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Safety Evaluation Report: Humboldt Bay Independent Spent Fuel Storage Installation

Author N/A

SAFETY EVALUATION REPORT

DOCKET NO. 72-27

HUMBOLDT BAY
INDEPENDENT SPENT FUEL STORAGE
INSTALLATION

Materials License No. SNM-2514

November 2005

Enclosure 2

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HUMBOLDT BAY ISFSI SER ACRONYMS

American Welding Society	AWS
as low as is reasonably achievable	ALARA
boiling water reactor	BWR
California Public Utilities Commission	CPUC
Certificate of Compliance	CoC
cyclic stress ratio	CSR
damaged fuel container	DFC
design basis earthquake	DBE
design earthquake	DE
deterministic seismic hazard analysis	DSHA
Final Safety Analysis Report	FSAR
finite element model	FEM
Greater than Class C	GTCC
Humboldt Bay Power Plant	HBPP
Independent Spent Fuel Storage Installation	ISFSI
Limiting Condition for Operation	LCO
mean higher high water	MHHW
mean lower low water	MLLW
mean sea level	MSL
megawatt-electric	MWe
multi-purpose canister	MPC
Pacific Gas and Electric Company	PG&E
peak ground accelerations	PGA
probabilistic seismic hazard analyses	PSHA
probable maximum flood	PMF
quality assurance	QA
Refueling Building	RFB
Safety Analysis Report	SAR
Safety Evaluation Report	SER
Senior Seismic Hazard Analysis Committee	SSHAC
soil-structure-interaction	SSI
spent fuel pool	SFP
spent nuclear fuel	SNF
standard penetration test	SPT
square root of the sum of squares	SRSS
structures, systems, and components	SSCs
surveillance requirement	SR
Thermoluminescent Dosimeter	TLD
U.S. Nuclear Regulatory Commission	NRC

EXECUTIVE SUMMARY

On December 15, 2003, the Pacific Gas and Electric (PG&E) Company submitted a license application in accordance with 10 CFR Part 72 to the U.S. Nuclear Regulatory Commission (NRC) to construct and operate an independent spent fuel storage installation (ISFSI) on the site of the Humboldt Bay Power Plant (HBPP). The application consists of the following documents:

(1) A **License Application** - the applicant describes itself and provides (i) general and financial information, as required by 10 CFR §72.22; (ii) an Emergency Plan as required by 10 CFR §72.32; (iii) Proposed Technical Specifications, as required by 10 CFR §72.26; (iv) a Training Program, as required by 10 CFR §72.192; (v) a Quality Assurance Program, as required by 10 CFR §72.24; and (vi) a Preliminary Decommissioning Plan, as required by 10 CFR §72.30.

(2) A **Safety Analysis Report (SAR)** - the applicant describes its plans for designing, constructing, operating, maintaining, and decommissioning the proposed ISFSI, as required by 10 CFR §72.24.

(3) An **Environmental Report** - the applicant provides the information the staff uses in performing its environmental assessment of the proposed ISFSI, as required by 10 CFR §72.34. This review is accomplished in parallel with the staff's safety evaluation and is documented in a separate environmental assessment by the NRC staff.

(4) A **Physical Security Plan** - the applicant describes its plans for ensuring that the ISFSI and nuclear material are appropriately protected. This is a separate safeguards document not releasable to the public. It includes the Security Training and Qualification Plan and Safeguards Contingency Plan, as required by 10 CFR §72.180 and §72.184. This review is accomplished in parallel with the staff's safety evaluation and is documented in a separate security evaluation by the NRC staff.

The staff has documented its review and conclusions on the safety-related aspects of the license application in this Safety Evaluation Report (SER). The technical review was carried out according to the applicable NRC regulations in 10 CFR Part 20 and Part 72. Review of the SAR was conducted following guidance in NUREG-1567 (U.S. Nuclear Regulatory Commission, 2000) and other applicable regulatory guides and interim staff guidance. This SER documents the NRC staff's review of the design, operation, and other safety aspects of the proposed Humboldt Bay ISFSI, as described in the above submittals, except for the Environmental Report and Physical Security Plan. The NRC staff's review of the Environmental Report is documented in a separate Environmental Assessment, and the staff's review of the Physical Security Plan is documented in a separate security evaluation issued on September 2, 2005. This executive summary provides a brief overview and summary of this SER.

Amendment 1 of the SAR (Pacific Gas and Electric Company, 2004a) was submitted in October 2004 and incorporated the applicant's responses to the staff's request for additional information (Pacific Gas and Electric, 2004b). Supplemental information related to the staff's request for additional information is documented in subsequent letters from the applicant (Pacific Gas and Electric, 2005). As documented in this SER, the staff's review of the SAR is primarily based on the amended information provided in the SAR and on the cited supplemental information.

The HBPP consists of five generating units. Unit 3, the only nuclear unit, is a boiling water reactor (BWR) that was operated for approximately 13 years before being shut down in July 1976. The reactor has remained inactive since that time. In 1983, PG&E concluded that the seismic and other plant modifications required, in part, as a result of the Three Mile Island accident in 1979, were not economical and opted to decommission the plant. The remaining spent nuclear fuel (SNF) from reactor operation is currently stored in the spent fuel pool (SFP) in Unit 3. The other electrical generating units are conventional units capable of operating on fuel oil or natural gas (Units 1 and 2) and two gas turbines.

The proposed Humboldt Bay ISFSI will store SNF and associated radioactive material from Unit 3. Spent fuel assemblies will be relocated from wet storage in the Unit 3 SFP to dry storage containers at the proposed ISFSI. The Humboldt Bay ISFSI will facilitate dismantling the existing Unit 3 structures and provide for earlier termination of the 10 CFR Part 50 license for Unit 3. A 10 CFR Part 50 license amendment request to permit cask handling activities in the HBPP refueling building (RFB) has been submitted to NRC. The SNF that will be stored in the proposed ISFSI will need to remain there until a U.S. Department of Energy or other facility is available for further interim storage or permanent disposal.

The Humboldt Bay ISFSI consists of a below-grade storage vault, onsite cask transporter, and dry cask storage system. The applicant will use a modified version of the Holtec International HI-STAR 100 dry cask storage system for the HBPP SNF, referred to as the HI-STAR HB dry cask storage system. The HI-STAR HB system incorporates a cask design that is suitable for both storage and transportation; however, the scope of this licensing action is limited to onsite SNF storage under 10 CFR Part 72. The HI-STAR HB cask provides structural protection and radiation shielding for the multi-purpose canister (MPC-HB) containing the SNF. The onsite handling of the HI-STAR HB cask will be accomplished using a tracked transporter. The transporter developed for the Diablo Canyon ISFSI will be used for the Humboldt Bay ISFSI.

Description of Humboldt Bay Independent Spent Fuel Storage Installation Site

According to the license application, the Humboldt Bay ISFSI will be co-located with the HBPP on PG&E-owned property, which is located on the northern California coast approximately 5 km [3 mi] south of Eureka, California. The applicant owns approximately 0.57 km^2 [143 acres] of land on the shore of Humboldt Bay opposite the bay entrance, with water areas extending approximately 150 m [500 ft] into Humboldt Bay from the land area. The owner-controlled area is not traversed by public highways or railroads. A public trail to access a breakwater for fishing traverses the owner-controlled area. However, 10 CFR §72.106(c) allows the controlled area to be traversed as long as appropriate and effective arrangements are made to control traffic and protect public health and safety. The public trail crossing the PG&E property to the north of the ISFSI will be controlled by fences and gates. The gates will be open to allow access to the public trail during normal ISFSI storage operation. During cask transfer and handling operations, the gates will be locked to prevent public access within the controlled area until the cask transfer activities and any corrective actions are completed. If an accident should occur within the controlled area during normal ISFSI storage operation, the applicant will assess radiological conditions. If radiation levels exceed the allowable levels for public health and safety, the gates will be closed and locked to prevent public access within the controlled area until radiological conditions return to allowable levels. The applicant has full authority to control all activities within the ISFSI site and owner-controlled area.

Description of the Humboldt Bay Independent Spent Fuel Storage Installation Storage System

The Humboldt Bay ISFSI consists of a below-grade storage vault, onsite cask transporter, and dry cask storage system. The ISFSI is designed to store up to 400 SNF assemblies from HBPP Unit 3 in five casks, with a sixth cask to store Greater than Class C (GTCC) waste.

The dry cask storage system selected by the applicant is the Holtec International HI-STAR HB system. This is a variation of the HI-STAR 100 system, which has been certified by NRC (U.S. Nuclear Regulatory Commission, 2001a,b) for use by 10 CFR Part 50 licensees under the general license provisions of 10 CFR §72.210. The HI-STAR HB system is comprised of the MPC-HB, which is a seal-welded canister containing up to 80 SNF assemblies; damaged fuel containers (DFC), which can be inserted into an MPC-HB and can hold an intact fuel assembly or damaged fuel; and the HI-STAR HB storage overpack (or cask). The design and operation of these components are described in detail in the HI-STAR 100 System Final Safety Analysis Report (Holtec International, 2002). Holtec developed the modified (shorter) HI-STAR HB cask system for use at Humboldt Bay because of the smaller HBPP fuel assembly dimensions (length and width). It should be noted that the issuance of a 10 CFR Part 72 site-specific license to PG&E only authorizes the applicant to use the HI-STAR HB storage system at the Humboldt Bay ISFSI; this licensing action is not a revision or amendment to the existing NRC approval for the HI-STAR 100 system.

The MPC-HB provides the confinement boundary for the SNF and associated nonfuel hardware. An integrally welded pressure vessel holds up to 80 HBPP SNF assemblies. The MPC-HBs are welded cylindrical structures consisting of a honeycomb fuel basket, a baseplate, a canister shell, a lid, and a closure ring. The honeycomb fuel basket uses geometric spacing and fixed neutron absorbers for criticality control. The MPC-HB is made entirely of stainless steel, except for the neutron absorbers and aluminum seal washers in the vent and drain ports. The HI-STAR HB storage cask provides an internal, cylindrical cavity of sufficient size to house the MPC-HB during loading, unloading, transfer and storage activities. The storage cask is a rugged, heavy-walled cylindrical container constructed of carbon steel. The overpack provides gamma and neutron shielding and protects the MPC-HB from missiles and natural phenomena during onsite transfer and storage.

The cask storage vault is comprised of six below-grade, cylindrical storage cells that are structural units constructed of steel-reinforced concrete with a carbon steel liner. The vault provides additional shielding and defense-in-depth of the casks from missiles and natural phenomena. The vault is sized to hold five HI-STAR HB casks with SNF and one GTCC certified cask. The storage vault is located at about 183 m [600 ft] from the RFB inside a security area that has applicable barriers, access, and surveillance controls that meet 10 CFR §73.51 requirements.

A transporter is used to move the HI-STAR HB cask from outside the RFB to the ISFSI. The transporter developed for the Diablo Canyon ISFSI will be used for the Humboldt Bay ISFSI. The transporter is a U-shaped tracked vehicle consisting of the vehicle main frame, hydraulic lifting towers, an overhead beam system that connects between the lifting towers, a cask restraint system, the drive and control systems, and a series of cask lifting attachments. The transporter design permits the HI-STAR HB cask to be handled vertically. The transporter also is used to lower the HI-STAR HB cask into the storage vault.

Safety of the Humboldt Bay Independent Spent Fuel Storage Installation

The staff has determined that the proposed Humboldt Bay ISFSI and the HI-STAR HB cask design are structurally sound and that the SNF will remain safe within the canister during all phases of operation for normal, off-normal, and accident conditions. The analyses included all plausible natural and human-made phenomena, many of which had already been accepted by the staff in its review of the HI-STAR 100 dry cask storage system (U.S. Nuclear Regulatory Commission, 2001a) and in previous staff reviews of HBPP licensing actions. After reviewing the applicant's analyses, the staff concluded that the Humboldt Bay ISFSI and the HI-STAR HB system design are structurally safe and will meet all applicable regulatory requirements.

The staff has also determined that the applicant has shown that the SNF within the storage casks will remain subcritical (i.e., unable to sustain a nuclear chain reaction) during all phases of operation for both normal conditions and credible accident conditions. The applicant has provided radiation dose estimates for the surrounding public and the workers at the ISFSI. The MPC-HB will be welded closed to prevent leakage of radioactive material. Additional shielding is provided by the overpack and the below-grade reinforced concrete vault.

The amount of radiation to which a person is exposed is called a dose. The applicant has estimated that members of the public nearest to the proposed ISFSI would receive doses below NRC regulatory requirements, which for normal conditions of operation is 0.25 mSv/yr [25 mrem/yr] and for credible accidents is 0.05 Sv/yr [5 rem/yr]. Radiation dose rates will be calculated within the vicinity of individual casks to demonstrate that workers at the proposed ISFSI will not receive doses that exceed 0.05-Sv/yr [5 rem/yr], the NRC annual regulatory limit for workers at nuclear facilities. These radiation dose limits have been established by NRC to prevent any undue risk and to ensure the safety of all members of the public and workers at a nuclear facility. The applicant has described its radiation protection program, which employs an as low as is reasonably achievable (ALARA) radiation protection principle. Radiation doses received by the workers and dose rates within the vicinity of the storage pad will be monitored to verify that radiation dose limits are not exceeded. The staff reviewed the analyses provided by the applicant and concluded that the Humboldt Bay ISFSI and HI-STAR HB system designs are radiologically safe and will meet regulatory requirements.

As required by 10 CFR Part 72, the applicant demonstrated that all components of its proposed ISFSI that are important to safety would continue to perform their design functions during normal, and off-normal conditions and during any credible accidents that could be postulated to occur. Based on its review and evaluation of the information provided, the staff concluded that the applicant has provided acceptable analyses of the design and performance of these structures, systems, and components important to safety under normal, off-normal, and accident conditions.

The staff further concluded that the applicant's analyses related to off-normal and accident events demonstrate that the proposed ISFSI will be sited, designed, constructed, and operated so that during all credible off-normal and accident events, public health and safety will be adequately protected.

The HI-STAR HB system was evaluated against the parameters and conditions specific to the site and the SNF to be stored. Based on its review, the staff finds that the use of the HI-STAR HB system as proposed for the Humboldt Bay ISFSI is acceptable, in accordance with the site-specific license provisions of 10 CFR Part 72, subject to all conditions of the license.

Other Requirements

To demonstrate its financial qualifications, the applicant identified anticipated sources of funds for the ISFSI project. The staff concludes in Chapter 13 of this SER that the applicant has provided reasonable assurance of its financial qualifications for construction, operation, and decommissioning of the proposed ISFSI.

The staff also found the revisions to the HBPP Physical Security Plan to incorporate the ISFSI to be acceptable. The staff's security evaluation of the revised plan was transmitted as a separate safeguards document that is not available to the public.

REFERENCES

Holtec International. *Final Safety Analysis Report for the Holtec International Storage, Transport, and Repository Cask System* (*HI-STAR 100 System*). Rev. 1. HI-2012610. Docket No. 72-1008. Marlton, NJ: Holtec International. 2002.

Pacific Gas and Electric Company. *Humboldt Bay ISFSI Safety Analysis Report.* Amendment 1. Docket No. 72-27. Avila Beach, CA: Pacific Gas and Electric Company. 2004a.

Pacific Gas and Electric Company. *Response to NRC Request for Additional Information for the Humboldt Bay Independent Spent Fuel Storage Installation Application* (*TAC No. L23683*). Letter (October 1). HIL-04-007. Avila Beach, CA: Pacific Gas and Electric Company. 2004b.

Pacific Gas and Electric Company. *Response to NRC Request for Additional Information for the Humboldt Bay Independent Spent Fuel Storage Installation Application.* Letter (April 8) HIL-05-003. Avila Beach, CA: Pacific Gas and Electric Company. 2005.

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

U.S. Nuclear Regulatory Commission. *Holtec International HI-STAR 100 Cask System Safety Evaluation Report.* Amendment 2. Docket No. 72-1008. Washington, DC: U.S. Nuclear Regulatory Commission. 2001a.

U.S. Nuclear Regulatory Commission. *10 CFR Part 72 Certificate of Compliance No.1008, Amendment 2, for the HI-STAR 100 System Dry Cask Storage System.* Docket No. 72-1008. Washington, DC: U.S. Nuclear Regulatory Commission. 2001b.

1 GENERAL DESCRIPTION

1.1 Conduct of Review

By letter dated December 15, 2003, the Pacific Gas and Electric Company (PG&E) submitted an application to the U.S. Nuclear Regulatory Commission (NRC) for a 10 CFR Part 72 license to build and operate an independent spent fuel storage installation (ISFSI) at the Humboldt Bay Power Plant (HBPP) site. The Safety Analysis Report (SAR) is included in the license application (Pacific Gas and Electric Company, 2004). Chapter 1 of the SAR explains the need for the Humboldt Bay ISFSI and provides a general description of the site, the major components and operations of the ISFSI, and the co-located HBPP. The objective of this chapter of the Safety Evaluation Report (SER) is to familiarize the reader with the pertinent features of the ISFSI. The NRC staff's review of the SAR was conducted in accordance with the guidance in NUREG-1567 (U.S. Nuclear Regulatory Commission, 2000).

1.1.1 Introduction to the Humboldt Bay Independent Spent Fuel Storage Installation

The proposed Humboldt Bay ISFSI will use spent nuclear fuel (SNF) dry cask storage technology. In accordance with 10 CFR §72.42, the initial term for an ISFSI license is 20 years. Before the end of this license term, an applicant may submit an application to renew the license. Prior to expiration of the 10 CFR Part 72 license, all SNF will be transferred from the ISFSI, and the ISFSI will be ready for decommissioning.

The Humboldt Bay ISFSI will be co-located with the HBPP on PG&E-owned property, which is located on the northern California coast approximately 5 km [3 mi] south of Eureka, California. The HBPP consists of five generating units. Unit 3, a boiling water reactor, operated for approximately 13 years before being shut down in July 1976. The reactor has remained inactive since that time. The fuel is currently stored in the spent fuel pool (SFP) in Unit 3. Units 1 and 2 are co-located, conventional 53 megawatt-electric (MWe) units capable of operating on fuel oil or natural gas. Two 15 MWe gas turbines in the vicinity of Units 1, 2 and 3 provide additional generating capacity.

HBPP Unit 3 received a construction permit on October 17, 1960. Provisional Operating License DPR-7 was issued in August 1962, and commercial operation began in August 1963. On May 17, 1976, NRC issued an order that required the satisfactory completion of a specified seismic design upgrade program and resolution of specified geologic and seismic concerns prior to power operation following the 1976 shutdown. In 1983, PG&E concluded that the seismic modifications and other modifications required (in response to the Three Mile Island accident in 1979) were not economical and opted to decommission the plant. In 1988, NRC approved the SAFSTOR decommissioning plan for Unit 3 and revised the operating license to a possession-only license that expires on November 9, 2015.

The SNF currently stored at HBPP will need to remain at the HBPP site until a U.S. Department of Energy or other facility is available for further interim storage or permanent disposal. The Humboldt Bay ISFSI will facilitate dismantling the existing Unit 3 structures by allowing the SNF to be transferred out of the SFP, thereby providing for earlier termination of the 10 CFR Part 50 license.

The Humboldt Bay ISFSI is designed to store up to 400 SNF assemblies in five casks, with a sixth cask to store Greater than Class C (GTCC) waste. The maximum average fuel burn-up per assembly of any fuel that will be stored at the ISFSI is less than 23,000 MWd/MTU. The maximum average initial fuel assembly enrichment is equal to or less than 2.51 percent.

The Humboldt Bay ISFSI consists of a storage vault, onsite cask transporter, and the dry cask storage system. PG&E will use the Holtec International HI-STAR 100 dry cask system, as modified for the HBPP SNF. The physical characteristics of the SNF assemblies and GTCC waste to be stored are described in Section 3.1 of the SAR. The Humboldt Bay-specific design is referred to as the HI-STAR HB dry cask storage system. The HI-STAR HB system incorporates a cask design that is suitable for both storage and transportation; however, the scope of this licensing action is limited to onsite SNF storage under 10 CFR Part 72. The HI-STAR HB cask provides structural protection and radiation shielding for the multi-purpose canister (MPC-HB) containing the SNF. The onsite handling of the HI-STAR HB cask will be accomplished using a tracked transporter. PG&E will use the transporter developed for the Diablo Canyon ISFSI.

The modified HI-STAR HB system design and associated analyses were performed in accordance with the analyses methodologies previously licensed by NRC for the HI-STAR 100 system (U.S. Nuclear Regulatory Commission, 2001), as appropriate. The Holtec HI-STAR 100 Final Safety Analysis Report (FSAR) (Holtec International, 2002) provides descriptions of the generic HI-STAR analyses and supplemental analyses for certain site-specific issues that are applicable to the Humboldt Bay ISFSI site and the HI-STAR HB system.

As discussed in Section 9.4.2 of the SAR, the applicant is requesting an exemption from 10 CFR §72.72(d), which requires that SNF and high-level waste records in storage be kept in duplicate at a separate, sufficiently remote location from the original records to ensure that a single event will not destroy both sets of records. Pursuant to 10 CFR §72.140(d), the applicant will use an NRC-approved Quality Assurance (QA) program that satisfies the criteria of 10 CFR Part 50, Appendix B, to implement the QA requirements for the ISFSI. An exemption from the record storage requirements of 10 CFR §72.72(d) will allow records of SNF storage to be maintained in the same manner as the HBPP QA records. The staff reviewed this exemption request and considered it acceptable (SER Section 10.1).

In order to support the earlier termination of the SAFSTOR license and dismantlement of the SFP, the applicant requested that the Humboldt Bay ISFSI license be issued by December 2005. Assuming that there are no delays in the review process and NRC issues the Humboldt Bay ISFSI license in late 2005, the applicant would apply to the California Public Utilities Commission (CPUC) to use Humboldt Decommissioning Trust funds for procurement and construction of the ISFSI and, after CPUC approval, will proceed with ISFSI procurement and construction of long lead time items. The applicant does not plan to initiate extensive facility construction activities until the NRC environmental review is completed, permits are obtained, the necessary environmental findings are made, and the Humboldt Bay ISFSI license is issued. A 10 CFR Part 50 license amendment request to permit Holtec HI-STAR HB cask handling activities in the HBPP refueling building (RFB) has been submitted to NRC.

1.1.2 General Description of the Location

The Humboldt Bay ISFSI will be located within the PG&E owner-controlled area at the HBPP. The HBPP is located near the coastal community of King Salmon on the shore of Humboldt Bay in Humboldt County in northwestern California. Eureka, the largest city in Humboldt County, is located approximately 5 km [3 mi] north of the ISFSI site. There are several small residential communities within 8 km [5 mi] of the ISFSI site, including King Salmon, Humboldt Hill, Fields Landing, and the suburban communities surrounding the City of Eureka.

The applicant owns approximately 0.57 km^2 [143 acres] of land on the shore of Humboldt Bay opposite the bay entrance with water areas extending approximately 150 m [500 ft] into Humboldt Bay from the land area. The owner-controlled area does not have public highways or railroads. The only access to the ISFSI site is from the south via King Salmon Avenue, which also serves the community of King Salmon situated on the western part of the peninsula. A public trail to access a breakwater for fishing traverses the controlled area. However, 10 CFR §72.106(c) allows the controlled area to be traversed so long as appropriate and effective arrangements are made to control traffic and to protect public health and safety. The public trail crossing the PG&E property to the north of the ISFSI will be controlled by fencing and gates. The gates will be open to allow access to the public trail during normal ISFSI storage operation. During cask transfer and handling operations, the gates will be locked to prevent public access within the controlled area until the cask transfer activities and any corrective actions are completed. If an accident should occur within the controlled area during normal ISFSI operation, the applicant will assess radiological conditions. If radiation levels exceed the allowable levels for public health and safety, the gates will be closed and locked to prevent public access within the controlled area until radiological conditions return to allowable levels. The applicant has full authority to control all activities within the ISFSI site and owner-controlled area boundaries.

The ISFSI will be located near the top of a small hill surrounded by wetlands to the east and Humboldt Bay to the west. The terrain in the vicinity of the HBPP rises rapidly from the bay on the north side to an elevation of approximately 22.1 m [72.7 ft] above mean sea level (MSL) at Buhne Point. Terrain to the north and east of the site is generally flat. To the south and east, the terrain rises rapidly forming Humboldt Hill, which reaches an elevation of over 153.5 m [503.7 ft] above MSL within 3.2 km [2 mi] of the ISFSI.

The staff finds that the site and Humboldt Bay ISFSI descriptions have sufficient detail to allow familiarization with the site characteristics of the proposed ISFSI.

1.1.3 General Systems Description

The Humboldt Bay ISFSI includes the following major structures, systems, and components (SSCs): dry cask storage system, storage vault, and the onsite transporter.

Dry Cask Storage System

The dry cask storage system selected by the applicant is the Holtec International HI-STAR HB system. This is a variation of the HI-STAR 100 cask system, which has been certified by NRC (U.S. Nuclear Regulatory Commission, 2001) for use by 10 CFR Part 50 licensees under the general license provisions of 10 CFR §72.210. The HI-STAR HB system is comprised of the MPC-HB, which is a seal-welded canister containing up to 80 SNF assemblies; Damaged Fuel Containers, which can be inserted into an MPC-HB and can hold an intact fuel assembly or damaged fuel; and the HI-STAR HB storage overpack (or cask). The design and operation of these components are generically described in detail in the HI-STAR 100 system FSAR (Holtec International, 2002). Holtec developed the modified (shorter) HI-STAR HB system and MPC-HB for use at Humboldt Bay because of the smaller HBPP fuel assembly dimensions (length and width).

The MPC-HB provides the confinement boundary for the SNF and associated nonfuel hardware (SAR Figure 4.2-2). An integrally-welded pressure vessel holds up to 80 HBPP SNF assemblies and meets the stress limits of Section III of the 1995 Edition ASME Boiler and Pressure Vessel Code with 1996 and 1997 addenda (ASME International, 1996). The MPC-HBs are welded cylindrical structures consisting of a honeycomb fuel basket, a baseplate, canister shell, a lid, and a closure ring. The honeycomb fuel basket uses geometric spacing and fixed neutron absorbers for criticality control. The MPC-HB is made entirely of stainless steel, except for the neutron absorbers and an aluminum seal washer in the vent and drain ports.

The HI-STAR HB storage cask (SAR Figure 3.3-3) provides an internal, cylindrical cavity of sufficient size to house an MPC-HB during loading, unloading, and transfer of the MPC-HB from the SFP to the storage vault. It is a rugged, heavy-walled cylindrical container constructed of carbon steel. The overpack provides gamma and neutron shielding and protects the MPC-HB from missiles and natural phenomena during onsite transfer and storage.

Storage Vault

The cask storage vault is comprised of six below-grade, cylindrical storage cells that are structural units constructed of steel-reinforced concrete with a carbon steel liner. The vault provides additional shielding and defense-in-depth of the casks from missiles and natural phenomena. The vault is sized to hold five SNF casks and one GTCC certified cask. The storage vault is about 183 m [600 ft] from the RFB. The vault will be located inside a security area that has applicable barrier, access, and surveillance controls that meet 10 CFR §73.51 requirements.

Onsite Transporter

A transporter is used to move the HI-STAR HB cask from outside the RFB to the vault. The transporter developed for the Diablo Canyon ISFSI will be used for the Humboldt Bay ISFSI. The transporter is a U-shaped tracked vehicle consisting of the vehicle main frame, hydraulic lifting towers, an overhead beam system that connects between the lifting towers, a cask restraint system, the drive and control systems, and a series of cask lifting attachments. The transporter design permits the HI-STAR HB cask to be handled vertically. The transporter also is used to lower the HI-STAR HB cask into the storage vault. Each loaded overpack is approximately 2.4 m [8 ft] in diameter, 3.2 m [10.5 ft] high, and weighs about 72,574.7 kg [160,000 lb].

The important-to-safety SSCs of the ISFSI are identified in Section 4.5 of the SAR. A general description of the major SSCs is provided in Section 1.3 of the SAR. More detailed descriptions of the HI-STAR HB system are contained in Section 4.2 of the SAR, and more details on the storage vault and transporter are provided in Sections 4.2 through 4.4 of the SAR.

The staff finds that the description of the storage cask system to be used at the ISFSI is sufficiently detailed to allow familiarization with its design.

1.1.4 Identification of Agents and Contractors

Section 1.4 of the SAR identifies the organizations responsible for providing the engineering, design, licensing, and operation of the SNF storage and transfer systems for the Humboldt Bay ISFSI. Engineering, site preparation, and construction of the ISFSI storage vault will be performed by the applicant (PG&E), Holtec, Enercon, and additional specialty contractors, as necessary.

Holtec International will provide the SNF storage system, consisting of the HI-STAR HB overpacks, the MPC-HB canisters, the transporter, and design for the ISFSI storage vault. Enercon will provide design of ancillary facilities, including the transfer route and security system. The applicant will be responsible for the operation of the ISFSI and for providing quality assurance services.

The staff finds that the agents and contractors responsible for the design and operation of the installation have been adequately identified.

1.1.5 Material Incorporated by Reference

Many chapters of the ISFSI SAR include a reference section that identifies documents referred to in those chapters. The primary document referenced in the Humboldt Bay ISFSI SAR is the HI-STAR 100 FSAR (Holtec International, 2002).

The staff finds that material incorporated by reference, including topical reports and docketed material, has been appropriately identified in the SAR.

1.2 Evaluation Findings

The staff finds that the site and Humboldt Bay ISFSI descriptions presented in Chapter 1 of the SAR have sufficient detail to allow familiarization with the pertinent site-related features of the proposed Humboldt Bay ISFSI, and therefore meet the requirements for the general description under 10 CFR Part 72.

1.3 References

ASME International. *ASME Boiler and Pressure Vessel Code. Section III. 1995 Edition with 1996 and 1997 Addenda*. New York City, NY: ASME International. 1996.

Holtec International. *Final Safety Analysis Report for the Holtec International Storage Transport, and Repository Cask System (HI-STAR 100 System)*. Rev. 1. HI-2012610. Docket 72-1008. Marlton, NJ: Holtec International. 2002.

Pacific Gas and Electric Company. *Humboldt Bay ISFSI Safety Analysis Report.* Amendment 1. Docket No. 72-27. Avila Beach, CA: Pacific Gas and Electric Company. 2004.

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

U.S. Nuclear Regulatory Commission. *10 CFR Part 72 Certificate of Compliance No. 1008, Amendment 2, for the HI-STAR 100 System Dry Cask Storage System.* Docket No. 72-1008. Washington, DC: U.S. Nuclear Regulatory Commission. 2001.

2 SITE CHARACTERISTICS

2.1 Conduct of Review

This chapter of the Safety Evaluation Report (SER) evaluates the geographical location of the Humboldt Bay Independent Spent Fuel Storage Installation (ISFSI) and the meteorological, hydrological, seismological, and geological characteristics of the site and surrounding area. This chapter describes the population distribution around the Humboldt Bay ISFSI, land and water uses, and associated site activities. This evaluation was based on information provided by Pacific Gas and Electric Company (PG&E) in Chapter 2, "Site Characteristics," of the Safety Analysis Report (SAR) (Pacific Gas and Electric Company, 2004a), associated supporting calculations (e.g., Pacific Gas and Electric Company, 2003a), the ISFSI Environmental Report (Pacific Gas and Electric Company, 2004b), and the applicant's responses to the staff's request for additional information (Pacific Gas and Electric Company, 2004c). Chapter 2 of the SAR and the corresponding review provided in this chapter of the SER also identify assumptions that are necessary for the evaluation of safety, installation design, and development of design bases for other safety-related evaluations in other chapters of the SAR. The review objectives for this chapter are to determine whether (i) the information about site characteristics properly identifies external natural and human-induced phenomena for inclusion in the design basis and whether design basis levels are adequate, (ii) local land and water use and population were adequately assessed such that important individuals and populations likely to be affected by the ISFSI can be identified, and (iii) transport processes that could move released contamination from the facility to the maximally exposed individuals and nearby populations were sufficiently characterized.

The information and analyses in Chapter 2 of the SAR were reviewed with respect to the applicable siting evaluation regulations in 10 CFR Part 72, Subpart E, and §72.122(b). Where appropriate, findings of regulatory compliance were made in this chapter of the SER for the 10 CFR Part 72 requirements addressed in Chapter 2 of the SAR. Findings of technical adequacy and acceptability were made for each section in Chapter 2 of the SAR. Because compliance with some regulations was determined by an integrated review of several sections in Chapter 2 and other chapters within the SAR, a finding of regulatory compliance was not made in each major section of this chapter unless the specific regulatory requirement was fully addressed.

The review considered how the SAR and related documents addressed the regulatory requirements of 10 CFR §72.24(a), §72.40(c), §72.90(a–f), §72.92(a–c), §72.94(a–c), §72.98(a–c), §72.100(a–b), §72.103(b–f), §72.120(a), and §72.122(b). Complete citations of these regulations are provided in the Appendix of this SER.

2.1.1 Geography and Demography

This section describes the staff's review of Section 2.1 of the SAR. Subsections discussed include (i) Site Location, (ii) Site Description, (iii) Population Distribution and Trends, and (iv) Land and Water Uses. The staff reviewed the discussion on geography and demography with respect to regulatory requirements 10 CFR §72.24(a), §72.90(a)–(f), §72.98(a)–(c), and §72.100(a).

2.1.1.1 Site Location

Section 2.1.1 of the SAR describes the site location. The Humboldt Bay ISFSI will be located within the PG&E owner-controlled area at the Humboldt Bay Power Plant (HBPP). The HBPP is located approximately 4.8 km [3.0 mi] south of the city of Eureka, California, on the eastern shore of Humboldt Bay. There are several small residential communities within 8 km [5 mi] of the ISFSI site, including King Salmon, Humboldt Hill, Fields Landing, and other suburban communities south of Eureka, California.

The PG&E-owned site consists of 58 hectares [143 acres] of land located on the northeastern part of Buhne Point opposite the entrance to Humboldt Bay. PG&E also owns the water areas extending approximately 150 m [500 ft] into Humboldt Bay from the HBPP site. The SAR reports the latitude and longitude, the Universal Transverse Mercator coordinates of the ISFSI site, appropriate maps, and aerial photographs.

The staff reviewed the description of the site location and found it acceptable because it clearly described the geographic location of the site, including its relationship to political boundaries and natural and anthropogenic features. The maps provided in the SAR are acceptable because they provide sufficient detail to review the geographical, geological, and engineering features of the Humboldt Bay ISFSI. This information is acceptable for use in other sections of the SAR to develop the design bases for the ISFSI, perform additional safety analysis, and demonstrate compliance with the regulatory requirements in 10 CFR §72.24(a), §72.90(a), §72.90(e), and §72.98(a) with respect to this topic.

2.1.1.2 Site Description

Section 2.1.2 of the SAR describes the site using maps to delineate the site boundary and controlled area. The Humboldt Bay ISFSI site will be located within the PG&E-owned area at the HBPP.

The location and orientation of the Humboldt Bay ISFSI structures with respect to nearby roads and waterways are shown on maps and plots, and there is no obvious way in which traffic on adjacent transportation links can interfere with ISFSI operations. The ISFSI site will be located within the site boundaries of the existing HBPP site near the top of a small hill surrounded by wetlands to the east and Humboldt Bay to the west. The terrain in the vicinity of the HBPP rises rapidly from the bay on the north side to an elevation of approximately 21m [69 ft] mean lower low water (MLLW)[1] at Buhne Point. Terrain to the northeast of the ISFSI site is generally flat. Figure 2.1-2 of the SAR shows the topography in the vicinity of the ISFSI site.

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[1]Tidal patterns along the western United States coast are mixed semidiumal such that there are two high and two low tides each day. The semidiurnal tidal pattern is considered "mixed" because the two daily high tides and two daily low tides are of different magnitudes. Elevations in the SAR reference three tidal elevations: (i) MLLW, which is the average of the lower of the two daily low tides; (ii) mean higher high water (MHHW), which is the average of the higher of the two daily high tides; and (iii) mean sea level (MSL), which is the overall average water elevation. In the SAR, the applicant provides analyses relative to MLLW. The applicant reports that at the Humboldt Bay ISFSI site, the difference between MLLW and MHHW is 2.1 m [6.9 ft], and the difference between MLLW and MSL is 1.13 m [3.7 ft].

The owner-controlled area shown in Figure 2.1-2 of the SAR varies between sea level and 19.5 m [64 ft] MLLW and is approximately 274.3 m [900 ft] in width. The only access to the ISFSI site is from the south via King Salmon Avenue, which also serves the community of King Salmon situated on the western part of the peninsula. The applicant has full authority to control all activities within the ISFSI site and owner-controlled area. A public trail to access a breakwater for fishing traverses the controlled area, a condition allowed by 10 CFR §72.106, so long as appropriate and effective arrangements are made to control traffic and protect public health and safety. The public trail crossing the property to the north of the ISFSI is controlled by fencing. Gates will be added as part of the ISFSI project. The location of these gates is shown in Figure 2.2-2 of the SAR. The fencing and gates will allow positive control of all land access within the controlled area. The gates will normally be open so that public access to recreational activities on the breakwater and in the bay will not be restricted by the applicant. In the SAR, the applicant states that the gates will be closed and locked during ISFSI cask transfer and handling activities.

The HBPP consists of five electric generation units. Unit 3 is a boiling water reactor that operated for approximately 13 years before being shut down in July 1976. The reactor has remained inactive since then. Units 1 and 2 are co-located units capable of operating on fuel oil or natural gas. There are also two gas turbines located in the vicinity of the Units 1, 2, and 3 structures. The five generating units, as well as the plant site, are owned by the applicant.

Two small streams near the site discharge into Humboldt Bay. Salmon Creek and Elk River are located within a mile south and north of the site, respectively. These streams are used for watering livestock, but are not used as a potable drinking water supply.

The staff reviewed the site description and relevant literature cited in the SAR. The staff finds that the site description is adequate because the descriptive information and maps clearly delineate the site boundary, controlled area, general natural and man-made features, topography, and surface hydrologic features. The maps have a sufficient level of detail and are of appropriate scale and legibility required for the review of the site and the Humboldt Bay ISFSI. The information is also acceptable to determine distances between the ISFSI site and nearby facilities and cities. This information is acceptable for use in other sections of the SAR to develop the design bases for the Humboldt Bay ISFSI, perform additional safety analysis, and demonstrate compliance with the regulatory requirements in 10 CFR §72.90(a–e) and §72.98(a) with respect to this topic.

2.1.1.3 Population Distribution and Trends

Section 2.1.3 of the SAR and relevant literature cited in the SAR describe the population distribution and trends. The population data used in the SAR were derived from the 2000 census and from estimates of future population provided by the California Department of Finance.

The area within a radius of 80 km [50 mi] of the HBPP site includes most of Humboldt County and a small sparsely populated portion of Trinity County. About half of the area within this 80 km [50 mi] radius is on land. The remaining area is marine and includes areas of Humboldt Bay and the Pacific Ocean.

According to the 2000 census, the population of Humboldt County was 126,518, and the population of Trinity County was 13,022. The same census data show that 49,740 people live within a 16 km [10 mi] radius of the HBPP site. The projected population distribution for 2010 and 2025 published by the California Department of Finance (SAR Figures 2.1-7 and 2.1-8) are based on the assumption that the land usage will not change in character during the next 25 years and that the population growth within 10 miles will be proportional to growth in Humboldt County as a whole (0.61-percent annual growth rate). The SAR also states that Humboldt County receives between 2.1 and 2.2 million visitors per year. There is a seasonal influx of vacation and weekend visitors within a 80-km [50-mi] radius, especially during the summer months.

The staff reviewed the information presented in the SAR and determined that the population distribution and trends in the region have been adequately described and assessed. The source of the population data used in the SAR is appropriate. The basis for population projections is reasonable. The region has been appropriately investigated with respect to the present and future character and distribution of the population; therefore, the staff finds that requirements of 10 CFR §72.98(c)(1) have been met. This information is also acceptable for use in other sections of the SAR to develop the design bases for the Humboldt Bay ISFSI, perform additional safety analysis, and demonstrate compliance with the regulatory requirements in 10 CFR §72.90(e), §72.98(a), and §72.100(a) with respect to this topic.

2.1.1.4 Land and Water Uses

Section 2.1.4 of the SAR describes land and water uses in the region surrounding the HBPP site. Humboldt Bay and the surrounding lowlands dominate the regions north, south, and west of the site. The lowland areas around the site are primarily vacant land and are used to a limited extent for grazing cattle. Most of the mountainous area east and southeast of the site is inaccessible; however, there are several small communities located on Humboldt Hill and in the larger valleys. Most of the dairies are located along the Elk River, while the coastal lowlands are used primarily for cattle grazing and ranching. The nearest dairy is 2.9 km [1.8 mi] east of the site. Figure 2.1-5 of the SAR identifies nine farms and ranches and one community vegetable garden within 5 miles of the ISFSI site. The primary industry in the area and in Humboldt County, is lumber and lumber/paper manufacturing. A lumber-loading shipyard is located less than 1 mile south of the ISFSI site. The SAR states that no major new developments are planned for the area within 8 km [5 mi] of the ISFSI site.

The ISFSI site is located in the vicinity of several ports that support commercial and sport fishing activities. Humboldt Bay, inland waterways, and the coastal waters of the Pacific Ocean are used for recreational fishing. Information regarding the level of activity for sport and commercial fishing in terms of the number of fish landed and the poundage of landings is presented in the SAR.

The Humboldt Bay Municipal Water District was identified as the public groundwater supplier to residential and industrial users in the Humboldt Bay area. Figure 2.1-5 of the SAR shows the location of three groundwater wells located within 0.6 km [1 mi] of the ISFSI site.

The staff reviewed the description of the land and water use in the SAR and finds that it has been adequately described and assessed. The region has been investigated, as appropriate, with respect to consideration of present and projected future uses of land and water within the region. This information is acceptable for use in other sections of the SAR to develop the design bases for the Humboldt Bay ISFSI, perform additional safety analysis, and demonstrate compliance with regulatory requirements in 10 CFR §72.98(a–c) with respect to this topic.

2.1.2 Nearby Industrial, Transportation, and Military Facilities

This section describes the staff review of Section 2.2 of the SAR. This information is necessary to evaluate credible potential hazards from these facilities that may endanger the radiological safety of the ISFSI site including onsite and offsite potential hazards. The staff reviewed the discussion on nearby industrial, transportation and military facilities with respect to regulatory requirements 10 CFR §72.24(a), §72.94(a–c), §72.98(a–c), and §72.100(a–b).

The identification of potential hazards includes identifying facilities and determining credible scenarios that may endanger the facility. The facilities identified in the SAR by the applicant include U.S. Highway 101; large cargo vessels and cruise ships in Humboldt Bay; Northwestern Pacific Railroad, which is adjacent to U.S. Highway 101; and aircraft flying in the vicinity of the ISFSI.

The SAR documents that there are no military facilities within 8 km [5 mi] of the ISFSI, except for the U.S. Coast Guard Reservation and Lifeboat Station that is located approximately 2.4 km [1.5 mi] from the HBPP. The U.S. Coast Guard Air Station is located approximately 32 km [20 mi] from the HBPP at the Eureka-Arcata Airport. There are no mining facilities with 8 km [5 mi] of the ISFSI site. There are several lumber mills with lumber storage yards within 40 km [25 mi]. As stated in the SAR, the lumber mills currently use U.S. Highway 101 for transportation.

In the SAR, the applicant notes that Humboldt Bay has two main shipping channels referred to as the North Channel and South Channel. The North Channel is used by private yachts, recreational vessels, large cargo vessels, and passenger cruise ships. The edge of this channel is approximately 1,350 m [4,500 ft] from the ISFSI site. All cargo and most other vessels remain within this shipping channel because navigational depth outside the channel reduces quickly. The smaller South Channel is approximately 770 m [2,600 ft] from the ISFSI site and is used by mostly private yachts and recreational vessels. Occasionally, barges use this shipping channel for transporting lumber. Several piers along the shorelines of the North Channel are used to dock boats and ships. Although the applicant states in the SAR that typically no more than several dozen vessels are docked at one time, a public marina and other nearby piers can accommodate approximately 100 small vessels.

In the SAR, the applicant identifies a possible explosion of a gasoline and diesel oil barge with a fuel capacity of 10,334,000 L [65,000 barrels] as the bounding scenario for potential fire and explosion hazards to the ISFSI site. Approximately once in every eight days, a barge delivers its cargo to the Chevron terminal located approximately 3.2 km [2 mi] north of the ISFSI site.

The Northwestern Pacific Railroad is adjacent to U.S. Highway 101 at a distance of approximately 360 m [1,200 ft] from the ISFSI site. This rail line is not currently active; however, several diesel locomotives remain in the area. These locomotives are used for short-haul movements of heavy equipment.

In the SAR, the applicant identifies (i) large trucks carrying hazardous cargo on U.S. Highway 101, (ii) the fuel barge in the bay, and (iii) locomotives at the Northwestern Pacific Railroad adjacent to the highway as potential explosion hazards. In addition, the applicant also identifies the possibility of civilian aircraft crashing onto the site as a potential explosion hazard. Civilian aircraft with the potential to crash at the facility site include aircraft taking off and landing at nearby Eureka-Arcata, Kneeland, Rohnerville, Eureka Municipal, and Murray Field airports. Aircraft flying along federal routes V-607, V-27, V-195, and V-257 and aircraft flying at high altitudes in the vicinity of the ISFSI are also identified by the applicant as potential aircraft crash hazards.

The staff reviewed the information presented in the SAR and determined that nearby industrial, transportation, and military facilities have been adequately described and assessed. The SAR adequately identifies all nearby facilities that may present a hazard to the ISFSI in accordance with the regulatory requirements in 10 CFR §72.24(a) and §72.94(a). Potential hazards from these facilities are evaluated further in Chapter 15 of this SER.

2.1.3 Meteorology

This section describes the staff's review of Section 2.3 of the SAR. Subsections discussed include (i) Regional Climatology, (ii) Local Meteorology, (iii) Onsite Meteorological Measurement Program, and (iv) Diffusion Estimates. The staff reviewed the discussion on meteorology with respect to regulatory requirements in 10 CFR §72.24(a), §72.90(a–f), §72.92(a–c), §72.98(a–c), and §72.122(b).

2.1.3.1 Regional Climatology

Section 2.3.1 of the SAR briefly describes the regional climatology for the region surrounding the HBPP. The climate information was derived from direct meteorological observations at the HBPP and published data from local, state, and federal climate and meteorological sources, including the National Weather Service, National Oceanic and Atmospheric Administration, and the California Department of Water Resources. The first weather station was established in the Eureka area in 1886, and there have been continuous weather observations since then. The current National Weather Service station is on Woodley Island, which is located approximately 10 km [6 mi] northeast of the HBPP.

The regional climate of the HBPP is strongly influenced by the proximity of the site to the Pacific Ocean. In the SAR, the applicant characterizes the climate as Mediterranean. Summers are cool, damp, and foggy, but with little rainfall. Winters are mild and wet, and have frequent passing Pacific winter storms. Temperatures and daily temperature variations are moderate. The average daily January temperatures for the 52-year span between 1949 and 2001 is 8.4 °C [47 °F]. Over the same interval, the average daily August temperature is 14.0 °C [57 °F]. The average difference between the daily maximum and daily minimum temperatures is approximately 5.6°C [10 °F]. The record maximum temperature in the region was 30.6 °C [87 °F] on October 26, 1993. The record minimum temperature in the region was -6.7 °C [20 °F] on January 14, 1888. Average rainfall is just under 100 cm/yr [39 in/yr]. Most of the rain falls between November and March. Snow is rare at the HBPP site. There are only 13 snowfall events in the past 110 years and only the 1907 event resulted in more than 2.5 cm [1 in] of snow accumulation. The largest recorded snowfall was in January 1907 and measured

18 cm [7 in]. Because the 1907 event was the only event with appreciable snow accumulation, it forms the design basis snowfall for the HBPP. Winds are generally light and from the north-northwest during the spring-summer-fall months and from the south-southeast during the winter months. The maximum wind speed recorded in Eureka was 111 kmph [69 mph], which occurred twice in 1981. The only recorded tornado in the Eureka area occurred on March 29, 1958. This was an F2 tornado on the Fujita scale. F2 tornados have maximum winds of 253 kmph [157 mph].

The staff reviewed the information presented in the SAR and determined that the regional climatology has been adequately described and assessed. The source of the climate data used in the SAR is appropriate, and the basis for design loads from climate hazards is adequate. The staff finds that the requirements of 10 CFR §72.90(a–c) have been met because the region has been appropriately investigated with respect to frequency and severity of external natural phenomena. This information is also acceptable for use in other sections of the SAR to develop the design bases for the Humboldt Bay ISFSI, perform additional safety analysis, and demonstrate compliance with regulatory requirements in 10 CFR §72.24(a), §72.90(a–f), §72.92(a–c), §72.98(a–c), and §72.122(b) with respect to this topic.

2.1.3.2 Local Meteorology

Section 2.3.2 of the SAR describes and characterizes the local meteorology of the HBPP site. The description is based on a summary of local meteorological information from the Environmental Report for Decommissioning (Pacific Gas and Electric Company, 1984). Because the Humboldt Bay ISFSI is within the HBPP site, the local meteorological conditions at the ISFSI site are considered to be the same as those identified at the HBPP and those described in the preceding section on regional climatology.

Solar radiation data were obtained from the National Renewable Energy Laboratory (2005), which is supported by the National Center for Photovoltaics and managed by the U.S. Department of Energy Office of Energy Efficiency and Renewable Energy. Solar radiation measurements were made at the Arcata Airport, which is located approximately 27 km [17 mi] north-northeast of the HBPP. The maximum flat-plate solar radiation measured insolation for a 24-hour period was 602 g-cal/cm^2/day, which is equivalent to 7.0 kWh/m^2/day [92.6 BTU/hr-ft^2].

The staff reviewed the description of the local meteorology in the SAR and finds that it has been adequately described and assessed. The staff finds the description of the local meteorology in the SAR to be acceptable because it is based largely on general information provided for the HBPP that is also applicable to the ISFSI site. The regulations at 10 CFR §72.40(c) indicate that a site does not require reevaluation when relevant information is covered under previous licensing actions, except where new information could alter the original site evaluation findings. The staff has previously accepted the local meteorology description for the HBPP and has discovered no new information that might alter the relevance of the local meteorology description for the ISFSI location. The staff, therefore, has determined that this information is acceptable for use in other sections of the SAR to develop the design bases of the Humboldt Bay ISFSI, perform additional safety analysis, and demonstrate compliance with the regulatory requirements of 10 CFR §72.92(a), §72.98(a), §72.98(c)(3), and §72.122(b) with respect to this topic.

2.1.3.3 Onsite Meteorological Measurement Program

Section 2.3.3 of the SAR describes the basis for onsite weather data at the HBPP site. The applicant does not maintain an onsite meteorological measurement program. Instead, the applicant relies on meteorological data collected at the nearby National Weather Service station on Woodley Island, which is located 10 km [6 mi] northeast of the HBPP. The applicant concludes that because of similar site characteristics and the proximity of the Woodley Island station to the HBPP site, the conditions recorded by the National Weather Service on the island are representative of those at the HBPP.

The staff reviewed the rationale for applying the National Weather Service data from the Woodley Island station in lieu of an onsite meteorological measurement program. The staff concurs with the applicant's approach as it relates to the Humboldt Bay ISFSI. The staff, therefore, concludes that this information is acceptable for use in other sections of the SAR to develop the design bases of the Humboldt Bay ISFSI, perform additional safety analysis, and demonstrate compliance with the regulatory requirements of 10 CFR §72.24(a), §72.92(a), §72.98(a), §72.98(c)(3), and §72.122(b) with respect to this topic.

2.1.4 Surface Hydrology

The staff has reviewed the information presented in Section 2.4 of the SAR. Subsections discussed include (i) Hydrologic Description; (ii) Floods; (iii) Probable Maximum Flood (PMF) on Streams, Rivers, and Bays; (iv) Potential Dam Failures; (v) Probable Maximum Surge and Seiche Flooding; (vi) Probable Maximum Tsunami Flooding; (vii) Ice Flooding; (viii) Flood Protection Requirements; and (ix) Environmental Acceptance of Effluents. The staff reviewed the discussion on surface hydrology with respect to the regulatory requirements of 10 CFR §72.24(a), §72.90(a–f), §72.92(a–c), §72.98(a–c), and §72.122(b).

2.1.4.1 Hydrologic Description

Sections 2.4 and 2.4.1 of the SAR describe and characterize the surface hydrological conditions and features pertaining to the ISFSI site. The applicant provides a map of Humboldt Bay and of the streams and rivers in the Humboldt Bay watershed, which comprise the most relevant surface water bodies surrounding the ISFSI site. The applicant summarizes the tidal characteristics of Humboldt Bay and the drainage characteristics of rivers, streams, and sloughs in the Humboldt Bay watershed. The applicant also describes the plant drainage system in the area of the ISFSI site.

The surface hydrologic conditions most relevant to the ISFSI site include those influencing tides within Humboldt Bay, especially when high tides coincide with winter rainfloods of streams and rivers in the Humboldt Bay watershed. Salmon Creek and the Elk River {greater than 3 km [2 mi] south and within 1.6 km [1mi] north of the ISFSI site} are the nearest streams. While used to water livestock, neither Salmon Creek nor the Elk River is used as a potable water supply. The area encompassing the drainage basin for the Elk River is approximately 132.9 km^2 [51.3 mi^2]. The maximum peak discharge measured for the Elk River, was 97,100 L/s [3,430 cfs] on December 22, 1965. Discharge measurements of this river ceased one year later. Elk River data analogous to that recorded for high flow in Jacoby Creek, located approximately 8 miles to the northeast, on March 2, 1972 and January 16, 1974, are not available. It is unknown whether peak discharges of the Elk River on these dates would have represented the annual maximum peak discharge for the year. Using available data, the 10-year average annual maximum peak discharge for Elk River is calculated to be 77,450 L/s [2,736 cfs], with standard deviation of 15,170 L/s [536 cfs]. The area encompassing the drainage basin for Salmon Creek is approximately 73.3 km^2 [28.3 mi^2]. Typical flows in the two streams are not described, but do not pose a flooding threat.

The staff reviewed the information in the SAR concerning the surface hydrologic features in the vicinity of the ISFSI site; including information on the location, drainage basins, and measured maximum discharge of the Elk River and other surface water features; topographic maps and watershed characteristics; relevant oceanographic and tidal data; and other applicable information. The staff also reviewed meteorological data significant to the characteristics and hazards associated with surface hydrology.

The staff finds the description of the surface hydrologic features in the SAR acceptable, because these features are adequately described and assessed. The staff, therefore, has determined that this information is acceptable for use in other sections of the SAR to develop the design bases for the Humboldt Bay ISFSI, perform additional safety analysis, and demonstrate compliance with the regulatory requirements of 10 CFR §72.24(a), §72.90(a–f), §72.92(a–c), §72.98(a), §72.98(c)(3), and §72.122(b) with respect to this topic.

2.1.4.2 Floods

Section 2.4.2.1 of the SAR discusses the potential for and effects of flooding at the ISFSI site. The applicant's flood design considerations pertain primarily to short duration wet season rainfloods that coincide with high tides. The applicant indicates that the elevation of the ISFSI area is approximately 13 m [44 ft] above MLLW and is approximately 10 m [32 ft] higher than the main power plant elevation, such that any drainage will be away from the ISFSI site. The applicant, therefore, maintains that flooding in the vicinity of the ISFSI is not a concern.

The staff reviewed the information in Section 2.4.2 of the SAR concerning the potential flooding of the ISFSI and considered the local precipitation data, characteristics of the Humboldt Bay drainage basin, and the specific locations and elevations of interest for the ISFSI site. The staff finds the information supplied by the applicant acceptable, based on the relative elevation differences between the ISFSI site and its drainage system, including the elevation of the bay at high tide. Thus, potential flooding is not considered a credible threat to the ISFSI site. The staff, therefore, has determined that this information is acceptable for use in other sections of the SAR to develop the design bases for the Humboldt Bay ISFSI, perform additional safety analysis, and demonstrate compliance with the regulatory requirements of 10 CFR §72.24(a), §72.90(a–d), §72.90(f), §72.92(a–c), §72.98(a), §72.98(c)(3), and §72.122(b) with respect to this topic.

2.1.4.3 Probable Maximum Flood on Streams and Rivers

Eureka and the Humboldt Bay ISFSI site are located in the rain shadow of surrounding hills; thus, this locality has one of the lowest annual average rainfall records in northwest California. Section 2.4.2.2 of the SAR discusses probable maximum flooding at the ISFSI site caused by winter rainfloods that coincide with high tides. The applicant indicates that because of the relatively low elevation of the area, snowfall and snowmelt are not considerations for flooding. Wet season rainfloods typically have sharp peaks and short durations. Mean annual precipitation, normal monthly precipitation, and annual maximum peak discharges for a river and stream in the area are provided in the SAR. As mentioned previously, the maximum peak discharge measured for the Elk River, was 97,100 L/s [3430 cfs]. A PMF model of the floodwater surface profile, based on 38 years of high tide data collected between 1920 and 1998 and which uses a 95 percent exceedence criterion, indicates that the freeboard estimated for the ISFSI site during the PMF is 10 m [34 ft]. This result supports the applicant's conclusion that flooding in the vicinity of the ISFSI is not a concern.

The staff's review of this information focused on a PMF model of the floodwater surface profile at the ISFSI location. The staff also considered local precipitation data, historical river discharge data, characteristics of the Humboldt Bay drainage basin, and the specific locations and elevations of interest for the ISFSI site. The staff finds the SAR description of PMFs on streams, rivers, and the bay caused by winter rainfloods coinciding with high tides acceptable because the PMF model of the floodwater surface profile at the ISFSI location has been adequately described and model results have been adequately assessed. The staff, therefore, has determined that this information is acceptable for use in other sections of the SAR to develop the design bases for the Humboldt Bay ISFSI, perform additional safety analysis, and demonstrate compliance with the regulatory requirements of 10 CFR §72.24(a), §72.90(a–d), §72.90(f), §72.92(a–c), §72.98(a), §72.98(c)(3), and §72.122(b) with respect to this topic.

2.1.4.4 Potential Dam Failures (Seismically Induced)

Section 2.4.3 of the SAR discusses the potential for flooding at the ISFSI site as a result of dam failure. The applicant states that the only major dam in the area is associated with the 10-million-m^3 [2.7-billion-gal] capacity Ruth Reservoir on the Mad River, located 21 to 24 km [13 to 15 mi] northeast of the site, which regulates the municipal and industrial water supply for the Arcata-Eureka area. If the Ruth Reservoir were to experience a dam failure, the applicant indicates that flows in the Mad River Sub-Basin would export water to the Eureka Plain Sub-Basin, and then to the Pacific Ocean without impact to the Humboldt Bay watershed area. The applicant, therefore, maintains that floods resulting from a breach of this dam would not be a threat to the ISFSI.

The staff reviewed the information concerning potential dam failures and finds it acceptable because no dams or reservoirs exist whose failure could cause the ISFSI to flood. Thus, dam failure is not considered a credible threat to the ISFSI site. The staff, therefore, has determined that this information is acceptable for use in other sections of the SAR to develop the design bases for the Humboldt Bay ISFSI, perform additional safety analysis, and demonstrate compliance with the regulatory requirements of 10 CFR §72.24(a), §72.90(a–d), §72.90(f), §72.92(a–c), §72.98(a), §72.98(c)(3), and §72.122(b) with respect to this topic.

2.1.4.5 Probable Maximum Surge and Seiche Flooding

Section 2.4.4 of the SAR discusses flooding from a maximum surge or seiche at the ISFSI site. The applicant modeled a number of peak wind gust scenarios based on measured peak wind gusts in Eureka, California. The most conservative scenario assessed was for the 100-year flood surface with an over-water wind gust of 124 kph [77 mph]. Estimated freeboard for the

ISFSI site was 7.8 m [25.5 ft] for all scenarios considered. The applicant indicates that because of the elevation of the ISFSI site, there is no credible scenario that could cause the ISFSI site to flood from a maximum surge or seiche.

The staff reviewed the information in the SAR concerning probable maximum surge and seiche flooding and finds it acceptable because surge and seiche scenarios were appropriately considered and wave runup estimates indicate that the ISFSI site is not likely to be flooded under such circumstances. The staff concludes that the probable maximum surge and seiche flooding do not pose credible threats to the ISFSI site. The staff, therefore, has determined that this information is acceptable for use in other sections of the SAR to develop the design bases for the Humboldt Bay ISFSI, perform additional safety analysis, and demonstrate compliance with the regulatory requirements of 10 CFR §72.24(a), §72.90(a–d), §72.90(f), §72.92(a–c), §72.98(a), §72.98(c)(3), and §72.122(b) with respect to this topic.

2.1.4.6 Probable Maximum Tsunami Flooding

Section 2.4.5 of the SAR summarizes probable maximum tsunami flooding at the ISFSI site. A detailed analysis of the potential tsunami hazards is provided in Section 2.6.9 of the SAR. This analysis considered (i) historical data on tsunamis in the Humboldt Bay area, (ii) geological information on past tsunamis along the northern California coast, (iii) a comparison of the Humboldt Bay tsunami hazard results to worldwide tsunami runup heights, and (iv) analytical models of potential tsunami inundation.

The applicant concludes that the tsunami hazard at the ISFSI site is dominated by a local tsunami generated by a large magnitude earthquake rupture in the Cascadia subduction zone. This tsunami scenario is consistent with the deterministic earthquake scenario described in Section 2.6.5.1 of the SAR and evaluated in Section 2.1.6.1 of this SER. The maximum runup height at the mouth of Humboldt Bay facing the open ocean from such a tsunami is estimated to be 9.1 to 12.2 m [30 to 40 ft] above MLLW. This wave height is expected to be attenuated within Humboldt Bay by 10 to 30 percent, resulting in a maximum inundation height at the ISFSI site of 6.4 to 11 m [21 to 36 ft] above MLLW. The elevation of the ISFSI vault is 13.4 m [44 ft] above MLLW, which is 2.4 m [8 ft] higher than the maximum tsunami runup height. The only condition in which tsunami runup would overtop the elevation of the ISFSI vault is if the tsunami was coincident with both MHHW and wave runup for a 100-year storm (as documented in SAR Table 2-4.5). The applicant considers that a scenario in which a tsunami is coincident with the 100-year storm is not credible. The applicant's analysis is supported by the geologic conditions at the ISFSI site. There is no geologic evidence of past tsunami inundation anywhere at the HBPP site. The applicant also notes that even if the tsunami waves were to overtop the ISFSI site, there would be no radiological consequences because the casks are protected from tsunami-generated flowing water and water-born debris within the vault. The HI-STAR HB casks can be temporarily wet with seawater without harm.

The staff reviewed the information in the SAR concerning probable maximum tsunami flooding and finds it acceptable because the ISFSI vault is located at elevations higher than runup from a potential tsunami. In addition, there are no dose consequences, even if a tsunami were to inundate the ISFSI vault. The staff finds that there is no credible radiological threat to safety from a probable maximum tsunami flood at the site. The staff, therefore, has determined that this information is acceptable to use in other sections of the SAR to develop the design bases of the Humboldt Bay ISFSI, perform additional safety analysis, and demonstrate compliance with the regulatory requirements of 10 CFR §72.24(a), §72.90(a–d), §72.92(a–c), §72.98(a), §72.98(c)(3), §72.103(f)(2)(iii), and §72.122(b) with respect to this topic.

2.1.4.7 Ice Flooding

In Section 2.4.6 of the SAR, the applicant concluded that flooding at the ISFSI caused by ice melt events is not credible, based on the climatic conditions at the HBPP site. In SAR Section 2.3, the applicant states that, on average, over a 51-year period, the ambient temperature in the Eureka area falls below freezing only 5 days per year. Frozen precipitation in this area falls as small hail or ice pellets following the passage of moderate to strong cold fronts with cold, unstable air masses. There are no published statistics available for the frequency of ice storms in the Eureka area, but they are considered rare events. Snowfall in the area is commonly recorded as "trace"—the exceptions consisting of 13 measurable snowfalls during a 110 year period of record. In January 1907, the largest recorded snowfall was measured at nearly 18 cm [7 in].

In reviewing the SAR in regard to ice flooding, the staff considered regional climatology, local meteorology, historical meteorological data, surface hydrology, and other information relevant to the potential for ice-jam flood formation, wind-driven ice ridges, and ice-producing forces that may affect the ISFSI site. The staff finds the information in the SAR regarding ice flooding acceptable because, based on current knowledge and data, the ISFSI site is not subject to ice-flooding hazards; thus, ice flooding is not considered to be a credible threat to the ISFSI site. The staff, therefore, has determined that this information is acceptable for use in other sections of the SAR to develop the design bases for the Humboldt Bay ISFSI, perform additional safety analysis, and demonstrate compliance with the regulatory requirements of 10 CFR §72.24(a), §72.90(a–d), §72.90(f), §72.92(a–c), §72.98(a), §72.98(c)(3), §72.100(b), and §72.122(b) with respect to this topic.

2.1.4.8 Flood Protection Requirements

Section 2.4.7 of the SAR discusses flood protection requirements for the ISFSI site. The applicant indicates that surface drainage around the ISFSI area flows naturally into the existing plant drainage system and then discharges into the cooling water intake canal, which flows through the plant and discharges to Humboldt Bay through the cooling water discharge canal. The applicant indicates that outside the area served by the plant drainage system, most of the surface runoff drains to the east and into the discharge canal, while the remainder drains into Buhne Slough, a natural drainage for the area, which drains directly into both the intake canal and Humboldt Bay. As a result of ISFSI construction, minor alterations in drainage patterns may occur in the immediate vicinity of the ISFSI site, however, such slight modifications are not expected to adversely affect the ISFSI drainage system (Pacific Gas and Electric Company, 2004b). The applicant states that the drainage system at the ISFSI site is efficient, and flooding of the ISFSI site is not a concern.

