8 CRITICALITY EVALUATION

8.1 Conduct of Review

The staff's review of the criticality evaluation included Chapter 3, "Principal Design Criteria;" and Chapter 4, "ISFSI Design" of the Diablo Canyon Independent Spent Fuel Storage Installation (ISFSI) Safety Analysis Report (SAR) (Pacific Gas and Electric Company, 2002). The purpose of the criticality review is to ensure that the stored materials remain subcritical under normal, off-normal, and accident conditions during all operations, transfers, and storage at the proposed Diablo Canyon ISFSI. This review considered how the information in the SAR addresses the following regulatory requirements:

- 10 CFR §72.40(a)(13) requires that there is reasonable assurance that: (i) The activities authorized by the license can be conducted without endangering the health and safety of the public and (ii) these activities will be conducted in compliance with the applicable regulations of this chapter.

- 10 CFR §72.124(a) requires that spent fuel handling, packaging, transfer, and storage systems must be designed to be maintained subcritical and to ensure that, before a nuclear criticality accident is possible, at least two unlikely, independent, and concurrent or sequential changes must occur in the conditions essential to nuclear criticality safety. The design of handling, packaging, transfer, and storage systems must include margins of safety for the nuclear criticality parameters that are commensurate with the uncertainties in the data and methods used in calculations and demonstrate safety for the handling, packaging, transfer and storage conditions and in the nature of the immediate environment under accident conditions.

- 10 CFR §72.124(b) requires that when practicable, the design of an ISFSI must be based on favorable geometry, permanently fixed neutron absorbing materials (poisons), or both. Where solid neutron absorbing materials are used, the design must provide for positive means of verifying their continued efficacy. For dry spent fuel storage systems, the continued efficacy may be confirmed by a demonstration or analysis before use, showing that significant degradation of the neutron absorbing materials cannot occur over the life of the facility.

- 10 CFR §72.124(c) requires that a criticality monitoring system shall be maintained in each area where special nuclear material is handled, used, or stored which will energize clearly audible alarm signals if accidental criticality occurs. Monitoring of dry storage areas where special nuclear material is packaged in its stored configuration under a license issued under this subpart is not required.

The applicant proposes to use the HI-STORM 100 System, which has been reviewed and approved for use by U.S. Nuclear Regulatory Commission (NRC) under the general license provisions of 10 CFR Part 72. Amendment 1 to the HI-STORM 100 System Certificate of Compliance became effective on July 15, 2002 (U.S. Nuclear Regulatory Commission, 2002a).

8.1.1 Criticality Design Criteria and Features

This section evaluates whether the proposed criticality safety design criteria and features will maintain the stored materials in a subcritical configuration. The Diablo Canyon ISFSI conditions for criticality safety are based on acceptance criteria outlined in NUREG–1567, Chapter 8, "Criticality Evaluation" (U.S. Nuclear Regulatory Commission, 2000). The Diablo Canyon ISFSI design criteria and features are described in the SAR, Sections 3.3.1.4, 3.2, and 3.4. Section 4.2.3.3.5, "Criticality Design," addresses criticality safety of the HI-STORM 100 System. The applicant did not rely on the use of burnup credit or fuel-related burnable neutron absorbers for the criticality safety analysis. In the analysis, the applicant took no more than 75 percent credit for the minimum B-10 isotope content in the fixed neutron absorbers.

8.1.1.1 Criticality Design Criteria

The description of the design criterion for criticality safety in SAR Section 3.3.1.4, "Nuclear Criticality Safety," is clearly identified and adequately described. The design criterion for criticality safety is that the effective multiplication factor, k_{eff}, including statistical biases and uncertainties, shall not exceed 0.95 during all credible normal, off-normal, and accident conditions and events. The staff reviewed the proposed design criterion of the ISFSI and the proposed HI-STORM 100 System design criteria to ensure consistency with the ISFSI.

The proposed cask system, the HI-STORM 100 System, is autonomous and provides a subcritical configuration of stored materials independent of any other ISFSI structures or components. The design criterion for criticality safety is consistent with the 10 CFR §72.124(a) requirement that at least two unlikely, independent, and concurrent or sequential changes to the conditions essential to criticality safety, under normal, off-normal, and accident conditions must occur before an accidental criticality is possible (adequate protection against accidental criticality is defined as maintaining k_{eff} below 0.95 at a 95-percent confidence level).

The staff found that the proposed design criterion will meet the double contingency requirements of 10 CFR §72.124(a).

