probability at a 95% confidence level. Further assuming the same uncertainty for fuel enrichment and density (0.0031 Δk) as in the flooded case, the maximum reactivity then becomes 0.880. This maximum reactivity is substantially less than the limiting k_{eff} value of 0.98 for optimum low density moderation and confirms that the new-fuel storage vault satisfies the criticality safety requirement for fuel of 4.5% enrichment.

4 ABNORMAL AND ACCIDENT CONDITIONS

Since the new-fuel storage vault is normally dry, the two limiting criteria constitute the accident conditions affected by an increase in authorized enrichment to 4.5%. No other safety concerns are affected, and no new or unreviewed safety considerations are introduced by the increase in enrichment. Under the double contingency principle of ANSI N16.1-1975, it is not necessary to consider the concurrent occurrence of other independent accident conditions.

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