The staff reviewed the information in the SAR pertaining to flood protection requirements and finds it acceptable because the analyses pertaining to surface hydrology and flooding indicate that the ISFSI will not be subject to significant flooding or uncontrolled moisture intrusion that would adversely affect the ISFSI. In addition, the proposed ISFSI technical specifications will provide controls and restrictions on cask transport during severe weather (Pacific Gas and Electric Company, 2004b, Attachment C). The staff, therefore, has determined that this information is acceptable for use in other sections of the SAR to develop the design bases for the Humboldt Bay ISFSI, perform additional safety analysis, and demonstrate compliance with the regulatory requirements of 10 CFR §72.24(a), §72.90(a–d), §72.90(f), §72.92(a–c), §72.98(a), §72.98(c)(3), §72.103(b), and §72.122(b) with respect to this topic.

2.1.4.9 Environmental Acceptance of Effluents

In Section 2.4.8 of the SAR, the applicant states that because the ISFSI site will not produce radioactive waste that can be incorporated into surface runoff, surface runoff from the site will have no radioactive contamination and will not adversely affect the surrounding ecosystem. Moreover, the applicant asserts that there is no surface or subsurface drinking water source at the HBPP (Pacific Gas and Electric Company, 2004b). Thus, the applicant concludes that because no radioactive waste will be produced by the ISFSI site and because onsite surface water and groundwater are not used by the public, a detailed analysis of the acceptance of effluents via surface waters or groundwater as a result of ISFSI operations is not necessary.

The staff reviewed the information in the SAR concerning the potential for the release and transport of radionuclides from the ISFSI site via the hydrologic system and finds it acceptable. The applicant has shown that the HI-STAR HB cask system will contain the spent nuclear fuel for all postulated normal, off-normal and accident conditions. Consequently, no radioactive waste will be released into surface or groundwater systems. Thus, the staff concludes there will be no release of radioactive effluents. The staff, therefore has determined that this information is acceptable for use in other sections of the SAR to develop the design bases of the Humboldt Bay ISFSI, perform additional safety analysis, and demonstrate compliance with the regulatory requirements of 10 CFR §72.24(a), §72.90(a), §72.92(a–c), §72.98(b), §72.100(b), and §72.122(b) with respect to this topic.

2.1.5 Subsurface Hydrology

Section 2.5 of the SAR discusses the characteristics of groundwater regionally and at the HBPP and ISFSI sites. The applicant indicates that the elevation of the ISFSI area is approximately 13 m [44 ft] above MLLW. Subsections discussed in the following text include (i) Stratigraphy; (ii) Aquifers; (iii) Groundwater Recharge, Gradients, and Discharge; (iv) Hydraulic Properties of Aquifers; (v) Groundwater Use; (vi) Groundwater Quality, and (vii) Contaminant Transport Analysis. The staff reviewed the discussion on subsurface hydrology with respect to the regulatory requirements in 10 CFR §72.98(a), §72.98(c) and §72.122(b)(4). Information presented in the SAR, and in the Humboldt Bay ISFSI Environmental Report (Pacific Gas and Electric Company, 2004b), shows that groundwater quality at the site will not be adversely affected by the ISFSI, nor will groundwater conditions at the HBPP site impact construction and operation of the ISFSI.

2.1.5.1 Stratigraphy

Sections 2.5.1 and 2.6.4.3 of the SAR summarize the stratigraphy directly beneath the ISFSI site. With the exception of a clayey surface layer of artificial fill 0 to 3.2 m [0 to 10.4 ft] thick, the SAR indicates that the ISFSI site is immediately underlain by the Hookton Formation, which is approximately 330 m [1,100 ft] thick beneath the ISFSI site area. Hookton Formation strata consists of interbedded shallow marine, estuarine, and fluvial facies, many that grade or interfinger laterally.

Important groundwater aquifers in the ISFSI vicinity reside in the Hookton Formation, which is composed of an upper and lower member. The upper member is 18 to 24 m [60 to 80 ft] thick and is divided into two informal lithologic units; the first contains silt, clay, and silty sand beds overlying the first bay clay, and the second contains sand and gravel beds overlying the discontinuous clay bed and aquitard known as the second bay clay. The lower member contains alternating sand, silty sand, gravel, gravelly sand, silty clay, and clay. The upper 8 to 46 m [26 to 150 ft] of this lower member consists of sand and gravel overlying the 15-m [50-ft]-thick Unit F clay, which functions as a regional aquitard. Below the Unit F clay lie alternating beds of clean, well-sorted sand and clay. Locally overlying the Hookton Formation in the vicinity of Buhne Point Hill are Holocene deposits consisting of colluvial, landslide, alluvial, and estuarine marsh facies.

As described in Section 2.5.1 of the SAR, the Unit F clay of the lower Hookton Formation lies at elevations between -29 and -34 m [-95 and -110 ft] with respect to MLLW and is at a depth of approximately 40 m [130 ft] immediately below the ISFSI site. The Unit F clay is observed to be continuous across an uplifted fault block between the Buhne Point Splay Fault and the Discharge Canal Fault. The SAR states that trench studies provide direct evidence that the upper part of the lower Hookton Formation (including the Unit F clay) and the upper Hookton Formation deposits are not faulted and, thus, exhibit continuous strata (except for facies gradations) in the near surface beneath the ISFSI site.

The staff finds the description of the stratigraphy in Sections 2.5.1 and 2.6.4.3 of the SAR as they relate to subsurface hydrologic conditions acceptable because the basic stratigraphic and structural characteristics of the site and vicinity are described in adequate detail to allow evaluation of the subsurface hydrology in the vicinity of the Humboldt Bay ISFSI site. The staff, therefore, has determined that this information is acceptable for use in other sections of the SAR to develop the design bases for the Humboldt Bay ISFSI, perform additional safety analysis, and demonstrate compliance with the regulatory requirements in 10 CFR §72.98(c)(2) and §72.122(b)(4) with respect to this topic.

2.1.5.2 Aquifers

Section 2.5.2 of the SAR reviews major aquifers in the region of the HBPP, including unconfined aquifers within alluvium, terrace deposits, and dune sands, and confined and unconfined aquifers within the Hookton Formation. In the immediate ISFSI site vicinity, the Elk River Valley alluvial aquifer is the main water-bearing unit. Terrace deposits at the ISFSI site are discontinuous and undeveloped as aquifers. Dune sand aquifers are not present at the ISFSI site. As discussed in the previous section, the lower Hookton Formation is an important water-bearing confined aquifer beneath the ISFSI site.

The 67 borings at the HBPP identify several aquifers and zones of perched groundwater. The first zone of perched groundwater in the area is located within Holocene silt and clay deposits; below this zone are several other discontinuous perched water bodies in the 9-m [30-ft]-thick upper Hookton silt and clay beds. No information is available regarding Holocene perched water in the immediate vicinity of the ISFSI site. Perched water is indicated, however, at depths from 3 to 4.6 m [10 to 15 ft] below the ISFSI surface elevation within the upper Hookton silt and clay beds. In comparison, the base of the HI-STAR HB cask system will be located at a depth of 3.3 m [10.7 ft], and the ISFSI vault will be located at a depth of 4.2 m [13.7 ft] below the ISFSI surface. Brackish groundwater is found in the semiconfined upper Hookton aquifer, which is greater than 33 m [100 ft] thick, and located between the Unit F clay and the overlying silt and clay beds of the upper Hookton Formation. The applicant indicates that the elevation of the ISFSI area is approximately 13m [44 ft] above MLLW. According to data collected in 1999, the piezometric surface of the semiconfined upper Hookton aquifer near the ISFSI site is estimated at approximately 1.3 m [4.4 ft] above MLLW, as reported in SAR Figure 2.5-9. Thus, there is approximately 12 m [40 ft] between the ISFSI surface elevation and groundwater table. The piezometric surface in the upper Hookton aquifer lags tidal variations in the bay and changes in elevation by approximately 1 m [3 ft] during each tidal cycle. The discontinuous second bay clay is present below the ISFSI, and where present, it confines the lower portion of the upper Hookton aquifer. Freshwater is found below the Unit F clay in the sands and gravels of the confined lower Hookton aquifer.

The staff finds the description of aquifers in Section 2.5.2 of the SAR acceptable because the regional and local water-bearing units are described in adequate detail to allow evaluation of the subsurface hydrologic characteristics of the Humboldt Bay ISFSI. The applicant indicates that the occurrence of perched groundwater at the base of an ISFSI excavation will not impact the construction or operation of the ISFSI site (Pacific Gas and Electric Company, 2004b). The staff, therefore, has determined that this information is acceptable for use in other sections of the SAR to develop the design bases for the Humboldt Bay ISFSI, perform additional safety analysis, and demonstrate compliance with the regulatory requirements in 10 CFR §72.98(c)(2) and §72.122(b)(4) with respect to this topic.

2.1.5.3 Groundwater Recharge, Gradients, and Discharge

Sections 2.5.3 and 2.5.4.2 of the SAR summarize groundwater recharge, gradients, and discharge regionally and in the vicinity of the ISFSI site. The SAR notes that groundwater level and flow direction at the site are largely controlled by topography, tides within Humboldt Bay, and stratigraphy.

Recharge to shallow water-bearing units in the area is generally from precipitation; lateral flow from adjacent formations; tide-induced seawater intrusion; and river, stream, and canal seepage. Deeper confined aquifers are recharged where the formations outcrop far from the ISFSI site (e.g., at Humboldt Hill) and also from the Elk River alluvial aquifers. Regionally, groundwater generally flows west to northwest toward the coast. Locally, some water flows upward because of leakage between water-bearing units. Because the stratigraphy dips to the southeast, discharge from local perched water bodies is directed to nearby marshes or to either the intake or discharge canal. Discharge in the region occurs through subsurface flow into springs, rivers, streams, tidal estuaries, the bay, and the ocean and by evapotranspiration and pumping or artesian flow from wells.

The staff finds the description of groundwater recharge, gradients, and discharge in Sections 2.5.3 and 2.5.4.2 of the SAR acceptable because groundwater sources, sinks, and gradients are described in adequate detail to allow evaluation of the subsurface hydrologic characteristics of the Humboldt Bay ISFSI. The staff, therefore, has determined that this information is acceptable for use in other sections of the SAR to develop the design bases for the Humboldt Bay ISFSI, perform additional safety analysis, and demonstrate compliance with the regulatory requirements in 10 CFR §72.98(c)(2) and §72.122(b)(4) with respect to this topic.

2.1.5.4 Hydraulic Properties of Aquifers

Section 2.5.4 of the SAR summarizes regional well yields and hydraulic properties of aquifers and perched water zones in the vicinity of the ISFSI site. Regional, along-river alluvial aquifers are significant water-bearing units in the Humboldt Bay area. Specific capacities for wells in these aquifers range between 4 and 72 L/s per meter [20 and 350 gpm per foot] of drawdown. Alluvial aquifers, however, do not lie below the ISFSI site. Specific capacities for wells in the lower Hookton aquifer are much lower than for wells in the nearby alluvial aquifers, with values on the order of 0.1 L/s per meter [0.5 gpm per foot].

The staff reviewed information concerning vertical and lateral groundwater gradients, vertical and lateral hydraulic conductivities, vertical and lateral flow velocities, transmissivities, and storativity in aquifers and perched water zones below the ISFSI site. The staff finds the description of regional well yields and hydraulic properties of aquifers in the SAR acceptable because these topics are described in adequate detail to allow evaluation of the subsurface hydrologic characteristics of the Humboldt Bay ISFSI. The staff, therefore, has determined that this information is acceptable for use in other sections of the SAR to develop the design bases for the Humboldt Bay ISFSI, perform additional safety analysis, and demonstrate compliance with the regulatory requirements in 10 CFR §72.98(c)(2) and §72.122(b)(4) with respect to this topic.

2.1.5.5 Groundwater Use

Section 2.5.5 of the SAR summarizes regional and local groundwater use, as well as use in the vicinity of the ISFSI site. The water supply needed for the nearby city of Eureka is exclusively met by surface water from the Mad River and Ruth Reservoir. All other water needs in Humboldt County are met by groundwater. Groundwater is used for irrigation, industrial, public, and domestic water supply needs. Groundwater is mainly extracted from shallow wells in along-river alluvial aquifers or in terrace deposits in the Eel, Mad, and Van Duzen River valleys. The lower Hookton Formation is an important aquifer, but well yields are substantially less than those from alluvial aquifers. There are at least 37 active wells located within a 3.2 km [2 mi] radius of the ISFSI site. Two of these wells are industrial; four are for monitoring; one is a test well; sixteen are domestic; six are for irrigation; one is a dual-purpose domestic/irrigation well; five are municipal, water companies, or commercial; and two are dual-purpose domestic/water company wells. Apart from small amounts of onsite water used for dust control and wash down of equipment during the construction phase, construction and operation of the ISFSI site is not expected to result in additional consumption of or discharge to groundwater below the ISFSI. Potable water for operations will come from existing HBPP supplies (Pacific Gas and Electric Company, 2004b). There is no surface or subsurface drinking water source on site (Pacific Gas and Electric Company, 2004b).

The staff finds the description of groundwater use in Section 2.5.5 of the SAR acceptable because the detail provided is adequate for evaluation of the degree to which aquifers below the ISFSI site are groundwater resources. The staff, therefore, has determined that this information is acceptable for use in other sections of the SAR to develop the design bases for the Humboldt Bay ISFSI, perform additional safety analysis, and demonstrate compliance with the regulatory requirements in 10 CFR §72.98(c)(2) and §72.122(b)(4) with respect to this topic.

2.1.5.6 Groundwater Quality

Sections 2.5.6 and 2.5.2.2 of the SAR provide information on regional groundwater quality, as well as quality in the vicinity of the ISFSI site. The staff reviewed information provided by the applicant regarding regional chloride concentrations. All perched water bodies in the vicinity of the ISFSI site are brackish, with electrical conductivity of the upper Hookton aquifer between 1,100 and 26,000 μ℧/cm and conductivity of the lower Hookton aquifer between 140 and 200 μ℧/cm. Apart from the naturally brackish conditions of perched water bodies and the semiconfined upper Hookton aquifer, there is no known groundwater contamination below the ISFSI site. The applicant concludes in the SAR that groundwater quality will not be affected by the ISFSI.

The staff finds the description of regional and onsite groundwater quality in the SAR acceptable because the detail is adequate to allow evaluation of the impact a potential ISFSI would have on groundwater quality. The staff, therefore, has determined that this information is acceptable for use in other sections of the SAR to develop the design bases of the Humboldt Bay ISFSI, perform additional safety analysis, and demonstrate compliance with the regulatory requirements in 10 CFR §72.98(c)(2) and §72.122(b)(4) with respect to this topic.

2.1.5.7 Contaminant Transport Analysis

In Sections 2.5.7 and 2.4.8 of the SAR, the applicant states that because the ISFSI will not produce radioactive waste that can be incorporated into surface runoff, no radioactive contamination will be produced that could adversely affect the surrounding ecosystem. Thus, the applicant indicates that because no radioactive waste will be produced by the ISFSI, a detailed analysis of contaminant transport in groundwater as a result of ISFSI operation is not necessary.

The staff reviewed the applicant's information in Section 2.5.7 of the SAR concerning the potential for the release and transport of radionuclides from the ISFSI site via the hydrologic system and finds it acceptable.

The applicant has shown that the HI-STAR HB cask system cask will contain the radioactive waste during all normal, off-normal and postulated accident conditions. Consequently, no waste will be incorporated into the groundwater system. Thus, the staff concludes there will be no radioactive contaminant transport. The staff, therefore, has determined that this information is acceptable for use in other sections of the SAR to develop the design bases for the Humboldt Bay ISFSI, perform additional safety analysis, and demonstrate compliance with the regulatory requirements in 10 CFR §72.98(c)(2) and §72.122(b)(4) with respect to this topic.

2.1.6 Geology and Seismology

Section 2.6 of the SAR describes the geological, seismological, and tectonic setting of the Humboldt Bay ISFSI. The staff reviewed Sections 2.6.1 through 2.6.8 of the SAR. The staff reviewed the geology and seismology with respect to the regulatory requirements in 10 CFR §72.90(a–d), §72.92(a–c), §72.94(a–c), §72.98(a–c), §72.103 (c–f), and §72.122(b)(4).

2.1.6.1 Basic Geologic and Seismic Information

Basic geologic and seismic characteristics of the site and vicinity are presented in Sections 2.6.1 through 2.6.5 of the SAR. This information forms the basis for establishing site geological and seismological conditions and supports the development of the seismic, faulting, and tsunami hazard assessments for the ISFSI site. Site investigations related to these natural hazards have been ongoing at the HBPP since before construction of the 63 MW Humboldt Bay nuclear reactor in 1962. In the SAR, the applicant summarizes the geological, geophysical, and tectonic studies conducted to develop site-specific seismic, faulting, and tsunami hazards for the ISFSI site. In addition to site-specific and region-specific data, the applicant examined recent earthquakes in Turkey and Taiwan, as well as tectonic and seismotectonic information from Alaska, as appropriate analogs to site conditions at the HBPP site.

<u>Tectonic Framework</u>

Section 2.6.2 of the SAR summarizes the tectonic framework of the Humboldt Bay ISFSI site. The ISFSI site lies within the southernmost extent of the Cascadia subduction zone and just north of the Mendocino triple junction. This region is structurally complex and seismically active. The active tectonics results from plate-boundary interactions between the North American, Gorda-Juan de Fuca, and Pacific tectonic plates. The Mendocino triple junction is a zone of complex deformation where all three tectonic plates meet. North of the Mendocino triple junction, the Gorda-Juan de Fuca tectonic plate subducts eastward beneath the North American plate along the 1,100 km-long Cascadia subduction zone. South of the triple junction, the Pacific tectonic plate is moving north-northwest relative to North America along a series of right-lateral strike slip faults within the San Andreas fault zone. West of the triple junction, the relative west-northwest motion of the Pacific tectonic plate with respect to the Gorda-Juan de Fuca plate occurs along the east-west Mendocino transform fault zone. The motion is transpressive, with components of right-lateral strike slip and contractional deformation. Historic seismic and paleoseismic data indicate large earthquakes [with moment magnitude (M_w) > 7.0] have occurred throughout the region as the results of these tectonic plate motions.

Convergence between the Gorda-Juan de Fuca and North American plates along the Cascadia subduction zone is accommodated by the plate boundary megathrust, which serves as the interface between the down-going oceanic and over-riding continental lithospheric plates. In addition, convergence is manifest in a broad west-vergent fold and thrust belt that is shortening the continental crust in response to tectonic convergence of the lithosphere plates.

According to the SAR, slip on the Cascadia subduction zone is partitioned among three megathrust segments. The main segment is 1,000 km [620 mi] long and extends from just north of Humboldt Bay to north British Columbia. Two smaller segments, the 80-km [50-mi]-

long Eel River segment and the 25- to 30-km [15- to 19-mi-]-long Petrolia segment, extend south from the ISFSI site to the Mendocino triple junction. Each of these three segments has a unique slip history based on seismic and paleoseismic information. As a result, the applicant treats them as three unique seismic sources in their seismic hazard assessment. The two smaller Petrolia and Eel River segments of the subduction zone are the result of a high degree of internal deformation within the southern Gorda-Juan de Fuca plate, possibly because of asymmetrical spreading at the Gorda rise coupled with left shear within the southern Gorda-Juan de Fuca plate.

The applicant identifies the main Cascadia subduction zone as belonging to a class of subduction zones in which the down-going and over-riding lithospheric plates are strongly coupled. Strongly-coupled subduction zones are characterized by long ruptures (up to 1,000 km [621 mi]), oblique convergence, subduction of relatively young ocean lithosphere leading to shallow subduction angles (10° or less), and moderate convergence rates (on the order of 2.0 to 5.0 cm/yr [0.8 to 2.0 in/yr] based on geophysical plate kinematic models). Worldwide data shows that strongly coupled subduction zones produce infrequent but large-magnitude earthquakes. The $M_W = 9.5$ 1960 Chilean earthquake and the $M_W = 9.2$ 1964 Good Friday earthquake in Alaska both occurred on megathrusts in strongly coupled subduction zones.

There are no direct historical accounts of such large-magnitude earthquakes on the Cascadia subduction zone. Paleoseismic data from numerous sites in the northwest United States indicate, however, that a great earthquake ruptured the Cascadia megathrust in approximately AD 1700. This event correlates with historical accounts of a large trans-pacific tsunami that struck Kuwagasaki, Japan, on January 27, 1700. Similarly, there are no historic earthquake records for the rupture of the Eel River segment. Paleoseismic evidence in that region, suggests, however, that a significant earthquake ruptured this megathrust segment in the early 1800s. There was a large $M_W = 7.1$ earthquake on the Petrolia segment in 1992, which produced a horizontal peak ground acceleration of 0.22 g at the HBPP. This earthquake serves as the model for the seismogenic potential of the Petrolia and Eel River subplates in the applicant's seismic hazard assessment.

In the SAR, the applicant concludes that slip on thrust faults in the west-vergent fold and thrust is directly related to the rupture of the Cascadia subduction zone megathrust. The two main thrust fault zones that make up the onshore portion of the fold and thrust belt are the Little Salmon and Mad River fault zones. Geologic evidence suggests that slip on the Little Salmon and Mad River fault zones is coseismic with the rupture of the main Cascadia subduction zone megathrust.

The applicant suggests that the Cascadia subduction zone and its associated fold and thrust belt are analogous to the Aleutian subduction zone and its uplifted accretionary prism fold. During the 1964 Good Friday earthquake in Alaska, the rupture of the eastern part of the Aleutian subduction zone produced coseismic slip on the Patton Bay and Hanning Bay faults, which are thrust faults within the accretionary prism. This earthquake is interpreted by the applicant as an appropriate analog for a large earthquake on the Cascadia subduction zone. In their seismic hazard assessment, the applicant develops seismic sources and ground motion attenuation models that explicitly incorporate the potential for coseismic rupture of the Little

Salmon fault system as the result of a megathrust earthquake in the Cascadia subduction zone. This scenario is directly analogous to the 1964 Good Friday earthquake in Alaska.

Stratigraphy

Section 2.6.3.2.1 of the SAR provides a summary of relevant information regarding the regional and local stratigraphy. In that summary, the applicant notes that the HBPP site is located within the broad Eel River forearc basin, which is filled by a thick accumulation of more than 3,500 m [11,500 ft] of Tertiary [65 to 2.0 Ma] and Quaternary [2.0 Ma to the present] marine sedimentary rocks. The youngest rocks of the sedimentary deposits are Pleistocene gravels, sands, silts, and clays of the Hookton Formation, which constitute the strata directly beneath the ISFSI site. The thick accumulation of marine sedimentary rocks rests unconformably over Late Jurassic to Early Tertiary basement rocks of the Franciscan Complex. The Franciscan Complex is a lithologically heterogenous assemblage, or mélange, of oceanic crust and mantle and deep marine sedimentary strata mixed chaotically with submarine landslide material (turbidites) shed from the continental margin. The applicant documents that the marine strata beneath the ISFSI site contains numerous horizontally continuous marker horizons, especially clay beds, that are used to denote the displacement history of nearby faults. The younger units also contain evidence of marine terraces, which also record the uplift and subsidence of the basins in response to faulting and the growth of fault-related folds.

Regional Structural Geology

Section 2.6.3.2.2 of the SAR, describes the regional structural geology as the result of accumulated deformation along north-northwest trending contractional structures that formed during three phases of plate tectonic convergence over the past 150 million years. These three phases are (i) Mesozoic [245 to 65 Ma] and early Tertiary [65 to ~35 Ma] accretion of the Franciscan Complex basement rocks; (ii) middle Tertiary [~35 to ~20 Ma] subduction of the Farallon plate, prior to the development of the San Andreas fault system and modern Cascadia subduction zone; and (iii) late Tertiary and Quaternary [~20 Ma to present-day] Cascadia subduction of the Gorda-Juan de Fuca plate coupled with the northward migration of the Mendocino triple junction.

Regional structures related to all three phases of plate tectonic convergence are evident in the Humboldt Bay region, although only those associated with the present-day Cascadia subduction are of primary concern to the seismic and fault-displacement hazard assessments. Near the HBPP site, contraction associated with the Cascadia subduction is manifest as the active Cascadia fold and thrust belt. In this fold and thrust belt, actively growing fault-related anticlines in the hanging walls of the thrust faults produce uplifted regions. Active hanging wall folds include the Table Bluff, Humboldt Hill, and Fickle Hill anticlines. Between the uplifts are broad and flat-floored footwall synclines that result in actively subsiding depositional basins, including the Freshwater, South Bay, and Eel River synclines. Asymmetry of the folds indicates that the structures verge to the south-southwest.

The applicant identified the Mad River and the Little Salmon fault systems as the two major thrust faults in the vicinity of the HBPP site. Both structures displace Franciscan Complex basement and lower Wildcat Group strata south-southwest thrust over upper Wildcat Group strata and younger sediments. Slip rate estimates for individual faults within the Mad River fault zone, based on marine terrace uplift rates and offsets of dated stratigraphic markers, are in the 1 to 2 mm/yr [0.04 to 0.08 in/yr] range. The applicant reports a combined slip rate across the entire Mad River fault zone, based on recently published information in the scientific literature, of 5 to 9 mm/yr [0.2 to 0.35 in/yr]. Slip rates for the Salmon River fault system are similar. The applicant cites published results showing that both the long-term slip rates, based on stratigraphic markers juxtaposed across the thrust faults, and short-term slip rates, based on paleoseismic investigations, are 8 to 13 mm/yr [0.3 to 0.5 in/yr]. Recurrence intervals are on the order of 500 years, with 1 to 6 m [3.3 to 19.7 ft] of fault displacement per event. Based on the coincidence of the earthquakes on individual thrust faults within the Little Salmon fault system with geologic evidence for rapid subsidence of the intervening synclinal basins, the applicant concludes that the thrust fault events were triggered by the coseismic rupture of the southern Cascadia subduction zone interface.

Historic Earthquake Record

Section 2.6.3.3 of the SAR provides a detailed summary of historic earthquakes, which includes historical and instrumentally recorded earthquakes from 1850 through April 2002. Historical earthquakes have inferred magnitudes based on damage intensity and, thus, are limited to events with a M_W of 5.0 to 5.5 and larger. Although seismographic stations have existed in the region since 1932, the reliable instrumental record began in 1974, with the installation of a seismic network at the HBPP site. The applicant's analysis includes a discussion of earthquakes with a M_W of 3 or greater within 160 km [100 mi] of the site and earthquakes with a M_W of 2.0 and greater within 40 km [25 mi] of the site.

The earthquake record compiled by the applicant documents 121 earthquakes with a M_W of 5 and larger within 160 km [100 mi] of the site since 1850. (An earthquake magnitude scale depends on the specific source for the tabulated information and includes moment magnitude, body wave magnitude, Gutenberg-Richter magnitude, Gutenberg local magnitude, and magnitudes estimated from intensity data). The number is a minimum because, prior to the deployment of seismographs and seismic networks, an undetermined number of moderate to large magnitude earthquakes could have occurred offshore without causing recordable damage to onshore structures. Details of each of these 121 earthquakes are provided in SAR Table 2.6-4. The detailed list considered a range of earthquake catalog sources, including the University of California at Berkeley (2002) and the U.S. Geologic Survey (2002). Of the 121 earthquakes listed in the SAR, 53 occurred after commercial operation began in August 1963.

In addition to the catalog of local and regional earthquakes, the SAR also lists two prominent earthquakes that are known or inferred from historical data. These inferred earthquakes are the 1700 great Cascadia subduction zone earthquake and the 1906 San Francisco earthquake. The earthquake on the Cascadia subduction zone is interpreted from regional paleoseismic and paleotsunami data coupled with historical data from native tribes and from a detailed historical account of a trans-pacific tsunami wave that struck Japan on January 27, 1700. There was considerable damage reported by nearby communities after the earthquake.

Strong-motion recordings have been collected at the site since 1974. Six earthquakes since then have produced peak ground accelerations at the site in excess of 0.10 g. The largest ground motion recorded at the site was a peak horizontal acceleration (north-south component) of 0.55 g produced by a $M_W = 5.4$ earthquake approximately 8 km [5 mi] west of the HBPP site.

None of these six earthquakes resulted in significant structural damage to existing facilities at the HBPP site.

Site Geology

Section 2.6.4 of the SAR provides a detailed description of the site geology that is consistent with the guidance provided in NUREG-1567 (U.S. Nuclear Regulatory Commission, 2000). The description of the site geology is based on surface mapping, boreholes, and trenching studies conducted over the past 40 years. The site is underlain by more than 900 m [2,950 ft] of predominantly Pleistocene (1.6 Ma to 10 ka) and Holocene (last 10 ka) sedimentary strata. These strata are well bedded and comprise the Rio Dell, Scotia Bluffs, and Hookton formations, as well as late Pleistocene (last 250 ka) and Holocene paleosols and other surficial deposits.

The ISFSI site is situated on the hanging wall of the Little Salmon fault zone, which consists of four mapped fault traces. These four fault traces are the Little Salmon, Bay Entrance, Buhne Point, and Discharge Canal faults. Although all faults show evidence for geologically recent displacements, the continuity of several strata markers across the site indicate that significant fault slip is largely confined to the individual fault surfaces. In addition, the applicant concludes that because the late Pleistocene (last 80 ka) upper Hookton Formation strata is continuous across the site, there has been no significant faulting at the site in the last 80,000 years.

Seismic Source Characterization

In Section 2.6.5 of the SAR, the applicant provides both probabilistic and deterministic seismic hazard assessments. As discussed in Section 2.1.6.2 of this SER, the Design Earthquake (DE) for the ISFSI is based on the deterministic hazard assessment, which the applicant shows envelopes the 2,000-year return period probabilistic uniform hazard spectra.

The approach used by the applicant to develop seismic source characteristics for their deterministic seismic hazard assessment is consistent with U.S. Nuclear Regulatory Commission (NRC) guidance (e.g., U.S. Nuclear Regulatory Commission, 2003a). The deterministic seismic hazard assessment is based on the Cascadia subduction zone earthquake developed by the California Division of Mines and Geology (Toppozada, et al., 1995). This scenario considers a large-magnitude rupture of the subduction zone interface along the 240-km-long [150-mi-long] Gorda segment coupled with a coseismic rupture of the Little Salmon thrust fault. Based on geometric characteristics of the subduction zone interface and Little Salmon fault zone, the applicant assigns a maximum M_w of 7.7 to the Little Salmon fault zone and a M_w of 8.8 to the subduction zone interface. Closest mapped approaches of the ISFSI site to these sources are used for site-to-source distances. The site-to-source distances are used in the ground motion attenuation relationships to define how close an earthquake rupture could occur. In the deterministic analysis, the applicant used the closest possible distance from the site to the source because this assumption is conservative.

For the probabilistic seismic hazard assessment, the applicant developed six contributing seismic sources: (i) the main Cascadia subduction zone interface; (ii) the Cascadia Eel River subplate; (iii) the Cascadia Petrolia subplate; (iv) Little Salmon fault; (v) the Gorda plate; (vi) Zone D, a background source zone (Geomatrix Consultants Inc., 1994); (vii) the Mad River fault zone; (viii) the Mendocino fault zone; and (ix) the North San Andreas fault. Source characteristics were derived from available geologic and geophysical information coupled with length- and area-scaling relationships for magnitudes (e.g., Wells and Coppersmith, 1994). Detailed source information is provided in calculation package GEO.HBIP.03.04 (Pacific Gas and Electric Company, 2003a).

The staff reviewed the information in the SAR concerning basic geology and seismic information and finds it acceptable because the applicant adequately considered all necessary and relevant information in their assessment. Consistent with 10 CFR §72.92(a–b) and §72.98(a), the information in the SAR is sufficient to identify and assess potential earthquake hazards with respect to the safe operation of the ISFSI. The information in the SAR provides a comprehensive evaluation of the tectonics setting, regional and local stratigraphy, regional and local structural geology, and historic seismicity such that reliable and robust seismic sources could be identified and characterized to support an estimation of the DE as prescribed in 10 CFR §72.103(f). The staff, therefore, determined that this information is acceptable for use in other sections of the SAR to develop the design basis ground motions for the Humboldt Bay ISFSI, perform additional safety analysis, and demonstrate compliance with the regulatory requirements in 10 CFR §72.92(a–b), §72.98(a), §72.103(f), and §72.122(b) with respect to this topic.

2.1.6.2 Ground Vibration

Section 2.6.6 of the SAR discusses the development of design basis vibratory ground motions associated with credible levels of vibratory ground motions that may be experienced at the ISFSI site. In reviewing the applicant's development of vibratory ground motions, the staff considered factors related to the principal elements of seismic hazard analyses and procedures for determining the DE. The staff reviewed the applicant's investigations of basic geologic and seismic information, as discussed in Section 2.1.6.1 of this SER, and the following essential aspects of ground vibration at the Humboldt Bay ISFSI: (i) applicable ground motion attenuation relations, (ii) synchronous rupture, (iii) near source effects, (iv) site response analyses, (v) deterministic and probabilistic seismic hazard analyses, and (vi) design spectra and spectrum compatible time histories.

The applicant cites 10 CFR Part 72 as the basis for determining ISFSI DE ground motions. Until its revision in October 2003, this regulation and, in particular, 10 CFR §72.102, required the development of a DE in accordance with 10 CFR Part 100, Appendix A. The seismic hazard methodology in 10 CFR Part 100, Appendix A, is based on a deterministic approach in which the largest credible earthquake that could occur on the closest approach of the seismic source to the site is considered as the DE. In 2003, 10 CFR Part 72 was amended. The rule change requires that uncertainties inherent in estimates of the DE be addressed through an appropriate analysis, such as probabilistic seismic hazard analyses (PSHA) or suitable sensitivity analyses, as set forth by 10 CFR §72.103. Regulatory Guide 3.73 (U.S. Nuclear Regulatory Commission, 2003a) provides general guidance on procedures acceptable to the NRC staff in conducting the PSHA and developing the DE to satisfy the requirement of 10 CFR Part 72. Regulatory Guide 3.73 (U.S. Nuclear Regulatory Commission, 2003a) further specifies that the controlling earthquakes are to be developed for the ground motion level corresponding to the mean reference probability of 5×10^{-4} per year, which is approximately equal to the 2,000-year return period earthquake.

The approach followed by the applicant in characterizing ground vibration consists of (i) developing the design basis response spectra based on a deterministic approach, consistent with the requirements of 10 CFR Part 100, Appendix A; (ii) developing the licensing basis response spectra based on a probabilistic approach, consistent with 10 CFR §72.103 and Regulatory Guide 3.73 (U.S. Nuclear Regulatory Commission, 2003a); (iii) demonstrating that the deterministic design basis spectra envelopes the corresponding PSHA-based licensing basis spectra at all spectral periods; and (iv) developing four sets of ground motion time histories that are compatible with the design basis spectra for use in analyses and design.

Ground Motion Attenuation

In the applicant's deterministic and probabilistic seismic hazard analyses, earthquakes occurring on the Cascadia interface and within the Gorda-Juan de Fuca Plate were considered subduction interface and subduction intra-slab earthquakes, respectively. All other earthquakes were considered crustal earthquakes. For the subduction interface and intra-slab earthquakes, the Youngs, et al. (1997) attenuation model was used to calculate horizontal rock motions, which were then scaled to soil surface ground motions using site-specific amplification factors (Pacific Gas and Electric Company, 2003a). The Youngs, et al. (1997) model does not include calculation of the vertical component of ground motion; therefore, surface vertical motions for subduction earthquakes were scaled from soil surface horizontal motions using the scaling factors of Abrahamson and Silva (1997). For crustal earthquakes, the attenuation models of Abrahamson and Silva (1997), Sadigh, et al. (1997), Idriss (1991, 1994, 1995), and Campbell (1997) were used with equal weight to calculate horizontal rock motions, which were then scaled to soil motions using site-specific amplification factors (Pacific Gas and Electric Company, 2002a,b). The vertical motions from crustal earthquakes were calculated using the Abrahamson and Silva (1997) model directly for the surface soil conditions. Spectral values for all calculations were extrapolated to a spectral period of 10 seconds to cover a broader spectral range.

In response to a request for additional information (Pacific Gas and Electric Company, 2004c), the applicant evaluated two recently published attenuation models, namely Gregor, et al. (2002) for subduction interface earthquakes and Atkinson and Boore (2003) for subduction intra-slab earthquakes. Hazard results were recalculated to include these two new models. The new results show that using the Atkinson and Boore (2003) model does not lead to a significant difference in hazard results. The Gregor, et al. (2002) model, on the other hand, produced much larger long period ground motions than the Youngs, et al. (1997) model. Nevertheless, the deterministic design spectra used for the evaluation of the facility envelope the updated spectra using the Gregor, et al. (2002) model and, therefore, are conservative. The applicant further concludes that the empirically based Youngs, et al. (1997) model is more reliable than the numerically based Gregor, et al. (2002) model because it predicts ground motions that are more consistent with recorded ground motions from past earthquakes. In addition, the current state of development of the numerical simulations is limited to a small range in spectral frequency and earthquake magnitudes. These observations are consistent with the staff independent evaluations of subduction interface ground motion attenuation models, including Gregor, et al. (2002), Atkinson and Boore (2003), and Youngs, et al. (1997).

Synchronous Rupture

As discussed in the previous section on seismic sources, the applicant considered that the Little Salmon fault is a splay of the main Cascadia Subduction interface and that the two structures rupture simultaneously (synchronous rupture). The effect of synchronous rupture was considered in the development of response spectra and time histories, based on the assumption that the Fourier phase angles for the two subsources are uncorrelated (random differences in the phase angles between the two subsources).

Based on the random vibration theory, the response spectra for synchronous rupture in both the deterministic seismic hazard analysis (DSHA) and PSHA were calculated as the square root of the sum of squares (SRSS) of the response spectral values of the individual subsources. The staff compared the SRSS and total moment approaches.

In general, the SRSS method yields higher ground motion, although the difference decreases with decreasing frequency. Consequently, the SRSS method is the more conservative method. The total moment approach estimates the total moment for multiple ruptures as the sum of seismic moments from each rupture. The corresponding combined magnitude is then calculated using the M_W relationship of Hanks and Kanamori (1979). The combined moment magnitude and site-to-source distance to the nearest rupture is used to calculate ground motion for multiple ruptures. The approach based on the random vibration theory is the approach taken by the applicant. This approach computes ground motion for multiple ruptures as the square root of the SRSS of the motions from the individual ruptures. This approach assumes that the motions from each rupture overlap in time at the site and that the motions from each rupture are uncorrelated (interfere randomly).

The staff analyzed the characteristic magnitudes and weight distributions assigned by the applicant (Pacific Gas and Electric Company, 2003a) for the Cascadia subduction interface and the Little Salmon fault zone and conducted a deterministic analysis for synchronous rupture using total earthquake moment and SRSS approaches. In the total moment approach, the M_W relationship of Hanks and Kanamori (1979) was used to calculate the earthquake moment for each subsource based on the PG&E characteristic magnitude distribution and assigned weight distributions. The moments from the two subsources were added to obtain total moment for synchronous rupture. The Little Salmon fault zone and the subduction interface were then treated as one single fault zone. The crustal attenuation relations of Abrahamson and Silva (1997), Sadigh (1997), and Campbell and Bozorgnia (2003) were used with equal weight. In the SRSS approach, the response spectrum for the Little Salmon fault zone was calculated using the attenuation relations of Abrahamson and Silva (1997), Sadigh (1997), and Campbell and Bozorgnia (2003) with equal weight. The spectrum for the Little Salmon fault zone was combined with the spectrum for the Cascadia subduction interface calculated using the attenuation relations of Youngs, et al. (1997) and Gregor, et al. (2002), respectively. These analyses show that the higher ground motion from the Cascadia interface predicted by Gregor, et al. (2002) causes notable increase in the spectrum for synchronous rupture.

In addition to spectral analyses, the applicant considered the effect of synchronous rupture in the development of ground motion time histories. Based on the assumption of random differences in the phase angles between the two subsources, time histories for synchronous rupture were obtained by adding time histories from individual sources in the time domain. In combining the time histories from individual sources, the applicant selected four different relative time shifts between the motions from individual sources to constrain the relative timing to reflect the uncertainty in rupture initiation locations on the main Cascadia interface. The time histories were combined such that the strong shaking from the Little Salmon fault source occurs during the strong shaking from the main Cascadia interface source. This approach for developing ground motion produced by synchronous rupture is new in earthquake engineering practice related to nuclear facilities. Although synchronous rupture had occurred in past subduction earthquakes (e.g., 1964 Alaska earthquake), there are no available strong motion recordings from such synchronous rupture that could be used to verify the approach.

To gain confidence and better understanding, the staff independently combined the time histories from individual sources following the applicant's approach, but with varying time shifts to account for uncertainties in the source-to-site travel times. The staff evaluation shows that the main effect of adding the subsource time histories is a slight increase in short period ground motions. The occurrence of constructive and destructive interferences appears to be random. An important aspect of the applicant's approach is that the resulting time history spectra are rematched to the soil spectra for synchronous rupture (i.e., the design spectra) to ensure that all spectral frequencies are fully represented in the resulting time history. With spectral rematching, the staff finds that the applicant's results are conservative.

Near Source Effects

Near source effects, including directivity and fling, were considered in the applicant's ground motion analyses because (i) the proposed ISFSI site is close to the earthquake sources and (ii) the existing empirical ground attenuation models do not include such effects. The methodology and scaling factors of Somerville, et al. (1997) were used to account for directivity effects. Fling is caused by permanent tectonic deformation and affects the long-period ground motions at sites near causative faults. Fling was accounted for by adding a fling acceleration time history to the fault normal and vertical directions of the design ground motion time histories. The development of fling parameters is documented in Pacific Gas and Electric Company (2002b, GEO.HBIP.02.05).

Site Response Analyses

The site for the proposed ISFSI at the HBPP consists of 122 to 183 m [400 to 600 ft] of medium dense to very dense alluvial soils, including clayey sand, silt, sandy and silty clay, clay, silty sand, sand, and gravel. The shear wave velocity increases from about 213.4 m/s [700 ft/sec] in the upper 6 m [20 ft] to about 609.6 m/s [2,000 ft/sec] near the base of the sediments. The applicant considered the effect of site soil responses using an equivalent linear procedure. Selected empirical ground motion time histories were propagated through three soil profiles, representing the median, upper bound, and lower bound soil properties, to develop site specific soil amplification factors (Pacific Gas and Electric Company, 2002a, 2003b). Two sets of site response analyses were conducted to calculate amplification factors for deterministic and probabilistic motions, respectively, using different characteristic earthquake magnitudes. It was observed that the equivalent linear procedure analysis tends to overdamp large input motions at high frequencies. Consequently, the applicant used large amplitude ground motions recorded during the 1994 Northridge, California, earthquake on seven soil sites to constrain the spectral shape of the site specific PSHA and DSHA spectra.

Deterministic Seismic Hazard

In the deterministic seismic hazard analysis (Pacific Gas and Electric Company, 2002c, GEO.HBIP.02.04), the applicant assumed that the deterministic ground motion at the site results from the synchronous rupture of the Cascadia subduction zone and Little Salmon fault. Specifically, the applicant considers a earthquake with a M_W of 7.7 on the Little Salmon fault zone with zero site-to-source distance (because the Little Salmon fault is located directly beneath the site) combined with an earthquake with a M_W of 8.8 on the main Cascadia interface with 7 km [4.3 mi] site-to-source distance. The analysis procedure included (i) calculating response spectra for each of the two controlling earthquakes using the applicable attenuation models discussed earlier; (ii) applying directivity effects to Little Salmon spectra, resulting in separated spectra for fault normal and fault parallel components; (iii) obtaining response spectra for synchronous rupture by combining response spectra of the two individual earthquakes using SRSS; (iv) obtaining soil surface spectra by multiplying the horizontal rock acceleration response spectra for synchronous rupture by the site-specific soil amplification factors; and (v) modifying the soil response spectra to expand the spectral range and to add constraints based on the 1994 Northridge earthquake. The deterministic analyses yielded a peak horizontal ground acceleration of 1.316 g for both fault normal and fault parallel components and a peak vertical ground acceleration of 1.673 g. The applicant's PSHA is based on well established methodologies and includes calculations of the seismic hazard from individual sources and calculations of total hazard from all potential seismic sources. The PSHA was performed generally in accordance with Regulatory Guide 3.73 (U.S. Nuclear Regulatory Commission, 2003a); however, the mean spectral ground motion levels were computed specifically at frequencies of 0, 0.33, 1.0, and 5.0 Hz, which are different from the Regulatory Guide 3.73 (U.S. Nuclear Regulatory Commission, 2003a) values of 1.0 and 10.0 Hz. The applicant's use of the revised frequencies is acceptable for use at the Humboldt Bay site because earthquake response at frequencies beyond 5 Hz will not be significant.

Probabilistic Seismic Hazard

The applicant's PSHA (Pacific Gas and Electric Company, 2003a) is based on well established methodologies and includes calculations of the seismic hazard from individual sources and calculations of total hazard from all potential seismic sources. Such calculations produce hazard curves that depict the relationship between levels of ground motion and probabilities at which the levels of ground motion are exceeded. The mean total hazard curves and hazard curves by source were calculated at 15 spectral ordinates. The final uniform hazard spectra were generated for fault normal, fault parallel, and vertical directions for a number of return periods. For the 2,000-year return period (5×10^{-4} annual exceedence probability), the mean peak horizontal ground acceleration is 0.967 g for both the fault normal and fault parallel directions. The mean peak vertical ground acceleration is 0.731 g.

In the PSHA, the applicant tracked both aleatory variability and epistemic uncertainty in the source models, ground motion attenuation, and site response models, consistent with recommendations in the Senior Seismic Hazard Analysis Committee (SSHAC) guidelines (Budnitz, et al., 1997). Aleatory variability was considered using appropriate distribution functions in rock ground motion, earthquake magnitude, rupture dimension, rupture location, and hypocenter location. Epistemic uncertainty was modeled using a logic tree structure. Because only one attenuation relation was used for the subduction sources, there was no epistemic uncertainty modeled for the rock ground motions for these sources. At both short and long periods, the hazard for the 2,000-year return period is dominated by the Little Salmon/Cascadia synchronous rupture. The epistemic uncertainty in these hazard curves is dominated by the uncertainty in the rock ground motion models for the Little Salmon fault source (i.e., different ground motions predicted using the different crustal ground motion models discussed previously) and by the uncertainty in the site response (because of different ground motions predicted using different site specific soil profiles discussed previously). At short periods (e.g., 0.2 seconds), the hazard is dominated by the offshore Gorda sources, and the epistemic uncertainty is dominated by the uncertainty in the recurrence rates of these sources and the site response uncertainty.

Design Basis Ground Motion and Spectrum Compatible Time Histories

The applicant chose the 84th percentile deterministic soil acceleration spectra at 5 percent damping as the design spectra for the proposed ISFSI. The regulatory basis for choosing the deterministic spectra as design spectra is that the horizontal and vertical deterministic soil spectra envelop the corresponding uniform hazard spectra at a 2,000-year return period. A comparison of the deterministic design spectra and the 2,000-year return period uniform hazard spectra is presented in the SAR (Figure 2.6-72). This figure shows that the design spectra envelop the 2,000-year return period uniform hazard spectra at all spectral periods. The applicant also shows that the design spectra have a much broader shape than the 2,000-year return period uniform hazard spectra.

Four sets of three component time histories that match the corresponding deterministic design spectra were developed for design and analyses (Pacific Gas and Electric Company, 2002b, GEO.HBIP.02.05). The development of time histories involved the following process: (i) selecting empirical time histories for individual subsources (i.e., Little Salmon and Cascadia main subduction interface sources), (ii) spectrally matching the empirical time histories to the corresponding soil spectra for individual sources, (iii) combining time histories for individual sources in the time domain to account for synchronous rupture, (iv) adding fling time histories to the fault normal and vertical directions to account for the permanent tectonic displacement, and (v) rematching the combined time histories with fling to the soil spectra for synchronous rupture to obtain final time histories. The spectral matching used the 75 frequencies recommended in Regulatory Guide 3.73 (U.S. Nuclear Regulatory Commission, 2003a) and an additional 29 frequencies to cover a broader frequency range. In all of the spectral matching processes, the following requirements were applied to the average of the spectra at multiple damping values from the multiple time histories: (i) no more than 5 of the 75 recommended ordinate frequencies fall below the target spectrum and (ii) no ordinates fall below 0.9 times the target spectrum.

Based on review of the SAR, the staff concludes that the design spectra are conservative because (i) the DSHA-based design spectra exceed corresponding uniform hazard spectra at the 2,000-year return period specified in Regulatory Guidance 3.73 (U.S. Nuclear Regulatory Commission, 2003a); (ii) uncertainties in ground motions were addressed using a PSHA, consistent with the guidelines of SSHAC (Budnitz, et al., 1997) and the requirements of 10 CFR §72.103; (iii) the PSHA is consistent with 10 CFR §72.103, the Regulatory Guide 3.73 (U.S. Nuclear Regulatory Commission, 2003a) procedure, and the state of practice; (iv) the DSHA uses conservative parameters for controlling earthquakes and is consistent with 10 CFR Part 100, Appendix A; and (v) the response spectra of time histories for the design analyses envelop the deterministic design spectra. The staff concludes, therefore, that the design spectra and their compatible time histories are acceptable for use in ISFSI design analyses. The earthquake information is also acceptable for use in other sections of the SAR to develop the design bases of the Humboldt Bay ISFSI, perform additional safety analyses, and demonstrate compliance with regulatory requirements in 10 CFR §72.92(a–b), §72.103(b), §72.103(f), and §72.122(b) with respect to this topic.

Design Basis Ground Motions For Transient Activities

Section 3.2.4 of the SAR concludes that the risk-scaled DEs for transient activities related to movement of the loaded casks along the transporter route and cask handling activities at the storage vault are significantly less than the 2,000-year return DEs used for the storage vault design. For cask transfer, the applicant uses the 50-year return period uniform hazard spectrum, which has a peak horizontal ground acceleration of 0.4 g. For the cask handling activities at the storage vault, the applicant uses the 25-year return period uniform hazard spectrum, which has a peak ground acceleration of 0.3 g. The staff assessment of the applicability of these risk-modified DEs is provided in Section 4.1.3.2 of this SER.

The staff reviewed the seismic information and concludes that the proposed levels of ground acceleration are sufficient to represent the 25- and 50-year return ground motions. The staff performed an independent check using the earthquake information provided in Tables 2.6-4 and 2.6-5 of the SAR and determined that the 0.3 g and 0.4 g peak horizontal ground accelerations are consistent with the nearly 150-year historical earthquake record. Thus, the staff concludes that the transient design spectra are acceptable for use in the ISFSI design analyses and for use in other sections of the SAR to develop the design bases of the Humboldt Bay ISFSI, perform additional safety analysis, and demonstrate compliance with the regulatory requirements in 10 CFR §72.92(a–b), §72.103 (b), §72.103(f), and §72.122(b) with respect to this topic.

2.1.6.3 Surface Faulting

Section 2.6.8 of the SAR describes the fault displacement hazard assessment performed by the applicant. Site investigations related to the potential for fault-displacement damage of the HBPP have been conducted by the applicant throughout the past 50 years related to the construction of the HBPP Unit 3 in 1962 and the ISFSI site. In the SAR, the applicant summarizes the geological information used to develop a technical basis to support the applicant's conclusion that surface faulting will not disrupt the ISFSI. In addition to site-specific information, the applicant examined surface fault damage from the recent 1999 earthquake with a $\mathbf{M}_W$ of 7.6 in Taiwan on the Chelungpu fault as an appropriate analog to the potential for surface faulting damage at the HBPP site.

The ISFSI site is situated on the hanging wall of the Little Salmon fault zone. At the HBPP, this fault zone is mapped as having four fault traces at the surface: the Little Salmon, Bay Entrance, Buhne Point, and Discharge Canal faults. The Little Salmon fault itself is a top-to-the-southwest thrust fault that projects to the surface about 2.2 km [1.4 mi] southwest of the site. The Bay Entrance and Buhne Point faults are synthetic splays of the Little Salmon fault. The surface projection of the Bay Entrance fault is no closer than 410 m [1,345 ft] southwest of the ISFSI site. The Buhne Point fault projects to the surface approximately 200 m [656 ft] southwest of the ISFSI site. The Discharge Canal fault is a small-displacement southwest dipping backthrust off the Buhne Point fault that projects to the surface no closer that 125 m [410 ft] from the ISFSI.

All four of these faults are considered active. Slip rates on the Little Salmon fault are in the range of 3 to 12 mm/yr [0.12 to 0.47 in/yr]. Slip rates on the Bay Entrance fault are estimated at 1 to 2 mm/yr [0.04 to 0.08 in/yr]. Given displacements of 1 to 3 m [3.3 to 9.8 ft], these slip rates suggest repeat times for large-magnitude earthquakes of 100 to 1,000 years on the Little Salmon fault and 500 to 1,000 years for the Bay Entrance fault, consistent with paleoseismic evidence. Nevertheless, geologic observations from surface observations and borings at the site indicate that deformation associated with repeated earthquakes on these faults is largely restricted to narrow fault-damage zones or on the slip surface. For example, the applicant shows that late Quaternary strata beneath the site are continuous and largely undisturbed by faulting between the Discharge Canal and Bay Entrance faults. Trenches reveal no evidence of surface faulting within 30 m [98 ft] of the ISFSI. The applicant supports these conclusions with trenching observations of fault deformation across nearby fault scarps, especially those at the College of the Redwoods, and with similarities to the style of deformation that resulted from the 1999 Chi-Chi earthquake on the Chelungpu thrust fault in Taiwan.

The staff reviewed the information in the SAR concerning surface faulting and finds it acceptable because the applicant adequately considered all necessary and relevant information in their assessment. Consistent with 10 CFR §72.92(a–b) and §72.98(a), the information in the SAR is sufficient to identify and assess potential surface faulting hazard with respect to the safe operation of the ISFSI site. The information in the SAR provides a comprehensive evaluation of the surface faulting potential. The staff finds that there is no credible radiological threat to safety from surface faulting at the site. The staff, therefore, has determined that this information is acceptable to use in other sections of the SAR to develop the design bases for the Humboldt Bay ISFSI, perform additional safety analyses, and demonstrate compliance with the regulatory requirements of 10 CFR §72.24(a), §72.90(b–d), §72.92(a–c), §72.98(b), §72.98(c)(3), and §72.122(b) with respect to this topic.

2.1.6.4 Stability of Subsurface Materials

The staff reviewed information presented by the applicant in Sections 2.6.7, 4.1, and 4.2 of the SAR. In addition, the staff reviewed supporting data reports: Data Report B (Pacific Gas and Electric Company, 2002d), Data Report C (Pacific Gas and Electric Company, 2002e), Data Report D (Pacific Gas and Electric 2002f), and Data Report E (Pacific Gas and Electric Company, 2002g). The staff also reviewed documents provided by the applicant in response to a request for additional information related to the stability of subsurface materials (Pacific Gas and Electric Company, 2004c).

Geotechnical Site Characterization

The applicant provided subsurface information from several boreholes drilled in the general area of the proposed ISFSI: 13 boreholes in 1973 by Dames and Moore, 5 boreholes in 1980 by Woodward-Clyde, and 5 boreholes in 1999 by Geomatrix (Pacific Gas and Electric Company, 2004c). Only 5 boreholes (GMX99-1-GMX99-5) were used for soil sampling or standard penetration testing. One of the sampled boreholes (GMX99-3) is located within the footprint of the proposed ISFSI pad, three (GMX99-2, GMX99-4, and GMX99-5) are close enough to rely on for site characterization of the pad foundation, but the other sampled borehole (GMX99-1) is too far from the pad. The depth of the boreholes GMX99-3 to GMX99-5 ranged from 19 to 22 m [62 to 72 ft], and GMX99-1 and GMX99-2 were drilled to depths of 29 m [95 ft] and 122 m [402 ft], respectively. None of the boreholes were continuously sampled. The applicant excavated two exploratory trenches with a total length of approximately 70 m [225 ft], and trenches were up to 4.8 m [16 ft] deep at the ISFSI site (Pacific Gas and Electric Company, 2002f, Data Report D). The trenches are shallow and, therefore, provide information only for the near-surface soil stratigraphy.

All boreholes were drilled by mud rotary drilling. Soil samples were collected using a modified California drive sampler, a standard penetration test (SPT) sampler, or a Shelby tube sampler advanced by pushing or Pitcher drilling. Samples at greater depths {61 m below [200 ft]} were obtained by coring. The SPT samplers in the GMX99-1 and GMX99-2 boreholes were driven using a rope and a cathead system with a 63.5 kg [140 pound] hammer and a 76.3 cm [30 in] drop height. An automatic trip hammer was used to drive the SPT sampler in GMX99-3, GMX99-4, and GMX99-5. The SPT resistance number, N, was determined by driving the sampler 45 cm [18 in] into the soil. SPT blowcount N was set to the number of blows needed to drive the sampler through the last 30 cm [12 in]. The approach used to perform the SPT is consistent with standard practice.

The soil samples were tested in the laboratory to evaluate physical, engineering, and index properties. The following laboratory tests were performed: moisture content and unit weight, Atterberg limits (liquid limit and plastic limit), consolidation, grain-size distribution, consolidated-undrained and unconsolidated-undrained triaxial compression, and unconfined compression. The applicant presented the soil laboratory test data and borehole logs for the five sampled boreholes in two data reports (Pacific Gas and Electric Company (2002g and 2002d, respectively).

The applicant also provided geophysical measurements from two boreholes (GMX99-1 and GMX99-2) consisting of compressional wave (P-wave) and horizontally polarized shear wave (S_H-wave) velocities (Pacific Gas and Electric Company, 2002e, Data Report C). The wave velocities are provided as functions of depth to a maximum depth of 26.5 m [87 ft] in GMX99-1 and 125.6 m [412 ft] in GMX99-2.

The applicant estimated the groundwater table to be approximately 1.8 m [6 ft] above MLLW. The groundwater level is approximately 11.3 m [37 ft] below the ground surface or about 6.7 m [22 ft] below the base of the ISFSI vault. Water table location was estimated based on P-wave velocity profiles as shown in Figures 4 and 5 of the calculation package GEO.HBIP.02.02 (Pacific Gas and Electric Company, 2003c). The water table location is consistent with measurements in the monitoring wells, as discussed in the calculation package GEO.HBIP.02.07 (Pacific Gas and Electric Company, 2003d).

The applicant classified the soils at the ISFSI site based on the laboratory and field investigations and visual observation of exposed soil stratigraphy in the exploratory trenches. The soil stratigraphy and approximate thickness of strata, as described in the calculation package GEO.HBIP.02.07 (Pacific Gas and Electric Company, 2003d), is as follows (downward from the ground surface): (i) medium dense clayey sand and stiff sandy clay {2.4 to 3.7 m [8 to 12 ft]}, (ii) very stiff silt and clays {2.4 to 3.4 m [8 to 11 ft]}, (iii) hard silty clay

{0.9 to 1.8 m [3 to 6 ft]}, (iv) very dense and silty sand {7.3 to 7.9 [24 to 26 ft]}, and (v) hard silt and silty clay with thin stratum of very stiff peat {3 m [10 ft]}. The soil below this layer is dense to very dense sand and gravel.

The staff reviewed the geotechnical site characterization information provided in the SAR and concluded that (i) the depth and thicknesses of soil layers and the water table depth at the site were determined using standard methods and procedures consistent with the staff guidance in Regulatory Guide 1.132 (U.S. Nuclear Regulatory Commission, 2003b), and (ii) the index properties and strength and compressibility of the soil layers were determined using an appropriate combination of field and laboratory testing consistent with regulatory guidance in Regulatory Guide 1.138 (U.S. Nuclear Regulatory Commission, 1978).

The staff finds that the small number of relevant boreholes and soil samples and the lack of a continuously sampled borehole leave some uncertainty regarding the subsurface conditions (e.g., such as depth, thickness, and lateral extent of soil layers) at the ISFSI site. The staff considered the applicant's information indicating that the reinforced concrete storage vault will be very stiff relative to the underlying soil and that there will not be any important-to-safety external connections to the vault. As discussed in more detail in Section 2.1.6.5 of this SER, potential deformation of the storage-vault soil foundation, owing to compression or shear failure of the soil, will likely cause a rigid rotation of the vault, but the capability of the vault to perform its safety functions is not likely to be impaired by such potential soil deformation. The staff also considered the regulatory guidance in Regulatory Guide 1.132 (U.S. Nuclear Regulatory Commission, 2003b, p. 1.132-8), which states that, "... foundation requirements should be considered in choosing the actual distribution, number, and depth of borings and other excavations for a site." Based on these considerations, the staff determined that, despite some uncertainty in the subsurface conditions, the information provided by the applicant is sufficient to assess the capability of the storage vault to perform its safety functions as required under 10 CFR §72.122(b).

The staff reviewed the information presented in the SAR and determined that the geotechnical site characterization has been adequately described and assessed. The staff, therefore, concludes that the geotechnical site characterization information presented in the SAR is adequate for use in other sections of the SAR to develop the design bases for the Humboldt Bay ISFSI, perform additional safety analysis, and demonstrate compliance with the regulatory requirements in 10 CFR §72.103(c–d) and §72.122(b).

Liquefaction Potential

The staff reviewed the information provided in Section 2.6.7 of the SAR and the calculation package GEO.HBIP.02.02 (Pacific Gas and Electric Company, 2003c) regarding liquefaction potential at the ISFSI site. The staff also reviewed information provided by the applicant in response to a request for additional information regarding liquefaction potential (Pacific Gas and Electric Company, 2004c–e).

The applicant addressed the safety of the proposed facility with respect to liquefaction by concluding that the subsurface soils are not susceptible to liquefaction. The applicant cited SPT and geophysical data from the site to support this conclusion.

As discussed previously, four of the boreholes (GMX99-2–GMX99-5) are in the vicinity of the proposed storage vault, and the SPTs in these borings were performed at reasonable depths below the vault. The other borings are located too far from the footprint of the vault to be relevant in this analysis. The staff considered only the data from the four boreholes above in assessing the applicant's SPT information regarding liquefaction potential.

The applicant evaluated the liquefaction potential of the ISFSI based on SPT blow counts (i.e., SPT resistance, N) and the empirical relationship presented by Youd, et al. (2001) between the blow count and seismically induced stress. This method outlined in Youd, et al. (2001) is a modification of the procedure proposed by Seed, et al. (1985). The method is based on a relationship between cyclic stress ratio (CSR) and the normalized blow count $(N_1)_{60}$ [e.g., calculation package GEO.HBIP.02.02 (Pacific Gas and Electric Company, 2003c), Figure 3], where $(N_1)_{60}$ is the SPT blow count normalized to an overburden pressure of approximately 100 kPa (1 ton/ft^2) and a hammer efficiency of 60 percent. The applicant determined the clean sand equivalent of the normalized blow count, $(N_1)_{60\text{-}CS}$ using the following equation:

$$(N_1)_{60\text{-}CS} = (N_1)_{60} + \Delta(N_1)_{60} \tag{2-1}$$

Where $\Delta(N_1)_{60}$ is the correction for the fine-particle content and is defined by the following equation:

$$\Delta(N_1)_{60} = \alpha + (\beta - 1)(N_1)_{60} \tag{2-2}$$

where α and β are coefficients related to the fine-particle content of the soil. The two equations used by the applicant are consistent with equations provided by Youd, et al. (2001). The applicant also applied other corrections suggested by Youd, et al. (2001) (e.g., for borehole diameter, rod length, and sampling method), as appropriate. The staff finds that the approach used by the applicant is based on standard methodology in accordance with the guidance in Regulatory Guide 1.198 (U.S. Nuclear Regulatory Commission, 2003c).

The applicant provided values of $(N_1)_{60\text{-}CS}$ plotted against depth below the ground surface in Figure 2 of calculation package GEO.HBIP.02.02 (Pacific Gas and Electric Company, 2003c) and assessed the liquefaction potential for soil layers based on the value of $(N_1)_{60\text{-}CS}$ relative to a threshold value of 30. The applicant concluded that a soil layer with a value of $(N_1)_{60\text{-}CS}$ greater than 30 blows per foot is not susceptible to liquefaction considering the relationships provided by Youd, et al. (2001) and reproduced in Figure 3 of the calculation package GEO.HBIP.02.02 (Pacific Gas and Electric Company, 2003c). As indicated in Figure 3, the value of CSR that may cause liquefaction approaches infinity asymptotically at approximately $(N_1)_{60\text{-}CS} = 30$. The value of CSR (τ_{av}/σ'_{vo}), which represents the seismic demand induced in the soil from earthquake ground motion, is evaluated using the following equation given by Youd, et al. (2001)

$$\tau_{av}/\sigma'_{vo} = 0.65(a_{max}/g)(\sigma_{vo}/\sigma'_{vo})r_d \tag{2-3}$$

where a_{max} is the peak horizontal acceleration at the ground surface; g is the gravitational acceleration; σ_{vo} and σ'_{vo} are total and effective vertical stresses, respectively; and r_d is the stress reduction coefficient, based on an empirical relationship provided in Youd, et al. (2001).