8.1.1.2 Features

The Diablo Canyon ISFSI criticality safety features are described in SAR Section 4.2.3.3.5, "Criticality Design," which focuses on the HI-STORM 100 System proposed for use at the Diablo Canyon ISFSI. This cask system maintains the stored materials in a subcritical configuration independent of the ISFSI design. The cask system is NRC certified and is described in Chapter 6, "Criticality Evaluation," of the HI-STORM 100 System Final Safety Analysis Report (FSAR) (Holtec International, 2002). For criticality prevention, the cask system relies on the MPC, which provides the confinement system for the stored fuel. At the Diablo Canyon ISFSI, the fuel will be dry and sealed within a welded MPC. Thus, there are no credible accidents in which water could enter the MPC during transportation inside the HI-TRAC 125 Transfer Cask, reloading into the HI-STORM 100 System storage overpack, and storage on the pad inside the storage overpack.

There are four types of MPCs that may be used at the Diablo Canyon ISFSI: the MPC–24, MPC–24E, MPC–24EF, and MPC–32. A loaded MPC is stored within the storage overpack in a

vertical orientation. The criticality safety features are the inherent geometry of the fuel basket designs within the canisters that provides sufficient separation of stored fuel assemblies, and the permanent neutron-absorbing Boral panels fixed to the fuel cell walls.

The criticality monitoring system requirements of 10 CFR §72.124(c) have been addressed by the applicant in Section 4.2.3.3.5 of the ISFSI SAR, and in a request for exemption from the requirements of 10 CFR §50.68 (Pacific Gas and Electric Company, 2003), which was reviewed as a separate action and granted by the staff on January 30, 2004. The monitoring features described by the applicant apply to cask loading activities performed in the FHB/AB. These features include the use of installed and portable radiation monitors that provide local and remote alarms if radiation levels are exceeded. The Diablo Canyon ISFSI Technical Specification requirements and administrative controls will ensure that a criticality event during spent fuel cask loading operations in the FHB/AB is extremely unlikely. Based on that fact and the radiation monitoring features to be provided, the staff finds that the applicant meets the requirements of 10 CFR §72.124(c). In accordance with 10 CFR §72.124(c), criticality monitoring of dry cask storage areas where the special nuclear material is packaged and sealed in its final storage configuration is not required.

The staff found that the design features important to nuclear criticality safety are clearly identified and adequately described, that the stored material will be maintained in a subcritical configuration, and that the design-basis, off-normal, and postulated accident events will not have an adverse effect on the design features important to criticality safety. Therefore, the staff concludes that the design features meet the requirements of 10 CFR §72.124(b) and §72.40(a)(13).

8.1.2 Stored Material Specifications

The proposed stored materials specifications are described in Section 3.1.1 of the Diablo Canyon ISFSI SAR. The materials include intact Diablo Canyon Power Plant (DCPP) fuel assemblies, damaged fuel assemblies, fuel debris, and nonfuel hardware approved for storage in the HI-STORM 100 System. Appendix B of CoC No. 1014, Amendment No. 1 (U.S. Nuclear Regulatory Commission, 2002a) specifies the requirements previously approved by the staff for materials to be stored in the system. As described in Section 6.1.2 of this SER, PG&E has revised its application to further limit the fuel types to be stored at the Diablo Canyon ISFSI.

The staff found that the materials proposed for storage at the Diablo Canyon ISFSI are bounded by the approved contents for the HI-STORM 100 System and the material specifications are adequate to ensure that the stored materials will be maintained subcritical. The staff finds that the proposed material specifications are adequate to ensure that the contents will be maintained subcritical and that, before a nuclear criticality accident is possible, at least two unlikely, independent, and concurrent or sequential changes must occur in the conditions essential to nuclear criticality safety, in compliance with 10 CFR §72.124(a).

8.1.3 Analytical Means

The staff reviewed the analytical means used by PG&E to demonstrate that the materials stored in the ISFSI will remain subcritical. SAR Section 4.2.3.3.5, “Criticality Design,” contains relevant information.

8.1.3.1 Model Configuration

The storage cask model configuration was reviewed and approved by the staff during the HI-STORM 100 System certification process. Results are documented in the HI-STORM 100 System Safety Evaluation Report (SER), Amendment No. 1 (U.S. Nuclear Regulatory Commission, 2002b). Holtec assumed in the cask system analysis for Amendment No. 1 that fresh fuel with various enrichments is stored in a configuration that yields maximum reactivity and is flooded with fresh water or borated at various densities depending on the initial enrichment. Nonfuel hardware, single cask, and arrays of storage casks were also considered in the analysis. No additional modeling was conducted by the staff in its review of the Diablo Canyon ISFSI application, because there are no site-specific conditions that would affect the generic criticality safety analysis of the HI-STORM 100 System.

8.1.3.2 Material Properties

For purposes of the criticality evaluation, the material properties for the Diablo Canyon ISFSI are the same as those used in the Holtec International HI-STORM 100 System FSAR, as amended by Holtec LAR 1014-1. The material properties relevant to criticality were reviewed and approved by the staff during the previous cask certification process, and staff's review results were documented in the HI-STORM 100 System Amendment No. 1 SER.

8.1.4 Applicant Criticality Analysis

The staff found that the applicant addressed the most reactive configurations and conditions in the cask system analysis. The results of the analysis are documented in the HI-STORM 100 System FSAR, Revision 1, and a brief description of the results is presented in SAR Section 4.2.3.3.5, "Criticality Design." The staff agreed that no additional criticality analysis is necessary for the Diablo Canyon ISFSI.

8.1.4.1 Computer Program

The applicant's principal criticality analysis code was Monte Carlo N-Particle (MCNP) 4A, a three-dimensional, continuous-energy, Monte Carlo N-Particle Code. MCNP 4A and the KENO-Va computer code, which was employed for verification purposes, are described in the HI-STORM 100 System FSAR, Revision 1. The NRC staff accepted use of both codes for criticality analyses. No additional criticality codes are necessary for analysis of criticality at the proposed Diablo Canyon ISFSI.

8.1.4.2 Multiplication Factor

All results of the applicant's analyses for all proposed fuel loadings yielded values for k_{eff}, including all biases and uncertainties, less than the staff's acceptance value of 0.95 for normal, off-normal, and accident conditions. These results are discussed in the HI-STORM 100 System FSAR, Revision 1. The HI-STORM 100 System for canister transfer, the HI-TRAC 125 Transfer Cask with lead overpack, was analyzed in a flooded condition for loading and unloading operations. The flooded condition represents the limiting case with highest reactivity. No additional calculations were performed for the Diablo Canyon ISFSI.

8.1.4.3 Benchmark Comparisons

The applicant relied on the benchmark analysis in the HI-STORM 100 System FSAR, Revision 1 where criticality benchmark experiments were discussed. The value of bias correction used for k_{eff} was 0.0021 with an uncertainty of 0.0006.

8.1.4.4 Independent Criticality Analysis

No confirmatory independent calculations were performed by the staff, because no additional criticality calculations are necessary for the Diablo Canyon ISFSI, as all fuel types used at the DCPP are bounded by the generic criticality analyses approved by the HI-STORM 100 System Certificate of Compliance, Amendment 1, which became effective on July 15, 2002 (U.S. Nuclear Regulatory Commission, 2002a).

8.2 Evaluation Findings

Based on a review of the SAR and the presentations and information supplied by PG&E, the staff finds, with reasonable assurance, that:

- The design, procedures, and materials to be stored at the proposed Diablo Canyon ISFSI provide reasonable assurance that the activities authorized by the license can be conducted without endangering the health and safety of the public in compliance with 10 CFR §72.40(a)(13).

- The design and proposed use of the Diablo Canyon ISFSI handling, packaging, transfer, and storage systems for the radioactive materials to be stored provide reasonable assurance that the materials will remain subcritical and, that, before a nuclear criticality accident is possible, at least two unlikely, independent, and concurrent or sequential changes must occur in the conditions essential to nuclear criticality safety. The Diablo Canyon ISFSI SAR demonstrates that the Diablo Canyon fuel is bounded by the fuel types analyzed and approved for the HI-STORM 100 System. Confirmatory analysis previously performed for that system by the NRC staff adequately shows that acceptable margins of safety will be maintained in the nuclear criticality parameters commensurate with uncertainties in the data and methods used in calculations. The analyses demonstrated that adequate safety will be maintained for the handling, packaging, transfer, and storage of spent fuel during normal, off-normal, and accident conditions in compliance with 10 CFR §72.124(a) and §72.124(b).

8.3 References

Holtec International. *Final Safety Analysis Report for the Holtec International Storage and Transfer Operation Reinforced Module Cask System (HI-STORM 100 Cask System)*. HI–2002444, Rev. 1. Docket 72-1014. Marlton, NJ: Holtec International. 2002.

Pacific Gas and Electric Company. *Diablo Canyon Independent Spent Fuel Storage Installation. Safety Analysis Report, Amendment 1*. Docket No. 72-26. Avila Beach, CA: Pacific Gas and Electric Company. 2002.

Pacific Gas and Electric Company. *Request for Exemption from 10 CFR 50.68, "Criticality Accident Requirements*," *for Spent Fuel Cask Handling.* Docket Nos. 50-275, 50-323. Avila Beach, CA: Letter DCL-03-0126, October 8, 2003. Pacific Gas and Electric Company. 2003.

U.S. Nuclear Regulatory Commission. *10 CFR Part 72 Certificate of Compliance No.1014, Amendment No.1, for the Holtec International HI-STORM 100 Cask System*. Docket 72-1014. Washington, DC: U.S. Nuclear Regulatory Commission. 2002a.

U.S. Nuclear Regulatory Commission. *Holtec International HI-STORM 100 Cask System Amendment No. 1 Safety Evaluation Report*. Docket 72-1014. Washington, DC: U.S. Nuclear Regulatory Commission. 2002b.

U.S. Nuclear Regulatory Commission. *Standard Review Plan for Spent Fuel Dry Storage Facilities*. NUREG–1567. Washington, DC: U.S. Nuclear Regulatory Commission. 2000.