The design basis ground motion at the ISFSI site gives an a_{max} of 1.3 g, based on Figure 2.6-72 of the SAR. The value of CSR for the soil layers below the groundwater table to a depth of approximately 18.3 m [60 ft] is estimated to be approximately 0.7 or greater. The relationship provided by Youd, et al. (2001) indicates that liquefaction susceptibility is likely insensitive to CSR for values of $(N_1)_{60\text{-}cs} \geq 30$. The empirical data supporting the Youd, et al. (2001) relationship, however, is limited to the values of CSR smaller than 0.6.

The applicant relied on the Youd, et al. (2001) relationship to conclude in Section 2.6.7 of the SAR that the ISFSI site is not susceptible to liquefaction because the majority of the $(N_1)_{60\text{-}CS}$ values for the site soils are greater than 30. Even if the Youd, et al. (2001) relationship were applicable, the applicant's data (Pacific Gas and Electric Company, 2003c; calculation package GEO.HBIP.02.02) indicate two $(N_1)_{60\text{-}CS}$ values smaller than 30. The two values appear to be significant because they suggest the occurrence of an approximately 3-m [10-ft] thick soil layer that is potentially susceptible to liquefaction. The potentially liquefiable soil layer was apparently encountered at a depth of approximately 14 m [46 ft] {elevation of 1.2 m [4 ft] below MLLW} in borehole GMX99-2 and approximately 16 m [53 ft] in borehole GMX99-3. The second borehole (GMX99-3) is the only borehole located within the footprint of the proposed storage vault foundation.

In response to the staff's request for additional information (Pacific Gas and Electric Company, 2004c), the applicant provided information indicating the occurrence of a relatively thin, silty soil layer at a depth of approximately 15 m [50 ft] below the ground surface at the ISFSI site. The thin layer encountered in the four boreholes (GMX99-2–GMX99-5) is approximately 1.5 m [5 ft] thick and varies in characteristics from low-plastic inorganic clay (CL) to low-plastic silt (ML). The thin layer is overlain by a thick stiff clay and underlain by dense sand and gravel with silt and clay lenses. The applicant also provided information to support the conclusion that the relatively low $(N_1)_{60\text{-}CS}$ values determined for the silty soil layer in boreholes GMX99-2 and GMX99-3 do not indicate a susceptibility to liquefaction. First, the applicant stated that the $(N_1)_{60\text{-}CS}$ value of 24 originally obtained for the silty soil layer in borehole GMX99-2 resulted from an incorrect interpretation of the measured SPT blow count. The applicant explained that the error occurred because the sampler was blocked by gravel during the attempted penetration of the gravel and sand layer. As a result, the underlying silty clay (or silt) layer was not reached, nor sampled. The applicant reinterpreted the $(N_1)_{60\text{-}CS}$ value as 32. Second, the applicant cited Regulatory Guide 1.198 (U.S. Nuclear Regulatory Commission, 2003c) to support the supposition that a low SPT blow count for a plastic fine-grained soil does not necessarily indicate liquefaction susceptibility because the low blow count is typically more indicative of the plasticity than the relative density of the soil. Third, the applicant provided analysis of shear wave velocities measured in borehole GMX99-2 that indicated soils encountered in the borehole are not susceptible to liquefaction. The analysis was performed based on procedures described in National Center for Earthquake Engineering Research (1997), Youd, et al. (2001), and Andrus and Stokoe (2000, 2004). Fourth, the applicant provided an external expert analysis (Pacific Gas and Electric Company, 2004e), which concluded that the two relatively low $(N_1)_{60\text{-}CS}$ values do not represent any appreciable liquefaction susceptibility for the site. The analysis indicated that the thin soil layers indicated by the low $(N_1)_{60\text{-}CS}$ values are surrounded by much thicker layers not susceptible to liquefaction, such that any liquefaction of the thin layers would be isolated and cause no detrimental effects to the site (Pacific Gas and Electric Company, 2004e).

The staff did not accept the first two arguments presented by the applicant; however, the staff does accept the third and fourth arguments presented. First, the data provided by the applicant were deemed insufficient to support the argument that a subset of the data was incorrect, especially since the data being judged as incorrect by the applicant indicate the potential occurrence of undesirable material behavior. Second, the information cited from Regulatory Guide 1.198 (U.S. Nuclear Regulatory Commission, 2003c) applies to plastic clays, whereas the applicant's data indicate that the soil layer of concern varies in characteristics from low-plastic CL to low-plastic ML. However, the applicant's geophysical and SPT data indicate that the preponderance of soils at the site are not susceptible to liquefaction. Even if lenses or thin layers of liquefaction-susceptible soil were present, any liquefaction of such lenses or thin layers will likely be isolated. Deformation resulting from such liquefaction may cause differential settlement of the ISFSI vault. The magnitude of such differential settlement will likely be negligible considering the small thickness of the silty soil layer relative to the total thickness of soil that may affect the behavior of the storage vault.

The staff reviewed the information presented in the SAR and determined that the liquefaction potential has been adequately described and assessed. The staff, therefore, concludes that the information presented in the SAR regarding the liquefaction potential of the storage vault foundation is adequate for use in other sections of the SAR to develop the design bases for the Humboldt Bay ISFSI and perform additional safety analysis, and demonstrate compliance with the regulatory requirements in 10 CFR §72.103(c–d) and §72.122(b).

2.1.6.5 Slope Stability

The staff reviewed Section 2.6.7 of the SAR, which provides an evaluation of the stability of natural slopes. The staff also reviewed applicant responses to the staff's request for additional information (Pacific Gas and Electric Company, 2004c).

The proposed ISFSI storage vault is located on a low and relatively flat terrain referred to as Buhne Point Hill. The hill has a maximum elevation of approximately 23 m [75.5 ft], but based on contour maps provided by the applicant, the elevation at the proposed location of the storage vault is 13.4 m [44 ft]. Buhne Point Hill extends approximately 480 m [1,575 ft] east-west and varies in width from 50 to 180 m [164 to 591 ft]. Buhne Point Hill is bordered on the north by a coastal bluff that drops off steeply (slope ratio of approximately 1:1) to the shore of Humboldt Bay. The hill is bordered on the east and south by the gentle slopes of a tidal marsh. The west side of the hill rises gently to the village of King Salmon, which is built on fill over tidal marsh and beach deposits.

Given these site conditions, potential slope stability problems at the facility are (i) landward retreat of the bluff toward the storage vault, (ii) rotational sliding along a surface that daylights at the bluff, (iii) a slide eastward or southward from the vault, or (iv) failure of the discharge-canal slope near the transporter route. Information provided by the applicant indicates that the retreat of the bluff toward the site is unlikely because such retreat was arrested by the placement of riprap along the base of the bluff in the early 1950's. The applicant analyzed the potential for a northward slide (bluff-side slope) or a southward slide (plant-side slope) considering static loading from the storage vault and dynamic loading from the design-basis ground motion. The potential for an eastward slide is bounded by the analysis for southward sliding. Although the east and south slopes have similar inclinations of 2- to 6-percent grade [based on Figure 7.1 in GEO.HBIP.02.07 (Pacific Gas and Electric Company, 2003d)], the south slope daylights into an existing excavation for fuel oil storage tanks, which makes failure of the east slope less likely than the south slope. The applicant also provided an analysis to evaluate the potential for the instability of the slope along this transporter route sliding toward the discharge canal. The staff reviewed these analyses to assess the safety of the proposed facility with respect to slope stability.

The applicant used information from one borehole (GMX99-4) to develop the soil stratigraphy and strength parameters for stability analysis of the bluff-side and plant-side slopes. To extrapolate the borehole information through the domain of the stability analysis, the applicant assumed that the soils encountered in the borehole extend laterally as horizontal layers, as depicted in Figures 7-6 and 7-7 of calculation package GEO.HBIP.02.07 (Pacific Gas and Electric Company, 2003d). This assumption that soil layers are horizontally continuous is inconsistent with the reasoning provided by the applicant to support its analysis of liquefaction potential. To address the staff's concerns regarding liquefaction, the applicant had previously asserted that a zone of relatively low SPT blow count encountered in boreholes GMX99-2 and GMX99-3 likely represents a laterally discontinuous and weak soil layer. The applicant did not account for the potential occurrence of such soil layers in choosing a model for its slope stability analysis. The occurrence of weak and laterally discontinuous layers is a consideration for slope stability analysis because such relatively weak soil may form a preferential path for a potential failure surface, which would result in an average shear resistance smaller than the shear resistance used in the applicant's analysis. The applicant based its soil strength parameters on standard laboratory testing, such as unconsolidated, undrained triaxial testing for cohesive soils and consolidated, undrained triaxial testing for dense sand [Figures 7-6 and 7-7, calculation package GEO.HBIP.02.07 (Pacific Gas and Electric Company, 2003d)]. To characterize the dynamic behavior of the soils, the applicant used measured shear wave velocities from boreholes GMX99-1 and GMX99-2 and used modulus reduction and damping data from the literature to determine the variation of shear modulus and damping with shear strain during a potential earthquake. The approach used by the applicant to determine values of soil parameters for static and dynamic analysis is consistent with standard practice, but the use of soil specimens from only one borehole for strength data results in some uncertainties in the strength parameter values and shapes of potential failure surfaces used for stability analysis. The potential impacts of such uncertainties are discussed in this section of the SER under "Potential Effects of Slope Instability on the Storage Vault."

The applicant considered a groundwater level at 1.8 m [6 ft] above MLLW {i.e., approximately 11.6 m [38 ft] below the ground surface} in its slope stability analysis. This assumed elevation is conservative with respect to the groundwater information reviewed previously in this section. Potential short-term increase in the groundwater level (e.g., during a tsunami event) was not accounted for in the applicant's slope stability analysis and is evaluated further in this section of the SER under "Stability of Slopes under Tsunami Conditions."

<u>Retreat of the Humboldt Bay Bluff toward the ISFSI</u>

The ISFSI site faces the entrance to Humboldt Bay and is located on Buhne Hill approximately 20 m [65 ft] from the edge of Red Bluff. The SAR notes that Red Bluff experienced 379 to 468 m [1,244 to 1,535 ft] of shoreline retreat between 1858 and 1952. The shoreline was reinforced in the 1950s with a riprap berm along the beach. The riprap berm was later reconstructed with larger riprap in 1989. The current riprap consists of four layers of 9 ton stones and is designed to withstand 3.7 to 4.0 m [12 to 14 ft] high waves. In response to the staff's request for additional information, the applicant provided a detailed analysis of the stabilization of the bluff since riprap was installed along the beach (Pacific Gas and Electric Company, 2004c). In the analysis, the applicant demonstrates that shoreline retreat was essentially abated by the riprap berm. The applicant concludes that the riprap is sufficient to withstand storm damage and even tsunami wave damage to the bluff (Pacific Gas and Electric Company, 2004c). The applicant also indicates it will monitor erosion of the bluff and take corrective measures if necessary (Pacific Gas and Electric Company, 2004c).

The staff concludes that the information provided in the SAR regarding the potential retreat of the Humboldt Bay bluff is adequate for use in other sections of the SAR to perform additional safety analysis and to demonstrate compliance with the regulatory requirements in 10 CFR §72.103(d) and §72.122(b).

Long-Term Stability of Slopes

The applicant evaluated the long-term stability of the plant-side and bluff-side slopes considering the self weight of soil layers and additional static loading from the storage vault [SAR Section 2.6.7.4 and calculation package GEO.HBIP.02.07 (Pacific Gas and Electric Company, 2003d)]. The evaluation was based on a two-dimensional limit-equilibrium analysis of the slopes using cross sections identified in Figure 7-1 of calculation package GEO.HBIP.02.07 (Pacific Gas and Electric Company, 2003d). The analysis consisted of numerically searching for a sliding mass with a minimum factor of safety from randomly selected circular slip surfaces. The analysis was performed using a method of slices based on the Spencer approach of satisfying force and moment equilibria (Abramson, et al., 2002). The analysis approach used by the applicant is consistent with standard practice.

The applicant calculated the values of the safety factor in the range of 2.7 to 4.9 from the limit equilibrium analysis. Values of the safety factor in the range of 1.25 to 1.5 indicate a stable slope based on accepted practice and NRC staff guidance (National Research Council Transportation Research Board, 1978, p. 172; Hoek and Bray, 1977; U.S. Nuclear Regulatory Commission, 1977). The values of the safety factor calculated by the applicant are significantly greater than this range. However, the representative values of long-term safety factor for the slopes at the ISFSI site may be smaller than those calculated by the applicant because of the potential existence of weak soil layers and the effect of such layers on the potential failure surfaces, as discussed earlier. Therefore, the staff's assessment of the capability of the storage vault to perform its safety functions included a consideration of potential instability of the ISFSI hill slopes under long-term static loading conditions. As discussed later in this section of the SER (under "Potential Effects of Slope Instability on the Storage Vault"), the staff finds that the capability of the storage vault to perform its safety functions would not be impaired because of potential slope instabilities.

The staff, therefore, concludes that the information provided in the SAR regarding slope stability under long-term static-loading conditions is adequate for use in other sections of the SAR to perform additional safety analysis and demonstrate compliance with regulatory requirements in 10 CFR §72.103(d) and §72.122(b).

Stability of Slopes under Tsunami Conditions

The staff's review of the applicant's information, as discussed in Section 2.1.4.6 of this SER, indicates that water levels at the ISFSI site can rise to 6.4 to 11 m [21 to 36 ft] above MLLW during a tsunami event. Such a water level rise can increase groundwater pressure head by 4.6 to 9.1 m [15 to 30 ft] above the groundwater pressure used in the applicant's slope stability analysis. The increased groundwater pressure would persist after the tsunami for a length of time that depends on the permeability and subsurface geometry of the soil layers. Therefore the staff's assessment of the capability of the storage vault to perform its safety functions includes a consideration of the potential instability of the ISFSI hill slopes under elevated water pressures due to a tsunami event. Despite this consideration, as discussed later in this SER (under "Potential Effects of Slope Instability on the Storage Vault"), the staff finds that the capability of the storage vault to perform its safety functions would not be impaired.

The staff, therefore, concludes that the information provided in the SAR is adequate for considering the potential effects of a tsunami on slope stability and for use in other sections of the SAR to perform additional safety analysis and demonstrate compliance with the regulatory requirements in 10 CFR §72.103(d) and §72.122(b).

Stability of Slopes under Seismic Loading Conditions

The applicant evaluated the stability of slopes under seismic loading conditions using an analysis based on the Newmark (1965) approach. The Newmark approach consists of calculating potential seismically induced displacements, which are interpreted as an instability index, using guidelines based on empirical data. The applicant's calculation of seismically induced displacements is provided in Section 2.6.7.5 of the SAR and calculation package GEO.HBIP.02.07 (Pacific Gas and Electric Company, 2003d). The applicant provided additional information in response to the staff's requests for additional information (Pacific Gas and Electric Company, 2004c, Attachment 2-7). The applicant concluded that potential seismically induced slope displacements indicate that the slopes would be stable during potential seismic events. The applicant also concluded that the potential seismically induced displacement would not cause radiological consequences to the public and that the resulting potential rotation of the storage vault would not impair cask retrievability.

The applicant analyzed slope displacement using two sets of ground motion time histories that produced the largest displacements in a rigid block Newmark-type analysis. The time histories are consistent with the design-basis ground motion as reviewed by the staff in Section 2.1.6.2 of this SER. The applicant transformed the ground motion time histories twice to obtain the input for the analysis. First, the horizontal component of the surface ground motion was rotated to the direction of the slope cross section. Second, the rotated time histories were transformed by deconvolution to obtain input time histories applied at the base of the slope cross-section in a dynamic finite element model (Pacific Gas and Electric Company, 2003a). The seismically induced displacements were calculated through a series of analyses based on an approach proposed by Newmark (1965). The calculation consists of three steps for a selected potentially unstable mass.

First, the value of yield acceleration, k_y, was calculated through a limit-equilibrium analysis similar to the analysis described previously in this section (under "Long Term Stability of Slopes"). The parameter k_y is the horizontal acceleration that would cause the value of the safety factor against sliding of the potentially unstable mass to decrease to 1.0 from the value calculated for the long-term static condition. The yield acceleration is represented in the analysis as a static horizontal force k_yM, where M is the mass of the potentially unstable mass. The calculation of k_y is documented in calculation package GEO.HBIP.02.07 (Pacific Gas and Electric Company, 2003d). The calculated values of k_y are 0.69 g for the bluff-side slope and 0.66 g for the plant-side slope.

Second, the seismic coefficient time history (i.e., an average horizontal acceleration time history, a_{ht}) for the potentially unstable mass was evaluated in calculation package GEO.HBIP.02.07 (Pacific Gas and Electric Company, 2003d). The average acceleration time history is typically based on the ratio F_t/M where F_t is the resultant down-slope force along the potential failure surface (e.g., Kramer, 1996, p. 446). The applicant conducted two-dimensional dynamic finite element analysis using equivalent linear approach for calculating seismic coefficient time histories. The seismic coefficient time histories for the bluff-side and plant-side slopes for two seismic motions are provided in Figures 7-14 through 7-17 of calculation package GEO.HBIP.02.07 (Pacific Gas and Electric Company, 2003d).

Third, the difference $a_{ht} - k_y$ for $a_{ht} > k_y$ was integrated twice with respect to time to obtain a displacement, referred to as the Newmark displacement. This evaluation is documented in Section 2.6.7.5 of the SAR and in calculation package GEO.HBIP.02.07 (Pacific Gas and Electric Company, 2003d). The calculated displacements, as documented in Table 7-6 of GEO.HBIP.02.07 (Pacific Gas and Electric Company, 2003d) are 6.1 to 15.2 cm [0.2 to 0.5 ft] for the bluff-side slope and 9.1 to 143.3 cm [0.3 to 4.7 ft] for the plant-side slope (Pacific Gas and Electric Company, 2003d, Table 7-6).

The applicant interpreted the calculated displacements using a guideline recommended by the California Department of Water Resources, Division of Safety of Dams (Babbit and Verigin, 1996). The guideline recommends three stability levels for earth dams based on displacements calculated using the Newmark approach (Babbit and Verigin, 1996): (i) a displacement of 0 to 1.52 m [0 to 5 ft] is considered sustainable; (ii) a displacement of 1.52 to 3.05 m [5 to 10 ft] is considered serious, and any related structural behavior is less predictable as the displacement approaches 3.05 m [10 ft]; and (iii) displacements greater than 3.05 m [10 ft] indicate continuing (post seismic) instability. The applicant concluded based on the dam safety guideline that ISFSI hill slopes will be stable even if subjected to ground motion from a design-basis earthquake. The applicant's conclusion relies on the calculated maximum displacement being equal to 1.4 m [4.7 ft], which in the applicant's view implies that the slopes belong to the first stability level based on the California dam safety guideline (Babbit and Verigin, 1996).

The applicant interpreted its calculated Newmark displacements as an absolute measure of potential seismically induced displacements of the slope material. However, in the staff's view, the calculated displacements should be considered order of magnitude estimates of potential seismically induced displacements because of uncertainties in soil properties, subsurface geometry of potential failure surfaces, and approximate representation of the distribution of seismically induced ground motion within the soil. Abramson, et al. (2002) for example, suggest that the Newmark displacement should be treated only as a qualitative indication of stability. The applicant's calculated displacements, interpreted as an order of magnitude estimate, indicate that the slopes could potentially experience several feet of soil deformation during a design-basis earthquake. Several feet of deformation would imply the second stability level (i.e., serious conditions with structural behavior increasingly less predictable) based on the California dam safety guideline chosen by the applicant (Babbit and Verigin, 1996). Another guideline proposed by the State of California for interpreting Newmark slope displacements (State of California Division of Mines and Geology, 1997, Chapter 5) recommends the following stability levels based on the Newmark displacements: (i) displacements of 0 to 10 cm [0 to 3.94 in] are unlikely to correspond to serious landslide movement or damage; (ii) for displacements of 10 to 100 cm [3.94 to 39.4-in] slope deformation may be sufficient to cause serious ground cracking or enough strength loss to result in continuing (post seismic) failure; and (iii) displacements greater than 100 cm [39.4 in] are very likely to correspond to damaging landslide movement, and such slopes should be considered unstable. The applicant argued that the State of California guideline is not applicable to the ISFSI slopes. Although the two guidelines differ in their definition of the stability categories, they both lead to the same conclusion that the several feet of slope displacement estimated based on the applicant's analysis indicates that the ISFSI slopes will likely be unstable during the design basis seismic events. Based on these considerations, the staff concludes that potential instability of slopes at the ISFSI site during a design-basis earthquake needs to be accounted for in assessing the capability of the storage vault to perform its safety functions, as required under 10 CFR §72.122(b). The staff's assessment of the capability of the storage vault to perform its safety functions, therefore, includes a consideration of the potential instability of the ISFSI hill slopes under seismic loading conditions. Even with consideration of the potential slope instability, the staff finds that the capability of the storage vault to perform its safety functions would not be impaired, as discussed in this section of the SER (under "Potential Effects of Slope Instability on the Storage Vault").

The staff, therefore, concludes that the information provided in the SAR regarding slope stability under seismic loading conditions is acceptable for use in other sections of the SAR to perform additional safety analysis and demonstrate compliance with regulatory requirements in 10 CFR §72.103(c–d) and §72.122(b).

Potential Effects of Slope Instability on the Storage Vault

Any deformation of the subsurface material at the ISFSI site, such as may be associated with slope instability, will likely cause a rigid-body rotation of the below-grade storage vault. The vault is expected to behave in a rigid manner because it is stiff relative to the soil. There are no important-to-safety connections to the vault that may rupture or be misaligned if the vault were to experience a rigid rotation. Such rotation of the vault is of concern only because of its potential impact on the retrievability of the casks.

The applicant estimated a maximum vault rotation of 0.67° owing to a slope displacement of 1.4 m [4.7 ft]. The applicant based its calculation of the rotation on the vault being rigid compared to the surrounding soil and soil deformation being localized in a narrow zone along the potential slip surface. The vault rotation was calculated with respect to the vertical axis of the vault and corresponds to a tilt of approximately 5 cm [1.96 in]. The calculated tilt is smaller than the cask-to-vault clearance of 14.0 cm [5.5 in]. The applicant concluded that such a tilt would not interfere with cask retrieval. The staff considered the effects of a slope displacement of 3.05 m [10 ft] using the applicant's approach, which indicates a vault rotation of 1.4° and tilt of 10.7 cm [4.2 in]. The vault rotation under such a condition would be smaller than the tolerable rotation considering cask retrievability.

The potential rotation and tilt of the vault, however, may exceed the values calculated using this approach because the soil in contact with the vault may not rotate in a rigid manner as assumed in the calculation. The applicant acknowledged that potential rotation of the vault could be larger because of this reason (Pacific Gas and Electric Company, 2004c). Any soil deformation associated with slope instability will likely be distributed among several slip surfaces instead of being localized on one slip surface as assumed in the applicant's calculation. Slip surfaces may develop close to the vault in association with more deep-seated slip surfaces. Such a deformation mode could cause a rotation of the vault that exceeds the rotation calculated with reference to one deep-seated slip surface. A rotation of the vault large enough to interfere with the vertical extraction of the cask can potentially result from slope instability. The vault also can potentially be submerged in mud due to soil deformation associated with slope instability. The applicant indicated that the capability of the vault to perform its safety functions would not be impaired even if the vault rotation were large enough to cause the casks to lie in a horizontal position (Pacific Gas and Electric Company, 2004c). The applicant also suggested that a crane could be used to remove the casks from the vault, if necessary. The staff finds that the capability of the storage vault to perform its safety functions would not be impaired even if the vault were to rotate or be submerged in mud due to potential slope instability.

The staff, therefore, concludes that the information provided in the SAR regarding slope stability at the ISFSI site is adequate for use in other sections of the SAR to perform additional safety analysis and demonstrate compliance with the regulatory requirements in 10 CFR §72.103(c–d) and §72.122(b).

Stability of Slope Along Transporter Route

The staff reviewed the information presented by the applicant in Section 2.6.7.6 of the SAR on the stability of the slope along the critical location where the transporter route is closest to the discharge canal. The staff also reviewed the information provided by the applicant in response to its request for additional information (Pacific Gas and Electric Company, 2004c). The applicant discussed the static slope stability and slope displacement during a seismic event in calculation package GEO.HBIP.02.08 (Pacific Gas and Electric Company, 2003e). The applicant used a 50-year return period uniform hazard spectrum to assess the stability of the slope. As discussed in Section 2.1.6.2 of this SER, the staff finds that a 50-year return period ground motion with peak horizontal ground acceleration of 0.4 g is appropriate during the transporter movement. Since the yield acceleration (0.84 g) of the slope evaluated in GEO.HBIP.02.08 (Pacific Gas and Electric Company, 2003e) is higher than the peak ground acceleration, the applicant concluded that permanent slope deformation resulting from the seismic ground motion commensurate with the return period during transit along the critical section is negligible. The staff concludes that the stability of the slope at the critical location close to the discharge canal along the transporter route will not be impaired by a seismic event during cask transfer.

The staff, therefore, concludes that the information provided in the SAR regarding slope stability along the transporter route during cask transfer is adequate and demonstrates compliance with the regulatory requirements in 10 CFR §72.103(c–d) and §72.122(b).

2.2 Evaluation Findings

Based on review of the information in the SAR, the staff makes the following findings regarding site characteristics of the Humboldt Bay ISFSI:

- The SAR adequately describes the site location, site description, population distribution and trends, and land and water use in compliance with 10 CFR §72.24(a), §72.90(a–f), §72.98(a–c), and §72.100(a).

- The SAR adequately describes and assesses nearby industrial, transportation, and military facilities with sufficient identification of the facilities that may pose a hazard to the ISFSI in compliance with 10 CFR §72.24(a) and §72.94(a). Potential hazards from these facilities are more fully evaluated in Chapter 15 of this SER.

- Regional climatology and local meteorology have been sufficiently characterized in compliance with 10 CFR §72.24(a), §72.90(a–f), §72.92(a–c), §72.98(a–c), and §72.122(b), including the application of meteorological descriptions previously accepted by the staff for the co-located HBPP as allowed in §72.40(c). The staff finds that an onsite meteorological program is not necessary because of the applicability of the information available from the National Weather Service station on Woodley Island, due to its proximity to the HB ISFSI site.

- Surface hydrologic conditions, including assessment of dam failure, stream flooding, surge and seiche flooding, tsunami inundation, and ice flooding, were adequately characterized and evaluated in compliance with the regulatory requirements in 10 CFR §72.24(a), §72.90(a–f), §72.92(a–c), §72.98(a–c), §72.100(b), §72.120(a), and §72.122(b). The staff finds that significant flooding will not occur at the ISFSI site. Even in the event of severe flooding, the HI-STAR HB casks can be temporarily wetted without harm, and will retain their ability to contain the waste without radioactive effluents.

- The SAR and Environmental Report provided an adequate description of the subsurface hydrology in compliance with the regulatory requirements in 10 CFR §72.98(a–c),§72.100(b), and §72.122(b)(4). The staff finds that groundwater quality at the site will not be adversely affected by the ISFSI, nor will groundwater conditions at the HBPP site impact construction and operation of the ISFSI.

- Geology and seismology of the site have been adequately characterized and assessed in compliance with the regulatory requirements in 10 CFR §72.90(a–d), §72.92(a–c), §72.94(a–c), §72.98(a–c), §72.103 (b–f), §72.120(a), and §72.122(b)(4). The DE for the ISFSI is conservatively based on the 84th percentile deterministic acceleration spectra that would result from coseismic rupture of the Cascadia subduction megathrust and nearby Little Salmon Fault system. The DE spectra envelops the 2,000-year return period probabilistic uniform hazard spectra specified in Regulatory Guide 3.73 (U.S. Nuclear Regulatory Commission, 2003a). The 25- and 50-year DE spectra that are used for transient operations, which include cask movement and vault loading operations, are appropriate and consistent with the historical earthquake record. The SAR also demonstrates that despite the presence of nearby thrust faults, the ISFSI is not likely to be disrupted by surface faulting.

- The geotechnical site characterization has been adequately described and assessed in compliance with the regulatory requirements in 10 CFR §72.103(c–d) and §72.122(b). The staff concludes that the geotechnical site characterization information presented in the SAR is acceptable for use in other sections of the SAR to develop the design bases for the Humboldt Bay ISFSI and perform additional safety analysis. The staff determined that the liquefaction potential has been adequately described and assessed in compliance with the regulatory requirements in 10 CFR §72.103(c–d) and §72.122(b).

- The stability of the slopes at the ISFSI site and transporter route has been adequately described and assessed in compliance with regulatory requirements in 10 CFR §72.103(c–d) and §72.122(b). The applicant provided sufficient information for the staff to conclude that the capability of the storage vault and the HI-STAR HB overpack to perform their safety functions will not be impaired during cask transfer to the ISFSI and during interim storage at the ISFSI.

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3 OPERATION SYSTEMS

3.1 Conduct of Review

This chapter of the Safety Evaluation Report (SER) evaluates the descriptions of all operations presented in the Safety Analysis Report (SAR) (Pacific Gas and Electric Company, 2004a) including systems, equipment, and instrumentation, for clarity and completeness. Particular emphasis was placed on how operation systems relate to handling and storing spent nuclear fuel (SNF), confining nuclear material, and managing expected and potential radiological dose. The review of the operation systems included selected sections of Chapters 3, "Principal Design Criteria;" 4, "ISFSI Design;" 5, "ISFSI Operations;" 8, "Accident Analysis;" 9, "Conduct of Operations;" and 10, "Operating Controls and Limits" of the SAR and documents cited in the SAR.

On-site cask handling outside the refueling building (RFB) and storage activities associated with the proposed Humboldt Bay Independent Spent Fuel Storage Installation (ISFSI) are operations to be covered by the 10 CFR Part 72 Humboldt Bay ISFSI license and are part of this review.

Certain fuel movement and cask handling operations in the Humboldt Bay Power Plant (HBPP) RFB are operations covered by a separate HBPP 10 CFR Part 50 license amendment request (Pacific Gas and Electric Company, 2004b). These activities are not part of this review.

The dry cask storage system to be used at the proposed facility is the HI-STAR HB System, which is a modified version of the HI-STAR 100 cask system (Holtec International, 2002). The U.S. Nuclear Regulatory Commission (NRC) has certified the HI-STAR 100 cask system for use by 10 CFR Part 50 licensees under the general license provisions of 10 CFR §72.210 (U.S. Nuclear Regulatory Commission 2001a). Thus, where applicable, the staff relied on the review carried out during the certification process of that cask system, as documented in the HI-STAR 100 Cask System SER (U.S. Nuclear Regulatory Commission, 2001b). The HI-STAR HB system consists of the MPC-HB, which is a seal-welded canister containing up to 80 Humboldt Bay SNF assemblies; optional damaged fuel containers, which can be inserted into an MPC-HB and can hold an intact fuel assembly or damaged fuel; and the HI-STAR HB storage overpack (or cask).

The review considered how the SAR and related documents address the regulatory requirements of 10 CFR §72.24(b), §72.24(f), §72.40(a)(3), §72.40(a)(5), §72.40(a)(13), §72.44(c)(1), §72.44(c)(2), §72.44(c)(3), §72.104(b), §72.104(c), §72.122(f), §72.122(h)(1), §72.122(h)(4), §72.122(i), §72.122(j), §72.122(k), §72.122(l), §72.126(a), §72.126(b), §72.126(c), §72.128(a)(1), §72.150, and §72.166. Complete citations of these regulations are provided in the Appendix of this SER.

3.1.1 Operation Description

The staff reviewed Section 5.1 of the SAR, which describes the general operating functions to be performed during preparation for storage, transfer, actual storage, and potential unloading operations of the HI-STAR HB dry cask spent fuel storage system.

The Humboldt Bay ISFSI will be located on the site of the HBPP. The operation of the Humboldt Bay ISFSI will use facilities and personnel that are part of the HBPP, and ISFSI operations will be conducted in conjunction with the operations of the power plant. The Humboldt Bay ISFSI will use structures, systems, and components (SSCs) that are designed, fabricated, constructed, and used in accordance with accepted industry standards during the operation sequence for cask system loading, sealing, testing, and onsite transfer and handling. These practices, along with the passive nature of the spent fuel storage system, ensure that the Humboldt Bay ISFSI operations will not pose an undue risk to the safe conduct of activities at the HBPP.

Figure 5.1-1 of the SAR shows the operation sequence flowchart for cask system loading, sealing, testing, and storage operations. Upon receipt, the HI-STAR HB overpack is verified to be free of foreign material, and the top lid sealing surface is visually inspected for damage. A clean and empty multi-purpose canister (MPC-HB) is then inserted into the overpack, and the HI-STAR HB overpack is transferred to the RFB using the cask transfer rail dolly.

Cask handling, SNF loading, and MPC-HB and overpack preparation for storage all take place in the RFB. Some of these activities are governed by the 10 CFR Part 50 license. The HI-STAR HB cask will be placed in the cask loading area of the spent fuel pool (SFP) using a davit crane. The transfer of SNF to the MPC-HB will use a combination of fixtures and equipment designed by the cask system vendor and equipment specifically designed for the Humboldt Bay ISFSI. Consistent with the generic requirements of the HI-STAR 100 Final Safety Analysis Report (FSAR) (Holtec International, 2002) and in accordance with the site specific requirements of the Humboldt Bay ISFSI technical specifications (Pacific Gas and Electric Company, 2004c, Attachment C), SNF assemblies chosen for loading are assigned specific storage locations in the MPC-HB. Damaged fuel will only be placed in the MPC-HB in damaged fuel containers. Fuel loading and verification of correct fuel assembly placement in the MPC-HB will be conducted in accordance with approved fuel handling procedures (Holtec International, 2002; Pacific Gas and Electric Company, 2004c). The potential for misloading the MPC-HB is discussed in Chapters 8 and 15 of this SER. Records will be kept to track each fuel assembly, its assigned MPC-HB, and its specific fuel storage location. Accountability and control of SNF will be maintained at all times during loading, transfer, and storage operations. The Humboldt Bay ISFSI will be treated as a separate material balance area from the HBPP.

After the insertion of SNF assemblies into the MPC-HB, the HI-STAR HB cask will be removed from the SFP and placed on the cask transfer rail dolly. The MPC-HB and cask closure welding, draining, drying, and helium inerting operations will be performed within the RFB. These operations are controlled in accordance with the Humboldt Bay ISFSI technical specifications (Pacific Gas and Electric Company, 2004c, Attachment C).

The HI-STAR HB cask will be transferred outside the RFB on the cask transfer rail dolly. The HI-STAR HB lifting trunnions will be attached to the transporter lift links, and the loaded overpack will be lifted off the cask transfer rail dolly. A restraining strap will be used to secure the overpack to the transporter. As identified in Section 5.4 of the SAR, SNF transfer from the RFB to the ISFSI storage vault will be accomplished using a specifically designed transporter that is classified as important to safety. The requirements for the pretransfer evaluation and control of the transfer operation are identified in the Humboldt Bay ISFSI technical specifications (Pacific Gas and Electric Company, 2004c), and these activities will be conducted exclusively on the HBPP site. At the storage vault, the storage cell lid will be removed, and the

HI-STAR HB cask will be lowered into the vault using the transporter. Once the HI-STAR HB cask is properly positioned in the storage cell, seismic shims will be attached at the top of the cask, and the storage cell lid will be installed. The system is then configured for storage.

As identified in Section 4.4.3 of the SAR, the HI-STAR HB overpack does not require any periodic maintenance during storage in the vault. Provisions for visual inspection of the vault interior are included in the design. During the initial period of storage, the air temperature in the storage cell will be monitored to ensure that the design temperatures are not exceeded as identified in Section 4.4.3.7 of the SAR. Operations that will be performed during storage to ensure that the facility does not endanger public health and safety are described. These activities include the following:

(1) Storage vault drainage systems and vault interiors are inspected for evidence of water intrusion as identified in Section 4.4.3.8 of the SAR.

(2) Security personnel control access to the storage area and identify/assess off-normal and emergency events as identified in Chapter 9 of the SAR.

(3) Health physics personnel ensure that contamination levels are consistent with as low as is reasonably achievable (ALARA) requirements and within limits as identified in Chapter 9 of the SAR.

(4) Maintenance personnel maintain the facilities, including the storage vault, HI-STAR HB casks, and transfer systems, as identified in Chapter 5 of the SAR.

(5) Personnel will inspect the cask transporter prior to each loading campaign as identified in Section 4.3.2.1.4 of the SAR.

(6) Inventory documentation management will be conducted as identified in Chapter 5 of the SAR.

The Humboldt Bay ISFSI storage configuration is a passive installation, and periodic surveillance is required only to check the material condition of the casks and vault interior. Prior to loading each MPC-HB, radioactive contamination will be removed from the exterior and interior of the HI-STAR HB overpack and the exterior of the MPC-HB. In addition, radioactive contamination will be removed from the exterior of the HI-STAR HB cask prior to storage. The HI-STAR HB cask is designed such that there is no credible leakage. The staff, therefore, concludes that there will be no effluent generated during storage for normal, off-normal, and accident conditions.

Operational procedures for removal of storage casks from the ISFSI and unloading of the SNF are identified in Section 5.1.1.4 of the SAR. Figure 5.1-2 of the SAR shows the operation sequence flow chart for cask system unloading operations. The staff found the general description of operation for the removal of storage casks from the ISFSI and unloading of SNF to be acceptable in compliance with 10 CFR §72.122(l). If it is necessary to return the storage cask to the RFB for unloading, certain activities will be controlled in accordance with the 10 CFR Part 50 license. Requirements to satisfy Technical Specification 3.1.3, "Fuel Cool-Down" (Pacific Gas and Electric Company, 2004c, Attachment C) will be controlled under the 10 CFR Part 72 license.

The evaluations of off-normal and accident events are provided in Chapter 8 of the SAR and are reviewed in Chapter 15 of this SER. The actual cause, consequences, corrective actions, and actions to prevent recurrence for any events will be determined through the HBPP Corrective Action Program on a case-specific basis.

The staff determined that the procedure descriptions for operating, inspecting, and testing are consistent with the operation system. The staff finds the general description of the proposed ISFSI operations to be adequate in compliance with 10 CFR §72.24(b) and §72.24(f). Based on the operational descriptions provided, the staff finds that the Humboldt Bay ISFSI operations can be conducted without endangering activities or personnel at the HBPP and are, therefore, in compliance with 10 CFR §72.40(a)(3). Based on the operational descriptions provided, the staff also concludes that the Humboldt Bay ISFSI operations can be conducted without endangering the health and safety of the public and are, therefore, in compliance with 10 CFR §72.40(a)(5) and §72.40(a)(13). Technical specifications for operations and evaluation findings for 10 CFR §72.44(c)(1), §72.44(c)(2), and §72.44(c)(3) are presented in Chapter 16 of this SER.

The ALARA considerations described by the applicant were reviewed, and the staff's evaluation findings for 10 CFR §72.104(b) are presented in Chapter 11 of this SER. The applicant's shielding, confinement, and radiation protection evaluations were reviewed, and the staff's findings for 10 CFR §72.104(c) are presented in Chapters 7, 9, and 11, respectively, of this SER.

The staff finds that the HI-STAR HB cask and storage vault comprise a system that can be inspected to satisfy the requirements of 10 CFR §72.122(f). As stated previously, the HI-STAR HB cask system is a modified version of the passive HI-STAR 100 system, which the staff has previously reviewed and found acceptable (U.S. Nuclear Regulatory Commission, 2001a, b). The design for the HI-STAR HB storage system is based on the HI-STAR 100 System FSAR (Holtec International, 2002). Though there are design differences between the HI-STAR 100 and HI-STAR HB cask systems, the staff finds that the HI-STAR HB cask system is also a passive system that complies with the regulatory requirements of 10 CFR §72.122(h)(1) and §72.122(h)(4). Because the HI-STAR HB system is passive, no instrumentation systems are required to monitor its state. The HI-STAR HB system is based on the sealed MPC-HB as the confinement boundary. Although there are geometrical differences between the HI-STAR 100 MPC and the MPC-HB, the applicant has demonstrated that the structural integrity of the MPC-HB confinement boundary is not compromised. The staff's evaluation of the design is given in Chapter 5 of this SER. Radiological protection for the HI-STAR HB system is provided by the overpack, which is constructed using the same materials and similar geometry as the HI-STAR 100 overpack. The radiation protection evaluation of the HI-STAR HB system is presented in Chapter 11 of this SER. The thermal characteristics of the HI-STAR HB system are based on passive heat transfer in the same manner as the HI-STAR 100 cask system.

The staff finds that the operational considerations of radiation protection systems in Section 5.1 of the SAR satisfy the requirements of 10 CFR §72.126(a–b). Thermoluminescent dosimeters are placed along or within the ISFSI restricted area fence to satisfy the direct radiation monitoring requirement of 10 CFR §72.126(c)(2). The HI-STAR HB system is based on the sealed MPC-HB with no credible leakage and does not require effluent monitoring. The requirements of 10 CFR §72.126(c)(1), therefore, are not applicable for this facility.

The staff finds that the design and operational procedures provide acceptable capability to test components important to safety during cask system loading and sealing activities. Once sealed, the HI-STAR HB cask system is passive and requires no monitoring. Compliance with 10 CFR §72.128(a)(1), therefore, is demonstrated. The quality assurance considerations of the applicant are reviewed in Chapter 12 of this SER, and evaluation findings for 10 CFR §72.150 are discussed in Section 12.2.

The staff finds that Section 5.1 of the SAR, the Technical Specifications (Pacific Gas and Electric Company, 2004c), and the HI-STAR 100 FSAR (Holtec International, 2002) contain sufficient details to satisfy the requirements of 10 CFR §72.166.

3.1.2 Spent Nuclear Fuel Handling Systems

Normal loading and unloading operations will take place in the HBPP RFB under local control and in coordination with the HBPP staff and will be subject to the controls established under the 10 CFR Part 50 and Part 72 licenses, as applicable. Spent fuel handling of the HI-STAR 100 cask system, including the MPC, is described in detail in the HI-STAR 100 Cask System FSAR (Holtec International, 2002), which the staff has previously reviewed and found acceptable (U.S. Nuclear Regulatory Commission, 2001a,b). Based on an assessment of the design difference between the HI-STAR 100 cask system and the HI-STAR HB system, the staff concludes that the handling operations at the Humboldt Bay ISFSI will be consistent with the handling operations described in the HI-STAR 100 FSAR. Specific operating procedures have been customized for the site-specific license at the HBPP and Humboldt Bay ISFSI as identified in the Humboldt Bay ISFSI Technical Specifications (Pacific Gas and Electric Company, 2004c) and Section 10.2 of the SAR. All the staff conclusions drawn in Section 3.1.1 of this SER are also applicable to the SNF handling systems.

3.1.3 Other Operating Systems

Other operating systems associated with the Humboldt Bay ISFSI include the transporter. This item is classified as important to safety. For the Humboldt Bay ISFSI, those SSCs classified as not important to safety, but having security or operational importance, are controlled under the Humboldt Bay ISFSI license and the requirements of 10 CFR Part 72.

The staff conclusions drawn in Section 3.1.1 of this SER are also applicable to the other operating systems. The proposed design of the ISFSI does not require utility systems during interim storage. The proposed design of the ISFSI does not include systems and subsystems that require continuous electric power to permit continued functioning. The requirement in 10 CFR §72.122(k) for emergency utility services, therefore, is not applicable for the Humboldt Bay ISFSI.

3.1.4 Operation Support Systems

The operation of the ISFSI is passive and self-contained and requires no permanently installed auxiliary systems. The ISFSI does not require any instrumentation or control systems to ensure safe operation. The staff finds, therefore, that 10 CFR §72.122(i) and §72.122(k) are not applicable for the Humboldt Bay ISFSI.

3.1.5 Control Room and Control Area

The staff reviewed the control room and control areas described in Section 5.2 of the SAR. The staff evaluated sections pertaining to monitoring instruments and limits and controls of the proposed cask system in the SAR. Based on the review, the staff finds that the Humboldt Bay ISFSI requires no permanent control room or control area to ensure safe operation; therefore, the requirements of 10 CFR §72.122(j) are not applicable.

3.1.6 Analytical Sampling

No analytical sampling associated with storage activities of the Humboldt Bay ISFSI is required. The HI-STAR HB system design will preclude the release of effluents generated during interim storage for normal, off-normal, and accident conditions. The waste management evaluation of the applicant was reviewed and an evaluation finding for 10 CFR §72.104(c) is presented in Chapter 14 of this SER.

3.1.7 Shipping Cask Repair and Maintenance

The HI-STAR HB system is both a storage and a transportation system. General maintenance is discussed in Section 3.1.1 of this SER. As identified in Section 4.4.3 of the SAR, the HI-STAR HB system does not require any periodic maintenance during storage operations. If visual inspections reveal the need for repairs or maintenance, these activities will be performed either *in situ* or in another appropriate location, based on the nature of the work to be performed. Radiation protection personnel will provide input and monitor these activities. The staff finds that the requirements of 10 CFR §72.122(f) are satisfied.

3.1.8 Pool and Pool Facility Systems

The Humboldt Bay ISFSI utilizes dry cask storage technology, which houses SNF inside sealed canisters that have an inert environment rather than in a SFP. Therefore, neither the use of a pool nor any system supporting a pool is incorporated into the Humboldt Bay ISFSI as covered by the 10 CFR Part 72 license. Note that the SNF will be transferred from the SFP into the MPC-HBs within the confines of the RFB. Activities associated with this operation are controlled under the 10 CFR Part 50 and Part 72 licenses, as applicable.

3.2 Evaluation Findings

Based on its review of the information in the SAR, the staff makes the following findings regarding the operation systems of the Humboldt Bay ISFSI:

- The SAR includes acceptable descriptions and discussions of the projected operating characteristics and safety considerations in accordance with 10 CFR §72.24(b) and §72.24(f).

- The Humboldt Bay ISFSI is to be located on the same site as another facility, the HBPP, licensed by the NRC. The potential interactions between these facilities have been evaluated in accordance with 10 CFR §72.40(a)(3).

- The SAR provides reasonable assurance that the operations to be authorized by the license at the Humboldt Bay ISFSI can be conducted without endangering the health and safety of the public in accordance with 10 CFR §72.40(a)(5) and §72.40(a)(13).

- The HI-STAR HB system and storage vault is a passive system that can be inspected in accordance with 10 CFR §72.122(f).

- The descriptions of the proposed Humboldt Bay ISFSI functions and operations systems with regard to retrieval of SNF from storage, in normal, off-normal, and accident conditions are acceptable and are in accordance with 10 CFR §72.122(h)(1), §72.122(h)(4), and §72.122(l).

- The HI-STAR HB system is a passive system with a radiation protection system and direct monitoring provided in accordance with 10 CFR §72.126(a), (b), and (c)(2).

- Acceptable capability to test and monitor components important to safety is provided by the applicant in accordance with 10 CFR §72.128(a)(1).

- The descriptions of the proposed Humboldt Bay ISFSI functions and operation systems with regard to preservation of materials and equipment to prevent damage or deterioration are acceptable and are in accordance with 10 CFR §72.166.

As identified, the evaluation findings addressing compliance with 10 CFR §72.44(c)(1), (c)(2), and (c)(3); §72.104(b–c); and §72.150 are contained in other chapters of this SER.

Because of the design and operational characteristics of the Humboldt Bay ISFSI, the following regulatory requirements identified in NUREG-1567 (U.S. Nuclear Regulatory Commission, 2000) are not applicable: 10 CFR §72.122(i), §72.122(j), §72.122(k), and §72.126(c)(1).

3.3 References

Holtec International. *Final Safety Analysis Report for the Holtec International Storage, Transport, and Repository Cask System* (*HI-STAR 100 Cask System*). Rev. 1. HI-2012610. Docket 72-1008. Marlton, NJ: Holtec International. 2002.

Pacific Gas and Electric Company. *Humboldt Bay Independent Spent Fuel Storage Installation Safety Analysis Report.* Amendment 1. Docket No. 72-27. Avila Beach, CA: Pacific Gas and Electric Company. 2004a.

Pacific Gas and Electric Company. *Humboldt Bay Power Plant Unit 3. License Amendment Request 04-02, Spent Fuel Cask Handling.* Docket No. 50-133. Avila Beach, CA: Pacific Gas and Electric Company. July 9, 2004b.

Pacific Gas and Electric Company. *Humboldt Bay Independent Spent Fuel Storage Installation License Application.* Amendment 1. Docket No. 72-27. Avila Beach, CA: Pacific Gas and Electric Company. 2004c.

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

U.S. Nuclear Regulatory Commission. *10 CFR Part 72 Certificate of Compliance No. 1008, Amendment 2, for the HI-STAR 100 Cask System.* Docket No. 72-1008. Washington, DC: U.S. Nuclear Regulatory Commission. 2001a.

U.S. Nuclear Regulatory Commission. *Holtec International HI-STAR 100 Cask System Safety Evaluation Report, Amendment 2.* Docket No. 72-1008. Washington, DC: U.S. Nuclear Regulatory Commission. 2001b.

4 STRUCTURES, SYSTEMS, AND COMPONENTS AND DESIGN CRITERIA EVALUATION

4.1 Conduct of Review

This section describes the staff's review of the principal design criteria and classification of structures, systems, and components (SSCs) provided by the applicant in Chapters 3, "Principal Design Criteria" and 4, "ISFSI Design," of the Humboldt Bay Independent Spent Fuel Storage Installation (ISFSI) Safety Analysis Report (SAR) (Pacific Gas and Electric Company, 2004a). The review focused on the spent nuclear fuel (SNF) that will be stored at the Humboldt Bay ISFSI site; the identification of SSCs important to safety; the design bases and criteria associated with structural design, mechanical design, shielding, confinement, criticality, and retrieval assessments; and the load combinations used for the design.

Section 3.1 of the SAR identifies the materials that will be stored in the Humboldt Bay ISFSI. The materials to be stored include intact and damaged SNF assemblies and Greater than Class C (GTCC) waste.

Section 4.5 of the SAR identifies the SSCs classified as important to safety. The SSCs important to safety are designed to maintain conditions required to safely store the SNF; prevent damage to the SNF or container during handling and storage; and provide reasonable assurance that the SNF can be received, handled, packaged, stored, and retrieved without undue risk to the health and safety of the public.

Chapter 3 of the SAR identifies the design criteria and appropriate load combinations for the Humboldt Bay ISFSI. The design criteria are derived from the requirements of 10 CFR Part 72; relevant U.S. Nuclear Regulatory Commission (NRC) regulatory guidance documents, and applicable industry codes and standards. Section 3.4 of the SAR provides a summary of the principal design criteria for the SSCs important to safety for the Humboldt Bay ISFSI.

The objective of the review was to ensure that the applicant acceptably defines: (i) the limiting characteristics of the SNF or other high-level radioactive waste materials to be stored; (ii) the classification of SSCs according to their importance to safety; and (iii) the design criteria and design bases, including the external conditions during normal and off-normal operations, accident conditions, and natural phenomena events (U.S. Nuclear Regulatory Commission, 2000). The review was conducted in accordance with NUREG-1567 (U.S. Nuclear Regulatory Commission, 2000). In addition, the review was closely coordinated with the review of Chapter 2 of the SAR.

The review considered how the SAR and related documents address the regulatory requirements of 10 CFR §72.2(a)(1), §72.24(c), §72.24(n), §72.103(f)(2)(iii), §72.106(a), §72.106(c), §72.120(a), §72.120(b)(1), §72.120(b)(2), §72.122(a), §72.122(b)(1), §72.122(b)(2), §72.122(c–e), §72.122(h)(5), §72.122(k)(1), §72.122(l), §72.124(a–c), §72.126(a–b), §72.126(d), §72.128(a), §72.144(a), and §72.144(c). Complete citations of these regulations are provided in the Appendix of this Safety Evaluation Report (SER).

4.1.1 Materials to be Stored

As identified in Section 3.1 of the SAR, the materials to be stored at the Humboldt Bay ISFSI are intact and damaged fuel assemblies, and GTCC waste. The fuel assemblies consist of General Electric Types II and III and Exxon Types III and IV assemblies. The General Electric Type II assemblies contain a 7 x 7 array of fuel rods, while the other types are made of 6 x 6 arrays of fuel rods. The applicant currently has 390 SNF assemblies and loose debris equivalent to one assembly stored at the Humboldt Bay Power Plant (HBPP) site. Among the 390 SNF assemblies, 11 were classified as damaged, and 16 were classified as fuel debris. Each fuel assembly contains approximately 87 kg [192 lb] of uranium dioxide. The cladding material for all intact or damaged fuel assemblies is Zircaloy-2; however, there are also small amounts of stainless steel cladding remnants in the spent fuel pool from fuel previously shipped offsite. The SNF is coated with a crud layer of undetermined thickness because of oxidation of the carbon steel piping system. Table 3.1-2 of the SAR provides a summary of the physical characteristics of the SNF that will be stored at the Humboldt Bay ISFSI. The SNF assemblies will be placed in five custom-designed multi-purpose canisters (MPC-HB). Each MPC-HB has the capacity to house 80 SNF assemblies. Damaged assemblies, assemblies classified as fuel debris, and loose debris, including unclad fuel pellets, Zircaloy cladding, and stainless steel cladding remnants from fuel previously shipped offsite, will be placed in a damaged fuel container (DFC). Each DFC will occupy the same space as an intact assembly in the MPC-HB.

Several limiting values for storing SNF assemblies at the Humboldt Bay ISFSI are provided in Section 3.1.1.2 of the SAR and Table 2.1-1 of the proposed Technical Specifications (Pacific Gas and Electric Company, 2004b, Attachment C). These limiting values include (i) a maximum total heat load of 2 kW [6,824 Btu/hour] for a single cask, (ii) a maximum heat load of 50 W [171 Btu/hour] for each assembly, (iii) a maximum of 23,000 MWd/MTU average burnup per assembly, (iv) a minimum cooling time of 29 years, and (v) a planar-average enrichment of no more than 2.60 and no less than 2.09 wt% of Uranium 235.

The potential amount and content of the GTCC waste is provided in Table 3.1-3 of the SAR. The SAR states that the actual waste quantity will be less than the amount provided in the table, and an accurate classification of the waste will be conducted before the waste is loaded into an MPC-HB. All GTCC waste will be stored in one cask. In addition, as required, and as stated in the SAR, the GTCC waste and the SNF will not be stored in the same cask.

The staff finds that the applicant has provided sufficient information in describing the materials to be stored to satisfy the regulatory requirements of 10 CFR §72.22(a)(1). The staff also finds the fact that GTCC waste will not be stored in a cask that also contains SNF is in compliance with the regulatory requirements of 10 CFR §70.120(b)(1). No liquid GTCC waste is planned to be stored in the Humboldt Bay ISFSI, as the ISFSI is a dry storage facility. Consequently, the regulatory requirements of 10 CFR §72.120(b)(2) have been satisfied.

4.1.2 Classification of Structures, Systems, and Components

The staff reviewed Section 4.5 of the SAR, which identifies safety protection systems and provides a brief description of the important characteristics of each system. SSCs important to safety are defined in 10 CFR §72.3 as items whose functions are to

- Maintain the conditions required to store SNF safely

- Prevent damage to the SNF container during handling and storage

- Provide reasonable assurance that SNF can be received, handled, packaged, stored, and retrieved without undue risk to the health and safety of the public

4.1.2.1 Classification of Structures, Systems, and Components - Items Important to Safety

According to the SAR, the SSCs are classified as important to safety if at least one subcomponent of the major component is classified as important to safety. In addition, the applicant divided the SSCs important to safety into three quality assurance (QA) categories: Classification Categories A, B, and C. This categorization is developed following the guidance provided in NUREG/CR-6407 (McConnell, et al., 1996). Classification Category A is defined for the SSCs important to safety that are critical to safe operation. Classification Category B is defined for the SSCs important to safety that may have major impacts on safety. Classification Category C is defined for the SSCs important to safety that may have minor impacts on safety.

The classification of the SSCs for the storage system is provided in Table 4.5-1 of the SAR. The SSCs important to safety include the (i) MPC-HB, (ii) fuel basket and basket spacer, (iii) DFC, (iv) HI-STAR HB overpack, (v) cask transporter, (vi) transporter lift links, (vii) ISFSI storage vault (the storage vault lid and lid bolts are considered not important to safety for certain beyond design basis seismic events), (viii) fuel spacers, (ix) transporter connector pins, (x) helium fill gas, and (xi) lid retention device. The first six items were determined to be in Classification Category A, and the remainder were determined to be in Classification Category B. The primary functions for the SSCs important to safety in Classification Category A are to provide confinement or shielding, or to prevent criticality. The function of Classification Category B SSCs important to safety is to prevent an unsafe condition. No Classification Category C SSCs important to safety were identified.

The staff reviewed the information concerning the classification of SSCs important to safety and finds that the SSCs listed in Table 4.5-1 of the SAR have been properly classified as important to safety items. The staff concludes that the SSCs important to safety identified and listed in the SAR are acceptable and are in compliance with the regulatory requirements of 10 CFR §72.24(n) and §72.144(a). In addition, the staff finds that the use of Classification Categories is consistent with the regulatory requirements of 10 CFR §72.122(a), which requires that the SSCs important to safety must be designed, fabricated, erected, and tested to quality standards commensurate with the importance to safety of the function to be performed.

4.1.2.2 Classification of Structures, Systems, and Components - Items Not Important to Safety

SSCs not important to safety do not involve a safety-related function and are not subject to special quality requirements or NRC-imposed regulatory requirements. SSCs not important to safety relevant to the proposed Humboldt Bay ISFSI are listed in Table 4.5-1 of the SAR. The staff reviewed Table 4.5-1 and agrees with the applicant's classification of SSCs. The classification is based on the function of the SSC and its potential to ensure that radiation dose rates remain within acceptable and analyzed limits, and that there are no uncontrolled releases, so that there is no undue risk to the health and safety of the public.

The staff concludes that the applicant has appropriately identified the components listed in Table 4.5-1 of the SAR as not important to safety.

4.1.2.3 Classification of Structures, Systems, and Components - Conclusion

The staff evaluated the classification of SSCs important to safety by reviewing Section 4.5 of the SAR. The staff determined that the classification of the SSCs important to safety and their associated categories meets the regulatory requirements of 10 CFR §72.122(a) and §72.144(a) and that the associated technical information is in compliance with 10 CFR §72.24(n). The staff's evaluation of the applicant's QA program is contained in Chapter 12 of this SER.

4.1.3 Design Criteria for Structures, Systems, and Components Important to Safety

The principal design criteria identified for SSCs important to safety at the Humboldt Bay ISFSI are described in Chapters 3 and 4 of the SAR. Section 3.2 of the SAR discusses the design criteria for environmental conditions and natural phenomena. Section 3.3 of the SAR discusses the design criteria for safety protection systems. Section 3.4 of the SAR provides a summary of design criteria. More detailed discussions of the design criteria are presented in Sections 4.1.3.1 and 4.1.3.7 of this SER.

4.1.3.1 General

As discussed in Section 4.1.1 of this SER, the SNF assemblies to be stored in the Humboldt Bay ISFSI consist of General Electric Types II and III and Exxon Types III and IV assemblies. There are 390 SNF assemblies and loose debris equivalent to one assembly to be stored at the HBPP site. These SNF assemblies will be loaded into five MPC-HBs, and the associated GTCC waste will be placed in one additional MPC-HB.

As indicated in Section 4.2 of the SAR, the major components for the Humboldt Bay ISFSI include a reinforced concrete storage vault and the HI-STAR HB casks. The reinforced concrete storage vault has six cells to accommodate five HI-STAR HB casks and one GTCC waste certified cask. A HI-STAR HB cask consists of a HI-STAR HB transportation and storage overpack and an MPC-HB. The HI-STAR HB cask system, including an overpack and an MPC-HB is a modified version of the HI-STAR 100 system. A cask transporter will be used to transfer the loaded HI-STAR HB cask from the HBPP Refueling Building (RFB) to the Humboldt Bay ISFSI. The Humboldt Bay ISFSI is located within the HBPP controlled area.

Normal, off-normal, and accident loads for the Humboldt Bay ISFSI are given in Sections 3.3.2.3.1, 3.3.2.3.2, and 4.2.3.3 of the SAR. The quality standards for the design bases of SSCs important to safety are provided in Chapters 3, 4, and 11 of the SAR.

The HI-STAR HB system is approximately 193 cm [76 in] shorter than the generic HI-STAR 100 system, but has a relatively larger capacity (80 Humboldt Bay spent fuel assemblies versus 68 standard BWR assemblies). Other modifications include a different upper fuel spacer, fuel basket, and overpack neutron shield enclosure design and the use of METAMIC® neutron absorber as an alternative to BORAL®. Because the HI-STAR HB system is shorter, it has a lower center of gravity. According to the SAR, the HI-STAR HB system is designed to withstand all design-basis loads related to Humboldt Bay site-specific environmental conditions and natural phenomena. The design criteria for the generic HI-STAR 100 system are used for the design of the HI-STAR HB system if these design criteria bound the Humboldt Bay site-specific conditions; otherwise, site-specific design criteria will be used. This approach provides additional safety to the performance of the HI-STAR HB system at the Humboldt Bay ISFSI site. Detailed design criteria and load combinations can be found in the HI-STAR 100 system Final Safety Analysis Report (FSAR) (Holtec International, 2002).

The design life for the reinforced concrete storage vault and the HI-STAR HB system is 40 years and is 20 years for the cask transporter. The design life of the SSCs important to safety is based on their ability to withstand the applied loads. The applied loads are defined using an annual probability of exceeding the design load. Analysis procedures are used to demonstrate the ability of the SSCs to withstand the applied loads with additional factors applied to the loads and material allowables as identified by the referenced codes and standards. The design life for the cask transporter is determined based on the industry experience on this type of vehicle with normal maintenance.

The staff finds that the design criteria discussed in the SAR satisfy the regulatory requirements of 10 CFR §72.24(c), §72.120(a), and §72.122(h)(5) because the design criteria are identified properly. The staff also finds that the SSCs important to safety will be designed to quality standards commensurate with their importance to safety functions to be performed, thereby satisfying the requirements of 10 CFR §72.122(a) and §72.144(c). The staff finds that the Humboldt Bay ISFSI has a controlled area that meets the regulatory requirements of 10 CFR §72.106(a) and §72.106(c).

The staff reviewed the information provided in the SAR and determined that (i) no SSCs important to safety have been identified to be shared between the Humboldt Bay ISFSI and other facilities, (ii) no control room has been identified as necessary to provide safe control of the Humboldt Bay ISFSI during off-normal or accident conditions, and (iii) no utility services or distribution systems have been identified to be important to safety. Based on this review, the staff finds that the regulatory requirements of 10 CFR §72.122(d) and §72.122(k)(1) have been met.

Structural design criteria and radiological protection and confinement criteria are identified in the SAR. A review of the structural criteria is presented in this chapter of the SER. The staff's assessment of the adequacy of the site-specific environmental conditions and natural phenomena-related design criteria is contained in Chapter 2 of this SER. Review of the radiological protection and confinement criteria is presented in Chapters 7, 8, 9, and 11 of this SER.

4.1.3.2 Structural

The staff reviewed the discussion on structural design criteria of SSCs presented in Sections 3.2, 3.3, 3.4, 4.2, 4.3, and 4.4 of the SAR.

The design of the reinforced concrete vault of the Humboldt Bay ISFSI is based on American Concrete Institute (ACI) 349-01 (American Concrete Institute, 2001) and, as applicable, the factored load combinations from Table 3-1 of NUREG-1536 (U.S. Nuclear Regulatory Commission, 1997) will be used. ACI 349-01 specifies the acceptable design and construction of concrete structures that form part of a nuclear power plant and have nuclear safety-related functions. Structures included in the ACI code are concrete structures inside and outside the containment system. According to the SAR, the critical sections of the vault are the sections between two adjacent storage cells, and the structural analyses of these sections indicate that the stresses are within the allowable limits specified in ACI 349-01 (American Concrete Institute, 2001).

The design loads, operating temperature ranges, and strength at 28 days for the reinforced concrete vault are listed in Table 3.4-3 of the SAR. The minimum dry densities for the reinforced concrete for both storage vault and storage cell lids are 2,339 kg/m^3 [146 lb/ft^3]. The steel reinforcing bars for the storage vault will be designed to meet American Society of Testing Materials (ASTM) A615, Grade 60 specifications. The steel liner and seismic restraints for storage cells, and the steel plates for storage cell lids will be constructed using SA36 or SA516 Grade 70 carbon steel. The storage cell lid closure bolts will be made of SA193 B7 material.

The design of the HI-STAR HB system, including the MPC-HB, DFC, and overpack, conforms to standard engineering practice, as identified in relevant subsections of Section III of the 1995 Edition ASME Boiler and Pressure Vessel Code with 1996 and 1997 addenda (ASME International, 1996). A detailed list of the subdivisions of the ASME Boiler and Pressure Vessel Code for design of the SSCs of the HI-STAR HB system is provided in Section 4.2.3.3 of the SAR. The ASME Boiler and Pressure Vessel Code establishes rules governing design, fabrication, and inspection during the construction of boilers and pressure vessels. This code contains mandatory requirements, specific prohibitions, and nonmandatory guidance for selection of materials, design, fabrication, examination, inspection, testing, certification, and pressure relief. Table 3.4-5 of the SAR lists the exceptions and alternatives to the ASME code for some systems or components.

The staff reviewed the information provided regarding codes and standards for the SSCs important to safety and the proposed exceptions and alternatives to the ASME code and finds the information acceptable.

In addition, ANSI N14.6 (American National Standards Institute, 1993), as referenced in NUREG-0612 (U.S. Nuclear Regulatory Commission, 1980), is identified for the design criteria of the (i) cask transporter lift points, overhead beam, vehicle body, and seismic restraints; (ii) overpack lifting trunnions and trunnion blocks; and (iii) lifting bolts of a DFC for compliance with a single-failure-proof system or component. NUREG-0612 (U.S. Nuclear Regulatory Commission, 1980) identifies controls for handling heavy loads at nuclear power plants. The staff finds that using a single-failure-proof design satisfies the regulatory requirements of 10 CFR §72.120(a) and §72.122(h)(5).

The off-normal and accident design basis internal pressures for the MPC-HB are 0.76 and 1.38 MPa gauge [110 and 200 psig]. The off-normal conditions correspond to a 10 percent SNF rod rupture and the nonmechanistic rupture of 100 percent of the SNF rods for the accident conditions. The off-normal and accident analysis results for the MPC-HB presented in Sections 8.1.1 and 8.2.11 of the SAR indicate that the off-normal and accident internal pressure limits are not exceeded.

As identified earlier, the SSCs important to safety are designed to withstand the effects of environmental conditions and natural phenomena for normal, off-normal, and accident conditions. The structural design loads for SSCs important to safety are provided in Section 3.2 of the SAR. Information on the derivation of site-specific design criteria for the meteorology, hydrology, and seismology is contained in Chapter 2 of the SAR.

Wind

Information provided in Section 2.3.1.3 of the SAR identifies a maximum recorded wind gust speed of 111 kmph [69 mph] at the Humboldt Bay ISFSI site. Section 2.3.1.3 of the SAR further indicates that the 1-minute average wind speed for the 50-year return period is 93 kmph [58 mph] with a peak gust of 114 kmph [71 mph]. The wind speed of 137 kmph [85 mph] with a gust factor of 1.1 is used as the design basis wind for the Humboldt Bay ISFSI.

The staff reviewed the design basis wind for the Humboldt Bay ISFSI and finds that it is consistent with that identified in ASCE 7-98 (American Society of Civil Engineers, 2000) for this location. The staff also finds that the requirements of 10 CFR §72.120(a), §72.122(b)(1), and §72.122(b)(2) have been satisfied, in that the effects of wind are considered in the design of the Humboldt Bay ISFSI.

Tornado

The design basis tornado wind loads for the Humboldt Bay ISFSI site are discussed in Section 3.2.1.1 of the SAR. In determining the design basis tornado, Regulatory Guide 1.76 (U.S. Atomic Energy Commission, 1974) was followed. The Humboldt Bay ISFSI site is located in tornado intensity Region II. According to Regulatory Guide 1.76 (U.S. Atomic Energy Commission, 1974), the design basis tornado characteristics associated with tornado intensity Region II are

- 483 kmph [300 mph], maximum speed
- 386 kmph [240 mph], rotational speed
- 97 kmph [60 mph], translational speed
- 15.5 kPa [2.25 psi], pressure drop
- 8.3 kPa/s [1.2 psi/s], rate of pressure drop

The parameters for the tornado identified have been reviewed, and the staff finds that the use of design basis tornado characteristics for tornado intensity Region II provided in Regulatory Guide 1.76 (U.S. Atomic Energy Commission, 1974) is acceptable.

In addition, the design basis tornado for the HI-STAR HB system is the same as that for the HI-STAR 100 system. The design basis tornado for the HI-STAR 100 system is defined for tornado intensity Region I given in Regulatory Guide 1.76 (U.S. Atomic Energy Commission, 1974). Because tornado intensity for Region I is stronger than that for Region II, the design basis tornado for the HI-STAR 100 system bounds the site-specific design basis and is, therefore, conservative. Specific design basis tornado characteristics for the HI-STAR HB system are given in Table 3.2-1 of the SAR.

The staff reviewed the information regarding design basis tornados and finds that the requirements of 10 CFR §72.120(a), §72.122(b)(1), and §72.122(b)(2) have been satisfied, in that the effects of site conditions and environmental conditions are considered in the design of the Humboldt Bay ISFSI and the HI-STAR HB system.

Tornado Missiles

The postulated tornado missiles for the Humboldt Bay ISFSI, the HI-STAR HB system, and the cask transporter are identified in Section 3.2.1.3 and Table 3.2-2 of the SAR. The postulated tornado missiles include three objects consistent with those specified as Spectrum I missiles in Section 3.5.1.4 of NUREG-0800 (U.S. Nuclear Regulatory Commission, 1981). The use of Spectrum I is considered acceptable by NRC. The mass and associated impact velocity for the three objects are provided in Table 3.2-2 of the SAR.

According to the SAR, tornado missiles may cause spalling on the storage cell lid and apron of the reinforced concrete storage vault. The reinforced concrete storage vault is below grade and, therefore, is shielded from the horizontal missile impacts. A HI-STAR HB system may be affected by tornado-generated missiles when the loaded HI-STAR HB system is transferred from the RFB to the ISFSI site and during the storage operations (lowering the HI-STAR HB system into the vault and installing seismic constraints) at the ISFSI site. The SAR indicates that the cask transporter will have redundant drop protection to prevent a drop of the loaded HI-STAR HB system caused by direct impacts of tornado missiles.

The staff reviewed the design basis tornado missiles for the Humboldt Bay ISFSI, the HI-STAR HB system, and the cask transporter and finds that they are able to withstand tornadoes, consistent with the design criteria specified in Section 3.5.1.4 of NUREG-0800 (U.S. Nuclear Regulatory Commission, 1981), and in accordance with the regulatory requirements of 10 CFR §72.120(a), §72.122(b)(1), and §72.122(b)(2).

Flood

Based on the elevation of the Humboldt Bay ISFSI and the site surface hydrology, the applicant concluded in Section 2.4 of the SAR that flooding is not a concern at the Humboldt Bay ISFSI site. Although flooding is not a concern, Section 3.2.2 of the SAR indicates that the HI-STAR HB system is designed "to withstand pressure and water forces associated with floods, based on the similarity in design to the HI-STAR 100 system." The design basis water pressure and horizontal load for the HI-STAR 100 system are 200 m [656 ft] of water head and 4 m/s [13 ft/s] of flow velocity. Also, the vault structure is designed to withstand 1.8 m [6 ft] of water head.

The staff reviewed the flood design criteria and concludes that the design of the Humboldt Bay ISFSI and the HI-STAR HB system is acceptable to withstand floods in accordance with the regulatory requirements of 10 CFR §72.120(a), §72.122(b)(1), and §72.122(b)(2).

Seismicity

The staff reviewed the data presented in the SAR associated with seismic design criteria for the Humboldt Bay ISFSI. Section 3.2.4 of the SAR gives the seismic design criteria based on deterministic and probabilistic ground motion studies for the Humboldt Bay ISFSI site as summarized in Section 2.6.6 of the SAR. The staff's assessment of the adequacy of the site-specific seismic design criteria is contained in Chapter 2 of this SER. The applicant's analysis of the SSCs important to safety during the site-specific design basis seismic ground motion is evaluated in Chapters 5 and 15 of this SER.

The applicant has used both the deterministic (10 CFR Part 100, Appendix A) and probabilistic (U.S. Nuclear Regulatory Commission, 2003a) methods to develop the design earthquake ground motion (DE) spectra. Since the deterministic spectra exceed the probabilistic uniform hazard spectra for a 2000-year return period at all spectral periods (SAR Figure 2.6-72), the applicant has used the deterministic spectra for the design of SSCs. Reviews of the development of the deterministic and probabilistic uniform hazard spectra are discussed in Chapter 2 of this SER. The use of the uniform hazard spectra with a 2,000-year return period as the seismic design basis is consistent with the staff position in Regulatory Guide 3.73 (U.S. Nuclear Regulatory Commission, 2003a).

For the limited duration transient activities, including transferring the HI-STAR HB system to the ISFSI storage vault and cask handling operations at the storage vault, the applicant has used a risk-informed approach by considering the total exposure times (durations) associated with these activities and has used design earthquake ground motions lower than the DE. According to the SAR, the estimated exposure time for transferring five HI-STAR HB systems to the ISFSI storage vault and completing the storage operations is 2.5 days. Based on the exposure time, the applicant determined that the ground motion corresponding to a 14-year return period earthquake is appropriate for the transient activities. The applicant used the ground motion associated with a 50-year return period earthquake as the design basis for the transfer activities, and the ground motion associated with a 25-year return period earthquake as the design basis for the storage vault cask handling operations. The ground motions for these return periods (SAR Figures 2.6-69–2.6-71) are evaluated in Section 2.1.6.2 of this SER.

The staff finds the applicant's risk-informed approach acceptable for establishing a level of design earthquake ground motion for transient activities commensurate with the risk posed by these activities to the public health and safety. This approach is consistent with the NRC Strategic Plan FY 2004–FY 2009 (U.S. Nuclear Regulatory Commission, 2004) Effectiveness Strategy, "Use state-of-the-art methods and risk insights to improve the effectiveness and realism of NRC actions," and with the Commission's Staff Requirements Memorandum (SECY-98-144, U.S. Nuclear Regulatory Commission, 1999) that was specifically focused on enhanced use of risk-informed, performance-based regulatory approaches for nuclear materials and radioactive waste disposal.

The staff performed an independent analysis based on the assumption that any two structural systems or activities with different lifetimes have the same risk significance if both have the same probability of exceedance. The probability of the exceedance of a certain ground motion intensity is the likelihood that at least one earthquake of certain ground motion intensity will occur during the service lifetime or the activity duration. The staff determined that the probability of exceedance for the reinforced concrete storage vault with a seismic design basis of a 2,000-year return period earthquake and a service life of 20 years [10 CFR §72.42(a)] is approximately 1 percent. Using this information and considering the transient activities durations as proposed by the applicant, the staff concluded that the 25- and 50-year return period earthquakes proposed by the applicant are sufficient to assure a probability of exceedance significantly less than 1 percent during the transient activities.

Additionally, the applicant has shown that the transporter could withstand the DE without any adverse effects to the transporter and the cask, except during the time when the transporter is going over a short segment {30.5 m [100 ft] length, which will take no more than 3 minutes to traverse} of the road next to the discharge canal. An occurrence of the DE during this very short time may cause the transporter and the cask to slide into the discharge canal. However, even in this extremely unlikely event, the cask is not likely to be damaged to the extent that any radioactivity may be released. Therefore, there is no risk to the health and safety of the public resulting from the use of the design earthquake ground motions for transient activities lower than the DE as discussed above.

Based on the review of the applicant's seismic design criteria for the SSCs important to safety at the Humboldt Bay ISFSI as described above, the staff finds that the applicant's consideration of seismic design criteria is appropriate, as required by 10 CFR §72.120(a), §72.122(b)(1), and §72.122(b)(2).

Tsunami

The tsunami hazards for the Humboldt Bay ISFSI site are described in Section 2.6.9 of the SAR, and the design considerations of tsunami hazards are discussed in Sections 3.2.3 and 4.2.3.3.2.7 of the SAR. The potential tsunami is estimated to be 9.1 to 12.2 m [30 to 40 ft] above the mean lower low water (MLLW)[1] at the bay entrance. Considering an attenuation factor of 0.7 to 0.9, the inundation height will be approximately 6.4 to 11 m [21 to 36 ft] above the MLLW at low tide and 8.5 to 13.1 m [28 to 43 ft] at high tide. The surface of the reinforced concrete storage vault is at an elevation of 13.4 m [44 ft] above the MLLW. The estimated maximum inundation height, therefore, remains below the elevation of the top of the reinforced concrete storage vault. Although the surface of the reinforced concrete storage vault will be above the projected tsunami runup elevation, the vault structure will be designed to withstand 1.8 m [6 ft] of water head and protect itself from flowing water. In addition, the HI-STAR HB system is designed to withstand 200 m [656 ft] of water head and 4 m/s [13 ft/s] of flow velocity.

As discussed previously, the seismic design basis for the transfer activities corresponds to a 50-year return period earthquake. According to the SAR, the 50-year return period earthquake does not have sufficient energy to create a tsunami that will cause flooding of the transfer route. The applicant indicated that a tsunami induced by a 2,000-year return period earthquake, if it occurred, could inundate the transporter with a maximum 8.5 to 13.1 m [28 to 43 ft] of sea water at high tide. As stated earlier, the HI-STAR HB system is designed to withstand 200 m [656 ft] of water head and 4 m/s [13 ft/s] of flow velocity. Consequently, inundation of the transporter along with the HI-STAR HB system with a tsunami induced by a 2,000-year return period earthquake will not compromise the confinement function of the HI-STAR HB system (Pacific Gas and Electric Company, 2004c). The SAR indicated that the fact that the confinement function of the HI-STAR HB system may not be compromised because of the potential inundation of the HI-STAR HB system with a tsunami induced by a 2,000-year return period earthquake provides further assurance of acceptable performance in the event of a tsunami exceeding the proposed 50-year period design basis tsunami.

The staff reviewed the tsunami considerations for the Humboldt Bay ISFSI and finds that the applicant's consideration of tsunami effects is appropriate and meets the regulatory requirements of 10 CFR §72.120(a), §72.122(b)(1), §72.122(b)(2), and §72.103(f)(2)(iii). The staff's evaluation of compliance with 10 CFR §72.103(f)(2)(iii) is discussed in Chapter 2 of this SER.

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[1]Tidal patterns along the western United States coast are mixed semidiurnal, such that there are two high and two low tides each day. The semidiurnal tidal pattern is considered "mixed" because the two daily high tides and two daily low tides are of different magnitudes. Elevations in the SAR reference three tidal elevations: (i) mean lower low water (MLLW), which is the average of the lower of the two daily low tides; (ii) MHHW, which is the average of the higher of the two daily high tides; and (iii) mean sea level (MSL), which is the overall average water elevation. In the SAR, the applicant provides analyses relative to MLLW. The applicant reports that, at the Humboldt Bay ISFSI site, the difference between MLLW and MHHW is 2.1 m [6.9 ft], and the difference between MLLW and MSL is 1.13 m [3.7 ft].

Snow and Ice

As indicated in Section 2.3.1.2 of the SAR, snowfalls are rare at the Humboldt Bay ISFSI site, with an annual trace amount of 0.76 cm [0.3 in]. Section 3.2.5 of the SAR states that designing for ground snow is not necessary for the Humboldt Bay ISFSI. Figure 7-1 of ASCE 7-98 (American Society of Civil Engineers, 2000) suggests that the snow load for the region is approximately zero, consistent with the regional monitoring data.

The staff reviewed the snow and ice loading criteria for the Humboldt Bay ISFSI and finds that there is no need to design for ground snow at the Humboldt Bay ISFSI site. The staff further determined that the applicant's consideration of snow and ice loads is appropriate and in accordance with the regulatory requirements of 10 CFR §72.120(a), §72.122(b)(1), and §72.122(b)(2).

Temperature Loads

The normal thermal loads for the Humboldt Bay reinforced concrete storage vault and the HI-STAR HB system include loads associated with normal condition temperatures, temperature distributions, thermal gradients within the structure, and the effects of expansion and contraction of structural elements. As identified in Table 3.4-1 of the SAR, the annual average site ambient temperature is approximately 11.1 °C [52 °F]. The normal site maximum and minimum ambient temperatures are 30.6 °C [87 °F] and -6.7 °C [20 °F], respectively. The off-normal site ambient temperature is 15.6 °C [60 °F]. The extreme site minimum and maximum temperatures are -9.4 and 32.2 °C [15 and 90 °F], respectively.

The design basis normal temperature for the HI-STAR 100 system is 32 °C [80 °F], as identified in Section 3.2.7 of the SAR. The off-normal minimum and maximum ambient temperatures for the HI-STAR 100 system are -40.0 °C [-40 °F] and 37.8 °C [100 °F], as identified in Sections 3.2.7 and 8.1.2.3 of the SAR. The accident (extreme) minimum and maximum ambient temperatures for the HI-STAR system are -40.0 °C [-40 °F] and 51.7 °C [125 °F] as identified in Section 3.2.7 of the SAR. Because the materials and design features of the HI-STAR HB system are consistent with those for the HI-STAR 100 system, the design temperatures for the HI-STAR 100 are applicable to the HI-STAR HB. These design temperatures bound the site-specific design temperature requirements for normal, off-normal, and extreme conditions.

The staff reviewed the thermal loading criteria established for the Humboldt Bay ISFSI and finds that they are appropriate and in accordance with the regulatory requirements of 10 CFR §72.120(a), §72.122(b)(1), and §72.122(b)(2).

Fire

The staff reviewed Sections 3.3.1.6, 4.2.3.3.3, and 8.2.5 of the SAR. Potential fire hazard sources are identified in Section 2.2.2.2.1 of the SAR. Fires are categorized as engulfing and nonengulfing fires.

The bounding case for the reinforced concrete storage vault structure is an engulfing fire postulated by burning a fuel source in a pool of fuel surrounding a HI-STAR HB cask. As a result of this fire, the short-term temperature limit for the reinforced concrete may be exceeded. To recover from this fire event, the applicant will conduct an inspection and a technical assessment to determine if the ability of the reinforced concrete storage vault structure to perform its intended function is maintained. As indicated in the SAR, appropriate compensatory and corrective actions will be taken as necessary.

The HI-STAR HB system is designed to withstand an engulfing transportation fire accident with a flame temperature of 802 °C [1,475 °F] for 30 minutes. The SAR indicates the short-term design temperature limits for the SNF cladding, and all steel components of the HI-STAR HB system will not be exceeded because of this fire. The short-term design temperature limit for the Holtite-A neutron shielding material, however, will be exceeded. The dose calculation performed by the applicant, assuming a complete loss of neutron shielding, has shown that the dose rates associated with this fire accident are within regulatory limits.

According to the SAR, administrative controls will be implemented as described in Section 10.2 of the SAR to (i) avoid concurrent oil, diesel, and propane deliveries and onsite cask transfer and storage operations and (ii) isolate and depressurize gas distribution lines during onsite cask transfer and storage operations. These administrative controls are expected to further reduce the effects of credible fire scenarios.

The staff reviewed the fire considerations in the SAR and finds that the design and location of the SSCs important to safety and the operational restraints are in compliance with the regulatory requirements of 10 CFR §72.122(c). The design criteria for the HI-STAR HB system are sufficient to ensure that the relevant SSCs important to safety will be designed to perform their safety functions effectively during credible fire conditions. Also, the staff finds that the applicant's proposed actions in response to an engulfing fire accident are acceptable. The proposed actions include performing inspection and technical assessment of the vault structure to determine whether compensatory and corrective action are needed.

Explosion

The staff reviewed Sections 3.3.1.6, 4.2.3.3.2.9, and 8.2.6 of the SAR. Potential explosion sources that may affect the onsite transfer and storage operations and interim storage in the reinforced concrete vault are identified in Section 2.2.2.2.2 of the SAR.

Accidents involving explosive materials may cause overpressure on the SSCs important to safety. The magnitude of overpressure is controlled by the quantity and type of the explosive material. As indicated in Section 4.2.3.3.2.9 of the SAR, the MPC-HB is designed for an external pressure of 0.41 MPa gauge [60 psig]. The HI-STAR HB overpack is designed to withstand a 2-MPa gauge [300 psig] external pressure. Section 8.2.6 of the SAR states that these design basis overpressures are sufficient for the credible explosion scenarios postulated at the Humboldt Bay ISFSI site. In addition, the potential detonation-induced missile impacts are bounded by the impacts from the design basis tornado-generated Spectrum I missiles. As indicated in Section 4.2.3.3.2.2 of the SAR, the internal and external pressure-induced stresses are within the code allowables.

Several postulated explosion scenarios are identified to be credible to produce overpressure on the reinforced concrete storage vault and the vault cell lid. The assessment presented in Section 8.2.6 of the SAR indicates that this overpressure will have minimal adverse structural effects given the massive size of the reinforced concrete storage vault and the thickness of the vault cell lids. The damage from detonation-induced missiles may involve only local spalling on the vault cell lid and vault apron.

Administrative controls will be implemented as described in Section 10.2 of the SAR to (i) avoid concurrent oil, diesel, and propane deliveries and onsite cask transfer and storage operations and (ii) isolate and depressurize gas distribution lines during onsite cask transfer and storage operations. These administrative controls are expected to further reduce the effects of credible explosion scenarios.

The staff reviewed the explosion considerations in the SAR and finds that these considerations are in accordance with Regulatory Guide 1.91 (U.S. Nuclear Regulatory Commission, 1978) and in compliance with the regulatory requirements of 10 CFR §72.122(c).

Lightning

The staff reviewed Sections 3.2.6 and 8.2.12 of the SAR. Section 8.2.12 of the SAR postulates that a lightning strike may be possible even though lightning events may be rare at the Humboldt Bay ISFSI site. The lightning strike to the HI-STAR HB system may occur during the transfer or storage operations. The loaded HI-STAR HB cask, however, will be protected from lightning strike by the reinforced concrete vault, and the vault cell lid will be protected while it is in interim storage in the reinforced concrete vault.

During onsite transfer, the gantry and rigging metal above the cask transporter may be sufficient to protect the HI-STAR HB system from direct lightning strikes. A lightning strike to the cask transporter will not cause much damage because the current will be transmitted to the ground. In addition, the HI-STAR HB overpack is made of conductive material. If the HI-STAR HB overpack were to be struck by lightning, the current will flow from the overpack outer shell into the cask transporter and eventually into the ground. Furthermore, the cask transporter will be designed to shut down in a fail-safe condition. A lightning strike that disables the operator, therefore, will not cause an instability problem for the cask transporter. The staff reviewed the lightning design criteria as discussed in the SAR and determined that the lightning design criteria are acceptable for the design of SSCs important to safety, in compliance with the regulatory requirements of 10 CFR §72.122(b)(1) and §72.122(b)(2).

Load Combinations

The load combinations presented in Sections 3.3.2.3.1 and 3.3.2.3.2 of the SAR are used in the analyses of the concrete vault storage system SSCs important to safety. The loads considered in the load combinations for the reinforced concrete storage vault include:

- Dead loads, including piping and equipment (D)
- Live load (L)
- Lateral soil and hydrostatic pressures (H)
- Internal moments and forces due to normal, off-normal, and extreme thermal loads (T_o)
- Design-basis earthquake loads, including earthquake-induced equipment reactions (E_{ss})
- Tornado loads (W_t)

- Accident loads (A)

The loads considered in the load combinations for the cask alignment plate in the reinforced concrete storage vault include:

- Dead weight (D)
- Normal temperature loads (T_n)
- Design-basis earthquake loads (DBE)
- Tornado loads (W_t)
- Accident pressure (P_a)
- Accident loads (A)

The specific load combinations identified for the reinforced concrete storage vault and cask alignment plates are, in general, consistent with those suggested in Section 9.2.1 of ACI 349-01 (American Concrete Institute, 2001), except for the load factor for T_o. For bounding purposes, the load factor for T_o is 1.275, as suggested in Table 3-1 of NUREG-1536 (U.S. Nuclear Regulatory Commission, 1997), instead of the 1.05 value suggested by ACI 349-01 (American Concrete Institute, 2001).

According to Section 3.2.8 of the SAR, the load combinations for the HI-STAR HB system are consistent with those for the HI-STAR 100 system and the load combinations given in the HI-STAR 100 FSAR (Holtec International, 2002).

The staff reviewed the information presented in the SAR concerning load combinations and determined that the load combination design criteria are appropriately considered for the design of SSCs important to safety, as required by 10 CFR §72.122(b)(1) and §72.122(b)(2). Appropriate combinations of the effects of normal and accident conditions and the effects of natural phenomena are considered.

<u>Structural Design Criteria Conclusion</u>

The structural design criteria discussed in the previous sections represent the structural loads that may be present at the site. The SSCs important to safety for the Humboldt Bay ISFSI must be designed to withstand these structural loads, as applicable. The ability of the SSCs to perform their intended safety functions under the applicable structural design loads is evaluated in Chapters 5 and 15 of this SER.

The Humboldt Bay ISFSI is located close to the HBPP. The HBPP consists of five electric generation units. Unit 3 is a boiling water reactor (BWR) that was permanently shut down in July 1976. Units 1 and 2 are conventional fossil units, and the remaining two units are gas turbines. There are no other nuclear facilities in the vicinity of the Humboldt Bay ISFSI. Unit 3 is undergoing decommissioning, and once the SNF is transferred from Unit 3 to the ISFSI, there will not be any effect from Unit 3 decommissioning operations to members of the public. There are, therefore, no potential cumulative effects on the combined operations of the ISFSI or any nearby nuclear facilities. Consequently, the regulatory requirements of 10 CFR §72.122(e) have been satisfied.

4.1.3.3 Thermal

The staff reviewed the discussion on thermal design criteria for SSCs important to safety for normal site maximum and minimum ambient temperatures. These thermal design criteria are presented in Section 3.2.7 of the SAR. The staff's assessment of the adequacy of the site-specific temperature design criteria is contained in Chapter 2 of this SER.

The staff reviewed the ambient condition loading design criteria and determined that these criteria are acceptable because they are based on site-specific information. Consequently, the ambient condition loading design criteria satisfy the regulatory requirements of 10 CFR §72.122(b)(1) and §72.122(b)(2) and are discussed in Chapter 6 of this SER.

Off-normal and accident thermal loads for the reinforced concrete storage vault are defined in Section 3.3.2.3.1 of the SAR. The off-normal and accident ambient temperatures for the reinforced concrete storage vault and the HI-STAR HB system are given in Section 3.2.7 of the SAR. In addition, the environmental design basis temperatures for the Humboldt Bay ISFSI site are listed in Tables 3.2-3 and 3.4-1 of the SAR. These design bases are discussed briefly in Section 4.1.3.2 of this SER. The off-normal and extreme maximum ambient temperatures are 72-hour averages. The minimum and maximum operating temperatures defined for the reinforced concrete storage vault and cask transporter are −9.4 and 32.2 °C [15 and 90 °F], which are consistent with the extreme temperature conditions estimated for the Humboldt Bay ISFSI site. Consequently, the loading design criteria for the off-normal and accident thermal load conditions satisfy the regulatory requirements of 10 CFR §72.122(b)(1) and §72.122(b)(2), as discussed in Chapter 6 of this SER.

Allowable fuel cladding temperatures for short-term operation, interim storage in the reinforced concrete vault, and off-normal and accident conditions are based on Interim Staff Guidance (ISG)-11 (U.S. Nuclear Regulatory Commission, 2003b). The limit is 400 °C [752 °F] for short-term operation and interim storage and 570 °C [1,058 °F] for off-normal and accident conditions. Stress allowable values for a range of temperatures for the SSCs of the HI-STAR HB system are provided in the ASME Boiler and Pressure Vessel Code (ASME International, 1996). The performance requirements of 10 CFR §72.120(a) have been met for all materials as demonstrated by the acceptable temperatures identified in conformance with the accepted standards.

As stated in Section 4.1.1 of this SER, the maximum total heat load of a single cask is 2 kW [6,824 Btu/hr] with the maximum for each assembly equal to 50 W [171 Btu/hr]. The maximum insolation values for the Humboldt Bay ISFSI site are 2,518 g-J/cm^2 [602 g-cal/cm^2] per day for a 24-hour period and 2,481 g-J/cm^2 [593 g-cal/cm^2] for a 12-hour period. The helium supply used in the backfill process for all MPC-HBs will have a purity no less than 99.995 percent. In addition, the helium backfill pressure will be verified during loading for all MPCs-HBs to ensure that it is greater than or equal to 312 kPa gauge [45.2 psig] and less than or equal to 336 kPa gauge [48.8 psig]. The HI-STAR HB system overpack annulus will be backfilled with helium of 99.995-percent purity and a pressure between 68.9 and 96.5 kPa gauge [10.0 and 14.0 psig] once it is vacuum dried.

Thermal design criteria are based on environmental conditions specific to the Humboldt Bay ISFSI site and heat generated by the materials stored. The storage systems are passive and incorporate passive heat removal. The staff reviewed the thermal design criteria for the SSCs important to safety for the Humboldt Bay ISFSI and determined that they are appropriately identified, as required by 10 CFR §72.120(a), §72.122(b)(1), §72.122(b)(2), and §72.122(c). The staff's review of the thermal evaluation of the Humboldt Bay ISFSI is provided in Chapter 6 of this SER.

4.1.3.4 Shielding and Confinement

The staff reviewed the discussion on shielding and confinement design criteria for the SSCs important to safety for the Humboldt Bay ISFSI presented in Sections 3.3.1.2, 3.3.1.5, 4.2.3.3.6, 4.2.3.3.8, and 4.4.3.5 of the SAR.

A security fence will be constructed to surround the concrete storage vault to control access. A controlled area is identified in accordance with the regulatory requirements of 10 CFR §72.106(a). No highway, railroad, or waterway traverses the controlled area; however, a public trail does pass through the controlled area boundary. According to the SAR, the public trail has been used occasionally. During cask transfer and storage operations, the public trail will be controlled using locked gates to keep members of the public out of the controlled area. The staff's review of the applicant's measures to control public access within the controlled area, as required by 10 CFR §72.106(c), is discussed in Chapter 11 of this SER.

Criteria used for radiological protection features and confinement design bases for the HI-STAR HB system are provided in the SAR. The basic concept for shielding the HI-STAR HB system is protection by multiple barriers and using a combination of steel and Holtite-A neutron shielding material to meet the regulatory requirements of 10 CFR §72.126(a) and §72.128(a). The multiple barriers include the MPC-HB, HI-STAR HB overpack, and the reinforced concrete storage vault. The MPC-HB provides the necessary confinement for the HI-STAR HB system. The MPC-HB is seal-welded in accordance with ISG–18 (U.S. Nuclear Regulatory Commission, 2003c). The use of the HI-STAR HB system, which is a sealed canister and overpack-based system, satisfies the regulatory requirements of 10 CFR §72.122(h)(5). The reinforced concrete storage vault is designed to be below grade. The concrete material and the surrounding soil backfill provide shielding during interim storage in the reinforced concrete vault. Operating procedures, shielding design, and access controls provide the necessary radiological protection to ensure radiological exposures to Humboldt Bay ISFSI personnel and the public are as low as is reasonably achievable (ALARA), as required by 10 CFR §72.126(d). Chapter 11 of this SER provides further details and procedural considerations for radiation protection to limit public and occupational doses from Humboldt Bay ISFSI operations.

As indicated in Section 3.3.1.5.3 of the SAR, airborne or area radiological alarm systems are not necessary at the Humboldt Bay ISFSI storage vault because the storage system is passive. Portable, hand-held radiation protection instruments and self-reading dosimeters will be used during cask transfer operations and routine maintenance at the ISFSI storage area. The staff concurs with the applicant's assessment and finds that the regulatory requirements of 10 CFR §72.126(b) have been satisfied.

The offsite dose collective exposures estimated for members of the public at the public trail and the nearest resident are given in Section 7.5 of the SAR. The estimated occupational dose exposures are given in Section 7.4 of the SAR. The estimates for the off-normal and accident conditions are discussed in Chapter 8 of the SAR. The staff's review of the dose estimates is discussed in Chapter 11 of this SER. The HBPP radiation protection program, shielding design, and access controls provide the necessary radiological protection to ensure that radiological exposures to facility personnel and the public are ALARA, as required by 10 CFR §72.126(d).

The staff reviewed the design criteria for the HI-STAR HB system, and cask transfer and storage operations and determined that they are appropriately identified as required by 10 CFR §72.128(a). Detailed evaluations on shielding, confinement, and radiation protection are provided in Chapters 7, 9, and 11 of this SER.

4.1.3.5 Criticality

The staff reviewed the discussion on criticality design criteria for the SSCs important to safety for the Humboldt Bay ISFSI in Sections 3.3.1.4, 4.2.3.3.7, and 4.4.3.6 of the SAR. Standard design and criticality control methods are used for the Humboldt Bay ISFSI to maintain a subcritical condition of the stored SNF with a multiplication factor (k_{eff}) below 0.95 for all normal, off-normal, and accident conditions. Principal design features and control methods include (i) identification of maximum allowable SNF assembly enrichment and physical properties (e.g., the summary of fuel physical characteristics presented in Table 3.1-2 of the SAR), (ii) favorable geometry design for the fuel basket of the MPC-HB, (iii) permanent neutron-absorbing material in the fuel basket structure, and (iv) use of the DFC to store damaged SNF.

Criticality safety analyses have demonstrated that there are adequate safety margins for handling and storage operations at the Humboldt Bay ISFSI, as discussed in the staff's evaluation in Chapter 8 of this SER. According to the SAR, the limiting reactivity condition involves loading SNF in the spent fuel pool. Both installed and portable radiation monitoring instruments are used during cask loading and unloading activities in the RFB. During the transfer operation at the Humboldt Bay ISFSI and interim storage in the reinforced concrete storage vault, the SNF is in a helium-filled and seal-welded MPC-HB; therefore, the reactivity is low.

The staff finds that the design criteria for criticality are identified appropriately in the SAR, as required by 10 CFR §72.124(a–c). The staff's criticality evaluation is discussed in Chapter 8 of this SER.

4.1.3.6 Decommissioning

The staff's review of Section 4.7 of the SAR is presented in Chapter 13 of this SER.

4.1.3.7 Retrieval

The staff reviewed the discussion on retrieval design criteria of the SSCs important to safety for the Humboldt Bay ISFSI in Sections 3.3.1.1.1, 3.3.1.7.1, 4.2.3.2.2, 4.2.3.3.2, 4.5.1.2, and 8.2.2.3 of the SAR. The SNF will be stored in a MPC-HB, which will be placed in the HI-STAR HB overpack. Both the overpack and MPC-HB provide structural protection to prevent damage to SNF and ensure retrievability. As discussed in Section 4.1.1 of this SER, damaged fuel will be placed in DFCs before being inserted in the MPC-HB. A DFC provides a safe geometry for and ensures retrievability of the damaged SNF. The SAR further indicates that the Humboldt Bay HI-STAR HB system is designed to ensure adequate safety and to protect fuel integrity and retrievability under design basis loads. Retrievability also is discussed for tornado-generated missile accident events.

Based on the foregoing discussion, the staff finds that the HI-STAR HB system will provide adequate safety and maintain SNF retrievability for the Humboldt Bay ISFSI site-specific conditions. The staff, therefore, finds that the consideration of the retrievability of the SNF in the Humboldt Bay ISFSI design meets the regulatory requirements of 10 CFR §72.122(l) and §72.128(a).

4.1.4 Design Criteria for Other Structures, Systems, and Components

No specific requirements are identified in 10 CFR Part 72 for other SSCs not important to safety. The staff's review of the information provided in the SAR is discussed in this section, but no evaluation findings are made. The SSCs not important to safety for the Humboldt Bay ISFSI include security systems, a fence, lighting, electric power, communication systems, an automated welding system, a forced helium dehydration system, a vacuum drying system, and a cask transfer rail dolly in the RFB.

The design criteria for SSCs classified as not important to safety, but which have security or operational importance, are addressed in Chapter 4 of the SAR. Normal and emergency power needs for security equipment are discussed in Section 9.6 of the SAR. These SSCs classified as not important to safety will be designed to comply with appropriate commercial standards and codes to ensure compatibility with the SSCs classified as important to safety.

The staff finds that the use of commercial standards and codes for design of the SSCs not important to safety is acceptable.

4.2 Evaluation Findings

Based on its review of the information presented in the SAR, the staff makes the following evaluation findings regarding the proposed Humboldt Bay ISFSI:

- The staff finds that the SNF that will be stored in the Humboldt Bay ISFSI has been appropriately identified and is in compliance with 10 CFR §72.2(a)(1).

- The staff finds that the GTCC waste and the SNF will not be stored in the same MPC-HB. This approach is in accordance with the regulatory requirements of 10 CFR §70.120(b)(1).

- The staff finds that no liquid GTCC waste will be stored in the Humboldt Bay ISFSI, as the Humboldt Bay ISFSI is a dry storage facility. The regulatory requirements of 10 CFR §72.120(b)(2), therefore, have been satisfied.

- The staff finds that (i) the SSCs important to safety have been properly classified, (ii) the associated Classification Categories are consistent with the regulatory requirements of 10 CFR §72.144(a), and (iii) the supporting technical information presented in the SAR is in accordance with 10 CFR §72.24(n). This list of SSCs is based on the definition of SSCs important to safety in 10 CFR §72.3. The use of classification categories to divide the SSCs important to safety into three QA categories is consistent with the regulatory requirements of 10 CFR §72.122(a).

- The staff finds that the SAR appropriately specifies the design criteria for the SSCs important to safety in accordance with the regulatory requirements of 10 CFR §72.24(c), §72.120(a), and §72.122(h)(5). The staff also finds that the

SSCs important to safety will be designed as per the quality standards commensurate with the important to safety functions to be performed in accordance with the regulatory requirements of 10 CFR §72.144(c).

- The staff finds that the design criteria are described in sufficient detail to satisfy the regulatory requirements of 10 CFR §72.24(c).

- The staff finds that the structural design criteria given in the SAR for the SSCs important to safety have been developed from site characteristics and used in the determination of structural loads. Appropriate consideration of the natural phenomena-related design bases has been demonstrated, in compliance with the regulatory requirements of 10 CFR §72.120(a), §72.122(b)(1), §72.122(b)(2), and §72.103(f)(2)(iii); and consideration of environmental conditions in the design has been demonstrated, in compliance with the regulatory requirements of 10 CFR §72.122(c). The values for these parameters form the basis for the structural design, mechanical design, shielding, confinement, and criticality assessments of the Humboldt Bay ISFSI.

- The staff finds that the load combination design criteria have been adequately considered for the design of SSCs important to safety, as required by 10 CFR §72.122(b)(1) and §72.122(b)(2). Appropriate combinations of the effects of normal and accident conditions and the effects of natural phenomena have been considered.

- The staff finds that the cumulative effects of the combined operations of the Humboldt Bay ISFSI and the HBPP are not a concern because the BWR unit of the HBPP (Unit 3) is no longer in operation. The staff finds that the regulatory requirements of 10 CFR §72.122(e) have been satisfied.

- The staff finds that (i) no SSCs important to safety have been identified to be shared between the Humboldt Bay ISFSI and other facilities, (ii) no control room has been identified as necessary to provide safe control of the Humboldt Bay ISFSI during off-normal or accident conditions, and (iii) no utility services or distribution systems have been identified to be important to safety. The staff finds that the regulatory requirements of 10 CFR §72.122(d) and §72.122(k)(1) have been satisfied.

- The staff finds that a controlled area has been identified, in accordance with the requirements of 10 CFR §72.106(a). As a public trail traverses the controlled area, the staff finds that the applicant will implement appropriate measures to control traffic and protect the public health and safety, as required by 10 CFR §72.106(c).

- The staff finds that radiological protection features and confinement design bases for the HI-STAR HB system satisfy the regulatory requirements of 10 CFR §72.126(a). The use of the sealed canister and overpack-based HI-STAR HB system allows handling and retrievability without the release of radioactive materials to the environment or radiation exposures in excess of 10 CFR Part 20 limits; thus, the design satisfies the regulatory requirements of 10 CFR §72.122(h)(5).

- The staff finds that the use of portable, hand-held radiation protection instruments and self-reading dosimeters during cask transfer operation and routine maintenance at the ISFSI storage area satisfies the regulatory requirements of 10 CFR §72.126(b).

- The staff finds that the use of operating procedures, shielding design, and access controls provides necessary radiological protection to satisfy the ALARA requirements of 10 CFR §72.126(d).

- The staff finds that design criteria for the storage and handling of SNF have been properly specified, as required by the regulatory requirements of 10 CFR §72.128(a).

- The staff finds that the design criteria for criticality have been identified in the SAR as required by 10 CFR §72.124(a–c).

- The staff finds that the Humboldt Bay ISFSI design, which includes the use of the HI-STAR HB system, allows for retrieval of SNF, in accordance with 10 CFR §72.122(l).

- The staff finds that the applicant has defined the design criteria for the cask transporter, trunnions, and lifting bolts to conform with the single-failure-proof systems in accordance with NUREG-0612 (U.S. Nuclear Regulatory Commission, 1980), and that these design criteria are in compliance with the regulatory requirements of 10 CFR §72.120(a) and §72.122(h)(5).

4.3 References

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5 INSTALLATION AND STRUCTURAL EVALUATION

5.1 Conduct of Review

This chapter describes the staff's review of the installation and structural evaluation presented in Chapter 4 of the Humboldt Bay ISFSI Safety Analysis Report (SAR) (Pacific Gas and Electric Company, 2004a). The staff also reviewed related information from Chapters 2, 3, 5, and 8 of the SAR. The objective of the structural evaluation review is to ensure the structural integrity of structures, systems, and components (SSCs) with emphasis on those that are important to safety.

Spent nuclear fuel (SNF) dry storage facilities are designed for the safe confinement and storage of SNF. The design of the proposed Humboldt Bay ISFSI is based on the use of the HI-STAR HB system, which is a modified version of the HI-STAR 100 system (Holtec International, 2002), which has been reviewed and approved for general use by the NRC (U.S. Nuclear Regulatory Commission, 2001a). Where applicable, the staff relied on the review carried out during the certification process of the HI-STAR 100 system, as documented in the HI-STAR 100 System Safety Evaluation Report (SER) (U.S. Nuclear Regulatory Commission, 2001b). The major categories of safety protection systems discussed in the following sections include (i) confinement SSCs, (ii) reinforced concrete structures, (iii) other SSCs important to safety, and (iv) SSCs not important to safety.

The staff's review considered how the SAR and related documents address the regulatory requirements of 10 CFR §72.24(a–d), §72.24(i), §72.103(b), §72.103(f)(2)(i), §72.103(f)(2)(iv), §72.120(a), §72.122(a), §72.122(b)(1), §72.122(b)(2), §72.122(b)(3), §72.122(b)(4), §72.122(c), §72.122(f), §72.122(g), §72.122(h)(1), §72.122(h)(4), §72.122(i), §72.122(l), and §72.128(a). Complete citations of these regulations are provided in the Appendix of this SER.

5.1.1 Confinement Structures, Systems, and Components

There are three confinement barriers for the radioactive contents stored in the HI-STAR HB System: fuel cladding of intact fuel assemblies, the multipurpose canister (MPC-HB), and the overpack. No credit is taken for the fuel cladding or the overpack in the confinement system storage design. The MPC-HB, which is a strength-welded enclosure vessel, provides the confinement boundary for all normal, off-normal, and accident conditions, including natural phenomena. The discussion about confinement SSCs is presented in Sections 3.3.1 and 4.2.3 of the SAR.

Section 4.5 of the SAR presents the classification of SSCs. The SSCs important to safety are divided in Categories A and B. Category A refers to items critical to safe operation and includes SSCs whose failure or malfunction could directly result in a condition adversely affecting public health and safety. The failure of a single item could cause loss of containment, leading to the release of radioactive material, loss of shielding, or unsafe geometry compromising criticality control. Category B items have a major impact on safety and include SSCs whose failure or malfunction could indirectly result in a condition adversely affecting public health and safety. Table 4.5-1 of the SAR provides a list of important to safety and not important to safety items.

5.1.1.1 Description of Confinement Structures

The MPC-HB is the main confinement structure of the HI-STAR HB system. The MPC-HB is a modified version of the MPC of the generic HI-STAR 100 system. A detailed description of the generic MPC is provided in the HI-STAR 100 System Final Safety Analysis Report (FSAR) (Holtec International, 2002). The modifications of the MPC-HB with respect to the generic MPC are listed in Section 4.2.3 of SAR. In addition to being a shorter confinement system, the MPC-HB can store up to 80 Humboldt Bay Power Plant (HBPP) fuel assemblies versus 68 fuel assemblies in the generically certified system. The staff finds that the confinement structure is sufficiently described in the SAR in accordance with 10 CFR §72.24(a–b); §72.122(h)(1), §72.122(h)(4), and §72.122(i).

5.1.1.2 Design Criteria for Confinement Structures

The design criteria for the generic MPC are presented in the HI-STAR 100 System FSAR (Holtec International, 2002) and evaluated in the related SER (U.S. Nuclear Regulatory Commission, 2001b). A summary of the design criteria is contained in Table 2.01 of the HI-STAR 100 System FSAR (Holtec International, 2002). Design criteria for the MPC-HB system are summarized in Table 3.4-2 of the SAR.

The design, fabrication, and inspection of the MPC-HB is in accordance with the guidelines followed for the generic MPC (Holtec International, 2002). Thus, the MPC-HB confinement boundary is designed in accordance with ASME Boiler and Pressure Vessel Code, Section III, Subsection NB, Articles NB-3200 and NB-3300 (ASME International, 1996). Fabrication of the MPC-HB is in accordance with ASME Boiler and Pressure Vessel Code, Section III, Subsections NB, Article NB-4000, and NG, Article NG-4000 (ASME International, 1996). The MPC-HB inspection is in accordance with ASME Boiler and Pressure Vessel Code, Section III, Subsection NB, Articles NB-5000 and NG-5000 (ASME International, 1996), and Section V (ASME International, 2001b).

Nondestructive examination techniques and acceptance criteria for the MPC-HB welds are provided in Sections 8.1 (transport) and 9.1 (storage) of the HI-STAR 100 System FSAR (Holtec International, 2002). MPC-HB confinement boundary welding is in accordance with the ASME Boiler and Pressure Vessel Code, Section IX (ASME International, 2001c); and Section III, Subsections NB and NG (ASME International, 1996). As indicated in Table 2.01 of the HI-STAR 100 System FSAR (Holtec International, 2002), the design criteria for the MPC-HB lifting points are in accordance with American National Standard Institute (ANSI) N14.6 (American National Standard Institute, 1993) and NUREG-0612 (U.S. Nuclear Regulatory Commission, 1980).

The staff finds that the design criteria of the confinement structures meet the requirements of 10 CFR §72.24(c)(1), §72.24(c)(2), §72.24(c)4, §72.120(a), §72.122(a), §72.122(b)(2), §72.122(b)(3), §72.122(c), §72.122(f), §72.122(g), §72.122(h)(1), §72.122(h)(4), §72.122(i), §72.122(l), and §72.128(a).

5.1.1.3 Material Properties for Confinement Structures

Materials Selection

A description of the MPC-HB, including materials of construction, fabrication details, and testing, is provided in Section 4.2.3 of the SAR. Engineering drawings and additional details of the storage system are included in Chapter 3 of the SAR and by reference in the HI-STAR 100 System FSAR (Holtec International, 2002). The nominal physical characteristics of the MPC-HB are provided in Table 4.2-1 of the SAR.

The structural components of the MPC-HB are constructed from Types 304, 304LN, 316, or 316LN austenitic stainless steel (Holtec International, 2002). Stainless steels were selected based on mechanical properties and corrosion resistance. Material procurement is in accordance with ASME Boiler and Pressure Vessel Code, Section II (ASME International, 2001d–f) and Section III, Subsections NB and NG, Articles NB-2000 and NG-2000 (ASME International, 1996). The staff concludes that the selection of these materials is acceptable for the MPC-HB, in compliance with 10 CFR §72.24(c), §72.122(a), and §72.122(c).

Welds

The MPC-HB welds are characterized in Figure 3.3-1 of the SAR. The drawing includes standard welding symbols and notations in accordance with American Welding Society (AWS) Standard A2.4 (American Welding Society, 1998). The stainless steel materials for the MPC-HB are readily weldable using commonly available welding techniques. MPC-HB closure welds are inspected using visual and ultrasonic testing or multilayer penetrant testing. Techniques and acceptance criteria are governed by ASME Sections V and III, respectively. The staff concludes that the welded joints of the MPC-HB meet the requirements of ASME and AWS codes and that the design complies with 10 CFR §72.24(c) and §72.122(a).

Mechanical Properties

Mechanical properties of the structural materials for the MPC-HB are provided in Section 4.2.3.2.1 of SAR and supplemented by Tables 3.3.1–3.3.5 of the HI-STAR 100 System FSAR (Holtec International, 2002). Qualification of the MPC-HB structure is accomplished using the least favorable mechanical and thermal properties of the entire group for all mechanical, structural, neutronic, radiological, and thermal conditions. The values in these tables were obtained from ASME Code Section II, Part D (ASME International, 2001f).

The staff finds that the material properties are acceptable for the expected loading conditions during the license period and comply with 10 CFR §72.24(c), §72.122(a), and §72.122(c).

Coatings

No coatings are used on the MPC-HB.

Chemical and Galvanic Reactions

Evaluation of possible chemical, galvanic, and other reactions among the materials in the range of possible exposure environments is included in Section 4.6 of the SAR. The evaluation includes stainless steels used in the MPC-HB. The staff finds that no adverse reactions are anticipated for stainless steels used in the MPC-HB.

Based on the previous discussion of the mechanical properties, coating, and chemical and galvanic reaction of the selected materials, the staff finds that the material selection for the confinement structures meets the requirements of the ASME and AWS codes, as applicable. The staff finds that the material properties for the confinement structure have been acceptably identified in accordance with 10 CFR §72.24(c)(3), §72.120(a), and §72.122(a).

5.1.1.4 Structural Analysis for Confinement Structures

Section 4.2.3.3.2 of the SAR states that the MPC-HB is identical in design to the generic MPC except for the height. Thus, the structural evaluation for the generic MPC forms the structural licensing basis for the MPC-HB. The structural design and analysis of the HI-STAR HB components have been performed for the following normal, off-normal, and accident conditions:

- Dead and Live Loads (SAR Section 4.2.3.3.2.1)
- Internal and External Pressure Loads (SAR Section 4.2.3.3.2.2)
- Thermal Expansion (SAR Section 4.2.3.3.2.3)
- Handling Loads (SAR Section 4.2.3.3.2.4)
- Overpack Tipover and Drop (SAR Section 4.2.3.3.2.5)
- Tornado Winds and Missiles (SAR Section 4.2.3.3.2.6)
- Flood and Tsunami (SAR Section 4.2.3.3.2.7)
- Earthquake (SAR Section 4.2.3.3.2.8)
- Explosion Overpressure (SAR Section 4.2.3.3.2.9)
- Humboldt Bay-Specific Structural Analyses (SAR Section 4.2.3.3.2.10)
- Turbine Missiles (SAR Section 4.2.3.3.2.11)

The review and acceptance of the generic MPC is documented in the HI-STAR 100 System SER (U.S. Nuclear Regulatory Commission, 2001b), which shows that the HI-STAR 100 system maintains structural integrity under all credible loads. Based on the similarity of the two designs, the staff finds that the stresses in the MPC-HB under the most critical load combinations are less than the allowable stresses of ASME Boiler and Pressure Vessel Code Section III (ASME International, 1996) for the confinement materials.

Although the structural configuration of the generic MPC and the MPC-HB are very similar, the decelerations due to potential seismic events for the MPC-HB are not bounded by the generic MPC. The peak ground accelerations of the design basis earthquakes are larger than the maximum acceptable seismic acceleration level for the HI-STAR 100 system (U.S. Nuclear Regulatory Commission, 2001a) for the top surface of an ISFSI pad. The Humboldt Bay ISFSI SAR, therefore, presents seismic dynamic analyses of the cask-storage vault interaction to ensure that the maximum impact forces do not impose a deceleration loading on the cask that exceeds the cask design basis (Holtec International, 2005a, HI-2033014). The analyses are carried out in the program Visual Nastran (MSC Software Corporation, 2002), and the obtained peak accelerations are below the design basis value when subjected to four design basis seismic events. The validation of this program for the computations required in the cask-vault dynamic interaction has been found acceptable by the staff. The staff, therefore, finds that the confinement structure analysis complies with 10 CFR §72.24(d)(1), §72.24(d)(2), §72.122(b)(2), §72.122(b)(3), §72.122(c), §72.122(f), §72.122(g), §72.122(h)(1), §72.122(h)(4), and §72.122(l).

5.1.2 Pool and Pool Confinement Facilities

This provision is not applicable to 10 CFR Part 72 dry storage facilities.

5.1.3 Reinforced Concrete Structures

This section contains a review of Section 4.2.2 of the SAR. The staff reviewed the discussion about reinforced concrete structures that are important to safety with respect to the applicable regulatory requirements.

5.1.3.1 Description of Reinforced Concrete Structures

The Humboldt Bay ISFSI reinforced concrete storage vault has been classified as important to safety. Its function is to provide a structurally competent facility for storing the loaded storage casks for all design basis loading conditions. The storage vault is composed of six below-grade, cylindrical storage cells of reinforced concrete with a carbon steel liner. The storage vault will accommodate five HI-STAR HB casks and one Greater than Class C (GTCC) certified cask in individual storage cells. Figure 4.1-1 of the SAR shows the layout of the cask storage cells. The storage vault will be inspected by a camera for overall cleanliness (Pacific Gas and Electric Company, 2004b). Figure 3.2-1 of the SAR shows the dimensions of the storage vault and components, and Drawing 4105 (Pacific Gas and Electric Company, 2004b) presents the properties of the concrete and steel reinforcement. Section 4.2.2.5 of the SAR presents a description of the storage vault and associated operations procedures, including inspection, maintenance, and testing. The staff finds that the design description of the vault provided in the SAR and supporting documents is sufficiently detailed to support a review and evaluation in accordance with 10 CFR §72.24(a), §72.24(b), §72.122(f), and §72.122(i).

5.1.3.2 Design Criteria for Reinforced Concrete Structures

The design bases for the reinforced concrete storage vault are given in Sections 3.3.2 and 4.2.2.5 of the SAR. Table 3.4-3 of the SAR identifies details of the storage vault design in compliance with the general design criteria of 10 CFR Part 72, Subpart F.

The cask storage vault design is based on a loaded cask weight that bounds the loaded weight of each HI-STAR HB overpack and the GTCC cask stored the ISFSI. The reinforced concrete vault is designed in accordance with the ultimate strength design methods specified in American Concrete Institute (ACI) 349-01 (American Concrete Institute, 2001) and NUREG-1536 (U.S. Nuclear Regulatory Commission, 1997). The ACI 349-01 Code specifies the minimum requirements for the design and construction of nuclear safety-related concrete structures and structural elements for nuclear power generating stations. Load combinations for the vault design are provided in ACI 349-01 (American Concrete Institute, 2001) and supplemented by the factored load combinations from Table 3-1 of NUREG-1536 (U.S. Nuclear Regulatory Commission, 1997). In addition, based on the assessment of the potential settlement of the reinforced concrete vault (Pacific Gas and Electric Company, 2004b), the staff concludes that the storage casks can be retrieved from the reinforced concrete storage vault.

The staff finds that the reinforced concrete structures design criteria and relevant codes and standards have been identified in accordance with 10 CFR §72.24(c)(1), §72.24(c)(2), §72.24(c)(4), §72.120(a), §72.122(a), §72.122(b)(2), §72.122(b)(3), §72.122(c), §72.122(f), §72.122(g), §72.122(h)(1), §72.122(h)(4), §72.122(i), §72.122(l), and §72.128(a).

5.1.3.3 Material Properties for Reinforced Concrete Structures

The staff reviewed the construction materials for the reinforced concrete storage vault, as identified in Section 4.2.2.4 of the SAR. The material selected is concrete with a compressive strength of 27.6 MPa [4,000 psi] at 28 days and reinforcing steel bars that meet ASTM A615, Grade 60, specifications. Additional information related to the durability of the reinforced concrete and rebar corrosion is presented in the applicant's response to the staff's RAI (Pacific Gas and Electric Company, 2004b). In this document, the applicant indicates that the cement used to fabricate the vault will be Type II. The upper limit of the concrete water-to-cement ratio shall be 0.45 to limit any possible attack on the cement paste. The applicant also indicates that the concrete cover (7.6 cm [3 in] minimum on all surfaces, except 5.1 cm [2 in] on the top surface) for the reinforcement will limit any aggravated corrosion of the reinforcement. This concrete cover complies with ACI 349-01 specifications (American Concrete Institute, 2001) and is measured to the outer edge of stirrups or ties. The water-to-cement ratio and concrete cover should be carefully monitored during the construction process because they are the two main factors that will prevent rebar corrosion in the reinforced concrete storage vault. The staff finds that materials for the reinforced concrete storage vault have been adequately identified in accordance with 10 CFR §72.24(c).

5.1.3.4 Structural Analysis for Reinforced Concrete Structures

Section 8.2.1.2.4.2 of the SAR summarizes the seismic analysis of the reinforced concrete storage vault. The objectives are to ensure that (i) the concrete maintains shielding under normal factored dead and live loads and (ii) cask spacing is maintained and the cask-to-vault liner shims maintain their ability to transfer loads under applicable load combinations that include seismic events.

Structural analyses were carried out to ensure that the storage vault would be able to withstand extreme environmental and natural phenomena without impairing its capability to perform its design functions. The storage vault was analyzed for the following normal, off-normal, and accident loading conditions:

- Dead loads
- Live loads
- Soil pressure loads
- Temperature gradients
- Earthquake loads
- Tornado-generated missile loads

- Lightning
- Blast and explosion overpressures

Flooding is inapplicable to the ISFSI site. This has been evaluated in Section 2.1.4.2 of this SER. Wind and tornado wind loads are also inapplicable because the vault is buried, and only the pressure differential was considered for the design of the vault lid. The relationship between the design criteria identified in Chapter 3 of the SAR and the analysis procedures was established in accordance with the requirements of 10 CFR §72.24(c)(2). The applicable codes and standards used in the analyses of the reinforced concrete structures also have been identified in the SAR, in accordance with the requirements of 10 CFR §72.24(c)(4).

The reinforced concrete storage vault was analyzed using the ANSYS finite element analysis code (ANSYS, Inc., 2002) to determine the end forces and displacements of the structure (Pacific Gas and Electric Company, 2004b; Holtec International, 2004a, HI-2033013). In the analyses, all materials are assumed to be homogenous, isotropic, and linear elastic. The capacities of the critical sections of the vault were calculated using the program ShapeBuilder (Integrated Engineering Software Inc., 2002), which produces axial force-bending moment interaction diagrams.

The following sections describe the specific analyses related to the reinforced concrete vault provided by the applicant.

Thermal analysis

The thermal analysis of the storage vault is a two-step process consisting of (i) calculating the temperature distribution and (ii) calculating the thermal stresses. For the temperature distribution, a loaded cell was assumed to have the maximum allowable local temperature applied to its inner surface. Empty cells were assumed to have adiabatic boundary conditions applied to their inner surfaces. The far-field boundary conditions were set at the site annual average soil temperature. Adiabatic boundary conditions were also assumed to exist over the top surface of the soil and vault. A steady-state solution method was used to solve for the nodal temperatures. The nodal temperatures were then used as input to the thermal stress analysis. The maximum local temperature of 93.3° C [200° F] is assumed as the temperature of the inside of cells. The thermal boundary conditions are discussed in Section 8.2 of Holtec International (2004a, HI-2033013) and evaluated in Chapter 6 of this SER. The staff concludes that the analysis performed complies with 10 CFR §72.24(d).

Soil Stability

Analysis of the stability of the subsurface materials under the reinforced concrete vault and the potential for failure are provided in the applicant's response to the staff's RAI (Pacific Gas and Electric Company, 2004b). Two loading cases have been considered for the vault settlement analysis: (i) one cell filled and (ii) all cells filled. The applicant indicates that the vault loading configurations were chosen to maximize the structural demand on various facets of the configuration. The staff determined that all intermediate loading cases are not necessarily bounded by these loading configurations, as the case with three cells loaded results in a larger vertical load and overturning moment than the case for one cell loaded. However, the settlement and bearing capacity results presented by the applicant have large safety factors because the load imposed by the vault is similar to the weight of the soil excavated. The staff determined that these large safety factors provide sufficient margin to compensate for any differences in the calculated maximum load; therefore, the staff finds that the applicant's subsurface soil stability analysis conclusions remain valid. Thus, the staff concludes that the analysis complies with 10 CFR §72.24(d) and §72.103(f)(2)(iv).

Seismic Analysis

The applicant used a static seismic analysis to apply the earthquake loads to the storage vault using the Newmark method for combining orthogonal seismic components. Because the vault is considered a rigid structure, inertial loads due to vault self-weight are computed based on the zero period acceleration of the deterministic uniform hazard spectra (UHS) evaluated in Chapter 2 of the SAR. Although the analysis does not consider potential amplifications of acceleration forces due to soil-structure interaction (SSI), several counteracting conservative factors have not been taken into account in the analysis. An independent staff analysis identified most of these conservative assumptions and quantitatively evaluated the assumptions that directly modify the input acceleration forces and the design safety factors. The main conservative assumptions quantitatively estimated are (i) the use of the deterministic UHS instead of the 2000 year probabilistic UHS, which present smaller spectral accelerations; (ii) the use of an elastic design without considering the structural performance of the reinforced concrete vault in the nonlinear range; and (iii) the conservatism in the capacity reduction factors used in the reinforced concrete design. Based on these conservative assumptions, the staff has concluded that the design of the reinforced concrete vault is acceptable, even if amplifications of acceleration forces occur in the soil-vault cask system due to SSI.

There are other conservative factors, such as additional damping of the soil-vault system and embedment of the vault that cannot be quantified without a comprehensive SSI analysis and have not been included in the review. The staff concludes that the reinforced concrete vault design complies with the requirements of 10 CFR §72.24(d), §72.103(b), §72.103(f)(2)(i), and §72.122(b)(2).

Soil Surcharge Pressure

The applicant indicates that the crawler (transporter) load on the crawler track extensions will not give rise to significant soil surcharge pressures on the walls of the vault (Holtec International, 2004a, HI-2033013). The crawler load is assumed to be a uniformly distributed pressure acting over the footprint of the treads. This load has been distributed over an approximate area consistent with the mesh density in the finite element model. The staff finds that this procedure complies with 10 CFR §72.24(d).

5.1.4 Other Structures, Systems, and Components Important to Safety

This section contains a review of Sections 4.2, 4.3, 4.4, 4.5, 4.6, and 8.2 of the SAR. The staff reviewed the discussion of other SSCs classified as important to safety with respect to the applicable regulatory requirements.

5.1.4.1 Description of Other Structures, Systems, and Components Important to Safety

The following SSCs were identified in the SAR as other SSCs important to safety.

HI-STAR HB Overpack [Quality Assurance (QA) Category A]

The HI-STAR HB overpack is a carbon steel cylindrical vessel that contains the MPC-HB. The overpack serves as a missile barrier and radiation shield and provides flow paths for natural convective heat transfer and stability for the system (SAR Section 4.2.3.2.3).

The HI-STAR HB overpack is shorter than the generic HI-STAR 100 overpack, does not include pocket trunnions, and has an updated design of the neutron shield enclosure (SAR Section 4.2.3.2.3). The neutron shield enclosure of the HI-STAR HB overpack is a one-piece cylindrical shell instead of several channels and steel plate panels welded together to form the enclosure shell. This neutron shield enclosure provides better shielding and simplified fabrication than the generically certified system.

The staff finds that HI-STAR HB overpack has been sufficiently described in accordance with 10 CFR §72.24(a), §72.24(b), §72.122(h)(1), §72.122(h)(4), and §72.122(i).

Fuel Basket (QA Category A)

The fuel basket provides support for the fuel assemblies and the geometry and fixed neutron absorbers for criticality control. In the SAR, a description of the fuel basket is provided in Section 4.2.3.2.1, and a layout is presented in Figure 3.3-2. The MPC-HB fuel basket is designed to store 80 fuel assemblies, whereas the generic MPC is designed to store only 68 fuel assemblies. The structural components of the MPC-HB fuel basket are similar to those of the generic MPC and are sufficiently described in the Humboldt Bay ISFSI SAR and in the HI-STAR 100 system FSAR (Holtec International, 2002), in accordance with 10 CFR §72.24(b).

Upper Fuel Spacers in MPC-HB (QA Category B)

The upper fuel spacers are fabricated from W4X13 beams and welded to the bottom of the MPC-HB lid. These spacers are described in Section 4.2.3 of the SAR and in Holtec International (2005b, HI-2033035). Because the intact fuel assemblies are shorter than a damaged fuel container (DFC), the function of these spacers is to maintain the position of the intact fuel assemblies relative to the fuel basket. The staff finds that the upper fuel spacers have been sufficiently described in accordance with 10 CFR §72.24(b) and §72.122(i).

Fuel Basket Spacers in MPC-HB Fuel Basket (QA Category A)

The MPC-HB fuel basket includes longitudinal fuel basket spacers welded to the top of the basket at several locations around the periphery to prevent the upper fuel spacers from impacting the top of the basket. The fuel basket spacers are described in Section 4.2.3 of the SAR and in Holtec International (2004b, HI-2033035). The staff concludes that fuel basket spacers have been sufficiently described in accordance with 10 CFR §72.24(b) and §72.122(i).

Damaged Fuel Container (QA Category A)

The description of the DFC is provided in Section 4.2.3.2.2 and Figure 4.2-3 of the SAR. The DFC is a long, square, stainless steel container used to retain the damaged fuel in its storage cell and to provide the means for ready retrievability. The DFC permits gaseous and liquid media to escape into the interior of the MPC-HB, but minimizes the dispersal of gross particles during interim storage. The staff finds that the DFC has been described adequately in accordance with 10 CFR §72.24(b) and §72.122(i).

Storage Cell Lid and Storage Cell Lid Closure Bolts (QA Category B)

The storage cell lid layout is presented in Figure 3.2-1 of the SAR. The lid consists of a steel bottom plate {2.5 cm [1 in] thick}, a steel top plate {0.6 cm [0.25 in] thick}, and a concrete fill {~38.1 cm [15 in] thick}. The lid has eight bolts to anchor it to the steel liner. The staff concludes that the description of the storage cell lid and lid bolts complies with 10 CFR §72.24(b).

Storage Cell Steel Liner and Seismic Lateral Restraints (QA Category B)

There are fixed cask seismic restraints at the bottom of the liner and removable seismic restraints at the top of the liner (SAR Figure 3.2-1). The staff finds that the storage cell steel liner and seismic lateral restraints have been sufficiently described in accordance with 10 CFR §72.24(b).

Lift Links (QA Category A), Transporter Connection Pins (QA Category B), and Lateral Cask Restraining System

As identified in Section 4.3.2.1.2 of the SAR, the cask transporter uses steel lift links that engage the HI-STAR HB overpack lifting trunnions via connector pins. The lateral cask restraining system is used to secure the load during transfer operations. The restraint system is designed to prevent lateral and transverse swinging of the load. The lift links, connector pins, and lateral restraining system are classified as important to safety, purchased commercial grade, and qualified for loading operations by testing prior to service. The design of the associated lifting devices also allows for control of loads in the event of emergencies. The staff concludes that lifting devices have been sufficiently described in accordance with 10 CFR §72.24(b), §72.122(f), and §72.122(g).

Cask Transporter (QA Category A)

Section 4.3 of the SAR indicates that the cask transporter is designed to lift, handle, and transfer a loaded HI-STAR HB overpack from the Refueling Building (RFB) to the ISFSI site. The cask transporter is a self-propelled, open front, tracked vehicle used for the handling and onsite transfer of loaded overpacks (SAR Figures 4.3-1–4.3-3). The same cask transporter licensed for use at the Diablo Canyon ISFSI will be used at the Humboldt Bay ISFSI.

The description of the cask transporter in Section 4.3.2.1 of the SAR includes consideration of inspection, maintenance, and testing in accordance with ANSI N14.6 (American National Standards Institute, 1993) and NUREG-0612 (U.S. Nuclear Regulatory Commission, 1980). This design also allows for emergency load carrying capability. The staff finds that the cask transporter has been sufficiently described in accordance with 10 CFR §72.24(b), §72.122(b)(4), §72.122(f), and §72.122(g).

5.1.4.2 Design Criteria for Other Structures, Systems, and Components Important to Safety

The design bases for other SSCs important to safety are given in Table 3.4-2 of the SAR. The design bases identify details of the design criteria of other SSCs important to safety and comply with the general design criteria of 10 CFR Part 72, Subpart F. The design criteria establish the minimum design, fabrication, construction, testing, maintenance, and performance requirements for SSCs important to safety.

HI-STAR HB Overpack (QA Category A)

The design criteria for the HI-STAR HB overpack are addressed in Section 3.3.1.1.2 of the SAR. A detailed description and summary of the design criteria for the certified HI-STAR 100 overpack are provided in Sections 1.2.1.2 and 2.0.2 of the HI-STAR 100 System FSAR (Holtec International, 2002). Due to the fact that the HI-STAR HB overpack design features are similar to the HI-STAR 100, the overpack top flange, closure plate, inner shell, and bottom plate are designed and fabricated in accordance with ASME Code, Section III (ASME International, 1996), Subsection NB. The remainder of the HI-STAR HB overpack steel structure is designed and fabricated in accordance with the requirements of ASME Code Section III, Subsection NF (ASME International, 1996). The overpack is designed for all normal, off-normal, and design basis accident condition loadings.

Welding of the overpack structure is in accordance with the ASME Boiler and Pressure Vessel Code Sections III and IX (ASME International, 1996, 2001c) Subsection NB [pressure (containment) boundary welds] and Subsection NF (noncontainment boundary welds) (ASME International, 1996).

Section 4.2.3.3.2.10 of the SAR indicates that the overpack neutron shield enclosure shell was analyzed for 0.2 MPa gauge [30 psig] internal design pressure. The hoop stress and longitudinal stress were computed, and the larger of the two (hoop stress) was compared to the allowable stress from ASME Section III, Subsection NF (ASME International, 1996).

The staff concludes that the HI-STAR HB overpack design criteria and relevant codes and standards have been identified in accordance with 10 CFR §72.24(c), §72.120(a), §72.120(b)(2), §72.120(b)(3), §72.122(f), §72.122(g), and §72.122(h)(1).

Fuel Basket (QA Category A)

The design criteria for the fuel basket are discussed in Section 4.2.3.3.2.10 of the SAR. The MPC-HB fuel basket is designed in accordance with ASME Boiler and Pressure Vessel Code, Section III, Subsection NG (ASME International, 1996). Fabrication of the MPC-HB internals is in accordance with ASME Code Section III, Subsection NG (ASME International, 1996), and inspection of MPC-HB internals is in accordance with ASME Code Section III, Subsection NG-5000 (ASME International, 1996), and Section V (ASME International, 2001b).

The staff finds that the design criteria of the MPC-HB basket meet the requirements of the ASME Code, and are in accordance with 10 CFR §72.24(c), §72.120(a), §72.122(b)(2), and §72.122(b)(3).

Upper Fuel Spacers in MPC-HB (QA Category B)

The upper fuel spacers are designed to remain intact under a 60 g deceleration. In the applicant's calculations for the design of the upper fuel spacers (Holtec International, 2004b, HI-2033035), the stresses generated by normal and accident conditions are compared with the appropriate stress limit from Section III, Subsection NF of the ASME Code (ASME International, 1996). The staff concludes that the upper fuel spacers design criteria and relevant codes have been identified in accordance with 10 CFR §72.24(c), §72.120(a), §72.122(b)(2), and §72.122(b)(3).

Fuel Basket Spacers in MPC-HB Fuel Basket (QA Category A)

Section 4.2.3.3.2.10 of the SAR states that manual calculations were performed to qualify the fuel basket spacer, fuel spacer, and associated weld designs for the loads imparted by a 60 g deceleration. The applicant's computed stresses (Holtec International, 2004b, HI-2033035) are compared with the appropriate stress limits from ASME Code Section III (ASME International, 1996) for acceptance. The staff finds that the fuel basket spacers design criteria and relevant codes have been identified according to 10 CFR §72.24(c), §72.120(a), and §72.122(b).

Damaged Fuel Container (QA Category A)

The design criteria for the damaged fuel container are summarized in Table 3.4-2 of the SAR. The steel structure of the DFC is constructed in accordance with ASME Code Section III, Subsection NG (ASME International, 1996). The lifting device at the top of the DFC is designed to meet the guidance of ANSI N14.6 (American National Standards Institute, 1993). The staff concludes that the design criteria of the DFC comply with 10 CFR §72.24(c) and §72.120(a).

Storage Cell Lid and Storage Cell Lid Closure Bolts (QA Category B)

The storage cells with the lids installed provide radiation shielding, security protection, protection from the environment, and defense-in-depth protection from tornado and explosion generated missiles. The steel storage cell liner includes internal support attachments that provide lateral restraint during seismic events to ensure that the casks will continue to provide adequate structural integrity, decay heat removal, shielding, and criticality control for the stored contents (SAR Section 4.2.2.1). The vault lids and closure bolts do not perform a design function with regard to restraining uplift of the cask.

Section 3.3.2 of the SAR details the design criteria for the storage vault, and a summary is provided in Table 3.4-3 of the SAR. The staff finds that the design criteria for the storage cell lid and lid closure bolts comply with 10 CFR §72.24(c), §72.120(a), §72.122(b)(2), and §72.122(b)(3).

Storage Cell Steel Liner and Seismic Lateral Restraints (QA Category B)

The steel storage cell liner includes internal support attachments that provide lateral restraint during a seismic event (SAR Section 4.2.2.1). The design criteria for the storage cell steel liner, seismic and lateral restraints, and storage cell lid are summarized in Table 3.4-3 of the SAR. The staff concludes that the design criteria of the steel liner and seismic lateral restraints meet the requirements of the ASME Code and have been sufficiently described in accordance with 10 CFR §72.24(b), §72.120(a), §72.122(b)(2), and §72.122(b)(3).

Lift Links (QA Category A), Transporter Connection Pins (QA Category B), and Lateral Cask Restraining System

Section 4.3.2.1.2 and Table 4.3-1 of the SAR indicate that the lift links and connector pins are designed in accordance with ANSI N14.6 (American National Standards Institute, 1993), per applicable guidance from Section 5.1.6 of NUREG-0612 (U.S. Nuclear Regulatory Commission, 1980). As identified in Section 4.3.2.1.2 and Table 4.3-1 of the SAR, the lateral cask restraining system is purchased commercial grade and tested prior to use to confirm its commercial rated capacity with a ultimate safety factor of 5. Details of the lateral cask restraining system and associated lifting hardware design criteria and relevant codes and standards are presented in the HI-STAR 100 System FSAR (Holtec International, 2002). The staff finds that this description is adequate and complies with 10 CFR §72.24(c) and §72.120(a).

Cask Transporter (QA Category A)

As identified in Section 4.3.2.1.2 and Table 4.3-1 of the SAR, the cask transporter will be purchased commercial grade and tested prior to use in accordance with NUREG-0612 (U.S. Nuclear Regulatory Commission, 1980). Section 4.3.2.1.2 of the SAR indicates that the cask transporter design is suitable for conditions at the ISFSI site, including the transfer route, with its maximum grade of approximately 8.5 percent. During cask handling activities at the storage vault, the transporter will remain stable and will not overturn or experience structural failure under the design seismic event. In addition, the cask transporter is designed to withstand HBPP design-basis tornado winds and tornado-generated missiles without overturning, dropping the load, or leaving the transfer route. Other natural phenomena, such as lightning strikes, floods, and fires have been evaluated and accounted for in the cask transporter design. The description of the cask transporter includes consideration of inspection, maintenance, and testing in accordance with ANSI N14.6 (American National Standards Institute, 1993) and NUREG-0612 (U.S. Nuclear Regulatory Commission, 1980). The staff concludes that the cask transporter design criteria and relevant codes and standards have been identified in accordance with 10 CFR §72.24(c), §72.120(a), and §72.122(b)(4).

5.1.4.3 Material Properties for Other Structures, Systems, and Components Important to Safety

The staff findings regarding the material properties for other SSCs important to safety with respect to the applicable regulatory requirements are described below.

HI-STAR HB Overpack

The overpack materials for the HI-STAR HB are the same as those specified in Table 2.2-6 of the HI-STAR 100 System FSAR (Holtec International, 2002). Mechanical properties of the overpack structural materials are provided in Tables 3.3-2, 3.3-3, and 3.3-4 of the HI-STAR 100 System FSAR (Holtec International, 2002). The inner cylindrical shell is constructed from SA203E steel. The outer cylindrical shell, base plate, and lid are constructed from SA516 Grade 70 carbon steel. The bottom plate, closure plate, and top flange are constructed from SA350-LF3. The neutron shield is Holtite-A neutron shielding material. This information is identified in Figure 3.3-3 of the SAR.

All weld materials utilized in the welding of overpack components comply with the provisions of Section III, Subsection NB (ASME International, 1996), and Section IX of the ASME Code (ASME, International, 2001c). All noncode welds will also be made using welding procedures that meet Section IX of the ASME Code (ASME International, 2001c). The minimum tensile strength of the weld wire and filled material (where applicable) will be equal to or greater than the tensile strength of the base metal listed in the ASME Code.

The staff concludes that the overpack materials have been identified in accordance with 10 CFR §72.24(c), §72.122(a), and §72.122(c).

Fuel Basket (QA Category A)

MPC-HB basket structural materials are the same as those used in the HI-STAR 100 MPC basket and comply with the requirements of ASME Section II, Part A (ASME International, 2001d). All structural materials are Alloy X, which correspond to any of the following stainless steel types: 316, 316 LN, 304, and 304LN. A summary of the materials and components of the fuel basket is presented in Table 2.2-6 of the HI-STAR 100 System FSAR (Holtec International, 2002). Table 3.1-17 of HI-STAR 100 System FSAR presents the structural properties of Alloy X, and Table 4.2-1 of the SAR provides a summary of the nominal physical characteristics of the MPC-HB cask.

MPC-HB welding will be performed using welders and weld procedures that have been qualified in accordance with ASME Boiler and Pressure Vessel Code, Section IX (ASME International, 2001c) and Section III, Subsections NB and NG (ASME International, 1996).

The staff finds that the material properties of the fuel basket have been described in accordance with 10 CFR §72.24(c), §72.122(a), and §72.122(c).

Upper Fuel Spacers in MPC-HB (QA Category B)

The material properties of the W4X13 beams are taken from ASME Section II, Part D (ASME International, 2001f) at 287.8 °C [550 °F] (Holtec International, 2004b, HI-2033035). This is consistent with the normal design temperature of the MPC-HB lid (Holtec International, 2002, Table 2.2.3). The staff finds that the material properties of the upper fuel spacers are acceptable and in accordance with 10 CFR §72.24(c), §72.122(a), and §72.122(c).

Fuel Basket Spacers in MPC-HB Basket (QA Category A)

Section 4.2.3.3.2.10 of the SAR states that material properties for the fuel basket spacers were taken from ASME Section II, Part D (ASME International, 2001f). Table 4.2-7 of SAR provides the results of calculations using accident allowable stresses from the ASME code. The staff finds that the material properties are in accordance with 10 CFR §72.24(c), §72.122(a), and §72.122(c).

Damaged Fuel Container (QA Category A)

The material used in fabricating the DFC will meet the requirements of ASME Section II, Part A (ASME International, 2001d). All DFC material is type 304 stainless steel, except bolts (SA-193-B8-Class 2), hex nuts (SA-194-GR 8), and washers (any type of stainless steel). The materials of construction for the DFC are readily weldable using commonly available welding techniques. The welding materials meet the requirements of ASME Section II, Part C (ASME International, 2001d).

The selection of materials for the DFC is acceptable and meets the requirements of ASME and alternative codes. The staff concludes that the DFC materials have been identified in accordance with 10 CFR §72.24(c), §72.122(a), and §72.122(c).

Storage Cell Lid and Storage Cell Lid Closure Bolts (QA Category B)

Information about the material for the storage cell components is provided in Section 4.2.2.4 of the SAR. The storage cell lids are constructed of SA-36 or SA-516 Grade 70 carbon steel plates, whereas the storage cell lid closure bolts are constructed of SA-193-B7 material. The staff finds that the storage cell lid and lid bolts materials have been identified in accordance with 10 CFR §72.24(c), §72.122(a), and §72.122(c).

Storage Cell Steel Liner and Seismic Lateral Restraints (QA Category B)

Section 4.2.2.4 of the SAR indicates that the steel liner and seismic restraints are constructed of SA-36 or SA-516 Grade 70 carbon steel and are coated with Carboline 890 (SAR Table 4.6-1) for protection against corrosion. The staff finds that the materials for construction of the storage cell steel liner and seismic lateral restraints have been selected in accordance with 10 CFR §72.24(c), §72.122(a), and §72.122(c).

Lift Links (QA Category A), Transporter Connection Pins (QA Category B), and Lateral Cask Restraining System

Materials for the lift links, transporter connection pins and lateral cask restraining system are not explicitly identified in the SAR. These components, however, are custom-designed and will be designed and fabricated in accordance with the applicable codes and standards. These standards identify the acceptable material characteristics. Additional details of the material properties for the associated lifting devices are provided in the HI-STAR 100 System FSAR (Holtec International, 2002). The staff concludes that the materials for the lift links, transporter connection pins, and lateral cask restraining system will be in accordance with 10 CFR §72.24(c)(3).

Cask Transporter (QA Category A)

Materials for the cask transporter are not explicitly identified in the SAR. This is a custom-designed system that will be designed and fabricated in accordance with the applicable codes and standards. These standards identify the acceptable material characteristics. The staff finds that use of the applicable codes and standards for the materials of construction will be in accordance with 10 CFR §72.24(c)(3).

5.1.4.4 Structural Analysis for Other Structures, Systems, and Components Important to Safety

Other SSCs important to safety were designed and analyzed to resist the loads and loading combinations specified in the design criteria.

HI-STAR HB Overpack

The structural functions of the HI-STAR HB overpack are to (i) serve as a missile barrier for the MPC-HB, (ii) ensure stability of the HI-STAR HB system, (iii) provide structurally robust support for the radiation shielding, and (iv) provide a helium retention boundary. The overpack also facilitates handling of the loaded system. The HI-STAR HB overpack is equipped with lifting trunnions that, along with the top flange of the overpack at the trunnion-overpack interface, are designed to meet the safety requirements of NUREG-0612 (U.S. Nuclear Regulatory Commission, 1980) and ANSI N14.6 (American National Standards Institute, 1993) for single-failure-proof lifting equipment (Appendixes 3.D and 3.Y of the HI-STAR 100 System FSAR (Holtec International, 2002). The structural analyses of the HI-STAR 100 system overpack are provided in the HI-STAR 100 System FSAR (Holtec International, 2002), and these analyses are generally applicable to the HI-STAR HB system.

However, the staff has identified a difference between the trunnion-top flange drawing in the Humboldt Bay ISFSI SAR and the structural calculations presented in the HI-STAR 100 System FSAR (Holtec International, 2002). The trunnion presented in Figure 3.3-3 of the Humboldt Bay ISFSI SAR has a larger diameter and length than that used in the structural calculation of Appendix 3.Y of HI-STAR 100 System FSAR (Holtec International, 2002). The staff agrees with the applicant that this modification to the HI-STAR HB overpack provides more contact area and reduces the stresses in the trunnion-top flange interface. The modification, however, also reduces the minimum dimension of the wall flange and produces a stress redistribution that cannot be accurately predicted based on available information. The single-failure-proof criterion used for lifting loads requires that the maximum primary stress near the trunnion-cask interface must be limited to the yield stress when three times the lifted load is applied. Failure of the top flange wall could result in overpack breaching, but the lifting operations would not be adversely affected. The top flange is part of several cask engineered barriers, and the cask (overpack) does not form part of the confinement boundary. In addition, the HI-STAR HB cask is lighter than the HI-STAR 100 cask weight assumed in the structural calculations. The staff, therefore, has reasonable assurance that there is adequate safety margin against breaching of the top flange during cask lifting activities, because it is extremely unlikely that the HI-STAR HB cask trunnion redesign will result in stress redistribution and residual stresses significant enough to result in structural failure of the overpack.

The loading conditions considered in the HI-STAR 100 System FSAR (Holtec International, 2002) are the following loads:

- Dead and live loads
- Tipover
- Handling accident
- Flood
- Explosion overpressure
- Tornado
- Earthquake
- Lightning

Section 8.2 of the Humboldt Bay ISFSI SAR demonstrates the capability of SSCs important to safety to withstand postulated accidents and environmental conditions. Based on the results presented in the HI-STAR 100 System FSAR (Holtec International, 2002) for corresponding components, the stresses in the HI-STAR HB overpack structures for the most critical load combinations are less than the allowable stresses of ASME Boiler and Pressure Vessel Code Section III (ASME International, 1996) for the structure materials.

The decelerations in the HI-STAR HB overpack due to potential seismic events are not bounded by the design of the generic overpack. For the seismic response of the HI-STAR HB cask in the vault, dynamic seismic analyses were performed using Visual Nastran Desktop (Holtec International, 2004c, HI-2033014). The analyses ensure that the maximum impact forces do not impose a deceleration loading on the overpack that exceeds the cask design basis. The analyses are carried out in the program Visual Nastran (MSC Software Corporation, 2002).

The applicant did not perform an SSI analysis to demonstrate that the free field input ground motion accelerations are not amplified when filtered into the soil-vault-cask system. Thus, the dynamic properties of the soil-vault-cask system have not been identified, and the UHS presented in Section 2 of the SAR can only be used to estimate the maximum potential amplifications (i.e., the bounding amplification values). The applicant, however, has reevaluated the dynamic model of the HI-STAR HB cask-vault using vertical input time histories amplified by a factor of 2, 3, 5, and 10 (Holtec International, 2004c, HI-2033014, Appendix E). The amplified accelerations in the vertical direction are intended to account for potential amplifications of the soil-vault-cask system due to SSI. The horizontal input time histories are not altered because the embedment of the vault and the lack of surface masses will prevent significant amplifications of accelerations in the horizontal direction. The maximum factors used to amplify the vertical time history are larger than the maximum expected amplification of accelerations due to SSI, and even in these cases, the resulting decelerations at the top and bottom of the cask are below the design basis limit value for the cask.

The design of the overpack neutron shield enclosure shell is presented in Section 4.2.3.2.3 of the SAR. The cylindrical shell design was analyzed for a 0.2 MPa gauge [30 psig] internal design pressure and a 60 g end drop. The structural calculations are shown in Supplement 5 of Holtec International (2003, HI-2033042) and Appendix 3.AG of the HI-STAR 100 System FSAR (Holtec International, 2002).

The HI-STAR HB overpack design meets the loading conditions identified in the HI-STAR 100 System FSAR (Holtec International, 2002), and the additional seismic loading conditions at the Humboldt Bay site. Thus, the staff conclusions for the HI-STAR 100 System SER (U.S. Nuclear Regulatory Commission, 2001b), with respect to the structural integrity of the HI-STAR 100 system overpack, are valid for the Humboldt Bay ISFSI. The staff concludes that the analysis complies with 10 CFR §72.24(c), §72.120(a), §72.122(a), §72.122(b)(2), §72.122(b)(3), §72.122(c), §72.122(h)(1), §72.122(l), and §72.128(a).

Fuel Basket (QA Category A)

The fuel basket is designed and fabricated as a core support structure in accordance with the applicable requirements of Section III, Subsection NG, of the ASME Code (ASME International, 1996). Supplement 1 of Holtec International (2004b, HI-2033035) presents a two-dimensional finite element model (FEM) of the cross-section of the fuel basket used to perform the analysis in ANSYS (2000). The method of analysis and the model are similar to those used previously to license the generic MPC designs. Supplement 2 of Holtec International (2004b, HI-2033035) presents the strength and stability capabilities of the fuel basket cell walls to withstand the compressive load transferred by the fuel basket spacers.

The staff concludes that the analyses of the MPC-HB fuel basket meet the requirements of the ASME Code and comply with 10 CFR §72.24(d), §72.122(b)(2), §72.122(b)(3), §72.122(c), §72.122(h)(1), and §72.128(a).

Upper Fuel Spacers in MPC-HB (QA Category B)

The upper fuel spacers, as well as the welds connecting the upper fuel spacers to the MPC-HB top plate, are designed to withstand a 60 g bottom end drop. The stresses are calculated using strength of materials formulae and compared with the appropriate stress limits from Section III, Subsection NF, of the ASME Code (ASME International, 1996). The applicant has provided this information in Supplement 3 of Holtec International (2004b, HI-2033035). The staff finds that the upper fuel spacers in the MPC-HB, therefore, are adequate to withstand the normal and accident loads and comply with 10 CFR §72.24(d), §72.122(b)(2), §72.122(b)(3), and §72.122(c).

Fuel Basket Spacers in MPC-HB Basket (QA Category A)

The structural analysis of the MPC-HB fuel spacers was not bounded by structural calculations of the generic MPC. The applicant has provided a structural analysis of the fuel basket spacers for the MPC-HB (Pacific Gas and Electric Company, 2005, and Supplement 2 of Holtec International, 2005b, HI-2033035). The staff concludes that the analysis meets the requirements of 10 CFR §72.24(d), §72.122(b)(2), and §72.122(c).

Damaged Fuel Container (QA Category A)

The applicant performed an analysis of the DFC for the HI-STAR HB system (Holtec International, 2003, HI-2033042, Supplement 1). The analysis demonstrates that the storage container is structurally adequate to support the loads developed during normal lifting operations and an end drop. The lifting bolt of the container is designed to meet the requirements set forth for ANSI N14-6 (American National Standards Institute, 1993). The stress levels of the remaining components of the DFC are compared to allowable stress levels in ASME Code Section III, Subsection NG (ASME International, 1996). The staff concludes that the DFC structural analysis has been adequately described and complies with 10 CFR §72.24(c), §72.24(d), §72.122(b)(2), and §72.128(a).

Storage Cell Lid and Storage Cell Lid Closure Bolts (QA Category B)

The storage cell lids are not included in the FEM of the storage vault (Holtec International, 2004a, HI-2033013), although the weight of the lids is applied as a uniformly distributed pressure in mechanical load cases. The structural analysis of the storage cell lid is performed separately from the FEM. This analysis only includes static and dynamic loads associated with the weight of the storage cell lid. Tornado missile analysis was not performed on the vault or lid because the overpack is qualified to withstand the impact of tornado missiles exceeding those required by the ISFSI site conditions according to Section 4.2.2 of the SAR and the HI-STAR 100 System FSAR (Holtec International, 2002).

The calculations include the structural adequacy of the bolts under seismic reactions on the lid considering self-weight for the seismic mass. Because the cask storage vault is buried, wind and tornado wind loads are not applicable; however, a tornado pressure drop on the outside of the vault produces an internal pressure on the lid. The net hydrostatic load on the lid, which is standing water on top of the lid caused by tsunami, is considered in the calculation.

The vault storage lids and lid closure bolts may be exposed to accidental loads that have not been analyzed by the applicant. As mentioned previously, the applicant reevaluated the dynamic model of the HI-STAR HB cask-vault system using amplified vertical time histories (Holtec International, 2005a, Appendix E, HI 2033014). As a result of the most severe of these vertical amplifications, the dynamic analysis of the cask-vault system indicates that the cask will impact the storage cell lid. However, the applicant calculated that the HI-STAR HB overpack would not exceed its design basis deceleration limit of 60 g for a value of vertical amplification from SSI effects up to 9.5, which is not considered credible for the Humboldt Bay site. Therefore, the overpack will maintain its integrity and continue to perform its design function following a seismic event. Thus, for beyond design basis seismic scenarios involving extreme vertical SSI amplification effects, the storage cell lid and lid closure bolts are not relied upon to perform a safety function, and are classified as not important to safety. In addition, the storage cell lid is not relied upon to provide a shielding function in this scenario, as the accident dose limits of 72.106(c) would not be exceeded even if the lid were damaged. The staff concludes that the structural analysis of the storage cell lid and lid bolts has been adequately described and complies with 10 CFR §72.24(c), §72.24(d), §72.122(b)(2), and §72.128(a).

Storage Cell Steel Liner and Seismic Lateral Restraints (QA Category B)

Structural calculations for the steel liner are not performed because its primary purpose is to provide a form for pouring concrete.

The applicant has provided static and dynamic analysis to demonstrate the structural integrity of the seismic lateral restraints to punching and potential buckling failure of the cask alignment plates due to seismic events (Pacific Gas and Electric Company, 2004b; Holtec International, 2004a, HI-2033013). The staff concludes that the structural analysis of the seismic lateral restraints meet the requirements of 10 CFR §72.24(d), §72.122(b)(2), §72.122(b)(3), §72.122(c), §72.122(h)(1), and §72.128(a).

Lift Links (QA Category A), Transporter Connection Pins (QA Category B), and Lateral Cask Restraining System

Structural analysis of the associated lifting hardware is provided in the HI-STAR 100 System FSAR (Holtec International, 2002). The staff's evaluation of the HI-STAR 100 system is documented in the HI-STAR 100 System SER (U.S. Nuclear Regulatory Commission, 2001b). No additional review was performed for this SER, as these components are identical for the HI-STAR HB system.

The lift links are designed as nonredundant lifting devices with a safety factor of 10 or greater for material ultimate strength and 6 or greater for yield strength. A dynamic load increase factor of 10 percent has been applied to the lifting loads. These elements, therefore, meet the NUREG-0612 stress limits (U.S. Nuclear Regulatory Commission, 1980) for nonredundant special lifting devices.

The connector pins are designed with a minimum safety factor of 3 for material yield strength and 5 for material ultimate strength, as well as a dynamic load increase factor of 10 percent. Multiple elements are used, and each can totally support the weight of the canister, thereby making them single-failure proof in accordance with NUREG-0612 (U.S. Nuclear Regulatory Commission, 1980).

The lift links, transporter connection pins, and lateral cask restraining system are custom designed for the site-specific criteria. Structural analysis to be completed by the applicant in accordance with the design criteria will demonstrate that these components are designed to resist the loads based on the site characteristics and environmental conditions during normal operations and during postulated off-normal and accident events, in accordance with the requirements of 10 CFR §72.122(b)(1). The structural analysis will also demonstrate that these components are designed to withstand the effects of natural phenomena such as earthquakes, tornadoes, lightning, and floods, without impairing the capability to perform safety functions in accordance with the requirements of 10 CFR §72.122(b)(2).

Cask Transporter (QA Category A)

The applicant analyzed the potential for the transporter to slide off the roadway during a seismic event. In the analysis, design basis earthquake (DBE) ground motions are applied in three orthogonal directions to the HI-STAR HB cask carried by the transporter at various locations on the path from the RFB to the ISFSI. The simulations are performed using Visual Nastran (MSC Software Corporation, 2002). The code models large motions of rigid bodies that may contact each other during the event. The HI-STAR HB overpack and the cask transporter are modeled as solid bodies using Solidworks, Inc. (2001). The HI-STAR HB overpack is assumed to be fixed to the transporter and to acquire the motion of the transporter for all degrees of freedom except for vertical relative movement. The HI-STAR HB overpack is supported by two long vertical arms that are given an appropriate spring stiffness reflecting anticipated system elasticity in the vertical direction. The ground is assumed fixed, and the driving seismic inputs are applied as known inertia forces to the mass centers of the HI-STAR HB and the transporter, respectively. The structural analysis demonstrates that the cask transporter will remain on the roadway and not tip over when subjected to the DBE (Holtec International, 2004d, HI-2033036).

The cask transporter is custom designed for the site-specific criteria in accordance with NUREG-0612 (U.S. Nuclear Regulatory Commission, 1980). As required by Humboldt Bay ISFSI Technical Specification 4.3.3, lifting of a cask outside the RFB shall be performed with load handling equipment that is designed, fabricated, inspected, maintained, operated and tested in accordance with the applicable guidelines of NUREG-0612. Structural analysis to be completed by the applicant in accordance with the criteria in NUREG-0612 will demonstrate that the cask transporter is designed to resist the loads based on the site characteristics and environmental conditions during normal operations and during postulated off-normal and accident events, in compliance with the requirements of 10 CFR CFR §72.122(b)(1). The structural analysis also will demonstrate that the cask transporter is designed to withstand the effects of natural phenomena such as earthquakes, tornadoes, lightning, and floods, without impairing the capability to perform safety functions in accordance with the requirements of 10 CFR §72.122(b)(2) and §72.122(b)(4).

5.1.5 Other Structures, Systems, and Components Not Important to Safety

Section 5.4.5 of NUREG-1567 (U.S. Nuclear Regulatory Commission, 1998) identifies the regulatory requirements that are applicable to other SSCs subject to NRC approval. There are no specific requirements identified in 10 CFR Part 72 for other SSCs not important to safety.

5.1.5.1 Description of Other Structures, Systems, and Components Not Important to Safety

As identified in Section 4.5.5 and summarized in Table 4.5-1 of the SAR, security systems, lighting and poles, electrical power, communication systems, rail dolly, and perimeter fencing are considered SSCs not important to safety. Also, portions of the cask transfer system, cask storage vault, drainage pipe (Pacific Gas and Electric Company, 2004b), and ancillary equipment without design functions directly related to protecting health and safety are classified as not important to safety (e.g., automated welding system, overpack vacuum drying system).

The other SSCs not important to safety are briefly described in Section 4.4.4 of the SAR to satisfy the requirements of 10 CFR §72.24(a) and §72.24(b). The descriptions are limited to a general description of the various systems. The majority of these systems will be based on commercially available systems that are designed, fabricated, constructed, tested, and maintained in accordance with approved engineering practices.

The HI-STAR HB system is a passive system, and no electrical power is required to ensure the safe, interim storage of the SNF.

5.1.5.2 Design Criteria for Other Structures, Systems, and Components Not Important to Safety

The design criteria identified for SSCs not important to safety are based on applicable commercial codes and standards to ensure, where interfaces exist, that there is compatibility with SSCs important to safety. The design of the other SSCs not important to safety permits inspection, maintenance, and testing.

5.1.5.3 Material Properties for Other Structures, Systems, and Components Not Important to Safety

No specific material properties are identified in the SAR for SSCs not important to safety. Material properties, however, will satisfy the codes or standards applicable to the SSCs as required and, therefore, satisfy the requirement of 10 CFR §72.24(c)(3).

5.1.5.4 Structural Analysis for Other Structures, Systems, and Components Not Important to Safety

SSCs not important to safety will be designed based on standard engineering practices that are in accordance with the applicable codes and standards. This demonstrates compliance with the requirements of 10 CFR §72.24(d) and §72.24(i) and the applicable section of 10 CFR §72.122.

5.2 Evaluation Findings

Based on the review of the Humboldt Bay ISFSI SAR and supporting documents, the staff made the following determinations:

- The SSCs important to safety are designed, fabricated, erected, and tested to quality standards commensurate with the functions to be performed. The SSCs important to safety are classified based on their primary function and importance to overall safety. The requirements of 10 CFR §72.122(a), therefore, have been satisfied.

- The SAR and docketed materials relating to the description of confinement SSCs important to safety meet the requirements of 10 CFR §72.24(a–b) in sufficient detail to allow evaluation of their structural effectiveness.

- The SAR and docketed materials relating to the design criteria of confinement SSCs important to safety, including applicable codes and standards meet the requirements of 10 CFR §72.24(c)(1), §72.24(c)(2), §72.24(c)(4), §72.120(a), §72.122(a), §72.122(b)(2), §72.122(b)(3), §72.122(c), §72.122(f), §72.122(g), §72.122(h)(1), §72.122(h)(4), §72.122(l), and §72.128(a).

- The SAR and docketed materials relating to the suitable material properties used in the design and construction of the confinement SSCs meet the requirements of 10 CFR §72.24(c).

- The SAR and docketed materials provide adequate analytical reports to ensure the structural integrity of the confinement SSCs important to safety. These SSCs are designed to accommodate the combined loads of normal, off-normal, accident, and natural phenomena events with an adequate margin of safety. Thus, the SSCs important to safety meet the requirements of

10 CFR §72.24(d)(1), §72.24(d)(2), §72.122(b)(2), §72.122(b)(3), §72.122(c), §72.122(f), §72.122(h)(1), §72.122(h)(4), §72.122(i), and §72.122(l).

- The design of the dry cask storage system and the selection of materials adequately protect the SNF cladding from degradation that might otherwise lead to gross rupture of the cladding. The applicant has met the requirements of 10 CFR §72.122(h)(1).

- The description of SSCs important to safety considers inspection, maintenance, and testing. Components requiring inspection and maintenance are identified, and operational procedures are summarized adequately. The requirements of 10 CFR §72.122(f), therefore, have been satisfied.

- The design of the lift links, transporter connection pins, and lateral cask restraining system also allows for emergency capabilities because access to critical locations and regions in the event of emergencies is possible. In addition, the lifting components are designed to hold the load in the event of emergencies. The requirements of 10 CFR §72.122(g), therefore, have been satisfied.

- The SAR and docketed materials relating to the description of the reinforced concrete storage vault meet the requirements of 10 CFR §72.24(a) and §72.24(b).

- The reinforced concrete storage vault is designed in accordance with ACI-349-01 (American Concrete Institute, 2001), and other applicable codes and standards. Structural analyses demonstrate that the reinforced concrete storage vault is designed to resist the loads based on the site characteristics and environmental conditions during normal operations and during postulated off-normal and accident events. The reinforced concrete storage vault meets the requirements of 10 CFR §72.24(c)(1), §72.24(c)(2), §72.24(c)(4), §72.103(b), §72.103(f)(2)(i), §72.103(f)(2)(iv), §72.120(a), §72.122(a), §72.122(b–c), §72.122(f–g), §72.122(h)(4), §72.122(l), and §72.128(a).

- The SAR and docketed materials relating to suitable material properties used in the design and construction of the reinforced concrete SSCs meet the requirements of 10 CFR §72.24(c)(3).

- The SAR and docketed materials relating to the description of other SSCs important to safety meet the requirements of 10 CFR §72.24(a), §72.24(b), §72.122(b)(4), §72.122(f), §72.122(g), §72.122(h)(1), §72.122(h)(4), and §72.122(i).

- The SAR and docketed materials relating to design criteria of other SSCs important to safety, including applicable codes and standards, meet the requirements of 10 CFR §72.24(c), §72.120(a), §72.122(a), §72.122(b)(1–4), §72.122(c), §72.122(f–g), §72.122(h)(1), §72.122(h)(4), §72.122(i), and §72.122(l).

- The SAR and docketed materials relating to the suitable material properties for use in the design and construction of other SSCs important to safety meet the requirements of 10 CFR §72.24(c), §72.122(a) and §72.122(c).

- The SAR and docketed materials provide an acceptable basis to ensure the structural integrity of other SSCs important to safety and meet the requirements of 10 CFR §72.24(c)(1), §72.24(c)(2), §72.24(c)(4), §72.24(d), §72.120(a), §72.122(a), §72.122(b)(2), §72.122(b)(3), §72.122(b)(4), §72.122(c), §72.122(f), §72.122(g), §72.122(h)(1), §72.122(h)(4), §72.122(i), §72.122(l), and §72.128(a).

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6 THERMAL EVALUATION

6.1 Conduct of Review

This chapter of the Safety Evaluation Report (SER) evaluates the decay heat removal systems; material temperature limits; thermal loads and environmental conditions; analytical methods, models, and calculations; and fire and explosion hazards of the Humboldt Bay Independent Spent Fuel Storage Installation (ISFSI). Review of the thermal evaluation included Sections 2.3, "Climatology and Meteorology;" 3.2, "Design Criteria for Environmental Conditions and Natural Phenomena;" 3.3, "Design Criteria for Safety Protection Systems;" 4.1, "Location and Layout;" 4.2, "Storage System;" 4.3, "Transport System;" 4.4, "Operating Systems;" 4.5, "Classification of Structures, Systems, and Components;" 8.1, "Off-Normal Operations;" and 8.2, "Accidents;" and Chapter 10, "Operating Controls and Limits;" of the Humboldt Bay ISFSI Safety Analysis Report (SAR) (Pacific Gas and Electric Company, 2004a). Additional supporting documentation cited in the SAR and responses to the U.S. Nuclear Regulatory Commission (NRC) request for additional information (Pacific Gas and Electric Company, 2004b, 2005) were considered.

The Humboldt Bay ISFSI uses the HI-STAR HB cask, which is a variation of the HI-STAR 100 cask system previously certified for general use in accordance with 10 CFR Part 72 by the U.S. Nuclear Regulatory Commission (2001a) and described in the HI-STAR 100 Final Safety Analysis Report (FSAR) (Holtec International, 2002). The proposed HI-STAR HB cask is designed specifically for confining spent nuclear fuel (SNF) and Greater than Class C (GTCC) waste generated at the Humboldt Bay Power Plant, Unit 3, within a reinforced concrete storage vault that is constructed entirely below grade. The scope of the review of the HI-STAR HB cask is limited to those design bases unique to the Humboldt Bay ISFSI site.

The review objectives for this chapter are to determine whether the (i) ISFSI design and operation procedures ensure that the decay heat removal system is capable of reliable operation so that the temperatures of materials used for systems, structures, and components (SSCs) important to safety, fuel assembly cladding material, and GTCC waste remain within allowable limits under normal, off-normal, and accident conditions; (ii) thermal design of the ISFSI has been analyzed using acceptable analytical or test methods; and (iii) fire and explosion hazards analysis and corresponding protection measures for the ISFSI are satisfactory.

The review considered how the SAR and related documents address the regulatory requirements of 10 CFR §72.92(a), §72.122(b)(1), §72.122(c), §72.122(h)(1), and §72.128(a). Complete citations of these regulations are provided in the Appendix of this SER.

6.1.1 Decay Heat Removal Systems

The HI-STAR HB storage cask is designed to be installed in a below grade reinforced concrete storage vault. The vault can accommodate up to six of these casks. Decay heat from the casks is transferred by convection, conduction, and radiation to the vault cavity wall liners and lids. The decay heat is transferred through the vault walls into the surrounding soil by conduction and from the exposed surface of the vault to the ambient air by convection.

There are numerous differences between the proposed HI-STAR HB cask and the certified HI-STAR 100 cask (SAR Section 4.2.3). Important feature differences pertinent to the comparison of the thermal performance of these two casks are (i) the proposed HI-STAR HB cask is intended to be used for below grade storage, and the certified HI-STAR 100 cask is approved for deployment above ground only; (ii) the proposed HI-STAR HB cask is 1.93 m [76 in] shorter than the certified HI-STAR 100 cask; and (iii) the proposed HI-STAR HB cask is designed to hold up to 80 Humboldt Bay Power Plant (HBPP) SNF assemblies as compared to the 68 SNF assemblies that can be stored within the certified HI-STAR 100 cask. As documented in the HI-STAR 100 system SER (U.S. Nuclear Regulatory Commission, 2001b), the staff has previously determined that the HI-STAR 100 storage cask provides adequate heat removal capacity under normal storage conditions as long as the fuel specifications and loading conditions defined in the Certificate of Compliance (CoC) (U.S. Nuclear Regulatory Commission, 2001a, Appendix B), are followed, and the environmental characteristics of the site are bounded by the corresponding design criteria. The methodology used to establish the decay heat removal characteristics of the HI-STAR HB cask is consistent with that used in the previously reviewed and approved approach for the HI-STAR 100 cask system (U.S. Nuclear Regulatory Commission, 2001b).

The staff reviewed the information provided by the applicant regarding the SNF decay heat removal capacity of the below grade storage vault for normal, off-normal, and accident conditions independent of the HI-STAR HB casks. This is justifiable because all of the decay heat that must be removed from the casks will pass through the vault structure regardless of the cask internal thermal performance characteristics. The staff found the methodology used to assess the transfer of decay heat through the vault to be acceptable (Holtec International, 2004; HI-2033033). Confirmatory thermal calculations performed by the staff also confirmed that heat transfer to the surrounding soil will be sufficient to ensure that the structures and components important to safety will not exceed their respective temperature limits. A detailed discussion of the determination of the effective heat transfer coefficient is presented in Section 6.1.4 of this SER.

The storage system temperatures are strongly dependent on the efficiency of heat transfer by conduction to the surrounding soil. As a result, the backfill material around the vault should have a thermal conductivity that is greater than or equal to the native soil assumed in the decay heat removal assessment analyses. Section 3.3.1.5.2 of the SAR states that soil will be used as backfill around the exterior of the vault. The applicant committed to use the excavated native soil as backfill around the storage vault. If additional backfill is needed, material with a thermal conductivity greater than or equal to that of the native soil will be used (Pacific Gas and Electric Company, 2005).

The applicant committed to monitor the temperature of the vault air space for a time period of 6 months to validate the actual heat rejection performance of the cask system (SAR Section 3.3.1.3.2). This monitoring will commence when the first loaded storage cask is emplaced within the vault and will continue for 6 months after all casks have been emplaced (Pacific Gas and Electric Company, 2005), consistent with the requirements of Technical Specification 5.1.4, ISFSI Operations Program.

Based on the foregoing evaluation, the staff finds that all of the applicable requirements of 10 CFR §72.122(h)(1) and §72.128(a) have been satisfied.

6.1.2 Material Temperature Limits

The material temperature limits for components of the HI-STAR HB cask and the ISFSI reinforced concrete storage vault are provided in the SAR and in responses to NRC requests for additional information (Pacific Gas and Electric Company, 2004b, 2005). These material temperature limits have been established for normal, off-normal, and accident conditions. In the case of the SNF cladding, the established temperature limits also consider the fuel age at initial loading and the level of burnup.

The HI-STAR HB cask is an all-metal, canister-based storage system designed to store SNF and GTCC waste from the HBPP under normal, off-normal, and accident conditions applicable to the Humboldt Bay site. The staff previously found the normal, off-normal, and accident condition material temperature limits for the structural components of the HI-STAR 100 system, which are given in the HI-STAR 100 system FSAR (Holtec International, 2002), to be acceptable (U.S. Nuclear Regulatory Commission, 2001a). The HI-STAR HB cask system uses the same structural materials as the HI-STAR 100 system; therefore the same material temperature limits are applicable.

No specific allowable temperature threshold is required for the optional METAMIC® neutron absorbing material because it is not a load carrying member and the temperature at which it would lose its efficacy exceeds that of the allowable temperatures for the SNF cladding.

The maximum average fuel burnup for the SNF to be stored at the Humboldt Bay ISFSI is 23,000 MWd/MTU. This fuel can be designated as low burn-up fuel (i.e., burnups less than or equal to 45,000 MWd/MTU). Moreover, the fuel proposed to be stored at the ISFSI is clad with a zirconium-based alloy, Zircaloy-2, which has been previously approved for storage in the certified HI-STAR 100 system (U.S. Nuclear Regulatory Commission, 2001a). The low-burnup fuel is subject to the assembly-specific physical parameters, burnup, cooling time, and decay heat limits specified in the proposed Humboldt Bay ISFSI technical specifications (Pacific Gas and Electric Company, 2004c, Attachment C, Tables 2.1-1 and 2.1-2), and in the SAR (Sections 3.1.1 and 10.2), which are consistent with the technical specification limits included in the HI-STAR 100 system CoC (U.S. Nuclear Regulatory Commission, 2001a, Appendix B).

A peak fuel cladding temperature limit of 400 °C [752 °F] for both normal, interim storage conditions and short term operations (i.e., drying, backfilling with inert gas, and transferring the cask to the storage vault) (SAR Table 3.4-2) was proposed for the Humboldt Bay ISFSI. This temperature limit is consistent with Interim Staff Guidance (ISG)-11 (U.S. Nuclear Regulatory Commission, 2003a). For off-normal and accident conditions, a peak fuel cladding temperature limit of 570 °C [1,058 °F] was proposed (SAR Table 3.4-2). This temperature limit is also consistent with ISG-11.

The applicant indicated in responses to the NRC request for additional information (Pacific Gas and Electric Company, 2004b) that the reinforced concrete storage vault would be constructed using Type II cement and fine and coarse aggregates that satisfy the requirements of ASTM C33-03 (ASTM International, 2003). Accordingly, since the reinforced concrete storage vault temperatures of general or local areas may exceed 93 °C [200 °F], but will not exceed 149 °C [300 °F], the applicant is not required to perform tests to prove the capability of the vault to withstand elevated temperatures, nor to assume any reduction of concrete strength in related analyses (U.S. Nuclear Regulatory Commission, 2000). The 177 °C [350 °F] short term accident temperature limit for the reinforced concrete is consistent with guidance provided by the American Concrete Institute (2001, Appendix A.4). The applicant has committed to revise SAR Table 4.2-10 to reflect a higher allowable concrete temperature of 149 °C [300 °F] (Pacific Gas and Electric Company, 2005).

The staff reviewed the information provided by the applicant pertaining to the Humboldt Bay ISFSI material temperature limits for normal, off-normal, and accident conditions. The staff found the material temperature limits acceptable because:

- The short- and long-term temperature limits for the HI-STAR HB cask structural materials are acceptable because their structural strengths will not be adversely affected for all potential off-normal and accident scenarios if these limits are not exceeded.
- The short- and long-term temperature limits for the HBPP SNF to be stored within the proposed ISFSI conform to ISG-11 (U.S. Nuclear Regulatory Commission, 2003a).
- The temperature limits for the reinforced concrete vault are acceptable because the structural strength of the concrete will not be adversely affected for all potential off-normal and accident scenarios if these limits are not exceeded.
- The short and long term temperature limits for the HI-STAR HB cask shielding materials are acceptable because their performance characteristics will not be adversely affected for all potential off-normal and accident scenarios if these limits are not exceeded.

Based on the foregoing evaluation, the staff finds that the applicable requirements of 10 CFR §72.128(a) have been satisfied.

6.1.3 Thermal Loads and Environmental Conditions

The proposed Humboldt Bay ISFSI is designed to provide interim dry storage for intact and damaged SNF assemblies and reactor-related GTCC waste from HBPP Unit 3. Specifically, the ISFSI is designed to store up to 400 SNF assemblies in five casks, with a sixth cask used for storing GTCC waste. The characteristics of the SNF proposed to be stored at the Humboldt Bay ISFSI, delineated in Table 3.1-2 of the SAR, are bounded by the previously approved contents for the HI-STAR 100 storage cask (U.S. Nuclear Regulatory Commission, 2001a, Appendix B). The maximum decay heat load for a single SNF assembly that is to be stored at the Humboldt Bay ISFSI is 50 W [171 BTU/hr] (SAR Table 4.2-9). Table 4.2-9 of the SAR also indicates that the maximum total decay heat load for a single HI-STAR HB cask is 2 kW [6,820 BTU/hr]. The staff determined that the methodology used to establish the decay heat rates of the SNF (Holtec International, 2004, HI-2033023) to be stored at the Humboldt Bay ISFSI is acceptable.

The meteorological conditions for the ISFSI site are documented in Section 2.3 of the SAR. The minimum, maximum, and average ambient temperatures for the proposed ISFSI site are derived from data recorded within the Eureka, California, region for a period of more than 100 years. Available records indicate that the minimum measured temperature was -6.7 °C [20 °F], and the maximum was 30.6 °C [87 °F]. Using hourly temperature data recorded at the Arcata/Eureka National Weather Service Station from 1949 through 2001, it was determined that, on average, the temperature will be below freezing {i.e., less than 0 °C [32 °F]} five times per year. Daily and monthly averages of temperatures, dew point temperature, and relative humidity are presented in Table 2.3-1 of the SAR. The maximum insolation measured at the Arcata Airport, located approximately 27.4 km [17 mi] north-northeast of the proposed site, was 602 g-cal/cm^2/day [2219 BTU/ft^2/day].

The staff reviewed the information provided by the applicant pertaining to the Humboldt Bay ISFSI thermal loads and environmental conditions. The staff finds the analysis acceptable because:

- The methodology used to establish the decay heat rates of the SNF (Holtec International, 2004, HI-2033023) to be stored at the Humboldt Bay ISFSI is acceptable.

- Reliable sources have been used to obtain temperature and insolation data at nearby sites that are applicable to the proposed ISFSI location.

- The temperatures and solar loads at the ISFSI site are bounded by, or equal to, the HI-STAR HB cask and the reinforced concrete storage vault system design parameters (Table 3.2-3 of the SAR).

Based on the foregoing evaluation, the staff finds that the applicable requirements of 10 CFR §72.92(a) and §72.122(b)(1) are satisfied.

6.1.4 Analytical Methods, Models, and Calculations

The staff reviewed the information provided by the applicant pertaining to the analytical methods, models, and calculations used to establish the decay heat removal characteristics of the HI-STAR HB storage cask and reinforced concrete storage vault. The staff determined that the information provided was sufficient to assess the fidelity of the computational fluid dynamics and finite element conduction numerical analyses used to model the relevant heat transfer mechanisms within the multi-purpose canister (MPC-HB). In addition, analytical models used to support various simplifications and solution parameters implemented within these numerical analyses were sufficiently documented.

The staff found that the thermal design analysis methodology used to establish the decay heat removal characteristics of the reinforced concrete storage vault was acceptable. The effective heat transfer coefficient between the storage vault and its surrounding soil, however, is appreciably influenced by the choice of the far-field soil isotherm contour and its surface area relative to that of the vault. The contour of the far-field soil isotherm assumed in the applicant's analysis (Holtec International, 2004, HI-2033033, Section 7.2) leads to an overestimation of the effective heat transfer coefficient between the storage vault and its surrounding soil. The basis for this conclusion is as follows. First, it can be demonstrated that the far-field isotherm contour is more accurately represented by a hemispherical geometry. Second, the heat equation used to calculate the conductance coefficient for the vault surface (Holtec International, 2004, HI-2033033, Eq. 8) is based on the assumption that the heat flux vectors are orthogonal to the far-field soil isotherm. The contour of the far-field soil isotherm used by the applicant does not satisfy this assumption. As a result, the staff has determined that the applicant overestimated the effective heat transfer coefficient between the storage vault and its surrounding soil, which, in turn, caused the storage system temperatures to be underestimated. However, independent confirmatory calculations performed by the staff found that the structures and components important to safety will not exceed their respective temperature limits when a hemispherical far-field isotherm is used. The staff also found that the remaining relevant thermal analysis parameters, boundary conditions, and assumptions were acceptably defined and satisfactorily substantiated.

The staff finds the methodology used to establish the thermal characteristics of the SNF, both intact and damaged, and GTCC waste provided in Section 10.2.1 of the SAR and in supplemental information (Holtec International, 2005, HI-2033005) to be acceptable. Based on the foregoing evaluation, the staff finds that the applicable requirements of 10 CFR §72.122(h)(1) and §72.128(a) have been satisfied.

6.1.5 Fire and Explosion Protection

6.1.5.1 Fire

The staff reviewed the fire analyses performed for the proposed Humboldt Bay ISFSI. The scope of the review included SSCs important to safety that are relied on for SNF handling operations and interim storage. The SSCs important to safety must be designed and located such that they can continue to perform their safety functions effectively under credible fire exposure conditions. Information used to identify the potential fire hazards, the likelihood of fire events of concern, and their potential effects on performance of the SSCs was presented in Section 8.2.5 of the SAR. The fire analysis review also considered the supporting calculation packages cited in that section of the SAR.

6.1.5.1.1 Bounding Events

The applicant performed fire analyses of the HI-STAR HB cask for onsite transfer activities and for placement and storage within the reinforced concrete vault. These fire scenarios included bounding cases for engulfing and nonengulfing fires and were evaluated using different analysis techniques. The bounding engulfing fire was analyzed using a one dimensional thermal model, which assumed the engulfing heat flux conditions of the pool fire were the inputs to the model (Holtec International, 2004, HI-2033006). The bounding nonengulfing events were analyzed assuming a steady-state radiative heat transfer model. Methods of analysis selected for each of the conditions were appropriate based on the dominant modes of heat transfer in each case.

The bounding engulfing fire scenario was based on a hypothetical cask transporter fuel spill occurring during transit identified as Hazard ID F-11 (Holtec International, 2004, HI-2033006). The maximum diesel fuel load of 190 L [50 gal] was assumed to spill from the transporter fuel tank, surround the cask, and ignite; producing a pool fire that would engulf the cask. No other credible engulfing fire scenarios were identified; given the locations of other potential sources of combustible material relative to the proposed transporter route and ISFSI storage vault, and the administrative controls that will be in effect.

The bounding nonengulfing fire scenario was based on a leak of a fuel oil tank identified as Hazard ID F-3 (Holtec International, 2004, HI-2033006). The fire analysis for this scenario assumed the largest potential volume of flammable liquid {10,448,000 L [2,760,169 gal]} spilled within a fixed containment area, located within 50 m [164 ft] of the ISFSI reinforced concrete vault. These parameters represent the largest fuel load at the closest proximity.

6.1.5.1.2 Engulfing Fire Thermal Evaluation

The applicant submitted an engulfing fire thermal evaluation for the Humboldt Bay ISFSI (Holtec International, 2004, HI-2033006). A one-dimensional thermal model was developed and used to assess the heat transfer into the cask as a result of the engulfing fire exposure. The fire duration was based on a 190 L [50 gal] spill, encompassing an area that is 1 m [3.28 ft] larger than the footprint of the cask. The resulting area of the presumed pool was 10.8 m^2 [116 ft^2], yielding a 18.25-mm [0.72-in] pool depth. At an assumed burning rate of 3.8 mm/min [0.15 in/min], the calculated fire duration was on the order of 5 minutes. For the purpose of conservatism, a 30-minute fire exposure duration was assumed. The applicant's thermal analysis indicated a peak cladding temperature from this event of approximately 434 °C [814 °F]. This temperature is below the allowable accident temperature threshold for the SNF cladding.

Although the Holtite-A neutron shield material temperature limit will be exceeded during exposure to the design basis fire scenario, the staff found appropriate provisions will be implemented to ensure that radiation dose limits will not exceed applicable regulatory requirements. The staff's evaluation of this accident scenario is described in greater detail in Section 15.1.2.5 of this SER.

6.1.5.1.3 Nonengulfing Fire Thermal Evaluation

The nonengulfing fire thermal evaluation was also documented in the applicant's evaluation of fire hazards (Holtec International, 2004, HI-2033006). A 10,448,000-L [2,760,169-gal] spill was assumed to be contained within the 67.2 × 51.7-m [221 × 170-ft] berm surrounding the Unit 2 Residual No. 6 Fuel Oil tank. The staff reviewed the geometry of the storage tank with respect to the ISFSI and the cask transporter route and found that the geometric assumptions made in the analysis were representative of the actual conditions.

View factors were calculated based on assumed fire geometry (source) and the cask and ISFSI vault surfaces (targets). The applicant's analyses evaluated various fire-to-target geometries, assuming a cylindrical fire source of differing heights. The goal of the analyses was to support the assumption that the geometries and resulting view factors were conservative. The in-transit cask was modeled as a vertical cylinder, and the ISFSI vault cover was modeled as a horizontal plane. The applicant determined the steady-state solution for storage cask and ISFSI storage vault surface temperature rise (Holtec International, 2004, HI-2033006).

The heat transfer analysis for the bounding nonengulfing fire scenario estimated a cask surface temperature rise of 174 °C [313 °F]. Adding this temperature rise to the conservatively assumed initial cask surface temperature of 93 °C [200 °F] gives a final temperature of 267 °C [513 °F]. This cask surface temperature is well below the design basis fire cask surface temperature of 800 °C [1,475 °F]. The same assumed fire exposure conditions yielded an estimated ISFSI vault cover temperature rise of 62 °C [111 °F]. Transient effects were not considered and a clear line of sight between the location of the fire and the cask or vault existed in these analyses, which are very conservative assumptions.

The staff reviewed the information provided by the applicant pertaining to the Humboldt Bay ISFSI fire protection. The staff finds the analysis acceptable because:

- The HI-STAR HB cask has been evaluated for a bounding, fully engulfing fire caused by a 190-L [50-gal] spill from the transporter fuel tank. The analysis indicated that the engulfing fire will result in temperatures that are below the design basis component temperatures of the cask.
- Both the HI-STAR HB cask and the ISFSI vault geometry have been evaluated for a bounding, radiant fire exposure caused by the spill and containment of 10,448,000-L [2,760,169-gal] of fuel oil. The analysis indicated that the radiant exposure will not induce temperatures in excess of the design basis temperatures for the cask or the ISFSI storage vault cavity cover lid.
- Based on the assessment of the potential fire hazards and the fire protection measures established for the Humboldt Bay ISFSI, there is reasonable assurance that the HI-STAR HB system will not be exposed to fires that exceed the design basis fire conditions.
- SSCs important to safety are designed and located so that they can continue to perform their safety functions effectively under credible fire exposure conditions.
- Noncombustible and heat-resistant materials are used wherever practical throughout the ISFSI.
- The design of the ISFSI includes provisions to protect against adverse effects that might result from fire.

Based on the foregoing evaluation, the applicable requirements of 10 CFR §72.122(c) have been satisfied. The effects of credible fires at the Humboldt Bay ISFSI are further evaluated in Chapter 15 of this SER.

6.1.5.2 Explosion

The staff reviewed the explosion analyses performed for the Humboldt Bay ISFSI. The review was performed to ensure that the SSCs important to safety are designed and located so that they can continue to perform their safety functions effectively under credible explosion conditions. This includes ensuring safety during transfer and storage conditions. Information provided for this review was presented in Section 8.2.6 of the SAR and in supporting calculation reports.

In general, explosions have little or no effect on the thermal performance of either the cask or the ISFSI. The explosions analyzed are of short duration and are not sufficient to exceed the design overpressure and temperature limits for the cask confinement boundary. Explosions and explosion-generated missiles may tip the cask or damage the storage vault cavity lids. A detailed discussion of the physical response of the cask and storage vault to both on-site and off-site explosions is presented in Chapter 15 of this SER.

6.1.5.2.1 In-Transit Explosions

The staff found that the cask transfer route and the overall layout of the facility will provide intrinsic protection from overpressures caused by off-site explosions. The majority of the transporter route is along a course parallel to the sea wall to the north of the ISFSI site. This sea wall includes a 12 to 15-m [40 to 50-ft] sheer drop. This geometry makes the ISFSI site and transfer route resistant to off-site explosions originating in the bay.

A similar elevation change is present to the south of the facility. A steep elevation change of approximately 7.6 m [25 ft] is realized in the vicinity of the Unit 1 and Unit 2 fuel oil tanks, and a more gradual elevation change of 7.6 m [25 ft] is realized towards the southeast.

The staff determined that an off-site accident capable of generating an unsafe overpressure on an in-transit cask was highly unlikely. Given the relatively short transfer time of a cask, the documented administrative controls for the Humboldt Bay ISFSI, and the unfavorable geometry for blast wave propagation, there were no credible off-site accident scenarios that would have a direct effect on a cask during transit to the storage vault.

Administrative controls will also be implemented to limit the likelihood of an on-site, in-transit explosion event. The dominant explosion hazards associated with an on-site explosion during transit are a local propane tank (Hazard ID F-8), a ruptured natural gas line (Hazard ID F-10), and an on-site boiler failure (Hazard ID F-19). Additional hazards, such as propane and gasoline delivery tanker explosions, were also discussed in the applicant's analysis (Holtec International, 2004, HI-2033041).

The staff found that acceptable administrative controls will be imposed to reduce the likelihood and impact of potential on-site explosions. A pretransfer survey of the route will be performed to identify and minimize any potential hazards before the cask is moved on the transfer route. In addition, the delivery of fuels during cask transfer will be prohibited, significantly reducing the likelihood of an explosion event.

6.1.5.2.2 Explosions Affecting the ISFSI in a Storage Configuration

Several hypothetical accident scenarios yielded conditions that could result in a vapor cloud release and explosion after the loaded casks have been placed in the storage vault. The staff reviewed the overall site geometry of the ISFSI and found that the elevated location of the storage vault and the prevailing weather conditions at the HBPP lead to conditions not favorable for an explosive vapor cloud to form and to congregate over it.

Furthermore, the storage vault is naturally resistant to explosion overpressures. Off-site explosion blast waves will have little impact on the storage vault because its cavity lids are parallel to the ground and are located at an elevation of over 12 m [40 ft] above sea level. These explosion scenarios include any explosion originating in the bay (barge explosions) or on nearby highways (motor vehicle or truck explosions).

A hypothetical worst-case explosion was analyzed to assess the potential effect of a natural gas leak vapor cloud igniting over the storage vault. The analysis demonstrated that the overpressure from this hypothetical scenario would not be sufficient to cause damage that would compromise the performance characteristics of the stored casks.

In conclusion, the staff finds the analysis of in-transit and storage explosion scenarios acceptable and that such events will not have an adverse effect on the thermal performance of the casks. The staff finds the explosion analysis acceptable because:

- Descriptions of potential explosion sources are sufficient.
- Sufficient administrative controls will be imposed to reduce the likelihood of in-transit explosions.
- Site geometry is such that an off-site explosion overpressure will have a reduced effect on the HI-STAR HB cask while in-transit to the storage vault and after emplacement within it.
- None of the explosion scenarios considered will be of sufficient duration to cause the allowable short-term accident temperatures of the HI-STAR HB cask or storage vault to be exceeded.
- The potential consequences attributable to the credible explosion hazards, including overpressures and explosion generated missiles, are conservatively estimated and the relevant design criteria for the confinement structures are not exceeded.

Based on the foregoing evaluation, the applicable requirements of 10 CFR §72.122(c) have been satisfied. The effects of credible explosions at the Humboldt Bay ISFSI are further evaluated in Chapter 15 of this SER.

6.2 Evaluation Findings

Based on review of the information provided in the SAR, responses to requests for additional information, and cited supporting documents, the staff makes the following findings regarding the decay heat removal systems; material temperature limits; thermal loads and environmental conditions; analytical methods, models, and calculations; and fire and explosion hazards of the Humboldt Bay ISFSI:

- The staff finds sufficient evidence that the decay heat removal system will ensure that the temperatures of the SNF, GTCC waste, and important to safety SSCs will remain within allowable limits under normal, off-normal, and accident conditions, in compliance with the applicable requirements of 10 CFR §72.122(h)(1) and §72.128(a).

- The staff finds that short-and long-term material temperature limits for the HBPP SNF, reinforced concrete storage vault, HI-STAR HB structural materials, and HI-STAR HB shielding materials ensure their functionality for normal storage conditions and all potential off-normal and accident scenarios if these limits are not exceeded, in compliance with the requirements of 10 CFR §72.128(a).

- The staff finds the information pertaining to the Humboldt Bay ISFSI thermal loads and environmental conditions acceptable because the methodology used to establish the decay heat rates of the SNF to be stored is satisfactory, and reliable sources are used to establish the site specific insolation and normal, off-normal, and accident temperatures in compliance with the requirements of 10 CFR §72.92(a) and §72.122(b)(1).

- The staff finds the analytical methods, models, and calculations used to establish the decay heat removal characteristics of the HI-STAR HB cask and reinforced concrete vault to be sufficient to demonstrate compliance with the applicable requirements of 10 CFR §72.122(h)(1) and §72.128(a).

- The staff finds the fire and explosion hazards analysis and corresponding protection measures for the ISFSI to be in compliance with the requirements of 10 CFR §72.122(c).

- The staff finds the potential consequences attributable to the credible fire hazards are conservatively estimated, and the material temperature limits of the SNF cladding and confinement structures are not exceeded, in compliance with the requirements of 10 CFR §72.122(c).

- The staff finds that appropriate operational procedures will be implemented to mitigate the potential consequences attributable to the loss of the Holtite-A shielding material during a credible fire, in compliance with the requirements of 10 CFR §72.122(c).

- The staff finds that the potential consequences attributable to the credible explosion hazards, including overpressures and explosion generated missiles, are conservatively estimated and that the relevant design criteria for the confinement structures are not exceeded, in compliance with the requirements of 10 CFR §72.122(c).

6.3 References

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7 SHIELDING EVALUATION

7.1 Conduct of Review

The objective of the staff's shielding review is to determine whether the shielding design features of the proposed Humboldt Bay ISFSI meet NRC criteria for protection against direct radiation from the material to be stored. Specifically, this evaluation establishes the validity of the dose rate estimates made in the Humboldt Bay ISFSI Safety Analysis Report (SAR) (Pacific Gas and Electric Company, 2004a). These estimates are used in the radiation protection review contained in Chapter 11 of this Safety Evaluation Report (SER) to determine compliance with regulatory limits for allowable dose rates and conformance with criteria for maintaining radiation exposures as low as is reasonably achievable (ALARA). The shielding evaluation includes a review of the information in Chapter 7, "Radiation Protection," and relevant sections of Chapter 3, "Principal Design Criteria;" Chapter 4, "ISFSI Design;" and Chapter 8, "Accident Analyses;" of the SAR, as well as supporting documentation.

The applicant proposes to use the HI-STAR HB cask system, which is comprised of the all-metal HI-STAR HB overpack and its integral multi-purpose canister (MPC-HB), that contains the fuel assemblies. Each HI-STAR HB cask is designed to store up to 80 Humboldt Bay Power Plant (HBPP) fuel assemblies. The HI-STAR HB system is a variation of the HI-STAR 100 system, which has been certified by NRC for use by 10 CFR Part 72 general licensees (U.S. Nuclear Regulatory Commission, 2001a). Holtec International developed the modified (shorter) MPC-HB for use at Humboldt Bay because of the smaller size (length and width) of the HBPP fuel assemblies. The modified HI-STAR HB system shielding analyses were performed in accordance with the methodologies documented in the Holtec HI-STAR 100 Final Safety Analysis Report (FSAR) (Holtec International, 2002a). There will be five HI-STAR HB casks stored at the ISFSI. The applicant also proposes to store an additional cask that contains reactor-related Greater than Class C (GTCC) waste at the ISFSI.

The review considered how the SAR and related documents address the regulatory requirements of 10 CFR §20.1201(a)(1), §20.1301(a), §20.1302(b), §72.24(b), §72.24(c)(3), §72.24(e), §72.104(a), §72.126(a)(6), and §72.128(a)(2). Complete citations of these regulations are provided in the Appendix of this SER.

7.1.1 Contained Radiation Sources

The gamma and neutron source specifications are presented in Section 7.2 of the SAR. The sources of gamma and neutron radiation are the intact spent nuclear fuel (SNF) assemblies, damaged fuel assemblies, fuel debris and nonfuel hardware to be stored in the HI-STAR HB system, as well as the reactor-related GTCC waste to be stored in a separate cask. HBPP Unit 3 was shut down in July 1976. For analysis purposes, the applicant used a cask loading date of July 2005, providing a minimum cooling and decay time of 29 years. The burnup of 23,000 megawatt-days per metric ton of uranium (MWd/MTU) is used as the bounding burnup value for all HBPP fuel assemblies (as this is the highest burnup of all HBPP fuel assemblies in the spent fuel pool inventory). Only fuel, associated hardware, and reactor-related GTCC waste irradiated at HBPP Unit 3 will be stored at the ISFSI. The SNF assemblies to be stored at the proposed ISFSI consist of four Zircaloy-2 clad boiling water reactor (BWR) designs. The four designs are the General Electric Type II, 7 x 7; General

Electric Type III, 6 x 6; Exxon Type III, 6 x 6; and Exxon Type IV, 6 x 6 assemblies. Their physical characteristics are described in Table 3.1-2 of the SAR. An enrichment of 2.09 wt % Uranium-235 was used for the shielding analysis as the lowest initial assembly planar average enrichment for all HBPP fuel. This adds conservatism to the analysis because lower enrichments for a given fuel burnup result in higher neutron source terms.

As discussed in Section 4.1.1 of this SER, the inventory of material to be stored includes some remnants of stainless steel cladding from fuel assemblies previously shipped offsite. This cladding was considered by the applicant; however, the amount of stainless steel clad debris present is small (less than the amount in one assembly) and the applicant determined that it would have no effect on the shielding analysis (Pacific Gas and Electric Company, 2005). The staff reviewed the applicant's description of the stainless steel clad debris and found that inclusion of this debris in the analysis would have a negligible effect.

7.1.1.1 Gamma and Neutron Sources

The gamma source term is composed of three distinct components. The first gamma source term is decay of radioactive fission products. The second gamma source term is secondary photons from neutron capture (neutron, gamma) reactions in fissile and nonfissile radionuclides. The third gamma source term is from hardware activation products generated during power operations. Nonfuel portions of a fuel assembly, such as the steel and Inconel end fittings, become activated during in-core operations to produce a radiation source that is primarily Cobalt-60. Crud on the fuel assemblies is not explicitly accounted for in the source term because the crud source strength is negligible compared to the fuel source strength in the Cobalt-60 gamma energy range. The crud Cobalt-60 source strength calculations are based on the maximum amount of crud measured on HBPP fuel assemblies. The staff reviewed the information and calculations presented by the applicant and found the characterization of the source term due to crud to be acceptable.

The Humboldt Bay ISFSI vault is designed to house six storage casks; five HI-STAR HB casks containing HBPP spent nuclear fuel, and one cask containing HBPP GTCC waste. In order to analyze a bounding radiation source term, the model used for shielding analyses assumes that all six storage casks contain SNF. The applicant will characterize the GTCC waste as part of the loading procedure to ensure that the calculated radiation dose rate from the GTCC waste cask does not exceed the calculated dose rate from a SNF cask and therefore, will be within the bounds of the shielding analysis provided in the SAR. As described in SAR Section 7.2.1.1, the applicant has committed to dose rate measurements of the loaded GTCC waste cask to ensure the validity of the bounding source term used in the shielding analyses. The description of the potential GTCC waste components and procedures for the storage of GTCC waste at the ISFSI is contained in SAR Sections 3.1, 3.1.1.4, 4.2.3.1, and 10.2.1.3. These sections of the SAR were reviewed in accordance with the recommendations provided to the staff in Interim Staff Guidance (ISG)-17 (U.S. Nuclear Regulatory Commission, 2001b).

The neutron source term is composed of four distinct components. These are neutrons resulting from spontaneous fission; alpha particle-neutron reactions in fuel materials; secondary neutrons produced by fission from subcritical multiplication; and gamma-neutron reactions.

The gamma and neutron source terms described previously are grouped into three components: the fuel-gamma source, the fuel-neutron source, and the nonfuel activation source. Gamma and neutron source terms were generated using the SAS2H (Hermann and Parks, 1998) and ORIGEN-S (Hermann and Westfall, 1998) modules of the SCALE 4.4 system.

The physical characteristics of the fuel used at HBPP Unit 3 and to be stored at the ISFSI are summarized in Table 3.1-2 and Section 10.2 of the SAR. Section 10.2 of the SAR provides the proposed operating controls and limits with the intact and damaged fuel assembly limits specified in Tables 10.2-1 and 10.2-2. The design basis fuel assembly chosen for the shielding analysis is the General Electric Type III. This fuel assembly was chosen because it has the highest uranium mass loading and makes up the largest percentage of the HBPP Unit 3 SNF inventory. The shielding design basis fuel assembly is described in Section 7.2.1.1 and Tables 7.2-1, 7.2-2, and 7.2-3 of the SAR. The design basis fuel assembly is specified with the minimum initial enrichment (2.09 wt% Uranium-235), the maximum burnup (23,000 MWd/MTU), and the minimum cooling time (29 years) of the fuel assemblies to be stored at the Humboldt Bay ISFSI. These specifications provide bounding source term analyses for all of the fuel assemblies proposed for storage. Regarding damaged fuel, the applicant stated in Section 10.2.1.1 of the SAR that the amount of material contained in a damaged fuel container (DFC) is limited to the equivalent of a single intact fuel assembly. Based on this statement, the staff finds the application of the calculated source term to damaged fuel to be acceptable. However, as discussed in Section 7.1.4.2 of this SER, the applicant relies upon a conservative model of the damaged fuel source to demonstrate the effect on dose rates of loading damaged fuel into a cask. The fuel-gamma source, fuel-neutron source, and nonfuel activation source discussed above are summarized in Section 7.2 and Tables 7.2-4, 7.2-5, and 7.2-6 of the SAR.

The staff evaluated the analyses of the bounding radiation source terms for the Humboldt Bay ISFSI. The staff finds that the specified design basis enrichment, burnup, and cooling time for the HBPP SNF are conservative and were determined correctly to provide a bounding source term for all fuel assemblies to be loaded into the SNF casks. Based its review of the applicant's descriptions of the crud and GTCC source terms, as discussed in this SER section, the staff also finds the analyses regarding these source terms to be acceptable.

7.1.2 Storage and Transfer Systems

7.1.2.1 Design Criteria

The design criteria for the proposed Humboldt Bay ISFSI are the regulatory dose limit requirements delineated in 10 CFR Part 20.1201(a)(1), §20.1301(a), §20.1302(b), and §72.104(a). The SAR specifies the shielding design criteria in Section 3.3.1.5.2 and Table 3.4-2. The HI-STAR HB system is designed to minimize radiation dose to workers and the public using a combination of the steel MPC-HB, overpack steel, and Holtite-A neutron shielding material. Significant shielding is also provided by the below-grade vault design of the ISFSI through its use of concrete, steel, and the surrounding soil. The staff finds the use of these design criteria to be appropriate. These design criteria provide reasonable assurance that the ISFSI will meet the dose limits delineated in 10 CFR §20.1201(a)(1), §20.1301(a), §20.1302(b), and §72.104(a). The Humboldt Bay ISFSI will provide adequate radiological safety based on the use of suitable shielding for radiation protection in accordance with 10 CFR §72.128(a)(2).

7.1.2.2 Design Features

The Humboldt Bay ISFSI system is designed to provide both gamma and neutron shielding for all fuel loading, transfer, and storage conditions. The shielding design features are described in Section 7.3 of the SAR. The six casks are designed to be in a single row positioned vertically in a below-grade concrete vault. ISFSI design features that ensure that dose rates are ALARA include:

- There are no radioactive systems at the ISFSI other than the GTCC cask and the overpacks containing the MPC-HB canisters.

- The MPC-HBs are shielded by the heavy-walled steel overpack (SAR Figure 3.3-3). The large mass of steel used to provide shielding by the overpack includes 21.6 cm [8.5 in] in the radial direction for gamma shielding. Additionally, there is a radial neutron shield (Holtite-A) that is a minimum of 10 cm [4 in] thick. The top and bottom of the overpack are shielded by a 15-cm [6-in] thick steel lid and the bottom forging, respectively. The shielding at the top, where there is no soil above the vault, is also enhanced by the 24.1-cm [9.5-in] thick steel lid of the MPC-HB (SAR Figure 3.3-1).

- The MPC-HBs are heavily shielded by the below-grade concrete vault (SAR Figure 3.2-1) and the surrounding soil. The vault design includes a vault lid composed of a minimum of 38-cm [15-in] thick concrete encased in inner and outer steel lid plates with a total thickness of 3.18 cm [1.25 in] of steel.

- The MPC-HB is loaded for storage and decontaminated in the HBPP Refueling Building (RFB) prior to transfer to the ISFSI. The overpack is a bolted, sealed pressure vessel that is leak tested. The MPC-HB is designed such that leakage from the confinement barrier is not credible. Confinement is evaluated in Chapter 9 of this SER.

The staff finds the shielding design features described above acceptable. The information provided in the SAR meets the requirements of 10 CFR §72.24(b) and (c)(3) and provides reasonable assurance that the shielding design features will meet the requirements of 10 CFR §72.126(a)(6) and §72.128(a)(2). The staff evaluated the radiation protection design features in Chapter 11 of this SER.

7.1.3 Shielding Composition and Details

7.1.3.1 Composition and Material Properties

The composition of the materials used in the shielding analysis is presented in Sections 3.3.1.5.2 and 7.3.2 of the SAR. These sections reference the HI-STAR 100 system FSAR (Holtec International, 2002a), specifically Section 5.3, as it relates to the shielding evaluation. The staff finds the description of the shielding composition to be sufficient to meet the requirements of 10 CFR §72.24(b) and §72.24(c)(3) by describing the design, the system shielding composition, and materials important to safety. This description is sufficiently detailed for the evaluation of shielding effectiveness for maintaining the dose rates at and around the Humboldt Bay ISFSI within regulatory limits.

7.1.3.2 Shielding Details

The shielding details are described in Section 7.3 of the SAR. The MPC-HB is heavily shielded by the overpack, the vault, and the surrounding soil. The HI-STAR HB system storage casks will be stored in a below-grade concrete vault in a 1 × 6 array. The overpack has a large mass of steel and a radial neutron shield to provide gamma and neutron radiation shielding. The neutron shield of the overpack has been specifically designed as a solid Holtite-A radial shield enclosed in steel to eliminate possible neutron streaming paths created by channel-based enclosure shell designs.

Based on evaluating the description and drawings provided, the staff finds the information on the shielding details to be sufficient to identify the geometric arrangement and physical dimensions of sources and shielding materials. This evaluation included the description of the design features used to minimize potential gamma and neutron streaming paths (SAR Section 7.3). The staff finds that the description satisfies the requirements of 10 CFR §72.126(a)(6) and provides reasonable assurance that the radiation protection systems are adequately modeled in the shielding analysis.

7.1.4 Analysis of Shielding Effectiveness

7.1.4.1 Computational Methods and Data

The computational methods and data used to analyze shielding effectiveness in reducing the dose rates at the ISFSI are presented in Section 7.3.2 of the SAR and supporting documents (Holtec International, 2004, HI-2033047), including a reference to the methods and approach of Section 5.4 of the HI-STAR 100 System FSAR (Holtec International, 2002a). Analyses were conducted to determine the surface and 1-m [3.28-ft] dose rates for the casks, as well as dose rates at the point of closest public access to the ISFSI {16 m [53 ft]}, the 100-m [328-ft] controlled area boundary during cask transfer and vault loading operations, and the location of the nearest resident {247 m [811 ft]}. Also, Section 8.2.5.3 of the SAR presents analyses conducted to calculate dose rates for accident conditions for a cask that has undergone a fire during transfer operations. The complete loss of Holtite-A radial neutron shielding in the overpack is assumed in this calculation, which represents the worst case condition for all cask accidents analyzed by the applicant.

The shielding analysis of the HI-STAR HB system casks was performed using the MCNP-4A code (Briesmeister, 1993). The MCNP code is a general purpose, continuous energy, coupled neutron-photon-electron Monte Carlo transport code system. The code system is able to model the complex surfaces associated with the storage casks. The individual cross-section libraries are data contained in the MCNP-4A code system and are based on the cross-section data recommended in the MCNP manual. The staff finds the use of MCNP acceptable, as discussed in NUREG-1567 (U.S. Nuclear Regulatory Commission, 2000), and agrees that the code and cross-section data used in the applicant's shielding analyses are appropriate for this application.

The flux-to-dose-rate conversion factors used in the MCNP-4A shielding calculations were from American National Standards Institute/American Nuclear Society (ANSI/ANS)-6.1.1 (American Nuclear Society Standards Committee Working Group, 1977), as verified by reviewing the MCNP shielding model input data provided by the applicant (Pacific Gas and Electric Company, 2004b). The computer code and the ANSI/ANS-6.1.1 flux-to-dose conversion factors used for shielding analyses are considered acceptable by the staff for use in shielding calculations.

7.1.4.2 Dose Rate Estimates

The estimates of dose rates and annual doses caused by direct neutron and gamma radiation at various onsite and offsite locations are presented in Sections 7.3.2.1, 7.3.2.2, 7.4, and 7.5 of the SAR.

The HI-STAR HB system is designed to reduce dose rates from direct radiation emanating from a loaded MPC-HB to levels that are ALARA. The design basis MPC for the shielding analysis is the MPC-HB loaded with fuel assemblies having a burnup of 23,000 MWd/MTU and a 29-year cooling period. The contact surface dose rate for the HI-STAR HB cask (SAR Table 7.3-1) was estimated to be approximately 99 μSv/hr [9.9 mrem/hr] outside the overpack lid in its center and 83 μSv/hr [8.3 mrem/hr] at the midplane of the overpack. The dose rate at all locations adjacent to a single storage cell with the ISFSI vault lid installed is estimated to be less than 1.5 μSv/hr [0.15 mrem/hr].

To assess onsite and offsite doses from direct radiation emanating from the SNF stored at the ISFSI, the applicant employed an approach described in Sections 7.4 and 7.5 of the SAR. The onsite assessment applies the calculated dose rates for the MPC-HB locations shown in Figure 7.3-1 of the SAR. The dose rate versus distance calculations used for onsite and offsite dose assessments for the storage phase of ISFSI operations were conducted using a simplified model, in which a single storage cell in the ISFSI vault contains a fully loaded HI-STAR HB cask. The single vault cell is modeled with reflective boundary conditions on both sides at a distance halfway between storage cells such that an infinite single line of cells is modeled as a conservative calculation of the 1 × 6 array of storage cells in the actual ISFSI vault. This approach models the single GTCC storage cask as a SNF storage cask to provide a bounding analysis, as discussed in Section 7.1.1.1 of this SER.

Table 7.4-1 of the SAR provides the estimated occupational exposures to the HBPP personnel during the operational phases of ISFSI operation including (i) loading SNF into the MPC-HB contained in the overpack, (ii) decontaminating the MPC-HB and overpack, (iii) transferring the HI-STAR HB cask from the RFB to the ISFSI vault, (iv) transferring the HI-STAR HB cask into a storage cell of the vault, and (v) closing the storage cell lid. Tables 7.4-1 and 7.4-2 of the SAR provide a list of the operational steps involved in loading and unloading an overpack and MPC-HB. These tables include the estimated number of personnel, dose rates, and time for each operational task. The number of personnel and operation duration estimates were based on industry experience with the Holtec HI-STAR and HI-STORM cask systems. The estimated dose from loading, transfer, and emplacement into the ISFSI vault of a single HI-STAR HB cask was 5.68 person-mSV [567.98 person-mrem]. When compared to similar systems, these doses are lower because of the long cooling time of the HBPP fuel.

Section 7.4 of the SAR discusses the dose estimates for routine maintenance operations with a summary presented in Table 7.4-3 of the SAR. The annual occupational exposure from ISFSI walkdowns was estimated to result in a dose of 92 person-μSv [9.2 person-mrem]. The estimated annual exposure for overpack repair activities was estimated at 36 person-μSv [3.6 person-mrem]. The staff reviewed the occupational dose estimates and found them acceptable. Based on these estimates, there is reasonable assurance that personnel exposures will be below the annual occupational dose limit of 0.05 Sv [5 rem] specified in 10 CFR §20.1201(a)(1).

The preceding analyses are limited to a HI-STAR HB cask loaded with intact spent fuel. However, damaged fuel may be loaded into the cask in the two different configurations shown in Figures 10.2-1 and 10.2-2 of the SAR. The applicant referred to an analysis performed for the HI-STORM 100 (Holtec International, 2002b) to demonstrate the effects of damaged fuel on cask dose rates. The results of that HI-STORM 100 analysis showed the dose rate above the cask to change negligibly and the dose rate at the side of the cask to increase by less than 20%.

The staff reviewed the HI-STORM 100 analysis, including the modeling of the damaged fuel source and the analyzed loading pattern. Based on this review and the applicant's statement in Section 10.2.1.1 of the SAR restricting the amount of damaged fuel material in a DFC to that equivalent to an intact fuel assembly, the staff finds the modeling technique for the damaged fuel source to be applicable to the HI-STAR HB evaluation. The staff also finds the results of the HI-STORM 100 analysis to be applicable to a HI-STAR HB cask loaded according to Figure 10.2-1 of the SAR. However, the HI-STORM 100 analysis is not bounding for a HI-STAR HB cask loaded according to Figure 10.2-2 of the SAR. For this case, the staff estimated that dose rates above the cask would have a non-negligible increase. Using this estimate, and the estimate for the increase in cask side dose rates from the HI-STORM 100 analysis, the staff determined that the dose rates from a HI-STAR HB cask loaded with damaged fuel would be greater than those estimated for a cask loaded with intact fuel only. However, the resulting increase in doses would still be within regulatory limits. The staff considers this analysis, particularly the model of the damaged fuel source term, to be conservative and to provide a bounding estimate of the dose rates resulting from a cask loaded with damaged fuel.

The staff evaluated the radiation dose analyses and the SAR shielding calculations and found them to be acceptable. The staff finds that there is reasonable assurance that the dose rates at the onsite and offsite locations will be below the limits specified in 10 CFR §20.1201(a)(1), §20.1301(a), and §72.104(a). The description in the SAR, combined with the review of input and output files (Pacific Gas and Electric Company, 2004b), provides reasonable assurance that the HI-STAR HB shielding was adequately evaluated. The MCNP input and output files were reviewed an found to be consistent with the description of the shielding model and the results provided in the SAR. Chapter 11 of this SER discusses the overall onsite and offsite dose rates from the Humboldt Bay ISFSI estimated from the combined radiation exposure to direct radiation and potential radioactive effluents. The staff has reasonable assurance that compliance with 10 CFR §20.1201(a)(1), §20.1301(a), §20.1302(b), and §72.104(a) will be achieved by means of the radiation protection design and radiological protection program described in the SAR and evaluated in Chapter 11 of this SER. Based on this finding, the staff has reasonable assurance that ALARA objectives will be met.

7.1.5 Confirmatory Calculations

The staff independently calculated the bounding source terms for the stored fuel at the proposed Humboldt Bay ISFSI. Neutron and gamma source terms, as well as the hardware Cobalt-60 radionuclide inventory, were generated using the ORIGEN-ARP module (Gauld, et al., 2004) of the SCALE Version 5 code. ORIGEN-ARP does not provide a default library for a BWR 6 x 6 fuel assembly geometry; therefore, the confirmatory source terms were generated using the default BWR 7 x 7 fuel assembly geometry library, and the design-basis fuel assembly parameter values provided in Table 7.2-1 of the SAR. This was done for ease of calculation using the ORIGEN-ARP module, as well as to provide confirmatory analysis of the General Electric Type II 7 x 7 fuel assembly also present in the SNF inventory at the HBPP. The staff independently confirmed the results provided in Tables 7.2-4 through 7.2-6 of the SAR. The confirmatory calculations provide reasonable assurance that design basis neutron and gamma source terms for the HI-STAR HB system are accurate and acceptable for the shielding analyses.

The staff independently calculated the dose rates that could be expected around the storage casks and annual doses at the point of closest public access to the Humboldt Bay ISFSI. A distance to the public trail of 15 m [50 ft] and an occupancy time of 2,080 hours per year was assumed for comparison to the applicant's analyses. The staff used the SCALE Version 5 code system SAS4 module (Tang and Emmett, 2004), the 27N-18COUPLE cross-section library supplied with the code, and neutron and gamma flux-to-dose conversion factors from ANSI/ANS-6.1.1 (American Nuclear Society Standards Committee Working Group, 1977). The SAS4 control module performs a three-dimensional Monte Carlo shielding analysis of a nuclear fuel transport or storage container using an automated biasing procedure. The coupled 27 neutron group, 18 gamma group (27N-18COUPLE) library based on ENDF/B-IV data is widely used in light water reactor SNF shielding calculations and has been validated against experimental data (Jordan, et al., 2004). The fuel assemblies were modeled within the MPC-HB basket cell as a homogenized fuel pellet and cladding material assembly. The SNF cask and vault geometry and associated material properties were modeled explicitly and developed using the dimensions and properties provided in Tables 7.2-1 and 7.2-2 of the SAR and the features and specifications that were discussed previously in Sections 7.1.2.2 and 7.1.3 of this SER.

The staff's analysis was conducted to confirm the applicant's calculations for normal conditions and the transporter fire accident scenario. A single cask geometry was considered, and the dose rates at various distances were computed, including a calculation assuming that no overpack Holtite-A neutron shielding was present for the fire accident scenario during cask transfer. Annual doses were computed from the dose rates for the ISFSI vault geometry. The annual dose was calculated for an individual located slightly inside {15 m [50 ft]} the point of closest public access to the ISFSI for a conservative occupancy time on the public trail of 2,080 hours per year. The dose rates and annual doses presented in Tables 7.3-1 and 7.5-1 through 7.5-3 of the SAR were independently confirmed by the staff through shielding calculations performed using the SCALE Version 5 code. The dose rates for the fire accident scenario discussed in Section 8.2.5.3 of the SAR were also confirmed.

The staff's calculations confirmed the onsite dose rates estimated by the applicant, providing reasonable assurance that the requirements of 10 CFR §20.1201(a)(1), §20.1301(a), and

§20.1302(b) will be met. The applicant has an established radiation protection program, as required by 10 CFR Part 20, Subpart B. This program will be used to meet ALARA objectives and demonstrate compliance with dose limits to members of the public by evaluations and measurements. The staff calculations also confirmed that the offsite dose rates will be less than the 0.25-mSv/yr [25-mrem/yr] whole-body dose allowable to any real individual located beyond the controlled area, as required by 10 CFR §72.104(a). Based on these confirmatory calculations, the staff finds that the applicant's shielding analysis is acceptable.

7.2 Evaluation Findings

The staff made the following findings regarding the shielding evaluation of the Humboldt Bay ISFSI:

- The design and description of the shielding system in the SAR satisfy the criteria for radiological protection of 10 CFR §72.24(b), §72.24(c)(3), §72.126(a)(6), and §72.128(a)(2).
- The design of the Humboldt Bay ISFSI provides acceptable means for controlling occupational radiation exposures within the limits given in 10 CFR §20.1201(a)(1) and for meeting the objective of maintaining exposures ALARA.
- The design of the Humboldt Bay ISFSI provides acceptable means for controlling exposures of the public to direct radiation within the limits given in 10 CFR §72.104(a), §20.1301(a), and §20.1302(b).
- The design of the Humboldt Bay ISFSI provides suitable shielding for radiation protection during normal and accident conditions in compliance with 10 CFR §72.128(a)(2).

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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 Humboldt Bay Independent Spent Fuel Storage Installation (ISFSI) Safety Analysis Report (SAR) (Pacific Gas and Electric Company, 2004a), as well as other applicable sections of the SAR and the criticality evaluation calculations, as referenced in the SAR. 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, transfer, and storage activities at the proposed Humboldt Bay ISFSI.

The review considered how the SAR and related documents address the regulatory requirements of 10 CFR §72.40(a)(13) and §72.124(a–c). Complete citations of these regulations are provided in the Appendix of this Safety Evaluation Report (SER).

The applicant proposes to use the HI-STAR HB system, which is composed of the all-metal HI-STAR HB overpack and its integral multi-purpose canister (MPC-HB), which contains the fuel assemblies. Each of the five HI-STAR HB casks is designed to store up to 80 Humboldt Bay Power Plant (HBPP) fuel assemblies, with one additional cask storing Greater than Class C (GTCC) waste. The HI-STAR HB system is a variation of the HI-STAR 100 system, which has been certified by the U.S. Nuclear Regulatory Commission (NRC) for use by general licensees (U.S. Nuclear Regulatory Commission, 2001a).

Holtec International developed the modified MPC-HB for use at Humboldt Bay because of the smaller size (length and width) of the HBPP fuel assemblies. The HI-STAR HB system is modified from the certified HI-STAR 100 system in that it can store up to 80 HBPP fuel assemblies versus 68 standard boiling water reactor assemblies. The applicant proposes to use METAMIC® neutron absorber panels as an alternative to BORAL®. This is further discussed in Section 8.1.3.2 of this SER.

The modified HI-STAR HB system criticality analyses evaluated in this SER were performed in accordance with the methodologies previously reviewed and accepted by U.S. Nuclear Regulatory Commission (2001a,b) and documented in the Holtec HI-STAR 100 Final Safety Analysis Report (FSAR) (Holtec International, 2002). The Humboldt Bay ISFSI conditions for criticality safety are based on acceptance criteria outlined in NUREG-1567 (U.S. Nuclear Regulatory Commission, 2000). The staff's evaluation is summarized in the sections that follow.

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 Humboldt Bay ISFSI design criteria and features related to criticality safety are described in Sections 3.3.1.4 and 3.3.1.7 of the SAR. Section 4.2.3.3.7 of the SAR addresses criticality design of the HI-STAR HB 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 Boron-10 isotope content in the fixed neutron absorbers.

8.1.1.1 Criticality Design Criteria

The design criterion for criticality safety in Section 3.3.1.4 of the SAR is clearly identified and adequately described. For criticality safety, the design criterion is that the effective k_{eff}, including statistical biases and uncertainties, shall not exceed 0.95 during all credible normal, off-normal, and accident conditions and events.

The proposed HI-STAR HB cask system 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 (American National Standards Institute/American Nuclear Society, 1998). Adequate protection against accidental criticality is defined as maintaining k_{eff} below 0.95 at a 95-percent confidence level. Criticality safety of the design is based on favorable geometry of the MPC-HB basket and permanently fixed neutron absorbing materials.

The staff finds that the proposed design criterion will meet the double contingency requirements of 10 CFR §72.124(a) and, therefore, will be protective of public health and safety in accordance with the requirements of 10 CFR §72.40(a)(13).

8.1.1.2 Features

The criticality safety design features for the HI-STAR HB system are described in Section 4.2.3.3.7 of the Humboldt Bay ISFSI SAR. This cask system maintains the stored materials in a subcritical configuration independent of the ISFSI design under normal, off-normal, and credible accident conditions during spent nuclear fuel transfer and storage operations. For criticality prevention, the cask system relies on the MPC-HB, which provides the confinement system for the stored fuel. At the Humboldt Bay ISFSI, the fuel will be dry and sealed within a welded MPC-HB. The confinement review is discussed in detail in Chapter 9 of this SER. The primary design features and control methods used to prevent criticality for MPC-HB configurations include (i) the favorable geometry provided by the MPC-HB fuel basket with a minimum pitch of the fuel cells {14.8 cm [5.83 in]}, (ii) the incorporation of permanent neutron absorbing material attached to the fuel basket walls with a minimum required loading of the Boron-10 isotope (0.01 g/cm^2), (iii) use of a damaged fuel container (DFC) to store damaged fuel to ensure there is no significant relocation of fuel material in the MPC-HB, and (iv) use of peripheral cells or a checkerboard pattern as required loading configurations for damaged fuel/fuel debris in DFCs.

The MPC-HB may contain up to 80 intact fuel assemblies with or without channels. Up to 28 damaged fuel assemblies/fuel debris may be stored in DFCs in the peripheral cells of the basket (Figure 2.1-1 of the Technical Specifications) (Pacific Gas and Electric Company, 2004b, Attachment C). Furthermore, up to 40 damaged fuel assemblies/fuel debris may be stored in DFCs in a checkerboard pattern (Figure 2.1-2 of the Technical Specifications). Both figures are referenced in Table 2.1-1 of the Technical Specifications. Intact fuel assemblies may also be stored in DFCs according to Table 2.1-1.

The criticality monitoring system requirements of 10 CFR §72.124(c) have been addressed by the applicant in Section 4.2.3.3.7 of the SAR. The monitoring features described by the applicant apply to cask loading and unloading activities performed in the Refueling Building (RFB). These features include a combination of installed and portable radiation monitoring instrumentation that are intended, in accordance with General Design Criterion 63, to detect conditions that may result in excessive radiation levels and to initiate appropriate safety actions. The radiation monitoring generally conforms to the guidance in American National Standards Institute/American Nuclear Society standard ANSI/ANS-8.3 (1979). Based on the radiation monitoring capability 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 in its stored configuration is not required.

The staff finds that (i) the design features important to nuclear criticality safety are clearly identified and adequately described; (ii) the stored material will be maintained in a subcritical configuration during SNF transfer, placement, and storage; and (iii) the design basis, off-normal, and postulated accident events will not have an adverse effect on the design features important to criticality safety. The staff, therefore, 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, Tables 3.1-1, 3.1-2, and 3.4-2 of the SAR. The fuel assembly limits and characteristics for the material to be stored are described in Sections 10.2.1.1, 10.2.1.2, and 10.2.1.3 of the SAR, and provided in Tables 10.2-1 and 10.2-2, respectively. Section 2.0 of the proposed Technical Specifications (Pacific Gas and Electric Company, 2004c, Attachment C) describes technical specifications for the stored materials.

The materials to be stored include intact HBPP fuel assemblies, damaged fuel assemblies/fuel debris, and GTCC waste. In the HBPP inventory, there are 390 fuel assemblies and a quantity of loose debris that is described in Section 3.1.1 of the SAR as constituting the equivalent of one additional assembly. The SNF assemblies to be stored consist of General Electric Type II (7 x 7 array of fuel rods), General Electric Type III, Exxon Type III, and Exxon Type IV (6 x 6 array) boiling water reactor (BWR) fuel assemblies. A summary of the physical characteristics of each type is presented in Table 3.1-2 of the SAR. In the review of this table, the fuel specifications important to criticality safety are:

- Maximum planar average initial enrichment
- Number of fuel rods
- Minimum clad outer diameter
- Maximum clad inner diameter
- Maximum pellet diameter
- Fuel rod pitch
- Maximum active fuel length
- Number of water rods
- Minimum water rod thickness
- Maximum channel thickness

These parameters represent the bounding parameters for BWR fuel assemblies (i.e., most reactive). The staff finds that the criticality analysis performed for the HI-STAR HB system (SAR Section 4.2.3.3.7) used the bounding fuel specifications discussed here and conservatively assumed fresh fuel with no credit for burnup, no credit for fuel-related burnable neutron absorbers, and a Boron-10 neutron absorber content of 75 percent of the minimum specified content. The justification provided in Section 4.2.3.3.7 of the SAR provides reasonable assurance of the continued efficacy of the neutron absorber material in the HI-STAR HB design and thus meets the requirements of 10 CFR §72.124(b).

The applicant stated that intact fuel assemblies may be stored in DFCs per Table 2.1-1 of the proposed Technical Specifications (Pacific Gas and Electric Company, 2004b, Attachment C). Because the applicant is relying on administrative controls to ensure that damaged fuel/debris is placed in appropriate locations within the MPC-HB, which is not easily verifiable because of the potential use of DFCs for both damaged and intact fuel, the applicant has committed to revise Technical Specification Section 5.1.3 to add the following administrative control to prevent misloading events (Pacific Gas and Electric Company, 2005):

> 5.1.3 MPC-HB and SFSC Loading, Unloading, and Preparation Program
>
> f. Loading is to be independently verified by a cognizant engineer to ensure that the fuel assemblies in the MPCs are placed in accordance with the original loading plan.

Based on the administrative controls provided in Section 5.1.3 of the Technical Specifications and the loading procedures for approved contents provided in Section 2.1, incorrect loading of an MPC-HB is not considered a credible accident. Section 10.2.1.4 of the SAR addresses the requirements of Section 2.2 of the Technical Specification should any of the fuel specifications or loading conditions be violated. This requires placing the affected fuel assemblies in a safe condition and reporting the event and proposed corrective actions to NRC. These requirements and stored material specifications provide reasonable assurance that the requirements of 10 CFR §72.40(a)(13) and §72.124(a) are met.

8.1.3 Analytical Means

The staff reviewed the analytical means used by the applicant to demonstrate that the materials stored in the ISFSI will remain subcritical. Section 4.2.3.3.7 of the SAR and supporting calculations contain the relevant information reviewed by the staff.

8.1.3.1 Model Configuration

The applicant used three-dimensional models in its criticality analyses. The fuel assemblies were modeled explicitly with all intact assemblies, including water channels, as is appropriate for BWR fuel assemblies using a conservative model assumption that increases reactivity. The models for damaged fuel assemblies considered fuel in the DFC as arrays of bare fuel rods or fuel fragments in both the periphery and checkerboard loading patterns shown in Figures 10.2-1 and 10.2-2 of the SAR, respectively. This approach conservatively neglects the presence of fuel cladding and other structural materials and replaces them with a moderator (water) to provide reasonable assurance that the requirements of 10 CFR §72.124(a) are met.

The staff reviewed the models described in the supporting calculations. Based on the information presented, the staff agrees that the models reviewed are consistent with the description of the cask and contents given in Chapters 3 and 4 of the SAR and that the most reactive combination of cask parameters and dimensional tolerances were incorporated into the calculation models.

8.1.3.2 Material Properties

The compositions and densities of the materials considered in the calculational models are provided in Tables 5.1, 5.2, and 5.3 in the applicant's criticality evaluation (Holtec International, 2004, HI-2033010). The models make a number of conservative assumptions on the material properties consistent with the guidance provided in Section 8 of NUREG-1567 (U.S. Nuclear Regulatory Commission, 2000). These include

- Fresh fuel isotopics (i.e., no burnup credit)
- No credit is taken for fuel-related burnable neutron absorbers
- 75-percent credit for the Boron-10 loading in fixed neutron absorber panels
- Fuel stack density of 96 percent of theoretical density (10.522 g/cm^3)
- The fuel rod pellet-to-gap regions are flooded with pure water at the highest reactivity density (1 g/cm^3) within the expected operating temperature range
- Manufacturing tolerances are assumed in the worst hypothetical combination (i.e., most reactive)
- Maximum planar-average enrichment is assumed for BWR fuel
- Neutron absorption in structural members is neglected, and those minor structural members are conservatively modeled as water moderator
- Configurations of the assemblies in the MPC-HB basket with centered and eccentric positions are considered

One of the most important materials concerning the criticality safety analysis is the fixed neutron absorber. The minimum Boron-10 content will be verified through the acceptance testing program described by the applicant (Pacific Gas and Electric Company, 2004c). The acceptance of the tests described is partly based on the use of only 75-percent credit of the minimum required Boron-10 content to be verified in the test procedure. The applicant has proposed and the staff has accepted the tests described as follows as a license condition. Prior to loading SNF into any dry storage cask, the following testing must be successfully completed:

For all fixed neutron absorbers

(i) Each plate of neutron absorbers shall be visually inspected for damage (e.g., scratches, cracks, burrs, peeled cladding, foreign materials embedded in the surface, voids, delamination, and surface finish) as applicable.

(ii) The required Boron-10 content (areal density) of the neutron absorber panels for the MPC-HB shall be verified to be greater than or equal to 0.01 gm/cm^2.

For BORAL®

After manufacturing, a statistical sample of each lot of BORAL® neutron absorber shall be tested using wet chemistry and/or neutron attenuation testing to verify the minimum Boron-10 content (areal density) in samples taken from the ends of the panel.

For METAMIC®

(i) Verification that the boron carbide (B_4C) content in the METAMIC® is not more than 33.0 weight percent

(ii) Verification that all lots of B_4C powder shall meet particle size distribution requirements

(iii) Qualification testing shall be performed on the first production run of METAMIC® panels to be used in a Holtec MPC to validate the acceptability and consistency of the manufacturing process and verify the acceptability of the METAMIC® panels for neutron absorbing capability.

1. The B_4C powder weight percent shall be verified by testing a sample from 40 different mixed batches. (A mixed batch is defined as a single mixture of aluminum powder and B_4C powder used to make one or more billets. Each billet will produce several panels.) The samples shall be drawn from the mixing containers after mixing operations have been completed. Testing shall be performed using the wet chemistry method.

2. The Boron-10 areal density shall be verified by testing a sample from one panel from each of 40 different mixed batches. The samples shall be drawn from areas contiguous to the manufactured panels of METAMIC® and shall be tested using the wet chemistry method. Alternatively, neutron attenuation tests on the samples may be performed to quantify the actual Boron-10 areal density.

3. To verify the local uniformity of the boron particle dispersal, neutron attenuation measurements of random test coupons shall be performed. These test coupons may come from the production run or from pre-production trial runs.

4. To verify the macroscopic uniformity of the boron particle distribution, test samples shall be taken from the sides of one panel from five different mixed batches before the panels are cut to their final sizes. The sample locations shall be chosen to be representative of the final product. Wet chemistry or neutron attenuation shall be performed on each of the samples.

(iv) For production runs of the panels to be used in the MPC-HB canisters, the following tests shall be performed:

1. Testing of mixed batches shall be performed on a statistical basis to verify that the correct B_4C weight percent is being mixed.

2. Samples from random METAMIC® panels taken from areas contiguous to the manufactured panels shall be tested via wet chemistry and/or neutron attenuation testing to verify the Boron-10 areal density. This testing shall be performed to verify the continued acceptability of the manufacturing process.

As stated previously, the justification provided in Section 4.2.3.3.7 of the SAR provides reasonable assurance of the continued efficacy of the neutron absorber material in the HI-STAR HB design and, thus, the requirements of 10 CFR §72.124(b) are met. The model configuration and material properties used in the criticality analyses provide reasonable assurance that the requirements of 10 CFR §72.40(a)(13) are met.

8.1.4 Applicant Criticality Analysis

The staff finds that the applicant addressed the most reactive configurations and conditions in the cask system analysis. The criticality analysis results are described and presented in Section 4.2.3.3.7 of the SAR and in the supporting calculation report, HI-2033010 (Holtec International, 2004). The applicant's criticality analysis references the previously reviewed and approved analysis described in Chapter 6 of the HI-STAR 100 FSAR (Holtec International, 2002) used in the licensing of the HI-STAR 100 system. The modified HI-STAR HB system analyses evaluated in this SER were performed in accordance with the methodologies previously reviewed and accepted by NRC (U.S. Nuclear Regulatory Commission, 2001a,b) and documented in the Holtec HI-STAR 100 FSAR (Holtec International, 2002). The staff finds that these methodologies are appropriate for the HI-STAR HB criticality analysis, and are therefore acceptable.

8.1.4.1 Computer Program

The applicant's principal criticality analysis code was Monte Carlo N-Particle (MCNP) Version 4A (Briesmeister, 1993), a three-dimensional, continuous-energy, MCNP code. The applicant's MCNP4A calculations used continuous energy cross-section data based on ENDF/B-V files provided with the MCNP4A code. The staff finds the use of MCNP acceptable, as discussed in NUREG-1567 (U.S. Nuclear Regulatory Commission, 2000), and agrees that the code and cross-section data used in the applicant's criticality analyses are appropriate for this application.

8.1.4.2 Multiplication Factor

The results of the applicant's analyses for all proposed fuel loadings yielded values for k_{eff}, including all biases and uncertainties, below 0.95 for normal, off-normal, and accident conditions, thus meeting the staff's acceptance criterion. These results are presented in Section 4.2.3.3.7 of the SAR and are described in the supporting calculations of HI-2033010 (Holtec International, 2004). The limiting reactivity condition occurs in the spent fuel pool during fuel loading where assemblies are loaded into the MPC-HB in unborated water. The bounding analysis for this condition with intact fuel assemblies provides a maximum k_{eff} of 0.8410. The limiting reactivity condition analyzed with 40 DFCs containing damaged fuel and fuel debris loaded in the checkerboard pattern of Figure 10.2-2 of the SAR results in the applicant's maximum calculated k_{eff} of 0.9003. In the storage condition, the HI-STAR HB system is helium-filled, and therefore, has no water moderator; thus, the reactivity of the system is very low (k_{eff} less than 0.40). The staff reviewed the applicant's calculated multiplication factor values and agrees that they have been appropriately adjusted to include all biases and uncertainties at the 95-percent confidence level.

Based on the applicant's criticality evaluation, the staff concludes that the HI-STAR HB system will remain subcritical, with an adequate safety margin, under all credible normal, off-normal, and accident conditions, and thus meets the requirements of 10 CFR §72.124(a).

8.1.4.3 Benchmark Comparisons

The applicant relied on the benchmark analysis discussed in Chapter 6, Appendix 6.A of the HI-STAR 100 System FSAR (Holtec International, 2002). The same analysis method and modeling assumptions are used in the supporting criticality calculations provided in HI-2033010 (Holtec International, 2004). The value of the bias correction used for k_{eff} was 0.0021 with an uncertainty of 0.0006. The benchmark analysis was previously reviewed by the staff and found to use critical experiments relevant to cask design; only biases that increase k_{eff} have been applied. The use of this benchmark analysis is, therefore, appropriate for the HI-STAR HB criticality analysis and provides reasonable assurance the requirements of 10 CFR §72.124(a) are met.

8.1.4.4 Independent Criticality Analysis

The staff performed independent criticality analyses for the HI-STAR HB system using the CSAS/KENO-Va code modules in the SCALE5 suite of analytical codes. The staff's modeling assumptions were similar to those used by the applicant. The staff's model considered the most reactive conditions in modeling each of the intact and damaged spent fuel configurations identified by the applicant. The results of the staff's analyses were in close agreement with the applicant's results.

8.2 Evaluation Findings

Based on a review of the SAR and the presentations and information supplied by the applicant, the staff finds that:

- The design, procedures, and materials to be stored at the proposed Humboldt Bay 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 Humboldt Bay 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, in compliance with 10 CFR §72.124(a).

- The SAR analyses adequately show that acceptable margins of safety will be maintained in the nuclear criticality parameters commensurate with uncertainties in the data and methods used in calculations and demonstrate safety for the handling, packaging, transfer, and storage of SNF during normal, off-normal, and accident conditions in compliance with 10 CFR §72.124(a) and §72.124(b).

- The radiation monitoring capability to be provided during cask loading and handling activities demonstrates compliance with the requirements of 10 CFR §72.124(c).

8.3 References

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9 CONFINEMENT EVALUATION

9.1 Conduct of Review

The staff reviewed the confinement evaluation presented in the Humboldt Bay ISFSI Safety Analysis Report (SAR) (Pacific Gas and Electric Company, 2004a). The Humboldt Bay ISFSI will use the HI-STAR HB system, which is a shortened version of the HI-STAR 100 system approved by the U.S. Nuclear Regulatory Commission (NRC) for use under the general license provisions of 10 CFR Part 72.

This review was conducted in accordance with the guidance presented in Chapter 9 of NUREG–1567 (U.S. Nuclear Regulatory Commission, 2000). This review focused on analyses and results presented and referenced by the applicant in the Humboldt Bay ISFSI SAR.

The review considered how the SAR and related documents address the regulatory requirements of 10 CFR §72.24(c), §72.24(d), §72.24(f), §72.24(g), §72.24(l)(1), §72.44(c)(1)(i), §72.104(a), §72.104(b), §72.104(c), §72.106(b), §72.122(h)(1), §72.122(h)(3), §72.122(h)(4), §72.122(h)(5), §72.122(i), §72.126(c)(1), §72.126(d), §72.128(a)(1), and §72.128(a)(3). Complete citations of these regulations are provided in the Appendix of this Safety Evaluation Report (SER).

9.1.1 Review of Design Features

The staff reviewed Sections 3.3.1.2, 3.3.1.5, 3.3.1.7, 4.2.3.2, 4.2.3.3, 6.1, 8.1.3, 8.2.8, and Chapter 7 of the SAR to identify the quantity of radionuclides that hypothetically could be released during normal, off-normal, and accident conditions, including design-basis accidents. The HI-STAR HB system is designed for interim confinement and dry storage of Humboldt Bay Power Plant spent nuclear fuel and Greater than Class C waste. The design of the HI-STAR HB system is discussed in detail in Section 4.2.3 of the SAR. In Section 4.2.3.3.8 of the SAR, the applicant states that all components of the confinement system are classified as important to safety.

The confinement boundary of the HI-STAR HB system is the sealed MPC-HB that consists of the MPC shell, base plate, lid, vent and drain port cover plates, and the closure ring, which together form a welded canister. The MPC-HB is designed to confine radioactive material during all normal, off-normal, and accident conditions. The welds, including the final closure weld, are described in detail in Section 4.2.3.3.8 of the SAR. Table 4.2-3 of the SAR provides a comparison of the MPC-HB design with the specific requirements of Interim Staff Guidance 18 (ISG–18), (U.S. Nuclear Regulatory Commission, 2003a). The MPC-HB is designed, fabricated, and tested in accordance with the applicable requirements of the ASME Code, Section III, Subsection NB, to the maximum extent practicable (ASME International, 1996). The MPC-HB lid weld ensures that no credible leakage of radioactive materials will occur during normal, off-normal, and accident conditions. The closure ring weld provides a redundant welded boundary. Based on the information on the confinement boundary design presented in the SAR, the staff finds that the requirements of 10 CFR §72.24(c–d) have been met.

The staff has reasonable assurance that the HI-STAR HB system at the Humboldt Bay ISFSI meets the requirements of 10 CFR §72.106(b). The staff concludes that the stainless steel welded canisters (with redundant welds in the lid enclosure of the canister), which will be manufactured and inspected according to the ASME Code as approved by staff, provide adequate confinement of radioactive materials, thereby meeting the requirements of 10 CFR §72.24(f) §72.24(f)(l)(1), §72.104(a–c), §72.126(d), and §72.128(a)(3).

The staff reviewed the applicable chapters of the SAR and found that the applicant's conclusions were consistent with those in the Holtec HI-STAR 100 System Final Safety Analyses Report (FSAR) (Holtec International, 2002) previously approved by the NRC staff. The staff also reviewed the Humboldt Bay ISFSI technical specifications (Pacific Gas and Electric, 2004b, Attachment C) proposed by the applicant and found those portions related to the confinement integrity of the HI-STAR HB system to be acceptable, with one addition. ISG-18 allows relief from the requirement for a helium leak test for the canister lid-to-shell structural weld; however, it does not relieve the requirement for helium leak tests of other closure welds. Specifically, the vent and drain port cover welds of the MPC-HB must be leak tested in accordance with ANSI –14.5. With the addition of this technical specification requirement to proposed TS 3.1.1, the staff finds that the confinement design of the HI-STAR HB system to be used at the Humboldt Bay ISFSI meets the requirements of 10 CFR §72.24(g), §72.44 (c)(1)(i), §72.122(h)(1), §72.126(d), and §72.128(a)(3).

9.1.2 Confinement Monitoring

The staff reviewed Sections 3.3.1.3, 3.3.1.5, 3.3.1.7, 4.2.3.3, and 6.1 of the SAR. The staff has found that casks closed entirely by welding do not require seal monitoring because there is no known plausible, long-term degradation mechanism that would cause the seal welds to fail.

Based on the staff's assessment of welded cask enclosures consistent with ISG–5 (U.S. Nuclear Regulatory Commission, 2003b), the MPC-HB, which is the confinement system for the HI-STAR HB system, provides reasonable assurance that no effluents will be released and, therefore, requires no monitoring of the MPC-HB for leakage. The seal welds will be inspected and tested as described in Section 4.2.3.3.8 of the SAR.

The staff finds the applicant's proposal to not provide leakage monitoring of the confinement barrier for the HI-STAR HB system at the Humboldt Bay ISFSI acceptable because the casks will be loaded, welded, inspected, tested, and surveyed in accordance with appropriate cask design requirements, thereby meeting the requirements of 10 CFR §72.24(l)(1), §72.44(c)(1)(i), §72.122(h)(3), §72.122(h)(4), §72.122(i), §72.126(c)(1), and §72.128(a)(1).

9.1.3 Protection of Stored Materials from Degradation

The staff reviewed the application to establish that the fuel cladding will not experience significant degradation during the storage period. The staff reviewed Sections 3.3.1, 4.4.1.1, 4.4.1.2, 5.1.1.2, and Table 3.4-2 of the SAR.

Following the loading of the MPC-HB, the main lid is welded, and a pressure test is performed on the seal weld. The MPC-HB cavity is then dried and filled with helium fill gas. The vent and drain ports are then welded into place, and a helium leak test is conducted on the vent and drain port covers. These steps are described in detail in SAR Section 4.4.1.2.3. The helium back-fill procedure ensures that the presence of oxidizing gases in the MPC-HB cavity will be minimized.

The thermal analysis of the HI-STAR HB system discussed in Chapter 6 of this SER indicates that the fuel cladding temperature will not exceed the limits established to prevent fuel clad degradation during storage. The staff verified that the SAR was consistent with the information provided in the HI-STAR 100 System FSAR (Holtec International, 2002) and that the staff's previous findings in this area were applicable to the HI-STAR HB system. The staff reviewed the proposed Humboldt Bay ISFSI Technical Specifications (Pacific Gas and Electric, 2004b, Attachment C) and found the conditions to ensure the protection of stored materials from degradation in the HI-STAR HB system to be acceptable, thereby meeting the requirements of 10 CFR §72.24(l)(1), §72.122(h)(1), and §72.122(h)(5).

9.2 Evaluation Findings

For this confinement evaluation, the staff assumed that only the HI-STAR HB system would be used at the Humboldt Bay ISFSI. The staff made the following findings, based on its review of the applicant's submittal and the applicable technical specifications:

- The confinement structures, systems, and components important to safety are described in sufficient detail to permit evaluation of their effectiveness in accordance with 10 CFR §72.24(c–d) and are evaluated in Chapter 4 of this SER.

- The staff concludes that the proposed technical specifications, with the addition of the requirement to perform a leak test of the vent and drain port cover welds, are sufficient to protect the stored materials from degradation in accordance with 10 CFR §72.24(g).

- The design of the MPC-HB provides redundant sealing of the confinement system.

- The design and proposed operation of the ISFSI provide adequate measures for protecting the stored materials from degradation. The SNF cladding is adequately protected from gross ruptures in accordance with 10 CFR §72.122(h)(1).

- The MPC-HB is welded and tested in accordance with acceptable methods, as described in the SAR, and is not expected to leak under normal, off-normal, and accident conditions. Therefore, the staff finds that the requirements of 10 CFR §72.122(h)(3), §72.122(h)(5), §72.126(d), and §72.128(a)(3) have been met.

- The radionuclide confinement analysis for the HI-STAR HB system and the Humboldt Bay ISFSI meets the requirements of 10 CFR §72.24(f) and §72.24(l)(1) by providing a description of how radioactive materials in gaseous and liquid effluents will be controlled such that they are as low as reasonably achievable.

- The staff concludes that the HI-STAR HB system, which uses an entirely redundant closure system, is not expected to leak and, therefore, does not require confinement monitoring. Based on this finding, the requirements of 10 CFR §72.24(l)(1), §72.44(c)(1)(i), §72.122(h)(3), §72.122(h)(4), §72.122(i), §72.126(c)(1), and §72.128(a)(1) have been met.

- The staff concludes that the design of the confinement system of the HI-STAR HB system complies with 10 CFR Part 72 and that the applicable design and acceptance criteria have been satisfied. The evaluation of the confinement system design provides reasonable assurance that the HI-STAR HB system will allow safe storage of SNF. This finding is reached on the basis of a review that considered the regulation itself, appropriate regulatory guides and interim staff guidance, applicable codes and standards, and accepted engineering practices. Based on this finding and the review discussed in Chapter 11 of this SER, the requirements of 10 CFR §72.104(a–c) and §72.106(b) have been met by the confinement system.

9.3 References

ASME International. *ASME Boiler and Pressure Vessel Code. Section III. 1995 Edition with 1996 and 1997 Addenda.* New York City, NY: ASME International. 1996.

Holtec International. *Final Safety Analysis Report for the Holtec International Storage, Transport, and Repository Cask System (HI-STAR 100 Cask System).* Rev 1. HI–2012610. Docket 72-1008. Marlton, NJ: Holtec International. 2002.

Pacific Gas and Electric Company. *Humboldt Bay Independent Spent Fuel Storage Installation Safety Analysis Report.* Amendment 1. Docket No. 72-27. Avila Beach, CA: Pacific Gas and Electric Company. 2004a.

Pacific Gas and Electric Company. *Humboldt Bay Independent Spent Fuel Storage Installation License Application.* Amendment 1. Docket No. 72-27. Avila Beach, CA: Pacific Gas and Electric Company. 2004b.

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

U.S. Nuclear Regulatory Commission. *The Design/Qualification of Final Closure Welds on Austenitic Stainless Steel Canisters as Confinement Boundary for Spent Fuel Storage and Containment Boundary for Spent Fuel Transportation.* Interim Staff Guidance 18 (ISG–18). Washington, DC: U.S. Nuclear Regulatory Commission. 2003a.

U.S. Nuclear Regulatory Commission. Interim Staff Guidance 5 (ISG–5), *Confinement Evaluation.* Rev. 1. Washington, DC: U.S. Nuclear Regulatory Commission. 2003b.

10 CONDUCT OF OPERATIONS EVALUATION

10.1 Conduct of Review

Chapter 9, "Conduct of Operations," of the Safety Analysis Report (SAR) (Pacific Gas and Electric Company, 2004a), describes the organization for the design, fabrication, construction testing, operation, modification, and decommissioning of the Humboldt Bay ISFSI, including the organizational structure, personnel responsibilities and qualifications, and the corporate interface with contractors and other outside organizations. The chapter includes discussions of the management and administrative control system, personnel qualifications, plans for preoperational and startup testing and operations, operational readiness review, training, and emergency planning. Chapter 9 also includes descriptions of the responsibilities of key personnel, the training program, standards and procedures that govern daily operations, and records generated as a result of those operations. The purpose of this review is to ensure that the infrastructure to manage, test, and operate the Humboldt Bay ISFSI, including provisions for effective training, is acceptable.

The staff evaluated the proposed conduct of operations by reviewing Chapter 9 of the SAR, documents cited in the SAR, and other supporting documents. The staff also considered information related to the conduct of operations that was submitted by the applicant in response to the staff's request for additional information (Pacific Gas and Electric Company, 2004b). The applicant has requested an exemption from the record keeping requirements of 10 CFR §72.72(d), which requires that spent nuclear fuel (SNF) and high-level waste records be stored in duplicate at a separate, sufficiently remote location to ensure that a single event will not destroy both sets of records. The applicant requested NRC approval to apply the same record keeping procedures used for records at the Humboldt Bay Power Plant (HBPP) to the Humboldt Bay ISFSI records. The HBPP record keeping program satisfies the criteria of 10 CFR Part 50, Appendix B. The staff reviewed this exemption request and considered it acceptable. The proposed record keeping program for the Humboldt Bay ISFSI was found acceptable because it (i) provides for a record keeping system equivalent to the requirements of 10 CFR §72.72(d) and (ii) avoids a redundant and unnecessarily complex record keeping system. The exemption will be included as a condition of the 10 CFR Part 72 license and will be effective upon issuance of the license.

The review considered how the SAR and related documents address the regulatory requirements of 10 CFR §72.24(h–k), §72.24(o) §72.24(p), §72.28(a–d), §72.40(a)(4), §72.40(a)(9), §72.40(a)(13), §72.72(d), §72.180, §72.184(a–b), §72.190, §72.192, and §72.194. Complete citations of these regulations are provided in the Appendix of this Safety Evaluation Report (SER).

Some of these regulations reference requirements of 10 CFR Part 73 regarding physical protection, including 10 CFR Part 72, Subpart H; however, these requirements are not addressed in this SER. The staff's review of conforming changes to the Humboldt Bay site security plan will be addressed in separate correspondence.

10.1.1 Organizational Structure

Section 9.1 of the SAR describes the organizational structure that will be used to manage and operate the Humboldt Bay ISFSI.

10.1.1.1 Corporate Organization

Sections 9.1.1, 9.1.2, 9.1.3, 9.1.4, 9.1.5, and 9.1.6 of the SAR describe the corporate organization that will be used to manage and operate the Humboldt Bay ISFSI.

The Humboldt Bay ISFSI will be managed by the same corporate structure that manages the HBPP Unit 3. The HBPP Decommissioning Trust, approved by the California Public Utilities Commission (CPUC), will fund the construction, operation, and decommissioning of the Humboldt Bay ISFSI.

Following termination of the HBPP Unit 3 10 CFR Part 50 license, the corporate management of the Humboldt Bay ISFSI will change, depending on revisions to the Pacific Gas and Electric (PG&E) organizational structure that will take place at that time. The NRC will be notified of any proposed changes in the corporate management structure governing the Humboldt Bay ISFSI. The applicant commits to maintaining compliance with 10 CFR Part 72 during this transition.

The Vice President of Nuclear Services, who reports to the Senior Vice President, Generation and Chief Nuclear Officer, has corporate responsibility for overall Humboldt Bay ISFSI safety and is responsible for staff performance in designing, fabricating, constructing, testing, operating, modifying, decommissioning, and providing technical support to the ISFSI. This person interfaces with the CPUC.

The HBPP Director and Plant Manager is responsible for providing engineering and design services, safety assessments, and licensing services, and will be responsible for ISFSI operations. This person reports to the PG&E Director for Fossil Generation and Asset Management in carrying out these responsibilities.

The existing HBPP Plant Staff Review Committee reviews matters affecting the safe storage of SNF. The committee is chaired and directed by the HBPP Director and Plant Manager. The committee's functions and responsibilities will include both the HBPP and the Humboldt Bay ISFSI.

The corporate management for the Humboldt Bay ISFSI is the same as that for the HBPP. Programs used for the HBPP, such as radiation protection, environmental monitoring, emergency preparedness, quality assurance (QA), and training will be adopted, as necessary, and will be employed to ensure safe operation of the Humboldt Bay ISFSI. Legal support will be provided from PG&E headquarters, and technical and operational support will be available from the HBPP personnel and outside consultants for licensing, QA, engineering, radiation protection, maintenance, testing, emergency planning, security, and decommissioning. Construction, testing, and operation of the ISFSI will be conducted by the same organization responsible for the design, testing, maintenance, and operation of the HBPP.

Quality control functions will be performed by individuals independent of the Humboldt Bay ISFSI line organization. During the preoperations phase, results of QA audits and recommendations for improvement will be provided to the ISFSI Project Manager. During the operations phase, audit results and recommendations will be reported directly to the Director and Plant Manager. During both phases, they will be provided to the Vice President of Nuclear Services. The frequency and scope of the QA audits are addressed in the HB ISFSI QA Program described in Chapter 11 of the SAR, which has been approved by NRC and will be applied to all ISFSI-related activities.

The Humboldt Bay ISFSI Project Manager manages the day-to-day activities during the preoperational phase and ensures that design, fabrication, construction, fuel loading, testing, and loading of casks into the ISFSI vault are safely completed. This person also is responsible for cost control for these activities. The ISFSI Project Manager develops the license application and is responsible for licensing coordination with federal and state officials. The Project Manager also reports to the Director and Plant Manager of HBPP, who has responsibility for overall safety of ISFSI activities during the preoperational phase.

All operations associated with the Humboldt Bay ISFSI, including those conducted by contractors and consultants, will be managed and approved by PG&E and will be conducted using approved procedures. Contractors and consultants may support various design and engineering activities for the ISFSI and its components. Tests performed by outside vendors will meet the requirements of a PG&E-approved QA program and will be approved by PG&E prior to use. PG&E personnel will witness the performance of preoperational tests performed by vendors. During operations, the onsite Director and Plant Manager is responsible for the oversight of consultant and contractor work.

The primary difference in the corporate management structure between the preoperational and operational phases is that during operations, day-to-day management of the Humboldt Bay ISFSI activities shifts from the ISFSI Project Manager to the onsite Director and Plant Manager.

The staff concludes that the corporate organizational structure meets the requirements of 10 CFR §72.24, §72.28, and §72.40(a). The corporate organization, technical qualifications, training, and experience of the applicant to conduct the proposed operations satisfy the requirements of 10 CFR §72.24(h) and (j). The technical qualifications, training and experience, operating organization, delegations of responsibility and authority, skills, and experience satisfy the requirements of 10 CFR §72.28(a) and §72.28(c). The applicant satisfies the requirement of 10 CFR §72.40(a)(4) to be qualified by reason of training and experience to conduct the operations covered by the regulations and the requirement of 10 CFR §72.40(a)(13) that the operations can be conducted without endangering the health and safety of the public.

10.1.1.2 Onsite Organization

Sections 9.1.3, 9.1.4, 9.1.5, and 9.1.6 of the SAR present the onsite organization for ISFSI activities, including responsibilities and reporting relationships.

The Humboldt Bay ISFSI will be constructed, tested, and operated by the same organization responsible for the testing and operation of the HBPP. The only difference is that after the preoperational phase, responsibility for day-to-day operations will shift from the ISFSI Project Manager to the HBPP Director and Plant Manager. It is anticipated that approximately two full-time-equivalent personnel will be used to support the operation of the Humboldt Bay ISFSI. These personnel will come from the existing HBPP organization but will be specifically trained as required by 10 CFR Part 72, Subpart I, to support ISFSI operations. The authorities, responsibilities, and reporting relationships of these personnel are presented in the SAR and will be updated in organization charts, functional descriptions, and job descriptions, as required.

The Director and Plant Manager will be responsible for the overall safety of ISFSI operations and for training and qualification of operations, maintenance, radiation protection, and security personnel. The Director and Plant Manager reports to the Vice President of Nuclear Services.

The Operations Supervisor reports to the Director and Plant Manager and is responsible for administering, coordinating, planning, and scheduling all Humboldt Bay ISFSI operating activities. The Operations Supervisor also provides operating procedures and ensures that operating personnel are familiar with them and use them.

The Maintenance Supervisor reports to the Director and Plant Manager. During the operational phase, the Maintenance Supervisor oversees Humboldt Bay ISFSI maintenance and work planning.

The HBPP personnel will conduct the day-to-day operations of the ISFSI including engineering, design, construction, QA, radiation protection, operations, and security. In conducting these activities, personnel will use license requirements, technical specifications, the physical security plan, plant procedures, and applicable regulations. The ISFSI specialists will report to either the Operations Supervisor or the Maintenance Supervisor, according to their discipline.

During both preoperational and operational phases, functions, such as engineering design, construction, QA, radiation protection, testing, operations, and security, will be performed by the HBPP personnel. The existing NRC-approved HBPP Plant Staff Review Committee will review and approve any issues affecting the safe storage of SNF. The Plant Staff Review Committee is chaired by the Director and Plant Manager. This committee reviews any procedures or procedure changes important to safety.

A formal order of succession and delegation of authority will be established to ensure continuity of operations and the ability to respond to off-normal events. The Director and Plant Manager will formally designate personnel qualified to act in his absence.

The staff concludes that the onsite organizational structure meets the requirements of 10 CFR §72.24, §72.28, and §72.40(a). The corporate organization, technical qualifications, training, and experience of the applicant to conduct the proposed operations satisfy the requirements of 10 CFR §72.24(h) and §72.24(j). The technical qualifications, training and experience, operating organization, delegations of responsibility and authority, skills, and experience of the applicant satisfy the requirements of 10 CFR §72.28(a) and §72.28(c). The applicant satisfies the requirement of 10 CFR §72.40(a)(4) to be qualified by reason of training and experience to conduct the operations covered by the regulations and the requirement of 10 CFR §72.40(a)(13) that the operations can be conducted without endangering the health and safety of the public.

10.1.1.3 Management and Administrative Controls

Sections 9.1.6, 9.2.1, 9.4.1, and 9.4.2 of the SAR describe management and administrative controls that will be employed for the Humboldt Bay ISFSI.

In general, the NRC-approved management and administrative controls that are in effect at the HBPP will also be applied to the ISFSI. QA audits conducted in accordance with the HB ISFSI QA Program will be used to evaluate the adequacy of management and administrative controls, including procedures. The audit program will describe audit frequencies, methods for conducting and documenting audits, and resolution and implementation of corrective actions. The HB ISFSI QA Program, as described in Chapter 11 of the SAR, is acceptable for defining audit frequencies, documenting and communicating results, resolving issues, and implementing corrective action.

Lines of authority, responsibility, and communication will be defined and documented for key personnel positions. The operations and security staff will operate the ISFSI in accordance with the requirements of the ISFSI license, technical specifications, the HB ISFSI QA Program , the physical security plan, written procedures, and applicable state and federal regulations. These requirements cover routine, emergency, and contingency operations. A formal order of succession and delegation will ensure continuity of operations and organizational responsiveness to off-normal situations.

In the SAR, PG&E has committed to conduct all activities important to safety for the Humboldt Bay ISFSI using detailed, written procedures. The procedures will be prepared, reviewed, and approved in accordance with the HBPP administrative program used for these purposes. PG&E also has committed to prepare these procedures, which qualified and trained personnel can implement without incident or abnormal event, in sufficient detail. Procedures will include preoperational and startup testing, operational startup testing, administration, radiation protection, maintenance and surveillance, operations, and quality assurance. The Plant Staff Review Committee reviews procedures important to safety.

Humboldt Bay ISFSI records will be maintained using established practices employed by the HBPP and the HB ISFSI QA Programs. The scope of the record keeping procedures includes the records retention period; QA requirements; operating records that document principal maintenance, alterations, and additions to components or facilities; records of off-normal occurrences and events associated with radioactive releases; records for decommissioning; and environmental surveys.

The staff concludes that the management and administrative controls committed to in the SAR satisfy the requirements of 10 CFR §72.24 and §72.28. The SAR includes a plan for conduct of operations, including the planned managerial and administrative controls system as required by 10 CFR §72.24(h). These administrative controls ensure that any structures, systems, and components (SSCs) important to safety, whose functional adequacy or reliability have not been previously demonstrated, will be properly tested and assessed as required by 10 CFR §72.24(i). The SAR includes a description of the applicant's operating organization, delegations of responsibility and authority, and minimum skills and experience, as required by 10 CFR §72.28(c).

10.1.2 Preoperational Testing and Startup Operations

Section 9.2 of the SAR describes the preoperational and startup testing plans for storage systems and any associated equipment and facility testing. PG&E has committed to complete this testing before loading any SNF for placement in the ISFSI vault. This testing will verify that the system components and the overall storage system perform as described in the SAR.

PG&E also has committed to prepare, review, approve, and perform test procedures for the Humboldt Bay ISFSI in accordance with existing HBPP administrative controls and the HB ISFSI QA Program, as described in Chapter 11 of the SAR. This commitment includes requiring any test procedures to be examined to determine any negative affects on HBPP Unit 3 SSCs. Preoperational tests used by outside vendors will meet the requirements of the PG&E approved QA program. PG&E will approve any such procedures, and qualified personnel will witness their performance.

10.1.2.1 Preoperational Testing Plan

Sections 9.2.1, 9.2.2, and 9.2.3 of the SAR describe various aspects of the Preoperational Test Program.

Preoperational testing verifies that the individual components of the storage system, facilities, and equipment meet respective functional requirements as described in the SAR. Preoperational testing must be successfully completed prior to beginning startup testing.

Any discrepancies identified during preoperational testing will be resolved in accordance with the existing HBPP procedures and processes for discrepancy resolution.

The preoperational test plan will include testing of the davit crane, the transporter, and all storage system ancillaries (e.g., the welder and drying system). These tests will confirm operation in accordance with functional specifications and the requirements of the SAR. Typical aspects tested will be controls, hydraulic systems, brakes, instruments, and protective devices. Other testing that will be performed according to the preoperational test plan includes security system testing and construction-related testing. Control and calibration of measuring and test equipment will be conducted according to the HB ISFSI QA Program, as described in Chapter 11 of the SAR .

The staff concludes that the preoperational test plan satisfies requirements of 10 CFR §72.24 and §72.40. The planned managerial and control system meets the requirements of 10 CFR §72.24(h). The description of the testing plans in the SAR satisfies the requirements of 10 CFR §72.24(p). As required by 10 CFR §72.40(a)(13), these plans provide reasonable assurance that the proposed activities can be conducted without endangering the health and safety of the public.

10.1.2.2 Startup Plan

Sections 9.2.1, 9.2.2, 9.2.4, 9.2.5, and 9.2.6 of the SAR describe various aspects of the Startup Test Program.

An overall startup testing program procedure will be used for this testing. ISFSI operating procedures will be supplemented by individual startup test procedures. Startup testing will verify the performance of the storage system and ensure compliance with the requirements of the SAR. Startup testing also will use actual system components and one or more mock-up multi-purpose canisters (MPC) to verify successful lid closure welding, lid weld removal, moisture removal, helium filling, and canister cool down.

Operators conducting this testing will have completed ISFSI training program requirements. The applicant commits to completing startup testing prior to handling SNF.

Any discrepancies identified during startup testing will be resolved in accordance with the existing HBPP procedures and processed for discrepancy resolution.

Startup testing at the Humboldt Bay ISFSI will include the following:

(1) Preparing the cask for movement into the spent fuel pool (SFP)

(2) Moving the cask into the SFP and placing a dummy fuel assembly in the cask

(3) Installing the MPC lid retention device and removing the cask from the SFP

(4) Decontaminating the cask

(5) Removing the MPC lid retention device, welding the MPC lid, removing moisture, filling the MPC with helium, cooling down the MPC, and removing the lid weld

(6) Installing the transfer cask top lid

(7) Loading the cask onto the rail dolly using the davit crane and removing it from the refueling building (RFB)

(8) Transferring the loaded cask from the RFB to the storage vault using the transporter

(9) Positioning and lowering the cask into the storage vault

Section 9.2.5 of the SAR provides for additional testing. The operational startup testing will be performed during the initial loading of an MPC. The applicant commits to limiting these tests to gathering information that is only available when SNF is loaded in an MPC or for final verification of data obtained during startup testing. The tests include a monitoring program for vault temperature to ensure that the temperature will remain within the design basis.

Section 9.2.6 of the SAR commits to execute an operational readiness review prior to initial MPC loading to verify that all appropriate actions have been completed. The operational readiness review will ensure, at a minimum, that:

(1) Results from operational and startup testing are satisfactory, and all associated corrective actions or lessons learned have been properly incorporated in Humboldt Bay ISFSI procedures

(2) Radiological procedures and controls are in place

(3) Operational procedures are approved and in place for surveillance, security, and emergency response

(4) All engineering issues related to the storage system have been resolved

(5) Fire protection procedures are approved and in place

(6) Maintenance procedures are approved and in place, and all required ISFSI systems and components are ready for use

(7) The Cask Transportation Evaluation Program is in place

The staff concludes that the startup test plan, the plans for additional testing, and the commitment to complete an Operational Readiness Review satisfy the requirements of 10 CFR §72.24 and §72.40. The planned managerial and control system meets the requirements of 10 CFR §72.24(h). The startup test plan ensures that any SSCs important to safety will be properly tested and assessed as required by 10 CFR §72.24(i). The SAR description of the testing plans satisfies the requirements of 10 CFR §72.24(p). These plans provide reasonable assurance that the proposed activities can be conducted without endangering the health and safety of the public, as required by 10 CFR §72.40(a)(13).

10.1.3 Normal Operations

Sections 9.4.1 and 9.4.2 of the SAR describe administrative controls and the conduct of operations for activities important to safety. These sections also describe the management controls applied to maintaining records.

10.1.3.1 Procedures

Section 9.4.1 of the SAR states that activities important to safety will be conducted in accordance with detailed, written, approved procedures. In addition, the applicant has committed to have preoperational, normal operating, maintenance, and surveillance testing procedures in place prior to beginning fuel loading. All procedures and revisions will be prepared, reviewed, and approved using existing HBPP administrative programs. All procedures important to safety will be reviewed by the Plant Staff Review Committee. These procedures also will be in compliance with the HB ISFSI QA Program, as described in Chapter 11 of the SAR. All procedures will be sufficiently detailed to allow qualified and trained personnel to perform the actions without incident or abnormal event. Section 9.4.1 of the SAR addresses administrative, radiation protection, maintenance and surveillance testing, operating, and QA implementing procedures separately.

The Humboldt Bay ISFSI administrative procedures will provide operating personnel with a clear understanding of operating philosophy and management policies. The scope of these procedures will include personnel conduct; procedure preparation, review, approval, and revision; personnel safety; the working environment; and procurement. The objective of these procedures is to ensure that these activities are completed with a high degree of readiness, quality, and safety.

Humboldt Bay ISFSI radiation protection procedures will implement a radiation protection program that demonstrates compliance with 10 CFR Part 20 requirements, including as low as is reasonably achievable principles. The scope of these procedures will include acquisition of data, use of equipment, and qualification and training of radiation protection personnel. Existing HBPP radiation protection procedures will be revised as necessary to address ISFSI operations. These existing procedures have proven adequate for monitoring exposure of employees, radiation surveys, maintenance monitoring, and radiation protection records maintenance. Revised ISFSI radiation protection procedures will specifically address the safety of personnel performing SNF loading, SNF transport, SNF unloading, surveillance testing, and maintenance. Any entrance to or work performed inside the ISFSI protected area will be controlled by a radiation work permit and appropriate security checks. The operation and use of radiation monitoring equipment and the use of measurement and sampling techniques will be covered by procedures.

Humboldt Bay ISFSI maintenance and surveillance testing procedures will be established for preventive and corrective maintenance and for surveillance testing of ISFSI equipment and instrumentation. An appropriate schedule will be established for preventive maintenance, surveillance testing, and calibrations to preclude degradation of systems, equipment, and components. Corrective maintenance to rectify unexpected system, equipment, or component failures will also be controlled using procedures and conducted as the need arises. Any SSCs important to safety that are commercial grade will be qualification tested prior to use. This testing will verify the functionality and the ability to carry a full-rated load, where appropriate. Subsequent to the qualification testing, standard preventive maintenance, surveillance testing, and corrective maintenance will be performed.

Humboldt Bay ISFSI operating procedures will include instructions for routine and projected off-normal operations. These operations include handling, loading, sealing, transferring, storing, unloading, and other operations important to safety.

Humboldt Bay ISFSI QA implementing procedures will be prepared for important-to-safety activities to ensure compliance with the HB ISFSI QA Program, as described in Chapter 11 of the SAR . Similarly, the requirements for qualification of personnel will be implemented through formal procedures, which will specify that responsibility for quality rests with each individual.

The staff concludes that the applicant's plans for normal operations satisfy the requirements of 10 CFR §72.24, §72.28, and §72.40(a). A plan for the conduct of operations has been provided as required by 10 CFR §72.24(h), and the applicant's technical qualifications to engage in the proposed activities have been described as required by 10 CFR §72.24(j). The SAR also includes a plan for initial operations as required by 10 CFR §72.24(p). The staff has reasonable assurance that the applicant is qualified by reason of training and experience to conduct the proposed operations, has an adequate training program, and can conduct the proposed operations without endangering the health and safety of the public as required by 10 CFR §72.40(a)(4), §72.40(a)(9), and §72.40(13).

10.1.3.2 Records

Section 9.4.2 of the SAR specifies that records will be maintained in accordance with established PG&E policies. The records management program is a part of the NRC-approved PG&E QA program.

PG&E has requested an exemption from 10 CFR §72.72(d), which requires that SNF and high-level waste records be stored in duplicate at a separate, sufficiently remote location to ensure that a single event will not destroy both sets of records. Pursuant to 10 CFR §72.140(d), PG&E proposes to use its NRC-approved QA program that satisfies the criteria of 10 CFR Part 50, Appendix B for the Humboldt Bay ISFSI. The applicant states that an exemption from the records storage requirements of 10 CFR §72.72(d) would allow records of SNF storage to be maintained in the same manner that other important plant records are currently maintained, consistent with the HB ISFSI QA Program, as described in Chapter 11 of the SAR and Appendix E of the License Application.

The staff concludes that the record keeping procedures committed to in Section 9.4.2 of the SAR satisfy the requirements of 10 CFR §72.24, §72.28, and §72.40. The planned record keeping managerial and administrative controls satisfy the requirements of 10 CFR §72.24(h). These controls and procedures also satisfy the requirements of 10 CFR §72.28(c) for an adequately defined operating organization. The staff finds that the granting of an exemption for the record keeping requirements in 10 CFR §72.72(d) is appropriate and acceptable.

10.1.4 Personnel Selection, Training, and Certification

Sections 9.1.7 and 9.3 of the SAR define the minimum qualification and training requirements for personnel involved in the operation of the Humboldt Bay ISFSI.

10.1.4.1 Personnel Organization

Section 9.3 of the SAR states that, pursuant to 10 CFR §72.190 and §72.192, the Humboldt Bay ISFSI personnel will receive training and indoctrination designed to provide and maintain a well-qualified work force for safe and effective operation. The existing HBPP general employee training program will be used as the ISFSI Operations Training Program because the General Employee Training portions are directly applicable to the Humboldt Bay ISFSI.

After training, the staff will be evaluated by written and practical examinations. Training records will be maintained consistent with the requirements for personnel involved in SNF handling operations. Training records will be maintained in accordance with the HB ISFSI QA Program, as described in Chapter 11 of the SAR . These records will include dates and hours of training, information on physical requirements, job performance criteria, copies of written examinations, and documentation of walk-throughs and retesting.

Supplemental training will be provided to the operations, maintenance, security, and emergency planning personnel who are assigned duties at the ISFSI. Supplemental training will be developed under the HBPP training program to provide a comprehensive, site-specific training, assessment, and qualification program for the ISFSI. This training program will include periodic requalification and retraining, record keeping, and medical requirements.

The staff concludes that the personnel organization satisfies the requirements of 10 CFR §72.24, §72.28, §72.40, §72.190, §72.192, and §72.194. The program satisfies the requirements of 10 CFR §72.24(h) for a program of personnel training and the requirements of 10 CFR §72.24(j) that the applicant be technically qualified to conduct the proposed activities. The application also meets the requirements of 10 CFR §72.28(a) to include the technical qualifications, training, and experience of the applicant; 10 CFR §72.28(b) that a description of the personnel training program required by 10 CFR Part 72, Subpart I be provided; 10 CFR §72.28(c) that a description of the operating organization, delegations of responsibility and authority, and skills and qualifications be included; and 10 CFR §72.28(d) that the applicant commit to an adequate complement of trained and certified personnel prior to the receipt of SNF for storage. The applicant also has committed that operation of equipment and controls important to safety will be limited to trained, certified, or properly supervised personnel, as required by 10 CFR §72.190. A program for training, proficiency testing, and certification of personnel that satisfies the requirements of 10 CFR §72.192, has been provided and this program will ensure that the general health and physical condition of the operators are considered when selecting personnel for activities that are important to safety, as required by 10 CFR §72.194.

10.1.4.2 Selection and Training of Operating Personnel

Section 9.1.7 of the SAR specifies that the HBPP personnel working at the Humboldt Bay ISFSI will meet or exceed the qualifications specified by NRC Regulatory Guide 1.8 (U.S. Nuclear Regulatory Commission, 1987), with specific exceptions as identified in the license application and consistent with the HBPP QA Program.

The Director and Plant Manager is required to have a minimum of 8 years of power plant experience, at least 3 years of which should be nuclear power plant experience. At most, 2 years of the remaining 5 years of power plant experience may be fulfilled by satisfactory completion of academic or related technical training on a one-for-one basis. The Director and Plant Manager must also be qualified in accordance with an NRC-approved training program that will be developed as committed to in Attachment D, Training Program, of the license application and Section 9.3.2 of the SAR.

The ISFSI operations personnel and security staff will have a high school diploma or have successfully completed the General Education Development test. The operations personnel must have at least 2 years of power plant experience, at least 1 year of which must be nuclear power plant experience. The operations personnel also will have received the required training for their specific assignments, as specified by Section 9.3.2 of the SAR.

The HBPP security staff who support the Humboldt Bay ISFSI will be trained and qualified in accordance with the HBPP Security Training and Qualifications Plan.

Humboldt Bay ISFSI fuel handling operations will be performed or supervised by personnel who have been trained and qualified through the Humboldt Bay ISFSI Operations Training Program and the HBPP certified fuel handler program. During operations, operation of equipment and controls that are important to safety will be limited to those personnel who have been qualified and trained through the Humboldt Bay Operations Training Program or personnel under the direct supervision of persons trained and qualified through the Humboldt Bay Operations

Training Program. Personnel who conduct SNF and cask handling operations will be evaluated to ensure that their physical condition and general health meet the requirements of 10 CFR §72.194.

All ISFSI personnel will be retrained at least every 2 years in accordance with Section 9.3.4 of the SAR. This training will incorporate appropriate topics from both general employee training and job-specific training.

The staff concludes that the program for selection, training and certification of personnel satisfies the requirements of 10 CFR §72.28(a) that the applicant has the technical qualifications, including training and experience, to engage in the proposed activities; 10 CFR §72.28(b) that the application include a description of the personnel training program; 10 CFR §72.28(c) that the personnel have the minimum skills and experience qualifications relevant to the various levels of responsibility and authority; and 10 CFR §72.28(d) that the applicant commits to have and maintain an adequate complement of trained and certified personnel.

The staff concludes that the program for selection, training, and certification of personnel meets the requirements of 10 CFR §72.40(a)(4) that the applicant be qualified by reason of training and experience to conduct the planned operations and 10 CFR §72.40(a)(9) that the personnel training program comply with the requirements of 10 CFR Part 72, Subpart I. The adequacy of the applicant's training program supports the staff finding of reasonable assurance that operations can be conducted without endangering public health and safety, as required by 10 CFR §72.40(a)(13).

The staff concludes that the program for selection, training, and certification of personnel satisfies the requirements of 10 CFR Part 72, Subpart I. Equipment and controls important to safety will be operated and supervised only by certified personnel, as required by 10 CFR §72.190. The applicant's program for training, proficiency testing, and certification of personnel has been submitted with the application and meets the requirements of 10 CFR §72.192. The program will ensure that the general health and physical condition of personnel certified for the operation of equipment and controls that are important to safety will be satisfactory, as required by 10 CFR §72.194.

10.1.4.3 Selection and Training of Security Guards

The results of the staff's review regarding the requirements for the ISFSI security organization are documented in separate correspondence dated September 2, 2005.

10.1.5 Emergency Planning

Section 9.5 of the SAR identifies that the Humboldt Bay ISFSI emergency plan (EP) meets the regulatory requirements in 10 CFR 72.32(a). The applicant has provided the revised EP as Attachment B to the license application. The revised EP provides a description of the organization, assessment actions, emergency action levels (EALs), notification procedures, emergency facilities and equipment, training requirements and recovery criteria.

Chapter 8 of the SAR contains the accident evaluation for the potential accident and off-normal conditions which could occur at the ISFSI. The EALs identified in the EP for the possible accident conditions have been developed based upon emergency planning guidance developed by the Nuclear Energy Institute in NEI 99-01, which has been endorsed by the NRC. The EALs listed for the various accident conditions are appropriate for an ISFSI.

Two accident classifications are identified in the EP, the Notification of Unusual Event (NOUE) and Alert. The Alert is the only accident classification required by 10 CFR 72.32(a). The NOUE is the lowest level accident classification of the four accident classifications required by 10 CFR Part 50.

The EP describes the Humboldt Bay ISFSI proposed emergency organization and the responsibilities of the emergency staff positions. Since the ISFSI staffing levels following plant decommissioning may be reduced from current levels, the applicant may need to revise the EP in the future to reflect the revised emergency organization.

The EP was provided to response agencies in the vicinity of the HBPP for comment as required by 10 CFR 72.32(a), and their comments have been submitted with the EP and license application. There were no comments indicating a significant problem with the revised plan.

Based upon the staff's review of the EP and the SAR Chapter 8 accident analysis, the staff finds that the EP meets the requirements in 10 CFR 72.32(a). The staff has reasonable assurance that the revised Humboldt Bay Emergency Plan will provide the appropriate guidance for ISFSI staff to adequately respond to potential accident conditions.

10.1.6 Physical Security and Safeguards Contingency Plans

The NRC staff evaluated the applicant's Physical Security and Safeguards Contingency Plans for the Humboldt Bay ISFSI and found them acceptable. The staff's review is documented in separate correspondence, dated September 2, 2005.

10.2 Evaluation Findings

Based on review of the information in the SAR and license application, the staff makes the following findings regarding the Conduct of Operations for the Humboldt Bay ISFSI:

- The SAR includes a plan for the conduct of operations, including the planned managerial and administrative controls system and the applicant's organization and program for training of personnel pursuant to Subpart I in compliance with 10 CFR §72.24(h).
- The proposed ISFSI incorporates no SSCs important to safety whose functional adequacy or reliability have not been demonstrated by prior use for that purpose or cannot be demonstrated by reference to performance data in related applications or to widely accepted engineering principles. The SAR, therefore, does not need to identify these SSCs along with a schedule showing how safety questions will be resolved prior to the initial receipt of SNF or high-level waste for storage. This satisfies the requirements of 10 CFR §72.24(i).

- The SAR includes the technical qualifications of the applicant to engage in the proposed activities, as required by 10 CFR §72.24(j).
- The SAR includes a description of the applicant's plans for coping with emergencies that satisfies the requirements of 10 CFR §72.24(k).
- The SAR includes a description of the program covering preoperational testing and initial operations that satisfies the requirements of 10 CFR §72.24(p).
- The application includes the technical qualifications, including training and experience, of the applicant to engage in the proposed activities, satisfying the requirements of 10 CFR §72.28(a).
- The application includes a description of the personnel training program required under Subpart I that satisfies the requirements of 10 CFR §72.28(b).
- The application includes a description of the applicant's operating organization, delegations of responsibility and authority, and the minimum skills and experience qualifications relevant to the various levels of responsibility and authority, as required by 10 CFR §72.28(c).
- The application contains a commitment to have and maintain an adequate complement of trained and certified installation personnel prior to the receipt of SNF or high level waste for storage, satisfying the requirements of 10 CFR §72.28(d).
- The applicant is qualified by reason of training and experience to conduct the operations covered by the regulations in this part, satisfying the requirements of 10 CFR §72.40(a)(4).
- The applicant's personnel training program complies with 10 CFR Part 72, Subpart I, satisfying the requirements of 10 CFR §72.40(a)(9).
- There is reasonable assurance that the activities proposed in the application can be conducted without endangering the health and safety of the public, as required by 10 CFR §72.40(a)(13).
- A detailed plan for security measures for physical protection that satisfies the requirements of 10 CFR §72.180 has been provided. The plan includes means for complying with the requirements of 10 CFR Part 73, the design for physical protection, a safeguards contingency plan, and a guard training plan. The plan lists tests, inspections, audits, and other means that will be used to demonstrate compliance with these requirements.
- The safeguards contingency plan meets the requirements of 10 CFR §72.184. The plan includes the licensee's plan for responding to threats and radiological sabotage and includes a background, generic planning base, licensee planning base, and responsibility matrix. Safeguards contingency plan procedures will meet the requirements of 10 CFR Part 73, Appendix C, for effecting the actions

and decisions contained in the responsibility matrix of the safeguards contingency plan.

- Operation of equipment and controls that have been identified as important to safety in the SAR will be limited to trained and certified personnel or to personnel under the direct visual supervision of an individual with training and certification in the operation. Supervisory personnel who personally direct the operations of equipment and controls that are important to safety will also be certified in such operations, as required by 10 CFR §72.190.

- An acceptable program for training, proficiency testing, and certification of ISFSI personnel has been provided, as required by 10 CFR §72.192.

- The physical condition and the general health of personnel certified for the operation of equipment and controls that are important to safety will be sufficient to preclude operational errors that could endanger other plant personnel or the public health and safety. Conditions that might cause impaired judgment or motor coordination will be considered in the selection of personnel for activities important to safety, as required by 10 CFR §72.194.

- The NRC is granting an exemption to the record keeping requirements of 10 CFR §72.72(d) because an acceptable record keeping system for equivalent records has already been established at the HBPP and granting the exemption would obviate the need for duplicate record keeping systems.

10.3 References

Pacific Gas and Electric Company. *Humboldt Bay Independent Spent Fuel Storage Installation Safety Analysis Report.* Amendment 1. Docket No. 72-27. Avila Beach, CA: Pacific Gas and Electric Company. 2004a.

Pacific Gas and Electric Company. *Response to NRC Request for Additional Information for the Humboldt Bay Independent Spent Fuel Storage Installation Application.* (TAC No. L23683). Letter (October 1). HIL-04-007, HIL-04-009. Avila Beach, CA: Pacific Gas and Electric Company. 2004b.

U.S. Nuclear Regulatory Commission. Regulatory Guide 8.8, *Information Relevant to Ensuring That Occupational Radiation Exposures at Nuclear Power Stations Will Be ALARA.* Rev. 3. Washington, DC: U.S. Nuclear Regulatory Commission. 1978.

U.S. Nuclear Regulatory Commission. Regulatory Guide 1.8, *Qualification and Training of Personnel for Nuclear Power Plants.* Rev. 2. Washington, DC: U.S. Nuclear Regulatory Commission. 1987.

U.S. Nuclear Regulatory Commission. *Humboldt Bay Independent Spent Fuel Storage Installation Application - Physical Security Plan (TAC No. L23683)* Letter from J. R. Hall to D. Jacobs, dated September 2, 2005.

11 RADIATION PROTECTION EVALUATION

11.1 Conduct of Review

The objective of Chapter 11 is to evaluate the capability of the organizational, design, and operational elements of the Humboldt Bay ISFSI radiation protection plan to meet regulatory requirements. The requirements for providing adequate radiation protection to personnel and members of the public are specified in 10 CFR Part 20, "Standards for Protection Against Radiation" and 10 CFR Part 72, "Licensing Requirements for the Independent Storage of Spent Nuclear Fuel, High-Level Radioactive Waste, and Reactor-Related Greater Than Class C Waste."

The review considered how the Safety Analysis Report (SAR) (Pacific Gas and Electric Company, 2004a) and related documents address the regulatory requirements of 10 CFR §20.1101(a–d), §20.1201(a), §20.1301(a–b), §20.1301(e), §20.1302(a), §20.1406, §20.1501(a)(1), §20.1701, §20.1702(a), §72.24(e), §72.104(a–c), §72.106(b–c), §72.122(e), §72.126(a), §72.126(c)(1), §72.126(c)(2), §72.126(d), and §72.128(a)(2). Complete citations of these regulations are provided in the Appendix of this Safety Evaluation Report (SER).

The applicant will use the HI-STAR HB system for spent fuel storage at the Humboldt Bay ISFSI. This cask system is a metal canister storage system designed to store boiling water reactor (BWR) fuel in a dry configuration in the below-grade ISFSI vault. The HI-STAR HB system is a modified version of the NRC-certified HI-STAR 100 system, which is described in the HI-STAR 100 Final Safety Analysis Report (FSAR) (Holtec International, 2002). The HI-STAR HB system is made up of an all-welded multipurpose canister (MPC-HB) designed to store up to 80 Humboldt Bay Power Plant (HBPP) spent nuclear fuel (SNF) assemblies inside a bolted-lid steel overpack.

The staff's review included the applicable sections of the SAR, additional supporting documentation cited in the SAR, and responses to the NRC staff's request for additional information (Pacific Gas and Electric Company, 2004b, 2005). Chapter 7 of the SAR describes the radiation protection features of the proposed ISFSI that ensure that radiation exposures to personnel and members of the public meet the regulatory requirements. Information included in the HI-STAR 100 system FSAR (Holtec International, 2002) relevant to radiation protection for the Humboldt Bay ISFSI was also considered in the review.

11.1.1 As Low As Reasonably Achievable Considerations

The objective of this section is to evaluate whether the applicant has appropriately considered the goal of maintaining occupational doses and doses to members of the public as low as is reasonably achievable (ALARA) during the operation of the ISFSI. Considerations related to maintaining doses ALARA are described in Section 7.1 of the SAR.

11.1.1.1 As Low As Reasonably Achievable Policy and Program

The primary objective of the Health Physics Program is to maintain radiation exposure to workers, visitors, and members of the public below regulatory limits and ALARA. The existing HBPP Health Physics Program complies with the requirements of 10 CFR Part 20 and

10 CFR Part 50. The Health Physics Program that will be implemented for the Humboldt Bay ISFSI is described in Section 7.6 of the SAR, with the policy and program for maintaining doses ALARA described in Section 7.1 of the SAR. The applicant will apply the existing HBPP SAFSTOR Health Physics Program for maintaining doses ALARA to all ISFSI-related activities governed by 10 CFR Part 72. The program and procedures will be revised and supplemented, as appropriate, to address ISFSI-related activities and to comply with the description of the ISFSI Health Physics Program as described in Section 7.6 of the SAR. The program for maintaining doses ALARA follows the guidance in Regulatory Guides 8.8 (U.S. Nuclear Regulatory Commission, 1978) and 8.10 (U.S. Nuclear Regulatory Commission, 1975).

11.1.1.2 Design Considerations

The description of the design considerations to maintain doses ALARA is provided in Section 7.1.2 of the SAR, which delineates the following specific features of the Humboldt Bay ISFSI:

- Use of the below-grade storage vault located approximately 16 m [53 ft] from a fenced public access trail will maintain doses ALARA to members of the public who occasionally use this trail.

- Placement of the storage vault at a sufficient distance {greater than 100 m [328 ft]} from administrative buildings and the currently operating fossil-fuel powered generating units, so that doses to workers are maintained ALARA.

- Use of a restricted area fence and a security perimeter fence with a locked gate to protect individuals against undue risks from radiation exposure and to prevent unauthorized access to the ISFSI.

- Use of thick biological shielding in overpacks to provide gamma and neutron shielding.

- Use of a dry inert environment inside the seal-welded MPC-HBs to preclude the possibility for release of radioactive effluents from inside the canister.

- Use of inflatable seals in the canister-cask annulus to prevent spent fuel pool (SFP) water from contacting the exterior of the MPC-HB smooth surfaces, and use of an overpack coating material to minimize surface contamination and reduce decontamination time.

The ISFSI will be located within the owner-controlled area around the HBPP. Therefore, the transfer of the SNF from the SFP to the ISFSI will not take place on any public roads. The Humboldt Bay ISFSI incorporates a below-grade concrete vault providing significant shielding in addition to that provided by each shielded HI-STAR HB cask, and the vault is located at a sufficient distance from the controlled area boundary such that offsite exposures will be further minimized.

The staff finds that the design of the Humboldt Bay ISFSI provides reasonable assurance that doses to personnel and members of the public will be maintained ALARA and meets the requirements of 10 CFR §72.126(a). The staff also finds that the requirements for minimization of contamination and the amount of generated radioactive waste outlined in 10 CFR §20.1406 are satisfied. The staff finds that the design of the seal-welded MPC-HBs, which are not opened at the ISFSI and allow no generation of effluents, meets the requirements of 10 CFR §72.126(d).

11.1.1.3 Operational Considerations

The operational considerations to maintain doses ALARA are described in Section 7.1.3 of the SAR. The operating procedures for the Humboldt Bay ISFSI, such as cask loading, unloading, and transfer to the ISFSI storage vault, are summarized in Chapter 5 of the SAR and discussed in Chapters 3 and 10 of this SER. Specifically, the program to maintain doses ALARA includes the following operational elements:

- Use of classroom training, mockups, and dry-run training to train personnel about canister transfer procedures, verify equipment operability and procedure efficiency and minimize radiation exposure
- Fuel loading procedures will follow accepted work practices that reflect lessons learned about maintaining doses ALARA from other facilities that use dry cask storage
- Filling the annulus between the MPC-HB and the HI-STAR HB cask with clean water and using an inflatable annulus seal and overpressure system to minimize contamination of the MPC-HB exterior
- Use of power-operated tools when possible in bolting operations to minimize personnel exposure time
- Use of temporary portable shielding during fuel transfer to minimize personnel exposure to direct radiation

The staff finds that the applicant's description of the operational considerations for maintaining doses ALARA satisfies the requirements of 10 CFR §72.24(e) and that the described use of Regulatory Guides 8.8 (U.S. Nuclear Regulatory Commission, 1978) and 8.10 (U.S. Nuclear Regulatory Commission, 1975) in SAR Section 7.1.3 for planning operations is appropriate and provides reasonable assurance that doses to personnel and members of the public will be maintained ALARA.

11.1.2 Radiation Protection Design Features

Information relevant to the proposed radiation design features of the ISFSI is contained in Section 7.3 of the SAR.

11.1.2.1 Installation Design Features

The ISFSI radiation protection design features are described in Section 7.3.1 of the SAR. The ISFSI will be located within the HBPP owner-controlled area and will house 6 storage cells in a below-grade vault. Five of the storage cells will contain HI-STAR HB casks filled with HBPP SNF fuel, and 1 cell will contain a Greater than Class C (GTCC) waste cask. The storage cells/casks will be positioned on a 3.28 m [10 ft, 9 in] pitch in a single row in the ISFSI vault. Periodic inspections, placement of loaded storage casks, and routine security checks are the planned operations that will be conducted at the ISFSI.

The major components of the HI-STAR HB system include a stainless steel cylindrical MPC-HB canister (confinement vessel) and an overpack (cask), consisting of a large mass of steel and neutron shield material (Holtite-A) in the radial direction and thick steel bottom forging and top lid components.

The fuel is stored dry inside the MPC-HB, so there is no credible leakage of radioactive liquid. Airborne radioactive materials will be prevented from leaking from the MPC-HBs by the welded seals, and once sealed, fuel is not removed from the MPC-HBs at any location outside of the Refueling Building (RFB). The storage system is passive and requires little maintenance. The system is not expected to leak during normal, off-normal, or accident conditions. The staff, therefore, concludes that airborne radioactive monitors specified in 10 CFR §72.126(c)(1) are not required at the ISFSI. Placement of the storage casks in the below-grade vault provides significant shielding.

The staff finds that the use of Regulatory Position 2 of NRC Regulatory Guide 8.8 (U.S. Nuclear Regulatory Commission, 1978), which provides guidance regarding facility and equipment features, as discussed in Section 7.1.2 of the SAR, is appropriate. The staff also finds that given the proposed design features described in the SAR, the applicant has satisfied the requirements of 10 CFR §72.126(a). Sections 3.3.1.5.1, 3.3.1.5.2, 4.2.3.2, 4.2.3.3, 7.1.2, and 7.3.4 of the SAR discuss design features that address radiation monitoring, control of airborne contaminants, instrumentation and controls, and other considerations related to maintaining doses ALARA.

The staff finds that the information in the SAR provides reasonable assurance that the use of the HI-STAR HB system for the Humboldt Bay ISFSI will meet the regulatory requirements of 10 CFR §20.1101(b), §20.1101(d), §20.1201(a), §20.1301(a–b), §20.1701, §20.1702(a), §72.104(a-c), and §72.106(b). Chapters 7, 9, and 15 of this SER discuss the staff's evaluations of the radiation shielding features and the confinement features during normal, off-normal, and accident conditions. Based on these evaluations, the staff finds that the radiation protection features for the proposed Humboldt Bay ISFSI are acceptable.

11.1.2.2 Access Control

The access control to the ISFSI is described in Sections 2.1.2, 3.3.1.5.1, 4.1, 7.6.2, and 9.6 of the SAR. The applicant's property line and owner-controlled area are shown in Figure 2.1-2 of the SAR. The applicant's property line extends well outside the 100-m controlled area boundary around the ISFSI as is also shown in Figure 2.1-2. The applicant's property and 100-m controlled area boundary also extend into the waters of Humboldt Bay. The applicant exercises authority to control all activities within the owner-controlled area boundaries. Access control to the restricted area around the ISFSI vault provides for both personnel radiation protection and stored fuel physical protection. Two fences will surround the Humboldt Bay ISFSI. A security fence with a locked gate will circumscribe the ISFSI storage vault. There is a minimum 6 m [20 ft] distance between the storage vault and the security fence on all sides of the vault. The second fence runs along the public trail to the north of the ISFSI site to control access to the owner-controlled area and is a minimum of 16 m [53 ft] from the ISFSI vault. Fences with lockable gates will be installed as indicated in SAR Figure 2.1-2 such that the 100-m [328 ft] controlled area boundary required by 10 CFR §72.106(b) can be established during cask movement, handling evolutions, or accident conditions requiring traffic control to protect public health and safety in the 100-m [328 ft] controlled area boundary. The Coast Guard will be relied upon, when required, to control access to water areas within the 100-m controlled area boundary. The gates on the public trail will be open during normal storage operations so that public access is not restricted by the applicant. This is consistent with 10 CFR §72.106(c), which allows the controlled area to be traversed so long as appropriate and effective arrangements are made to control traffic and protect public health and safety.

Once the Humboldt Bay ISFSI is operational, entrance to and work within the ISFSI protected area will be controlled by radiation protection and security personnel who will maintain a list of individuals authorized for access. During normal storage operations, personnel will conduct infrequent, short-duration checks on the material condition of the ISFSI vault. Higher occupancy activities will occur during the construction and placement of loaded overpacks. Radiation work permits will be required for authorized work. The ISFSI protected area will have an intrusion detection system to detect unauthorized entry. The dose rate outside the controlled area, including direct radiation from ISFSI operations and any other radiation from uranium fuel cycle operations within the region, will not exceed 0.25 mSv/yr [25 mrem/yr], as specified in 10 CFR §72.104(a).

The staff finds that the proposed access control at the Humboldt Bay ISFSI, as described in the SAR, is acceptable and meets the radiation protection requirements of 10 CFR §20.1301(b) and §72.126(a). The physical security plan describes the measures to prevent the entry of unauthorized personnel into radiologically controlled areas. The staff's review of the Security Program for the ISFSI is the subject of separate correspondence.

11.1.2.3 Radiation Shielding

The shielding evaluation is contained in Chapter 7 of this SER. The staff evaluated the SAR shielding calculations and found them to be acceptable. The dose rates at the onsite and offsite locations were found to be below the limits specified in 10 CFR §20.1101(d), §20.1201(a), §20.1301(a), §20.1302(a), §72.104(a) and §72.106(b). Based on its review of the information in the SAR and the sample calculation files provided by the applicant, the staff finds that there is reasonable assurance that the ISFSI shielding was adequately analyzed and meets the requirements of 10 CFR §72.128(a)(2).

11.1.2.4 Confinement and Ventilation

The evaluation of the MPC-HB confinement system is provided in Chapter 9 of this SER. The MPC-HB is a welded cylindrical enclosure with no mechanical joints or seals in the confinement boundary and is not vented. The evaluation of site-generated waste confinement and management is provided in Chapter 14 of this SER. Based on these evaluations, the staff finds that the requirements specified in 10 CFR §72.126(c)(1) are not applicable to the Humboldt Bay ISFSI design.

11.1.2.5 Area Radiation and Airborne Radioactivity Monitoring Instrumentation

Area radiation and airborne radioactivity monitoring instrumentation are described in SAR Sections 3.3.1.3.2, 3.3.1.5.3, 6.2, and 7.3.4. All SNF at the ISFSI will be stored in seal-welded MPC-HBs. There are no credible events that could result in the release of radioactive materials from within MPC-HBs. There are also no credible events that could increase dose rates from direct radiation from the casks stored in the ISFSI vault. Area radiation and airborne radioactivity monitors, therefore, are not needed at the Humboldt Bay ISFSI vault. Continuous monitoring and audible high-radiation level alarms will be used in the RFB and SFP area as part of the existing HBPP SAFSTOR license program. Thermoluminescent dosimeters (TLDs) will be used to monitor and record area doses at appropriate intervals along and within the ISFSI restricted-area fence. Hand-held radiation protection instruments and dosimeters will be provided during fuel transfer operations and routine maintenance at the ISFSI vault.

The staff finds that the radiation monitoring instrumentation described in the SAR meets the requirements of 10 CFR §72.126(c)(2) and provides reasonable assurance that actual dose rates around the ISFSI will be adequately monitored to verify compliance with the radiological limits specified in 10 CFR Parts 20.1301(a) and 72.104(a) for members of the public, and that any unexpected increases in dose rates will be properly detected in a timely manner.

11.1.3 Dose Assessment

Dose assessments are presented in Sections 7.3.2, 7.4, 7.5, 8.1, and 8.2 of the SAR. The Humboldt Bay ISFSI has been designed as a single row of 6 storage cells in a below-grade vault with steel and concrete lids. This design provides a significant amount of shielding such that the estimated dose rate at the vault lid of a storage cell is expected to be less than 1.5 μSv/hr [0.15 mrem/hr].

11.1.3.1 Onsite Doses

Table 7.4-1 of the SAR provides the estimated occupational exposures to the HBPP personnel during the different phases of ISFSI operation including (i) loading fuel into the MPC-HB contained in the overpack, (ii) decontaminating the MPC-HB and overpack, (iii) transferring the cask from the RFB to the ISFSI vault, (iv) transferring the cask into a storage cell of the vault, and (v) closing the storage cell lid. Tables 7.4-1 and 7.4-2 of the SAR provide a list of the operational steps involved in loading and unloading an overpack and MPC-HB, respectively. These tables include the estimated number of personnel, the estimated dose rates, and the estimated time for each operational task. The estimated dose from loading, transferring, and emplacing a single MPC-HB in a storage overpack in the ISFSI vault was estimated at 5.68 person-mSv [567.98 person-mrem].

Section 7.4 of the SAR discusses the dose estimates for routine maintenance operations with a summary presented in Table 7.4-3 of the SAR. Routine inspections of the ISFSI are estimated to include a single-person 10-minute walkdown of the vault area every day for an estimated annual occupancy time of 61 hours. Routine maintenance and repair operations were estimated by the applicant at 1 per month, requiring 2 personnel for 1 hour for an annual occupancy time of 24 hours. The annual occupational exposure from ISFSI walkdowns was estimated to result in a dose of 92 person-μSv [9.2 person-mrem]. The estimated annual exposure for repair activities was estimated as 36 person-μSv [3.6 person-mrem]. Based on these estimates, there is reasonable assurance that personnel exposures will be below the annual occupational dose limit of 0.05 Sv [5 rem] specified in 10 CFR §20.1201(a). Evaluation of the conduct of operations is presented in Chapter 10 of this SER.

11.1.3.2 Offsite Doses

Offsite collective dose for normal conditions is addressed in Section 7.5 of the SAR. Off-normal and accident offsite doses are addressed in Sections 8.1 and 8.2 of the SAR, respectively. The applicant calculated offsite dose estimates for two primary locations: the public trail at a point 16 m [53 ft] from the edge of the ISFSI, and the nearest resident, 247 m [811 ft] from the center of the ISFSI. Although the public trail is used only occasionally, and is within the owner-controlled area, the applicant assumed an occupancy at the closest point of public access of 2,080 hours per year, based on a 40-hour working week for 52 weeks per year. The dose estimate for the nearest resident was made assuming a continuous occupancy of 8,760 hours per year. As evaluated in Chapter 7 of this SER and described in Section 7.3.2.2 of the SAR, the dose rates from the ISFSI are conservatively calculated using a reflective boundary condition that simulates an infinite row of HI-STAR HB casks in the storage vault. The dose analyses assume that all 6 storage cells are loaded with HI-STAR HB casks containing HBPP fuel at the design-basis burnup and cooling time evaluated in Chapter 7 of this SER. This provides a bounding dose rate calculation for the ISFSI, since the ISFSI will have only 5 casks that contain HBPP fuel. The applicant will verify, through measurement, that the source strength of the sixth cask containing GTCC waste is bounded by the source strength of a SNF cask (Pacific Gas and Electric Company, 2004c, Attachment C).

Table 7.5-1 of the SAR presents the dose rate and annual doses for the locations and occupancy times discussed above. The applicant estimated the dose rate at the closest point of public access to be 0.0816 μSv/hr [8.16 μrem/hr], which corresponds to 0.17 mSv/yr [17.0 mrem/yr] for 2,080-hour annual occupancy from direct radiation exposure. As discussed in Chapter 9 of this SER, no release of radioactive materials, airborne or otherwise, is expected during normal operations; therefore, doses caused by effluents, both gaseous and liquid, are not considered. The applicant estimated an annual direct radiation dose to the nearest resident located 247 m [811 ft] away from the ISFSI as 0.0448 mSv [4.48 mrem], assuming the resident is continually present at the residence for 8,760 hours per year.

The staff's review of the controlled area boundary and nearest resident dose assessments, and of the shielding evaluation of direct radiation doses, including confirmatory calculations, is contained in Chapter 7 of this SER. Based on the evaluation in Chapter 9 of this SER, doses caused by effluents were not considered. The use of dosimeters and periodic radiological surveillance at the ISFSI, as described in SAR Section 7.7, will detect any unexpected significant releases of radioactive materials; therefore, these measures will meet the requirements of 10 CFR §72.126(c)(2), §20.1301(e), and §20.1302(a).

All of the HI-STAR HB system casks and the GTCC waste cask are assumed to be loaded and placed in the ISFSI storage vault within a single year. The applicant's offsite dose analysis also includes the estimated dose from these operations in relation to the annual dose limits specified in 10 CFR §72.104(a). The analysis assumes that the licensee will restrict access by members of the public to areas outside the 100-m controlled area boundary during loading operations. The analysis also assumes that each cask requires 8 hours to be transferred to and loaded into the vault, but for dose analysis estimation, each cask is assumed to be at the vault for the entire loading operation. This provides a conservative calculation in that each of the 6 casks is assumed to be at the closest possible location to a member of the public {100 m [328 ft]} for the duration of the loading operation. As shown in Table 7.5-3 of the SAR, for the year in which the ISFSI vault is loaded, the applicant estimates doses from ISFSI loading operations to be 24.5 μSv/yr [2.45 mrem/yr] at the 100-m [328 ft] controlled area boundary and 18.3 μSv/yr [1.83 mrem/yr] for the nearest resident {247 m [810 ft]}.

Contributions to the dose rates from other nuclear fuel-cycle facilities (HBPP Unit 3) located within the region of the proposed ISFSI were taken into account in the total offsite collective dose assessment. As described in Section 7.5.3 and listed in Table 7.5-3 of the SAR, the annual dose from the other uranium fuel cycle operations was estimated as <20 μSv/yr [<2 mrem/yr] at the closest point of public access and <1.0 μSv/yr [<0.1 mrem/yr] at the nearest resident location. The combined annual dose from the proposed ISFSI, including vault loading operations in a single year, and other nuclear fuel-cycle facilities was estimated as a maximum of 0.2145 mSv [21.45 mrem] at the closest point of public access and 0.0641 mSv [6.41 mrem] to the nearest resident. These dose values are less than the 0.25 mSv/yr [25 mrem/yr] whole-body dose limit specified for a real individual in 10 CFR §72.104(a). The staff reviewed the applicant's assumptions and analysis of the total off site collective dose presented in the SAR and determined that the assessment provides reasonable assurance that the cumulative effects of the combined operations of the ISFSI and HBPP will not constitute an unreasonable risk to the health and safety of the public, in compliance with 10 CFR §72.104(a) and §72.122(e).

Section 8.1 of the SAR evaluates the HI-STAR HB system and concludes that the system can withstand the applicable off-normal events such that the confinement boundary of the MPC-HB and shielding integrity are not affected. The staff finds the applicant's analyses of off-normal events acceptable and has reasonable assurance that off-normal events will have no radiological impact. Section 8.2 of the SAR demonstrates that the HI-STAR HB system can withstand the analyzed accident events without affecting the design function of the system such that the confinement boundary of the MPC-HB is not affected. Shielding integrity is also maintained in the accident analyses, with the exception of one accident condition. The analysis of a fire accident during transfer operations indicates that the temperature limits of the neutron shield in the overpack would be exceeded. Section 8.2.5.3 of the SAR summarizes the analysis for the complete loss of the neutron shield during transfer and estimates the accident condition dose rate at 100 m to be 4.5 μSv/hr [0.45 mrem/hr]. The applicant assumes full occupancy at the 100-m controlled area boundary for a full 30-day accident recovery period, resulting in a dose of 3.24 mSv [324 mrem]. This dose value is less than the 0.05 Sv [5 rem] whole-body dose limit from any design basis accident specified in 10 CFR §72.106(b). The applicant's accident analyses are reviewed and evaluated in Chapter 15 of this SER.

Based on its review and evaluation of the applicant's offsite dose assessments for the ISFSI and relevant information referenced from the HI-STAR 100 system (Holtec International, 2002), the staff finds the applicant's offsite dose assessments for the Humboldt Bay ISFSI acceptable.

The results of these site-specific assessments and the staff's evaluations of the previously approved HI-STAR 100 system (U.S. Nuclear Regulatory Commission, 2001), as applicable to the HI-STAR HB system, provide reasonable assurance that doses to personnel and members of the public will be maintained ALARA and will meet the requirements of 10 CFR §20.1101(d), §20.1201(a), §20.1301(a), §72.24(e), §72.104(a), and §72.106(b).

11.1.4 Health Physics Program

The Health Physics Program is described in Section 7.6 of the SAR.

11.1.4.1 Organization

The Health Physics Program organization is described in Section 7.6.1 of the SAR and references the organization that will implement the Health Physics Program during ISFSI operations described in the SAR Section 9.1.3 and shown in Figure 9.1-2. The ISFSI organization is evaluated in detail in Section 10.1.1 of this SER. The Radiation Protection Manager is responsible for health physics activities related to ISFSI operations. The Radiation Protection Manager is independent of the Engineering Manager. The Radiation Protection Manager and the Engineering Manager report directly to the Director and Plant Manager. The staff finds that this element of the proposed Radiation Protection Program satisfies 10 CFR §20.1101(a). Once the ISFSI is completed, the applicant intends to decommission HBPP Unit 3 and terminate the 10 CFR Part 50 license. Following this action, the ISFSI organization may be revised, and the applicant has committed to notify NRC concerning any changes to the ISFSI organization prior to terminating the 10 CFR Part 50 license.

11.1.4.2 Equipment, Instrumentation, and Facilities

The equipment, instrumentation, and facilities pertinent to the ISFSI Health Physics Program are described in Section 7.6.2 of the SAR. The ISFSI is located within the Humboldt Bay owner-controlled area, and the applicant has full authority to control all activities within the ISFSI and owner-controlled area boundaries. Equipment, instrumentation, and facilities described in Sections 7.6.2.1, 7.6.2.2, and 7.6.2.3 of the SAR will be used for ISFSI operations and radiation surveys, in accordance with the policies and procedures described in Section 7.6.3 of the SAR. Prior to termination of the 10 CFR Part 50 SAFSTOR license of the HBPP, the health physics equipment, instrumentation, and facilities of the HBPP will be provided for use during the preoperations phase of the ISFSI. The applicant's description of the Health Physics Program provided in Section 7.6 of the SAR will be applicable to ISFSI operations during and after the 10 CFR Part 50 license termination. The applicant proposes to use a contracted, offsite facility for this program that will be governed by the ISFSI QA program described in Chapter 11 of the SAR. The staff finds, based on the program description in the SAR, that the requirements of 10 CFR §20.1101(a) will be met.

The Environmental Monitoring Program will be applied to ISFSI operations as described in Section 7.7 of the SAR. Additional TLDs will be used to determine dose rates at the restricted area and owner-controlled area boundaries. There will be no additional effluent monitoring because no radioactive effluents are expected during ISFSI operations. The staff finds that compliance with the dose limits specified in 10 CFR §72.104(a) will be demonstrated through the Environmental Monitoring Program using direct radiation measurements, thereby meeting the requirements of 10 CFR §20.1501(a)(1).

11.1.4.3 Policies and Procedures

The policies and procedures pertinent to the ISFSI Health Physics Program are described in Section 7.6.3 of the SAR. The Health Physics Program at the Humboldt Bay ISFSI will be implemented in accordance with the applicant's program directives, administrative procedures, and working-level procedures, which will be revised as needed to address ISFSI operations prior to operation of the ISFSI. The operation and use of radiation monitoring equipment will be described in written procedures consistent with the requirements of 10 CFR §20.1101(a), §20.1101(b), and §20.1101(c). The staff finds that the Health Physics Program policies and procedures described by the applicant in Section 7.6.3 of the SAR are acceptable and provide reasonable assurance that the requirements of 10 CFR §20.1101(a-c) are met.

11.2 Evaluation Findings

Based on the review of information in the SAR and its supporting documentation, the staff makes the following findings regarding the Radiation Protection Program for the proposed ISFSI:

- The design and operating procedures of the Humboldt Bay ISFSI provide acceptable means for controlling and limiting occupational radiation exposures within the limits given in 10 CFR §20.1201(a) and for meeting the objective of maintaining exposures ALARA.

- The SAR and other documentation submitted in support of the application are acceptable and 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 §20.1301(a), §20.1301(b), and §20.1301(e).

- The proposed Humboldt Bay ISFSI is to be on the same site as the Humboldt Bay Power Plant. The cumulative effects of the combined operations of these facilities will not constitute an unreasonable risk to the health and safety of the public, in compliance with 10 CFR §72.122(e).

- The SAR provides analyses showing that releases to the general environment during normal operations and anticipated occurrences will be within the exposure limits given in 10 CFR §72.104(a-c) and §72.106(b).

- The design of the Humboldt Bay ISFSI provides suitable shielding and confinement for radiation protection under normal and accident conditions, in compliance with 10 CFR §72.126(a), §72.126(c)(2), §72.126(d), and §72.128(a)(2).

- The staff finds that the Health Physics Program, as described by the applicant, satisfies the requirements of 10 CFR §20.1101(a–c), §20.1302(a), §20.1406, and §20.1501(a)(1).

11.3 References

Holtec International. *Final Safety Analysis Report for the Holtec International Storage, Transport, and Repository Cask System (HI-STAR 100 Cask System).* Rev. 1. HI-2012610. Docket 72-1008. Marlton, NJ: Holtec International. 2002.

Holtec International. *ISFSI Dose Assessment for Humboldt Bay.* Rev. 1. HI-2033047. Marlton, NJ: Holtec International. June 15, 2004. (Non-proprietary version).

Pacific Gas and Electric Company. *Humboldt Bay Independent Spent Fuel Storage Installation Safety Analysis Report, Amendment 1.* Docket No. 72-27. Avila Beach, CA: Pacific Gas and Electric Company. 2004a.

Pacific Gas and Electric Company. *Response to NRC Request for Additional Information for the Humboldt Bay Independent Spent Fuel Storage Installation Application (TAC No. L23683).* Letter (October 1). HIL-04-007. Avila Beach, CA: Pacific Gas and Electric Company. 2004b.

Pacific Gas and Electric Company. *Humboldt Bay Independent Spent Fuel Storage Installation License Application.* Amendment 1. Docket No. 72-27. Avila Beach, CA: Pacific Gas and Electric Company. 2004c.

Pacific Gas and Electric Company. *Response to NRC Request for Additional Information for the Humboldt Bay Independent Spent Fuel Storage Installation Application.* Letter (April 8). HIL-05-003. Avila Beach, CA: Pacific Gas and Electric Company. 2005.

U.S. Nuclear Regulatory Commission. Regulatory Guide 8.10, *Operating Philosophy for Maintaining Occupational Radiation Exposures As Low As Reasonably Achievable.* Rev 1-R. Washington, DC: U.S. Nuclear Regulatory Commission. 1975.

U.S. Nuclear Regulatory Commission. Regulatory Guide 8.8, *Information Relevant to Ensuring That Occupational Radiation Exposures at Nuclear Power Stations Will Be As Low As Reasonably Achievable.* Rev. 3. Washington, DC: U.S. Nuclear Regulatory Commission. 1978.

U.S. Nuclear Regulatory Commission. *Holtec International HI-STAR 100 Cask System Amendment No. 1, Safety Evaluation Report.* Docket 72-1008. Washington, DC: U.S. Nuclear Regulatory Commission. 2001.

12 QUALITY ASSURANCE

12.1 Conduct of Review

The purpose of this review is to determine whether Pacific Gas and Electric Company (PG&E) has a quality assurance (QA) program that complies with the requirements of 10 CFR Part 72, Subpart G, to be applied to activities at the Humboldt Bay ISFSI. The basis for that determination is a review and evaluation of the applicant's QA program submitted as part of the application in accordance with 10 CFR 72.24(n).

Paragraph (b) of 10 CFR 72.140 states in part, that each licensee shall establish, maintain, and execute a QA program satisfying each of the applicable criteria of 10 CFR Part 72, Subpart G. Paragraph (d) states that a Commission-approved QA program which satisfies the applicable criteria of Appendix B of 10 CFR Part 50 and which is established, maintained, and executed with regard to an ISFSI will be accepted as satisfying the requirements of 10 CFR 72.140(b).

The staff reviewed the following aspects of the applicant's proposed QA program for the Humboldt Bay ISFSI, as described in Chapter 11 of the SAR, Attachment E of the License Application (Pacific Gas and Electric Company, 2004b), and associated references :

- QA Organization (10 CFR 72.142)
- QA Program (10 CFR 72.144)
- Design Control (10 CFR 72.146)
- Procurement Document Control (10 CFR 72.148)
- Instructions, Procedures and Drawings (10 CFR 72.150)
- Document Control (10 CFR 72.152)
- Control of Purchased Material, Equipment and Services (10 CFR 72.154)
- Identification and Control of Materials, Parts, and Components (10 CFR 72.156)
- Control of Special Processes (10 CFR 72.158)
- Licensee Inspection (10 CFR 72.160)
- Test Control (10 CFR 72.162)
- Control of Measuring and Test Equipment (10 CFR 72.164)
- Handling, Storage, and Shipping Control (10 CFR 72.166)
- Inspection, Test, and Operating Status (10 CFR 72.168)
- Nonconforming Materials, Parts or Components (10 CFR 72.170)
- Corrective Action (10 CFR 72.172)
- Quality Assurance Records (10 CFR 72.174)
- Audits (10 CFR 72.176)

PG&E is currently licensed under 10 CFR 50 to operate the Diablo Canyon Power Plant (DCPP), Units 1 and 2, and has a Commission-approved quality assurance program meeting the requirements of 10 CFR Part 50, Appendix B. In Chapter 11 of the Humboldt Bay ISFSI Safety Analysis Report, PG&E states the governing document for this QA program is the DCPP Quality Assurance Program, as described in Chapter 17 of the DCPP Final Safety Analysis Report (FSAR) Update. PG&E further states that it will apply this QA program to the design, purchase, fabrication, handling, shipping, storing, cleaning, assembly, inspection, testing, operation, maintenance, repair, modification, and decommissioning of Humboldt Bay ISFSI structures, systems, and components to an extent that is commensurate with the importance to safety, and to managerial and administrative controls used to ensure safe ISFSI operation.

Given that the existing approved QA program satisfies Appendix B to 10 CFR Part 50 and that PG&E's stated intent is to apply that program to the Humboldt Bay ISFSI, the staff concludes that PG&E has met the conditions of 10 CFR 72.140(d) and, therefore, satisfies the requirements of 10 CFR 72.140(b).

The staff reviewed Chapter 17, "Quality Assurance," of the DCPP Units 1 & 2 FSAR Update, and concludes that the description of PG&E's QA program for the Humboldt Bay ISFSI satisfies the requirements of 10 CFR Part 72, Subpart G. The QA program is comprehensive and will provide adequate control over activities affecting quality.

12.2 Evaluation Findings

The staff made the following findings regarding the QA program for the Humboldt Bay ISFSI:

- The QA program describes requirements, procedures, and controls that when properly implemented, comply with the requirements of 10 CFR 72, Subpart G.
- The QA program covers activities affecting SSCs important-to-safety as identified in Section 4.5 of the SAR.
- The organizations and persons performing QA functions have the independence and authority to perform their functions without undue influence from those directly responsible for costs and schedules.
- The applicant's description of the QA program is in compliance with applicable NRC regulations and industry standards, and the QA program can be implemented for the design, fabrication and construction, operation, and decommissioning phases of the installation's life cycle.

12.3 References

Pacific Gas and Electric Company. *Humboldt Bay Independent Spent Fuel Storage Installation Safety Analysis Report, Amendment 1.* Docket No. 72-27. Avila Beach, CA: Pacific Gas and Electric Company. 2004a.

Pacific Gas and Electric Company. *Humboldt Bay Independent Spent Fuel Storage Installation License Application.* Amendment 1. Docket No. 72-27. Avila Beach, CA: Pacific Gas and Electric Company. 2004b.

13 FINANCIAL QUALIFICATIONS AND DECOMMISSIONING EVALUATION

13.1 Conduct of Review

The objectives of this evaluation are to ensure that the applicant's financial qualifications for constructing and operating the ISFSI and its provisions for the eventual decommissioning of the ISFSI provide reasonable assurance of adequate protection of public health and safety. The evaluation addresses the applicant's financial qualifications, the design and operational features of the ISFSI that facilitate decommissioning, the proposed decommissioning plan, and the associated financial assurance and record keeping plan for decommissioning.

Financial qualification requirements are specified in 10 CFR §72.22(e). Requirements regarding the decommissioning of the ISFSI are given in 10 CFR §72.24(q), §72.30 and §72.130. Complete citations of these regulations are provided in the Appendix of this SER.

13.1.1 Financial Qualifications Evaluation

13.1.1.1 Humboldt Bay Power Plant Decommissioning Funding

The HBPP was permanently shutdown in July 1976 and has since been in a SAFSTOR decommissioning configuration, with spent fuel stored in the facility's spent fuel pool. The NRC approved an initial decommissioning plan in July 1988, which was subsequently converted into the Defueled Safety Analysis Report (DSAR), followed by the Post-Shutdown Decommissioning Activities Report (PSDAR), issued by the licensee in February 1998. At that time, PG&E anticipated that the HBPP spent fuel would remain stored in the spent fuel pool until 2015 and then transferred to DOE. Active decommissioning of the HBPP would not commence until after 2015.

As an electric utility, PG&E's operating budget for maintaining the SAFSTOR condition for the permanently shutdown HBPP is authorized by the California Public Utility Commission (CPUC) to be included in the utility's base rates. The costs of maintaining Humboldt Bay in SAFSTOR, including costs associated with storage of the spent fuel in the spent fuel pool, are funded on an annual basis from the utility's operating budget. The current costs associated with storage of the spent fuel in the spent fuel pool will continue to be funded annually from the utility's operating budget. However, in pursuing the licensing and construction of a dry cask storage facility for interim storage of spent fuel, PG&E has provided additional information specific to the costs of the Humboldt Bay ISFSI.

13.1.1.2 Financial Qualifications for Humboldt Bay ISFSI

In its application dated December 15, 2003, as amended October 1, 2004 (Pacific Gas and Electric Company, 2004a), and as supplemented by letters dated April 23, 2004 (Pacific Gas and Electric Company, 2004b), and July 27, 2004 (Pacific Gas and Electric Company, 2004c), PG&E provided information to address the financial qualification requirements of 10 CFR §72.22(e). This required information includes estimated ISFSI construction costs, estimated operating costs over the life of the ISFSI, and the estimated decommissioning costs and necessary financial arrangements to provide reasonable financial assurance that decommissioning will be carried out after the removal of spent fuel from the ISFSI.

PG&E estimates that the total costs associated with the long-term management of spent fuel in dry cask storage from ISFSI licensing to decommissioning will be $68 million (2004 Dollars) of which approximately $5.5 million had been disbursed through the end of 2003. Because these anticipated ISFSI costs are not covered by the annual operating budget, PG&E established, as required by 10 CFR §50.54(bb), a decommissioning fund and enumerated how monies for the fund are collected, reserved and expended for ISFSI related expenses. PG&E developed an accounting spreadsheet to partition their decommissioning trust fund into three areas:
1) radiological decommissioning costs; 2) non-radiological decommissioning costs; and
3) ISFSI and spent fuel management related costs.

At the end of 2003, the Humboldt decommissioning trust fund balance was $213.9 million. Table 13-1, "Humboldt Bay Decommissioning Funding Status as of December 31, 2003," summarizes the information provided by PG&E on the allocation of funds within the decommissioning trust for each cost area, including the spent fuel management funding for ISFSI-related costs. Table 13-1 also includes known future additions to the funds authorized by the CPUC and current unfunded balances.

Table 13-1: Humboldt Bay Decommissioning Funding Status as of December 31, 2003 ($ in Millions)

	Radiological Decommissioning	Non-Radiological Decommissioning	ISFSI [1] Related	Total
Trust Account Balance	$172.9	$1.1	$39.9	$213.9
Additional Funds to be Collected	$41	$0.2	0.3	$41.5
Estimated Funds Needed to Complete Each Activity (Shortfall)	$53.8	$2.1	$22.3	$78.2
Total Estimated Costs	$267.7[2]	$3.4	$62.5[2]	$333.6

[1]The ISFSI related costs were based on a site-specific cost estimate prepared by TLG, include engineering, licensing, construction, operation, and decommissioning costs (Pacific Gas and Electric Company, 2004b).

[2]These amounts do not include funds previously disbursed.

PG&E stated that a significant portion of the funding shortfall will be obtained from investment growth of the decommissioning trust and tax-savings related to the trust. PG&E also stated that any future funding shortfalls resulting from poor investment returns or unforseen expenses would necessitate requests for additional rate recovery from the CPUC to fully fund the decommissioning activities in each trust sector. The information in Table 13-1 is based on a site-specific decommissioning cost estimate for HBPP, Unit 3, prepared by TLG Services

(Pacific Gas and Electric Company, 2004b). In PG&E's estimates, the costs for ISFSI decommissioning are projected to be less than $1 million.

10 CFR 72.30(b) and (c) require that an applicant must provide a decommissioning funding plan that describes the financial assurance method for the decommissioning the ISFSI, and that this mechanism must be provided by some combination of prepayment; a surety method, insurance or other guarantee; or an external sinking fund. The Humboldt Bay decommissioning trust fund is an external sinking fund that contains monies designated specifically for spent fuel management costs and non-radiological decommissioning activities (including the ISFSI costs), in addition to the radiological decommissioning funds in support of 10 CFR §50.82 decommissioning requirements.

The NRC staff previously found that PG&E's approach to decommissioning funding is consistent with the NRC's regulatory Statements of Consideration concerning the spent fuel management program (67 FR 78340, December 24, 2002, or 61 FR 39385, July 29, 1996), in that the decommissioning regulations do not prohibit commingling of decommissioning funds with spent fuel management (ISFSI) funds and other non-radiological decommissioning funds, provided that accounting mechanisms are employed to ensure that funds for each type of activity are appropriately identified and segregated (Nuclear Regulatory Commission, 2004). PG&E has established an accounting mechanism to maintain the segregation of decommissioning funds and will adhere to the intent of this funding segregation.

The NRC staff finds the applicant's spent fuel management cost estimates to be reasonable based on a cost comparison with some similar decommissioning reactors. These cost estimates account for all ISFSI-related expenses, in addition to other spent fuel management costs. The staff recognizes the current funding shortfalls but expects that the CPUC would likely approve justifiable requests for additional rate recovery as necessary to fully fund the decommissioning trust for circumstances that could not be foreseen or reasonably avoided by PG&E. The CPUC has provided funding for HBPP costs since Unit 3 shut down in July 1976, a period of more than 29 years. The staff finds that the licensee's proposed plan to transfer the spent fuel to an ISFSI and its associated funding mechanism provides reasonable assurance that adequate funds will be available to complete radiological decommissioning of the ISFSI. Furthermore, the NRC staff considers the transfer of spent fuel to dry cask storage to be a necessary step toward radiological decommissioning of Humboldt Bay Power Plant, Unit 3.

The NRC staff finds that the revised PG&E plan for the interim storage of spent fuel is adequate and provides sufficient details on associated funding mechanisms. The staff therefore concludes that the PG&E spent fuel management program for Humboldt Bay provides reasonable assurance that sufficient funds are available to build, operate and decommission the ISFSI. The staff finds that PG&E has submitted sufficient information to address the requirements of 10 CFR §72.22(e)(1) and (2). The staff reviewed PG&E's estimates of the costs to construct, operate and decommission the ISFSI and concluded that the estimates are reasonable. The staff also concludes that the existing balance of funds and cost recovery mechanisms provide reasonable assurance that sufficient funds will be available to construct, operate, and decommission the ISFSI, recognizing that the CPUC has been authorizing funding of reasonable costs for the HBPP since 1976.

On the bases of the foregoing evaluation, the staff finds that the financial requirements of 10 CFR §72.22(e) and 10 CFR §72.30(b) and (c) have been met.

13.1.2 Decommissioning Evaluation

13.1.2.1 Design and Operational Features

The requirements of 10 CFR §72.130 specify that the ISFSI must be designed for decommissioning. Provisions must be made to facilitate decontamination of structures and equipment, minimize the quantity of radioactive wastes and contaminated equipment, and facilitate the removal of radioactive wastes and contaminated materials at the time the ISFSI is permanently decommissioned. Also, 10 CFR §72.30(a) requires the submittal of a proposed decommissioning plan that contains sufficient information on proposed practices and procedures for the decontamination of the site and facilities and for disposal of residual radioactive materials after all spent fuel and other stored material has been removed. This plan must identify and discuss those design features of the ISFSI that facilitate its decontamination and decommissioning at the end of its useful life.

The NRC staff has previously reviewed the design of the Holtec HI-STAR 100 storage system, and concluded that its design features will facilitate decontamination and decommissioning. The design and operational features of the HI-STAR HB storage system to be used at the Humboldt Bay ISFSI are very similar (with the exception of the storage vault) and will likewise minimize contamination and facilitate decommissioning at the end of the useful life of the ISFSI. These features include procedures for preventing contamination of MPC outer surfaces during loading in the spent fuel pool and for decontaminating the HI-STAR HB cask and MPC top lid prior to movement to the ISFSI. The confinement design of the MPCs, which are loaded and seal welded before transfer to the storage vault, and the passive design of the storage system, minimize the potential for radioactive contamination to occur and to spread. The neutron flux levels generated by the spent fuel are expected to be sufficiently low that any activation of the overpacks or storage vault components will be insignificant. Any HI-STAR HB overpacks meeting the free release criteria may be made available to other parties for their use or disposed of as non-controlled material. If these components do become slightly contaminated, the steel-lined surfaces will facilitate decontamination efforts. In the unlikely event any residual contamination cannot be sufficiently removed, the overpacks will still be suitable for disposal as low specific activity material in a licensed near-surface disposal site.

Through the imposition of administrative controls, the applicant will limit any contamination on each HI-STAR HB cask prior to its movement, so that neither the cask transporter, nor the storage vault or other supporting components are expected to become contaminated. Unlike the HI-STAR 100 overpack design, the HI-STAR HB overpacks are sealed with a bolted closure and backfilled with helium, greatly reducing the already very low potential for spread of contamination to supporting equipment and structures. PG&E will perform surveys of all supporting equipment and structures at the time of decommissioning, and they will be decontaminated as necessary so as to be in a condition suitable for free release. If, in the unlikely event that the equipment or structures cannot be decontaminated to appropriate levels, PG&E will dispose of them in a licensed near-surface disposal site. Radiation survey measurements will be made of all components prior to their final dispensation to determine whether they will be subject to further decontamination efforts, disposed of as low-level radioactive waste, or released for re-use or commercial disposal.

13.1.2.2 Decommissioning Plan

The requirements of 10 CFR §72.30(a) specify that each application for an ISFSI license include a proposed decommissioning plan that contains sufficient information on proposed practices and procedures for the decontamination of the site and facilities and for disposal of residual radioactive materials after all spent fuel and other stored material have been removed, in order to provide reasonable assurance that the decontamination and decommissioning of the ISFSI at the end of its useful life will provide adequate protection to the health and safety of the public. The requirements of 10 CFR §72.30(b) specify that the proposed decommissioning plan must also include a decommissioning funding plan containing information on how reasonable assurance will be provided that funds will be available to decommission the ISFSI. This information must include a cost estimate for decommissioning and a description of the method for assuring funds for decommissioning. The requirements of 10 CFR §72.30(c) specify that financial assurance for decommissioning must be provided by some combination of prepayment; a surety method, insurance, or other guarantee; or an external sinking fund. The requirements of 10 CFR §72.30(d) specify that records of information important to the decommissioning of a facility shall be kept in an identified location until the site is released for unrestricted use. These include records of spills or other unusual occurrences involving the spread of contamination around the site; as-built drawings and modifications of structures and equipment in restricted areas where radioactive materials are used or stored; a list of designated, or previously designated, restricted areas, and any contaminated areas requiring documentation; and records of the cost estimate performed and the funding method for the decommissioning funding plan.

The Humboldt Bay ISFSI Preliminary Decommissioning Plan (Pacific Gas and Electric Company, 2004a, Appendix F) was prepared and submitted in accordance with the requirements of 10 CFR §72.30. The plan discusses the ISFSI decommissioning objective, activities and tasks; records; cost estimate; funding plan and decommissioning facilitation. The ISFSI decommissioning plan is based on PG&E's assumption that the fuel assemblies will remain sealed in the loaded MPCs and will be transported offsite. The HI-STAR HB overpacks, storage vault, and other ISFSI components will be decontaminated as necessary, then disposed of as low-level radioactive waste at a licensed disposal site, or as non-controlled material at a commercial facility, as appropriate, or otherwise dispositioned to allow release of the ISFSI site for unrestricted use.

13.1.2.2.1 General Provisions

Each of the elements listed in 10 CFR §72.30 have been provided in the Humboldt Bay ISFSI License Application, SAR or in the ISFSI Preliminary Decommissioning Plan. As discussed in Section 13.1.2.1 of this SER, PG&E has described the measures that will provide for the necessary decontamination of the site and facilities and the disposal of residual radioactive materials after all spent fuel and other stored material have been removed.

13.1.2.2.2 Cost Estimate

The cost for decommissioning the Humboldt Bay ISFSI was estimated to be roughly $900,000, as stated in the Humboldt Bay ISFSI Preliminary Decommissioning Plan and supplemental information (Pacific Gas and Electric Company, 2004a, b). This estimate covers the costs for decontamination of ISFSI structures and components, as well as the disposal of any ISFSI-related material as low-level radioactive waste. As discussed in Section 13.1.1.2 of this SER, the ISFSI decommissioning costs represent a small fraction of the total estimated decommissioning costs for HBPP Unit 3.

13.1.2.2.3 Financial Assurance Mechanism and Record Keeping

The decommissioning funding mechanism for the Humboldt Bay ISFSI is described in the ISFSI Preliminary Decommissioning Plan. An external sinking trust fund account has been established by PG&E for the decommissioning of the HBPP, Unit 3, and that account contains monies for the decommissioning of the ISFSI. The ISFSI decommissioning costs are identified as separate line items in the detailed cost estimates provided in the decommissioning funding reports for the Humboldt Bay Power Plant, Unit 3. The PG&E decommissioning funding program meets the appropriate requirements of 10 CFR §72.30(c), as described in the ISFSI Preliminary Decommissioning Plan and in the decommissioning funding reports for Humboldt Bay Power Plant, Unit 3.

In the ISFSI Preliminary Decommissioning Plan, PG&E also committed to maintain records in support of ISFSI decommissioning, as required by 10 CFR §72.30(d). Specifically, these records will include records of spills or unusual occurrences involving the spread of contamination around the site, as-built drawings and modifications of structures and equipment in the ISFSI restricted area(s), and decommissioning cost estimates and funding methods. These records will be maintained in accordance with PG&E's existing records management program, which falls under the Diablo Canyon Power Plant Quality Assurance Program, as amended to include the Humboldt Bay ISFSI activities as discussed in Appendix E of the Humboldt Bay ISFSI License Application.

13.2 Evaluation Findings

The staff made the following findings regarding the applicant's financial qualifications and decommissioning plans for the Humboldt Bay ISFSI:

- The staff has determined that the applicant has adequately demonstrated its financial qualifications to construct, operate and decommission the proposed ISFSI, in accordance with 10 CFR §72.22(e).

- The staff has determined that the decommissioning plan submitted by the applicant provides reasonable assurance that the decontamination and decommissioning of the ISFSI at the end of its useful life will provide adequate protection to the health and safety of the public. The staff, therefore, concludes that the proposed decommissioning plan complies with 10 CFR §72.24(q), §72.30(a) and §72.130.

- The staff has determined that the decommissioning funding plan submitted by the applicant is sufficient to provide reasonable assurance that costs related to decommissioning as characterized by the proposed decommissioning plan have been adequately estimated. The staff, therefore, concludes that the cost estimate in the decommissioning funding plan complies with 10 CFR §72.30(b).

- The staff has determined that the financial assurance mechanisms submitted by the applicant are sufficient to provide reasonable assurance that adequate funds will be available to decommission the ISFSI so that the site will ultimately be available for unrestricted use for any private or public purpose. The staff, therefore, concludes that the financial assurance mechanisms in the decommissioning funding plan comply with 10 CFR §72.30(c).

- The staff has determined that the applicant will maintain all records of information important to the decommissioning of the ISFSI, consistent with the requirements of the Quality Assurance Program. The staff, therefore, concludes that the record keeping commitments made by the applicant comply with 10 CFR §72.30(d).

13.3 References

Pacific Gas and Electric Company. *Humboldt Bay Independent Spent Fuel Storage Installation Safety Analysis Report, Amendment 1, Preliminary Decommissioning Plan, Appendix F to License Application.* Avila Beach, CA: Pacific Gas and Electric Company. October 1, 2004. 2004a.

Pacific Gas and Electric Company. *Humboldt Bay Independent Spent Fuel Storage Installation Supplemental General and Financial Information - 10 CFR 72.22.* Letter HIL-04-003, Pacific Gas and Electric Company, April 23, 2004. 2004b

Pacific Gas and Electric Company. *Response to NRC Request for Supplemental Humboldt Bay Independent Spent Fuel Storage Installation Financial Information.* Letter HIL-04-006, Pacific Gas and Electric Company, July 27, 2004. 2004c.

U.S. Nuclear Regulatory Commission. *Humboldt Bay Nuclear Power Plant - Review and Preliminary Approval of Spent Fuel Management Program (TAC L52613)* Docket Nos. 50-133, 72-27. U.S. Nuclear Regulatory Commission. June 14, 2004. 2004.

14 WASTE CONFINEMENT AND MANAGEMENT EVALUATION

14.1 Conduct of Review

This chapter of the Safety Evaluation Report (SER) evaluates the waste management systems of the Humboldt Bay ISFSI. Chapter 6, "Waste Management," of the Safety Analysis Report (SAR) (Pacific Gas and Electric Company, 2004) provides information about the waste confinement and disposal systems that are a part of the facility. This review specifically focused on radioactive wastes that would be generated by site activities involving the handling and storage of spent nuclear fuel (SNF). These activities may produce (i) gaseous wastes, (ii) liquid wastes, and (iii) solid or solidified wastes during loading and unloading of the multi-purpose canister (MPC-HB). Neither the actual SNF nor the waste generated by the Humboldt Bay Power Plant (HBPP) falls within the scope of this review. The review objective for this chapter is to determine whether the ISFSI design and procedures provide safe confinement and management of radioactive waste generated from ISFSI operations.

The review considered how the SAR and related documents address the regulatory requirements of 10 CFR §72.24(f), §72.24(l), §72.40(a)(13), §72.104(a), §72.122(e), §72.122(h)(3), §72.126(c)(1), §72.126(d), §72.128(a)(5), and §72.128(b). Complete citations of these regulations are provided in the Appendix of the SER.

14.1.1 Waste Source

A review of the sources of radioactive waste described in Chapter 6 of the SAR included consideration of various sources during the operation of the facility. As described in Section 6.2 of the SAR, some amounts of liquid, gaseous, and solid radioactive wastes may be generated during loading and decontamination activities before storage.

A small quantity of low-level solid waste may be generated during MPC-HB loading operations and will be processed using the existing HBPP radioactive waste control systems, which are described in Sections 3.2.1, 3.2.2.7, and 4.4.5.2 of the HBPP Defueled Safety Analysis Report (DSAR) (Pacific Gas and Electric Company, 2002). Contaminated water from the loaded MPC-HBs is drained back into the spent fuel pool (SFP) with no additional processing. Liquid wastes from the decontamination activities in the Refueling Building (RFB) are directed to the existing liquid radwaste treatment system of the HBPP. Potentially contaminated air and helium that may be released from the MPC-HB during loading and unloading operations in the RFB will be routed and processed through the RFB ventilation exhaust and stack filtration system before release.

The staff finds that the use of the existing HBPP facilities for processing solid and liquid wastes generated during fuel loading and decontamination activities related to ISFSI operations satisfies the requirements of 10 CFR §72.128(b). The passive design of ISFSI components minimizes the volume of radioactive waste that could be generated by the operation of the ISFSI. The staff finds that the Humboldt Bay ISFSI satisfies the requirements of 10 CFR §72.128(a)(5) and §72.24(f). The details provided in the SAR regarding the treatment of the generated solid, liquid, and gaseous wastes satisfy the requirements of 10 CFR §72.24(l).

No radioactive waste material is generated during transfer and storage at the ISFSI. The dry cask storage system is a passive design requiring no active systems to ensure adequate decay heat removal and to ensure adequate confinement. The system also does not require intrusive periodic maintenance. The staff finds, based on a review of the system design, that radioactive waste is not generated during cask transfer and storage at the ISFSI.

14.1.2 Off-Gas Treatment and Ventilation

As described in Section 6.1 of the SAR, the MPC-HB is designed to endure normal, off-normal, and accident conditions of storage with maximum decay heat loads without loss of confinement. Permanent area radiation and airborne radioactivity monitors are not needed at the ISFSI because the storage system is passive and system design makes leakage non-credible. During fuel loading, existing SFP instrumentation will monitor for any releases of airborne radioactivity. Operators will have the capability to manually change the building ventilation exhaust system from normal to emergency mode upon detection of radiation levels above preset alarm levels. The applicant intends to perform fuel handling activities with the RFB ventilation system in operation, to collect and process potentially contaminated air through the gaseous radioactive waste system. However, even with the RFB ventilation system inoperable, the applicant has conservatively calculated the radiological dose consequences from a heavy load drop in the RFB to be well below 10 CFR Part 100 criteria. That accident analysis is part of a pending license amendment request for the HBPP 10 CFR Part 50 license that is outside the scope of this 10 CFR Part 72 license review.

The MPC-HB confinement boundary ensures that, after the MPC-HB is seal-welded, there will be no release of radioactive materials under any postulated condition. Therefore, no radioactive wastes are produced by the HI-STAR HB system during transfer from the RFB to the ISFSI site or while the fuel is in storage.

The staff finds that the applicant has provided sufficient design features and controls to ensure the confinement of airborne radioactive particulate materials during normal, off-normal and accident conditions, in compliance with 10 CFR §72.122(h)(3). In addition, the staff finds that the proposed design and operation of the ISFSI satisfy the requirements of 10 CFR §72.104(a) and §72.126(d). Because no effluents are expected under normal or accident conditions, the requirements of 10 CFR §72.126(c)(1) regarding measurement and dilution of effluents are not applicable.

14.1.3 Liquid Waste Treatment and Retention

Contaminated water from the loaded MPC-HBs is drained back into the SFP and is subjected to the normal treatment for the SFP water. A small amount of liquid waste is generated due to the decontamination of the exterior surfaces of the HI-STAR HB overpack in the RFB. These liquid wastes will be processed using existing HBPP radioactive waste control systems and procedures.

The applicant will be using the existing HBPP facilities to process the liquid waste generated in the RFB. The HI-STAR HB dry cask storage system will not generate any liquid effluents due to the operations at the ISFSI. Thus, the staff finds that no special liquid radioactive waste treatment and retention systems are needed at the ISFSI. Therefore, the staff finds that the requirements of 10 CFR §72.128(b) are satisfied. Use of the HBPP facilities to process radioactive waste, subject to the provisions of 10 CFR Part 50, satisfies the requirements of 10 CFR §72.128(b).

14.1.4 Solid Wastes

A small quantity of low-level solid waste may be generated during MPC-HB loading operations. The solid waste may include disposable anti-contamination garments, paper, rags, tools, and such, which will be processed using the existing HBPP radioactive waste control systems as described in HBPP DSAR (Pacific Gas and Electric Company, 2002). The staff finds that the requirements of 10 CFR §72.128(b) will be met, based on the applicant's representations that the HBPP facilities under the Part 50 license will be used to process radioactive wastes generated during loading operations and that such waste will not be generated during any other phase of ISFSI operations.

14.1.5 Radiological Impact of Normal Operations

Based on the staff's assessment of welded cask enclosures, as stated in Interim Staff Guidance 5 (ISG-5) (U.S. Nuclear Regulatory Commission, 2003a) and ISG-18 (U.S. Nuclear Regulatory Commission, 2003b), the staff finds that the MPC-HB, which is the confinement system for the HI-STAR HB system, provides reasonable assurance that no effluents will be released during normal, off-normal, or accident conditions and, therefore, requires no monitoring for leakage. The seal weld will be inspected and tested in accordance with the description in Section 4.2.3.2.1 of the SAR. This inspection protocol is the same as that licensed generically for the HI-STAR 100, for which additional detail is provided in Section 9.1.1.1 of the HI-STAR 100 Final SAR (Holtec International, 2002). These requirements were reviewed during the certification of the HI-STAR 100 system and were found to be acceptable. These requirements were also reviewed specifically for the HI-STAR HB system and evaluated in Section 9.1.1 of this SER. The cumulative effects of generated wastes due to combined operations at the ISFSI and HBPP will not constitute an unreasonable risk to the health and safety of the public in compliance with 10 CFR §72.122(e), as discussed in Section 11.1.3.2 of this SER. Based on its review of waste confinement and management activities described in the SAR, the staff finds these activities to be in compliance with 10 CFR §72.40(a)(13).

14.2 Evaluation Findings

The staff makes the following findings regarding waste confinement and management of the Humboldt Bay ISFSI, based on its review of the information in the SAR:

- The SAR adequately describes acceptable features of the ISFSI design and operating modes that reduce, to the extent practical, the radioactive waste volume generated by the installation in compliance with 10 CFR §72.128(a)(5) and §72.24(f).
- Use of HBPP facilities approved under the provisions of the HBPP 10 CFR Part 50 license for processing solid and liquid wastes generated

during loading and decontamination activities related to ISFSI operations satisfies the requirements of 10 CFR §72.128(b) and §72.104(a).

- Because no effluents are expected to be generated under normal or accident conditions, the requirements of 10 CFR §72.126(c)(1), regarding measurement and dilution of effluents are considered not applicable.

- Use of HBPP facilities approved under the provisions of the HBPP 10 CFR Part 50 license to ensure the confinement of airborne radioactive particulate materials during normal and off-normal conditions satisfies the requirements of 10 CFR §72.122(h)(3).

- The design of the ISFSI provides acceptable means to limit the release of radioactive materials in effluents during normal operation to levels as low as reasonably achievable and to control the release of radioactive materials under accident conditions in compliance with 10 CFR §72.126(d).

- The effects of the operation of the proposed ISFSI combined with those of other nuclear facilities at the site (HBPP) will not constitute an unreasonable risk to the health and safety of the public, in compliance with 10 CFR §72.122(e).

- The waste confinement and management activities described in the SAR support the conclusion 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 SAR adequately describes acceptable equipment to be used to maintain control over radioactive materials in gaseous and liquid effluent produced during normal operations and expected operational occurrences in compliance with 10 CFR §72.24(l).

14.3 References

Holtec International. *Final Safety Analysis Report for the Holtec International Storage, Transport, and Repository Cask System (HI-STAR 100 Cask System).* Rev. 1. HI-2012610. Docket 72-1008. Marlton, NJ: Holtec International. 2002.

Pacific Gas and Electric Company. *Humboldt Bay Power Plant Unit 3 Defueled Safety Analysis Report.* Rev. 4. Avila Beach, CA: Pacific Gas and Electric Company. August 2002.

Pacific Gas and Electric Company. *Humboldt Bay Independent Spent Fuel Storage Installation Safety Analysis Report.* Amendment 1. Docket No. 72-27. Avila Beach, CA: Pacific Gas and Electric Company. 2004.

U.S. Nuclear Regulatory Commission. Interim Staff Guidance 5 (ISG-5), *Confinement Evaluation.* Rev. 1. Washington, DC: U.S. Nuclear Regulatory Commission. 2003a.

U.S. Nuclear Regulatory Commission. Interim Staff Guidance 18 (ISG-18), *The Design/Qualification of Final Closure Welds on Austenitic Stainless Steel Canisters as Confinement Boundary for Spent Fuel Storage and Containment Boundary for Spent Fuel Transportation.* Washington, DC: U.S. Nuclear Regulatory Commission. 2003b.

15 ACCIDENT ANALYSIS

15.1 Conduct of Review

The staff evaluated accident analyses related to the proposed Humboldt Bay Independent Spent Fuel Storage Installation (ISFSI) by reviewing Chapter 8, "Accident Analysis," of the Safety Analysis Report (SAR) (Pacific Gas and Electric Company, 2004a). The staff also reviewed documents cited in the SAR, and other relevant publicly available information, including web sites on the Internet.

The applicant evaluated off-normal events and accidents associated with the transfer of HI-STAR HB casks from the Refueling Building (RFB) to the proposed Humboldt Bay ISFSI site, lowering of the casks from the transporter to the reinforced concrete storage vault, and interim storage of the casks in the vault. HI-STAR HB cask handling activities inside the RFB fall within the scope of the 10 CFR Part 50 license, and hence, off-normal events and accidents associated with HI-STAR HB cask operations within the RFB were not addressed in this Safety Evaluation Report (SER).

As discussed in Chapter 5 of this SER, the dry cask storage system to be used at the proposed facility is the HI-STAR HB System, which is a modified version of the HI-STAR 100 cask system (Holtec International, 2002). The U.S. Nuclear Regulatory Commission has certified the HI-STAR 100 cask system for use by 10 CFR Part 50 licensees under the general license provisions of 10 CFR §72.210 (U.S. Nuclear Regulatory Commission 2001a). Thus, where applicable, the staff relied on the review carried out during the certification process of that cask system, as documented in the HI-STAR 100 Cask System SER (U.S. Nuclear Regulatory Commission, 2001b). The HI-STAR HB system consists of the MPC-HB, which is a seal-welded canister containing up to 80 spent nuclear fuel (SNF) assemblies; an optional damaged fuel container(s), which can be inserted into an MPC-HB and can hold an intact fuel assembly or damaged fuel; and the HI-STAR HB storage overpack (or cask).

This review considered how the SAR and related documents address the regulatory requirements of 10 CFR §72.90, §72.92, §72.94, §72.98(a), §72.98(c), §72.106(b), §72.122(b), §72.122(c), §72.122(h)(1), §72.122(h)(4), §72.122(h)(5), §72.122(i), §72.122(l), §72.124(a), and §72.128(a)(2). Complete citations of these regulations are provided in the Appendix of this SER.

The proposed ISFSI must be sited, designed, constructed, and operated such that the above-mentioned regulatory requirements are met to adequately protect public health and safety during all credible off-normal and accident events.

15.1.1 Off-Normal Events

This section of the SER documents the staff's review of potential off-normal conditions arising from facility operations, as described in Section 8.1 of the SAR. According to American National Standards Institute/American Nuclear Society (ANSI/ANS) 57.9 (American National Standards Institute/American Nuclear Society, 1992), the off-normal events, referred to as Design Event II, are those events expected to occur with moderate frequency or approximately once per calendar year. The staff reviewed the information given in the SAR to ensure that all relevant off-normal events are considered in accordance with the guidance in NUREG-1567 (U.S. Nuclear Regulatory Commission, 2000) and evaluated with respect to appropriate regulations. Six off-normal events addressed in the SAR are discussed in this section of the SER.

15.1.1.1 Off-Normal Pressures

The staff reviewed the information presented in Sections 4.2.3.3.2.2 and 8.1.1 of the SAR, Holtec calculation package HI-2033033 (Holtec International, 2004a), and the applicant's response to a request for additional information (Pacific Gas and Electric Company, 2004b), to assess the applicant's analysis of the off-normal pressure event.

The SAR indicates that an off-normal pressure within the MPC-HB is caused by the release of gases from a nonmechanistic rupture of fuel rods. The MPC-HB, which is the sole pressure boundary for the HI-STAR HB storage cask, is seal-welded and designed in accordance with Interim Staff Guidance 18 (ISG-18, U.S. Nuclear Regulatory Commission, 2003a). Consistent with the guidance provided in NUREG-1536 (U.S. Nuclear Regulatory Commission, 1997) and ISG-5 (U.S. Nuclear Regulatory Commission, 2003b), the applicant evaluated off-normal pressure by considering the breakage of 10 percent of the fuel rods and assuming that a breach of a fuel rod releases 30 percent of the radioactive gas and 100 percent of the fill gas in the rod. These released gases are added to the initial helium fill in the MPC-HB cavity. The applicant computed the resulting MPC-HB internal pressure, and the analysis showed that the evaluated internal pressure is bounded by the MPC-HB off-normal design pressure of 0.76 MPa gauge [110 psig], as given in Table 3.4-2 of the SAR.

The staff reviewed the analysis given in calculation package HI-2033033 and the supporting calculations provided in response to a request for additional information. The staff finds that the applicant used standard methodology, and appropriate assumptions and data for evaluating the off-normal pressure event. The staff considers the information provided to be adequate to support the applicant's assessment of off-normal pressure. The confinement and shielding of the HI-STAR HB cask system are not affected by this off-normal event because the off-normal pressure is within the MPC-HB design pressure. As a result, no radiological consequence is expected, and the shielding capability of the MPC-HB will not be compromised from the off-normal pressure event.

The staff concludes, based on the foregoing evaluation, that the off-normal pressure will not impair the ability of the structures, systems, and components (SSCs) important to safety to maintain subcriticality, confinement, and sufficient shielding. The applicant's evaluation provides adequate assurance that operations at the proposed Humboldt Bay ISFSI can be conducted without endangering the health and safety of the public.

15.1.1.2 Off-Normal Environmental Temperatures

The staff reviewed the information presented in Section 8.1.2 of the SAR for this event. The staff also reviewed the thermal analysis presented in Section 4.2.3.3.5 of the SAR and in the calculation package HI-2033033 (Holtec International, 2004a).

The applicant evaluated the impact of off-normal ambient temperature on interim storage of the HI-STAR HB overpack in the vault. The normal (average annual) and off-normal environmental temperatures at the proposed Humboldt Bay ISFSI site, as given in Table 3.2.3 of the SAR, are 11 °C [52 °F] and 16 °C [60 °F], respectively. The environmental temperature during the off-normal condition is elevated by 5 °C [8°F]. As discussed in Section 6.1.4 of this SER, through confirmatory analysis the staff determined that, under normal conditions, the temperature of all the materials of the SSCs important to safety are within the applicable temperature limits. Based on this analysis, the staff concludes that the cladding temperature rise due to off-normal environmental temperature will not exceed the maximum allowable off-normal temperature limit of 570 °C [1,058 °F], as described in Interim Staff Guidance 11, "Cladding Considerations for the Transportation and Storage of Spent Fuel," Rev. 2 (U.S. Nuclear Regulatory Commission, 2003c).

The applicant considered the evaluation of brittle fracture of overpack material at low off-normal environmental temperatures for the previously-licensed HI-STAR 100 storage cask (U.S. Nuclear Regulatory Commission, 2001a,b) as the bounding analysis for the HI-STAR HB cask. These results are applicable because both cask systems use the same material and design standards. The brittle fracture of the HI-STAR 100 cask material was evaluated at an environmental temperature of −40 °C [−40 °F] with no solar insolation (Holtec International, 2002). This limiting temperature bounds the temperature ranges expected at the Humboldt Bay ISFSI site, as indicated in Section 2.3.1.1 of the SAR.

The staff concludes that the HI-STAR HB design criteria bound both the temperature and insolation values expected at the Humboldt Bay ISFSI site. Thus, the integrity of the confinement and shielding capability of the HI-STAR HB system is not affected by this event. As a result, no radiological consequences are expected from this event, and neither temperature monitoring for detecting this event nor corrective actions are required.

Based on the foregoing evaluation, the staff concludes that off-normal environmental temperatures will not impair the ability of SSCs important to safety to maintain subcriticality, confinement, and sufficient shielding. The applicant's evaluation provides adequate assurance that operations at the proposed Humboldt Bay ISFSI can be conducted without endangering the health and safety of the public.

15.1.1.3 Confinement Boundary Leakage

Leakage from the MPC-HB confinement boundary as an off-normal event is not considered credible because the MPC-HB design meets all criteria in ISG-18 (U.S. Nuclear Regulatory Commission, 2003a). Evaluation of a confinement boundary leakage event is discussed in Section 15.1.2.8 of this SER.

15.1.1.4 Cask Drop Less Than Design Allowable Height

The staff reviewed the information presented in Section 8.1.4 of the SAR. Additionally, the staff reviewed the information on the transporter design in Sections 3.3.3 and 4.3 of the SAR. A potential drop of the HI-STAR HB cask from less than the design allowable height can only occur during onsite transfer of the cask from the RFB to the ISFSI. The overpack is suspended vertically from the transporter during transit. The applicant precluded this event on the basis of the cask transporter and the cask lifting trunnion designs.

As discussed in Section 5.1.4 of this SER, the staff determined that the cask transporter design bases, including the load supporting components (e.g., lift links, connector pins, and lift beam), comply with the single-failure-proof design requirements in accordance with NUREG-0612 (U.S. Nuclear Regulatory Commission, 1980) and ANSI N14.6 (American National Standards Institute, 1993). The applicant also indicated that the transporter, which is classified as important to safety, will have redundant drop protection features in conformance with NUREG-0612 to prevent load drops.

The overpack is handled by the two lifting trunnions attached to the overpack, as shown in Figure 3.3-3 of the SAR. The force from the loaded overpack is transmitted to the transporter by the trunnions and the lift links attached to the trunnions. Section 4.2.3.3.2.1 of the SAR states that the lifting trunnion of the HI-STAR HB cask system meets the single-failure-proof requirements of NUREG-0612 (U.S. Nuclear Regulatory Commission, 1980) and ANSI N14.6 (American National Standards Institute, 1993). This statement is based on the similarity of the trunnion design with that of the HI STAR 100 cask (Holtec International, 2002). In addition, the applicant indicated that the design basis live load for the HI-STAR 100 cask system bounds that for the HI-STAR HB cask system. As discussed in Section 5.1.4.4 of this SER, the staff determined that the lifting flange at the trunnions and the trunnion/overpack interface region for the HI-STAR HB cask satisfy the single-failure-proof design criteria in accordance with NUREG-0612 and ANSI N14.6.

Based on the foregoing evaluation, the staff concludes that the cask drop from less than the allowable drop height as a potential event will not impair the ability of SSCs important to safety to maintain subcriticality, confinement, and sufficient shielding. The applicant's evaluation provides adequate assurance that the operations at the Humboldt Bay ISFSI can be conducted without endangering the health and safety of the public.

15.1.1.5 Loss of Electrical Power

The staff reviewed the information presented in Section 8.1.5 of the SAR. The total loss of external alternating current power is postulated to occur during facility operations. Electrical power may be lost at the proposed Humboldt Bay ISFSI because of natural phenomena, such as lightning, high wind, or as a result of failure of the electrical distribution system or equipment. The loss of electrical power will be detected through the loss of functions of the electric-powered equipment.

Lifting and attaching the HI-STAR HB storage cask to the transporter outside the RFB will not be affected by the loss of power because these operations will be conducted by the cask transporter, which is driven by an on-board diesel engine. Similarly, transferring and lowering the cask into the vault at the proposed ISFSI storage site are also conducted using the cask transporter and, therefore, do not involve using electric power. Electrical power is also not required during interim storage of the cask inside the storage vault. As a result, MPC-HB confinement and overpack shielding are not compromised by a loss of electrical power.

Based on the foregoing evaluation, the staff concludes that loss of power during ISFSI operations will not impair the ability of SSCs important to safety to maintain subcriticality, confinement, and sufficient shielding. The applicant's evaluation provides adequate assurance that the operations at the proposed Humboldt Bay ISFSI can be conducted without endangering the health and safety of the public.

15.1.1.6 Cask Transporter Off-Normal Operation

The staff reviewed the information provided in Section 8.1.6 in the SAR. Several off-normal events can occur involving the cask transporter, including driver error or incapacitation, failure because of mechanical problems, or loss of hydraulic fluid in the transporter hydraulic system.

The cask transporter, which is classified as important to safety, will be used to lift, handle, and transport a loaded HI-STAR cask during ISFSI operations. The transporter with a loaded cask will travel a distance of approximately 384 m [0.24 mi] along the transporter route from the RFB to the proposed ISFSI storage site and will take approximately 0.6 hours per trip. At the ISFSI site, the transporter will lower the cask into the storage vault. As discussed in Section 8.1.6 of the SAR, a support team will walk alongside the transporter during transfer of the cask from the RFB to the storage site and will detect driver error or incapacitation at the sight of driver distress or swerving of the transporter. The support personnel have the capability to stop the transporter using stop switches located outside the transporter. The transporter is also equipped with automatic shutoff control to stop the vehicle in the event the driver is unable to function because of a medical emergency. The same control will also be used for emergency stops when lowering casks into the storage vault. In addition, a selector switch ensures that the transporter only performs one function at a time to reduce any potential human error. As discussed by the applicant, engine failure will stop the transporter if it is in motion or engage hydraulic brakes to stop lifting or lowering operations. Hydraulic system failure will be detected by the onboard instrumentation, and any loss of hydraulic fluid will also engage hydraulic brakes to stop lifting or lowering operations. Additionally, the transporter is designed to operate in a "fail-safe" mode. As a result, the applicant precludes any uncontrolled lowering of a loaded cask during operations. The staff concludes that implementation of the transporter design features and operational procedures, as discussed by the applicant, will likely prevent cask drops caused by human errors or failure of the transporter engine or hydraulic system. Thus, off-normal events associated with cask transporter operation are not expected to cause a radiological dose because the confinement and shielding of SNF will not be affected.

Based on the foregoing evaluation, the staff concludes that the cask transporter off-normal operation will not impair the ability of SSCs important to safety to maintain subcriticality, confinement, and sufficient shielding. The applicant's evaluation provides adequate assurance that the operations at the proposed Humboldt Bay ISFSI can be conducted without endangering the health and safety of the public.

15.1.2 Accidents

This section of the SER discusses results from reviewing potential accident events, as described in Section 8.2 of the SAR, arising from natural phenomena and facility operations. The accident events, referred to as Design Events III and IV (American National Standards Institute/American Nuclear Society, 1992), are those events expected to occur infrequently during the lifetime of the facility. Review of the accident analysis focused on the effects of natural phenomena and human-induced events on SSCs important to safety. Analytical techniques, uncertainties, and assumptions in the SAR and supporting documents were examined. Each event was reviewed with a focus on (i) the cause of the event, (ii) the means to detect the event, (iii) an analysis of the consequences and the protection provided by devices or systems designed to limit the extent of the consequences, and (iv) any actions required by the operator.

The SAR includes a discussion of potential accidents resulting from both external natural and human-induced events at the proposed facility. Sections 15.1.2.1 to 15.1.2.14 of this SER discuss the evaluation of 14 accidents addressed in the SAR. In addition, an aircraft crash hazard, discussed in Section 2.2 of the SAR, is evaluated in Section 15.1.2.15 of this SER.

15.1.2.1 Earthquake

The staff reviewed the information presented in Section 8.2.1 of the SAR. In addition, the staff reviewed information presented in Sections 2.6.6, 3.2.4, and 4.3.2.2 of the SAR. The staff also reviewed information presented by the applicant in response to the request for additional information (Pacific Gas and Electric Company, 2004b).

Seismic Evaluation of Operations Involving the Cask Transfer Rail Dolly

As described in Section 4.3.2.2 of the SAR, a cask-transfer rail dolly is used to transfer the HI-STAR HB cask in and out of the RFB along a rail system. The rail dolly is a circular steel plate fitted with two rows of heavy capacity rollers that raise the HI-STAR HB cask approximately 23 cm [9 in]. The rail system is fabricated from standard railroad track with C-channels welded to the top of the rails to accommodate the rollers. The length of the rail system is sufficient for the davit crane to handle the HI-STAR HB cask inside the RFB and to allow room for the cask transporter to lift the HI-STAR HB cask outside the RFB.

Operations associated with the rail dolly include transfer of the empty HI-STAR HB cask into the RFB. After the MPC-HB is loaded and sealed, the HI-STAR HB cask will be transferred outside the RFB on the rail dolly such that the HI-STAR HB cask lifting trunnions can be attached to the transporter lift links and the loaded overpack lifted off the rail dolly and supported by the cask transporter.

The process of moving the HI-STAR HB cask on the rail dolly into the RFB and then back out after the SNF is loaded is expected to take less than one hour per cask. The applicant has conservatively assumed 0.5 day (12 hours) per cask. The applicant considered the occurrence of a 14-year return period earthquake during this operation, as described in Section 3.2.4 of the SAR. The applicant, however, conservatively analyzed for the full deterministic design basis earthquake (DBE) ground motions in order to impose the maximum demand load on the system (Holtec calculation package HI-2033046, Holtec International, 2004g). The dynamic simulation of the HI-STAR HB cask on the rail dolly was performed using Visual Nastran (MSC Software Corporation, 2001), where components were modeled as rigid bodies. The simulation results show that the rail dolly will tilt and the HI-STAR HB cask will slide off the rail dolly and overturn under the DBE ground motion. The applicant determined that the decelerations experienced by the contained fuel during the overturning and subsequent ground impact will not exceed the HI-STAR HB cask design basis limit of 60 g. The contained SNF and the HI-STAR HB cask, therefore, meet all the design basis requirements for the system.

To demonstrate the integrity of the MPC-HB internal components during the DBE, the applicant performed an analysis for a lateral deceleration of 60 g, the design basis deceleration for the HI-STAR HB cask as given in Holtec calculation package HI-2033035 (Holtec International, 2004i). The estimated safety factors of the confinement boundary of the MPC-HB and the fuel basket were shown to be greater than 1.0. In addition, the applicant evaluated the adequacy of the lid restraint system during a tipover event in Holtec calculation package HI-2033042 (Holtec

International, 2004b). Results of this analysis show that the lid restraint system will remain in place and contain the fuel within the fuel basket during a tipover.

The analyses performed by the applicant are based on a tipover of the HI-STAR HB cask onto a substrate impact surface assuming the effective Young's Modulus of the substrate and any concrete or asphalt overlay to be less than or equal to 193 MPa [28,000 psi] (Pacific Gas and Electric Company, 2005). The safety factor for the MPC-HB confinement boundary appears to be sufficient to ensure that the confinement boundary will not be breached during a tipover event, assuming 60 g is the peak deceleration. The safety factors associated with the fuel basket and the lid restraint are such that these systems may be damaged during a tipover of the HI-STAR HB cask onto the substrate at decelerations greater than 60 g. Therefore, the effective Young's Modulus of the substrate plus any concrete or asphalt overlay shall be carefully monitored during the construction process to assure that it is less than or equal to 193 MPa [28,000 psi].

The applicant has provided sufficient documentation to demonstrate the validation of the Visual Nastran (MSC Software Corporation, 2001) code for dynamic simulations of nonlinear systems under seismic events. The staff, therefore, concurs with the findings of the applicant for the tipover of the HI-STAR HB cask under a seismic event. The structural analysis presented by the applicant gives reasonable assurance that the rail dolly and HI-STAR HB cask can withstand a DBE without impairing the capability of these components to perform their safety functions.

Seismic Evaluation of Cask Transfer to ISFSI

This section discusses the seismic stability evaluation of the cask transporter used at the Humboldt Bay ISFSI site. After the HI-STAR HB cask exits the RFB on the rail dolly, the HI-STAR HB lifting trunnions will be attached to the transporter lift links, and the overpack will be lifted off the rail dolly. The lift links, slings, and rigs are designed as nonredundant lifting devices to meet the NUREG-0612 (U.S. Nuclear Regulatory Commission, 1980) stress limits for nonredundant special lifting devices. A restraining strap will be used to secure the overpack to the transporter. The design of the restraining straps is based on a minimum factor of safety of 5 on ultimate strength.

The cask transporter moves the HI-STAR HB cask from the RFB along the transfer route to the storage vault approximately 385 m [0.24 mi] with an incline grade of less than 8.5 percent (nominal). While this transfer is expected to take less than 1 hour per cask, the applicant conservatively used 0.5 day (12 hours) per cask for this operation. The applicant estimated the occurrence of a 14-year return period earthquake during transfer, as described in Section 3.2.4 of the SAR. The seismic evaluation of the transporter during cask transfer, however, is based on a 50-percent DBE ground motion, which equates to a greater than 50-year return period earthquake.

The applicant evaluated transporter stability while carrying a loaded overpack using the computer code Visual Nastran (MSC Software Corporation, 2001). Simulations were performed for the loaded transporter on level ground and on the design basis grade for the path from the RFB to the ISFSI site. The HI-STAR HB cask is supported by two lift links that were assigned an appropriate spring stiffness reflecting anticipated system elasticity in the vertical direction. The HI-STAR HB cask and the cask transporter are modeled as solid bodies. The HI-STAR HB cask is assumed to be restrained from motion relative to the transporter. The driving seismic inputs are applied as known inertia forces proportional to the DBE ground acceleration time histories at the mass centers of the HI-STAR HB cask and the transporter, respectively. Results from the dynamic simulations were used to demonstrate that the transporter carrying the loaded cask will not overturn and will not depart from the roadway. Details of the analysis are presented in Section 8.2.1.2.2 of the SAR and in Holtec calculation package HI-2033036 (Holtec International, 2004c). As discussed in Section 2.1.6.5 of this SER, the stability of the slope at the critical location close to the discharge canal along the transporter route will not be impaired due to a seismic event during cask transfer.

The staff, therefore, finds that the transporter loaded with a HI-STAR HB cask will remain stable under postulated seismic conditions during cask transfer from the RFB to the ISFSI site.

Seismic Evaluation of Lowering the Casks into the Vault

This section discusses the seismic stability evaluation of the cask transporter while lowering the cask into the storage vault at the proposed Humboldt Bay ISFSI site. Following transfer of the HI-STAR HB cask to the storage vault, the cask will be lowered into its storage cell in the vault. This process is performed by the cask transporter and is conservatively estimated to take 0.5 day (12 hours) per cask. As stated in Section 3.2.4 of the SAR, the occurrence of an earthquake during cask lowering operations is bounded by a return period of 14 years. The actual analysis, however, is performed with a time history equal to 25 percent of the DBE, which is equivalent to an earthquake with a return period in excess of 25 years. The analysis, conducted using Visual Nastran (MSC Software Corporation, 2001), shows that the transporter slides no more than 4 cm [1.6 in] (SAR Table 8.2-3), which is less than the clearance between the overpack and the vault cell walls. As discussed in Section 5.1.4.4 of this SER, the lift links, slings, and rigs are designed as nonredundant lifting devices, meeting the requirements of NUREG-0612 (U.S. Nuclear Regulatory Commission, 1980) stress limits. The HI-STAR HB cask, therefore, will not drop from the transporter if an earthquake takes place during cask lowering operations. The staff concurs with the conclusions drawn by the applicant for operations associated with lowering the HI-STAR HB cask into the storage vault using the transporter.

The staff finds that the structural analysis demonstrates that the transporter and HI-STAR HB cask can withstand the effects of natural phenomena, such as 25-percent DBE, in that the system will not be placed in an unanalyzed condition that may cause the cask to drop into the storage vault.

Seismic Evaluation of the HI-STAR HB Overpack Restrained in the ISFSI Storage Vault

Loads from the restraint of movement of the storage casks during a design basis seismic event are transmitted to the walls of the vault through seismic restraint shims. The loads are determined by modeling a loaded cask, the cylindrical walls and the floor of a cask pit in the vault, and the top and bottom shims. The vault behavior is driven by the time history of ground accelerations associated with the DBE and the resulting equations of motion solved using direct integration in the time domain. Visual Nastran (MSC Software Corporation, 2001) was used for the dynamic simulation of the HI-STAR HB cask system inside the vault cavity. The results for the shim loading at each of the shims (eight each, top and bottom) used to restrain the cask in a vault cask pit (cell) are determined at each instant of time during the simulation and include the effect of the clearance gap between the shims and the cask body. Analyses details are presented in Section 8.2.1.2.4 of the SAR. Holtec calculation package HI-2033013, Appendix E (Holtec International, 2004h) also presents an analysis of the seismic impact of the HI-STAR HB cask seismic restraints. The demand stress is shown to be less than the allowable stress. The staff finds that the HI-STAR HB cask restraint shims maintain the ability to transfer load during a seismic event.

Based on the foregoing evaluation, the staff concludes that the seismic evaluation of the (i) operations involving the cask transfer rail dolly, (ii) cask transfer to the ISFSI site, (iii) lowering of the cask into the vault, and (iv) HI-STAR HB overpack restraints in the ISFSI storage vault will not impair the ability of SSCs important to safety to maintain subcriticality, confinement, and sufficient shielding. The applicant's evaluation provides adequate assurance that operations at the proposed Humboldt Bay ISFSI can be conducted without endangering the health and safety of the public.

15.1.2.2 Tornadoes and Missiles Generated by Natural Phenomena

The staff reviewed the information presented in Sections 2.3.1.4, 3.2.1, 4.2.3.3.2.6, and 8.2.2 of the SAR. This evaluation assumed that site personnel will not have any prior warning before the facility SSCs are impacted by a potential design basis tornado and a tornado missile.

Characteristics of the design basis tornado and tornado missile are given in Section 3.2.1 of the SAR. The SAR developed the characteristics of the design basis tornado in accordance with Regulatory Guide 1.76 (U.S. Nuclear Regulatory Commission, 1974). The proposed site is located within Region II, as defined in Regulatory Guide 1.76. The design basis tornado for Region II is defined as a tornado with a maximum wind speed of 480 kmph [300 mph], a rotational speed of 384 kmph [240 mph], a translational speed of 96 kmph [60 mph], a radius of maximum rotational speed of 45 m [150 ft], and a 15.5-kPa [2.25-psi] pressure drop at a rate of 8.3 kPa/s [1.2 psi/s]. For the period 1950 to 1995, the Eureka area experienced one tornado, which occurred on March 29, 1958. This tornado was an F2 with wind speed between 181 and 251 kmph [113 and 157 mph]. The highest recorded peak wind gust at the Humboldt Bay Power Plant (HBPP) site is 110 kmph [69 mph].

The design basis tornado missiles are based on Spectrum I missiles of Section 3.5.1.4 of NUREG-0800 (U.S. Nuclear Regulatory Commission, 1981a). These missiles include an automobile with a weight of 1,800 kg [4,000 lb], a 200-mm [8-in] diameter, 125-kg [275-lb] armor-piercing artillery shell, and a 25-mm [1-in]-diameter solid steel sphere. It is assumed, based on Section 3.5.1.4 of NUREG-0800, that all three missiles will impact at 35 percent of the maximum horizontal wind speed of the design basis tornado {i.e., 122 kmph [105 mph]}. The first two missiles are assumed to impact at normal incidence. The last missile impinges on the barrier openings in the most damaging directions. These objects are postulated to be picked up and transported by the winds of a design basis tornado.

SSCs important to safety that may be affected by design basis tornado missiles are (i) HI-STAR HB storage casks during transfer from the RFB to the ISFSI, lowering into the vault, and interim storage in the vault; (ii) the site transporter; and (iii) the storage vault. These SSCs are required to function during this design basis event.

The HI-STAR 100 storage cask (Holtec International, 2002) is designed to withstand a 576 kmph [360 mph] tornado with a 20.7 kPa [3.0 psi] instantaneous pressure drop. Additionally, it is designed to withstand a 200-mm [8-in]-diameter artillery shell weighing 125 kg [275 lb] impacting at a speed of 202 kmph [126 mph], a solid sphere of 25-mm [1-in] diameter weighing 0.22 kg [0.49 lb] impacting at a speed of 202 kmph [126 mph], and a 1,800-kg [4,000-lb] automobile with a velocity of 202 kmph [126 mph]. These parameters bound the proposed facility design basis tornado and tornado missiles characteristics. The applicant stated in the SAR that the HI-STAR HB system will also be able to withstand impacts from these design basis tornado and tornado-generated missiles because of the similarity of its design with the HI-STAR 100 system. The HI-STAR HB overpack is shorter, lighter, and has a lower center of gravity than the HI-STAR 100 system. Materials of construction of structural components will be the same for both (Pacific Gas and Electric Company, 2004a); therefore, it is anticipated that the HI-STAR HB system will be able to withstand the design basis tornado and tornado missile loads and, consequently, will be able to withstand the tornadoes and tornado-generated missiles at the proposed ISFSI site.

The applicant will evaluate the predicted weather conditions before commencing transfer of a loaded cask to the storage vault (Pacific Gas and Electric Company, 2004b). The impact of a tornado missile from a design basis tornado during transfer, therefore, is not considered credible. Section 4.3.2.1.2 of the SAR states that the cask transporter is designed to prevent overturning by the design basis tornado wind and on impact by a design basis tornado missile, as specified in Table 3.4-1 of the SAR. The applicant proposes to use the same cask transporter licensed for use at the Diablo Canyon ISFSI (SAR Section 4.3.2.1). During the licensing review of the Diablo Canyon ISFSI, the staff concluded that the transporter will not tipover due to an impact from a larger tornado-generated missile (i.e., a 1,800-kg [4,000-lb] car traveling at a speed of 202 km/hr [126 mph]) (U.S. Nuclear Regulatory Commission, 2004). The staff, therefore, concludes that the cask transporter proposed to be used in this facility will remain stable during a design basis tornado event.

During interim storage in the below grade vault, the vault structure provides additional protection to the storage casks from an impact of tornado missiles. The vault is a massive reinforced concrete structure; each of the 6 storage cells is covered with a thick concrete lid enclosed in steel. The applicant anticipates some localized denting of the vault lid and spalling at the vault apron from a direct vertical hit by a tornado missile; however, no structural damage that could be detrimental to the continued storage or retrieval of the storage casks is expected. Each lid is approximately 41.3 cm [16.25 in] thick (SAR Figure 3.2-1). Therefore, the lid will be able to withstand any direct impact of a tornado-generated missile, based on Section 3.5.3 of NUREG-0800 (U.S. Nuclear Regulatory Commission, 1981b). Additionally, it is expected that concrete spalling, if any, will not prevent the retrieval of the storage casks from the vault.

The staff reviewed the information provided by the applicant and evaluated the analyses of potential hazards from design basis tornadoes and tornado missiles at the proposed facility. The staff finds the information and analyses acceptable because:

- The characteristics of tornadoes and tornado missiles for the proposed site have been adequately assessed.

- Acceptable methodologies have been used to characterize the design basis tornadoes and tornado missiles for the proposed site.

- SSCs important to safety that may be affected by the design basis tornados and tornado missiles have been identified.
- The storage cask is adequately designed to withstand postulated tornado wind loads and loads imparted by the postulated tornado missiles.
- The cask transporter is designed to preclude tipover if impacted by a design basis tornado-driven missile.
- The storage vault is designed to withstand a design basis tornado and associated missiles without losing the ability to perform its intended safety function.

The information presented in the SAR demonstrates that appropriate methodologies have been adopted to investigate the potential tornado severity and frequency at the proposed site along with the associated missile hazards. The applicant has identified the severity of hazards associated with a design basis tornado for the proposed site and incorporated it into the design of the affected SSCs. The information presented is sufficient to conclude that the design of the affected SSCs is adequate to withstand the design basis tornado loadings and the associated tornado missiles such that the SSCs important to safety will be protected.

Based on the foregoing evaluation, the staff finds that a tornado or tornado-generated missile will not impair the ability of the SSCs important to safety to maintain subcriticality, confinement, and sufficient shielding of the stored fuel. The applicant's evaluation provides adequate assurance that operations at the proposed Humboldt Bay ISFSI can be conducted without endangering the health and safety of the public.

15.1.2.3 Flood

The staff reviewed the information in Sections 2.4 and 8.2.3 of the SAR relating to floods.

As discussed in Section 2.1.4 of this SER, the freeboard estimated for the proposed ISFSI site during probable maximum flood is 10 m [34 ft], and the applicant demonstrated that local natural and man-made drainage systems are sufficient to prevent potential flooding of the proposed storage site. If the ISFSI site were to flood, the ISFSI vault could withstand a 1.83-m [6-ft] static head of water, as indicated in Section 4.1.3.2 of this SER. Based on the elevation and historic data, the applicant does not consider flooding as a credible event at the proposed Humboldt Bay ISFSI site or during cask transfer to the ISFSI site.

Section 5.1.5 of the proposed Technical Specifications (Pacific Gas and Electric Company, 2004c, Attachment C) states that prior to cask transfer, the potential for severe weather during the transfer will be evaluated. Additionally, as discussed in Section 4.1.3.2 of this SER, the HI-STAR HB cask system is designed to withstand the design-basis water pressure {water head of 200 m [656 ft]} and horizontal load {flow velocity of 4 m/s [13 ft/s]} associated with floods based on the similarity of its design with the HI-STAR 100 system (Holtec International, 2002). The staff, therefore, concludes that the proposed ISFSI can withstand the effects of floods, and the containment, criticality, and shielding capabilities of the HI-STAR HB system will not be affected.

Based on the foregoing evaluation, the staff concludes that any credible flood event will not impair the ability of SSCs important to safety to maintain subcriticality, confinement, and sufficient shielding. The applicant's evaluation provides adequate assurance that the operations at the proposed Humboldt Bay ISFSI can be conducted without endangering the health and safety of the public.

15.1.2.4 Tsunami

The staff reviewed the information on tsunami hazards in Section 8.3.4 of the SAR. Additional information regarding tsunami hazards is given in Section 2.4.5 of the SAR. A detailed analysis of the potential tsunami hazards at the site is provided in Section 2.6.9 of the SAR. Details of the staff's review of the tsunami hazard assessment are given in Section 2.1.4.6 of this SER.

Based on the staff's review described in Section 2.1.4.6 of this SER, the staff agrees that the proposed ISFSI vault is located at an elevation higher than expected run-up from a potential tsunami. The staff notes that even if the tsunami runup were to overtop the vault, there is no dose consequence because the HI-STAR HB casks are protected from tsunami-generated flowing water and water-born debris within the vault. The staff also concurs with the applicant's assessment that a tsunami accident is not credible for transient operations. During cask transfer or cask handling at the vault, the staff agrees with the applicant that the 50-year return period earthquake, which constitutes the design basis for these transient operations, is too small to generate a tsunami at the HBPP. The staff, therefore, concludes that the applicant's analysis provides reasonable assurance that the containment, criticality, and shielding capabilities of the HI-STAR HB system will not be affected by a tsunami.

Based on the foregoing evaluation, the staff concludes that a tsunami will not impair the ability of SSCs important to safety to maintain subcriticality, confinement, and sufficient shielding. The applicant's evaluation provides adequate assurance that the operations at the proposed Humboldt Bay ISFSI can be conducted without endangering the health and safety of the public.

15.1.2.5 Fire

The staff has reviewed the information on fire hazards presented in Section 8.2.5 of the SAR, and in Holtec Report HI-2033006, "Evaluation of Fires for the HBPP ISFSI," (Holtec International, 2004d). Additional information presented in Sections 2.2.2.2.1, 2.3.1.4, 3.2.6, 4.2.3.3.3, 4.2.3.3.4, and 4.6 of the SAR was also reviewed. The review was performed to ensure that the SSCs important to safety exposed to credible fires are designed and located such that they perform their intended safety functions. This review includes safety against potential fires during cask transfer and interim storage in the vault.

Potential locations within the proposed ISFSI site where a fire may affect SSCs important to safety that fall within the purview of the 10 CFR Part 72 review are the transfer route from the RFB to the storage vault and at the storage vault itself. The applicant discussed the fire hazards at the proposed facility by categorizing them as either engulfing or nonengulfing fires. Classifying a fire as engulfing or nonengulfing is a function of the fuel quantity and proximity to the cask.

Engulfing Fire Scenarios

The applicant has identified two engulfing fire scenarios at the proposed ISFSI site. These scenarios are:

(1) Fire from fuel tanks of the cask transporter and other onsite vehicles

(2) Fire inside the storage vault

Cask Transporter and Other Onsite Vehicle Fuel Tanks

The applicant states that the capacity of the fuel tank of the cask transporter is 189 L [50 gal] of diesel fuel, which bounds the tank capacities of other onsite vehicles. Based on the information presented by the applicant, the capacity of other onsite vehicles is generally not more than 76 L [20 gal]. The bounding engulfing fire scenario for all onsite vehicles, therefore, will be a spill of the entire 189 L [50 gal] of diesel fuel from the tank of the transporter and the subsequent ignition at the transporter itself. It has been assumed that the fire occurs during cask transfer or lowering operations.

The applicant analyzed this scenario as a fire engulfing the storage cask (Holtec International, 2004d, HI-2033006). Results of this analysis show that the estimated burn time for 189 L [50 gal] of diesel will be less than 5 minutes. The similar HI-STAR 100 cask has been designed as a dual-purpose cask for both storage and off-site transportation and, therefore, has been demonstrated to meet the requirements of 10 CFR §71.73(c)(4) (Holtec International, 2002). The regulation 10 CFR §71.73(c)(4) requires that a transportation cask shall be able to perform its safety functions following an engulfing pool fire of 30-minutes duration. The staff finds that the HI-STAR HB cask is sufficiently similar in design to the HI-STAR 100 cask with respect to short-duration heat transfer behavior; therefore, similar fire resistance can be expected.

The applicant conducted an additional analysis of an engulfing fire with duration of 30 minutes (Holtec International 2004d, HI-2033006, Scenario F-11). The postfire duration for estimating the temperatures was selected to be 12 hours to allow the development of peak temperatures. The estimated peak temperatures from this engulfing fire are given in Table 8.2-11 of the SAR. The applicant provided updated values for Table 8.2-11 to reflect higher temperatures for some of the cask system components (Pacific Gas and Electric Company, 2005). Temperatures of all steel components and spent fuel cladding are less than their short-term temperature limits. In particular, the MPC-HB confinement boundary and the seals of the overpack remain below their short-term temperature limits from this design basis fire. The short-term design temperatures of 177 °C [350 °F] for the Holtite-A neutron shield material in the overpack, however, would be exceeded. Because there are no radioactive materials present in the annulus, loss of the helium retention boundary will not produce a dose consequence. As with most "thermally thick" objects, the time to reach the peak temperature is well after the fire event has expired. For example, as calculated by the applicant (Holtec International 2004d, HI-2033006), a 30-minute duration fire will result in peak temperatures after 370 minutes. It is expected that some cooling may take place following exposure to the fire that could reverse the heat flow into the cask, resulting in lower peak temperatures. The estimated temperatures, therefore, are conservative as the calculations neglected these potential cooling effects. Nevertheless, the applicant provided a shielding analysis in Holtec calculation package HI-2033047 (Holtec International, 2004e), that assumes a complete loss of the radial neutron shield of the HI-STAR HB overpack.

This analysis has been reviewed in Section 7.1.5 and the results evaluated in Section 11.1.3.2 of this SER. The shielding effectiveness of the steel structure of the cask is not significantly reduced for this fire scenario. The applicant proposes to place temporary shielding around the affected areas and to implement recovery activities as necessary to restore radiation doses to acceptable levels within 30 days. The HI-STAR HB cask can be expected to maintain its intended safety functions during and after an engulfing fire scenario discussed above.

Fire Inside Storage Vault

The onsite transporter must enter the proposed vault area to place the loaded casks inside the storage vault. One hypothetical engulfing fire accident scenario involves a fire as the cask is being lowered into the vault. This scenario assumes the transporter tank ruptures while lowering the casks into the vault and that spilled fuel enters the vault and ignites inside. The fuel source for this scenario is conservatively assumed to be the entire 189 L [50 gal] of diesel fuel onboard the transporter.

The geometric characteristics of the vault provide only a 15.24-cm [6-in] clearance between the outer skin of the cask and the inner wall of the vault. This small clearance will not allow the complete combustion of a pool of diesel fuel at the bottom of the vault due to insufficient air circulation to support complete combustion. Consequently, this scenario is bounded by the scenario of open engulfment of the cask from a fire initiated by the rupture of the transporter tank previously discussed. Therefore, any potential fire at the storage vault will not impair the intended safety functions of any SSCs important to safety.

Nonengulfing Fire Scenarios

The applicant has identified the following sources of combustibles that have the potential to generate credible nonengulfing fire scenarios:

(1) Stationary fuel and diesel oil tanks

(2) Fuel or diesel oil tanker truck with a fuel capacity of 28,390 L [7,500 gal]

(3) Gasoline tanker truck with a fuel capacity of 11,340 L [3,000 gal] and a gasoline storage tank with a fuel capacity of 454 L [120 gal]

(4) Propane storage tank

(5) Propane tanker truck

(6) Mineral oil from the Unit 3 main bank transformers

(7) Natural gas pipeline

(8) Surrounding vegetation

(9) Barge in the bay with a fuel capacity of 10,334,000 L [65,000 barrels]

(10) Combustion of other local combustible materials

Stationary Fuel Oil and Diesel Oil Storage and Service Tanks

The applicant states that all stationary fuel oil storage and service tanks are located at a distance of more than 69 m [230 ft] from the proposed ISFSI storage vault and are surrounded by berms. Based on Fire Protection Association Handbook (National Fire Protection Association, 1997), the flash point of a liquid must be less than 37.8 °C [100 °F] to be classified as a flammable liquid. The No. 6 fuel oil stored in these above-ground tanks has a flashpoint of 65.5 °C [150 °F] and has a high viscosity at the average ambient temperature encountered at Humboldt Bay. The fuel has an auto ignition temperature of 407 °C [765 °F], making it not readily ignitable. Similarly, the flash point of diesel oil is 51.7 °C [125 °F]. Additionally, there is lack of ignition sources in the vicinity of the proposed facility. Although all this information suggests that a spill leading to an ignition of the No. 6 fuel oil and diesel fuel oil is an unlikely scenario, the applicant, nevertheless, analyzed potential nonengulfing fires from each of these storage tanks because of moderate fire ratings of both No. 6 fuel oil and diesel oil.

The applicant's analysis of this accident scenario assumed the entire available 10,448,000 L [2,760,169 gal] of flammable liquid spilled within a fixed containment area, located within 50 m [164 ft] of the proposed storage area (Holtec International, 2004d, HI-2033006). The exposure provided by Unit 2 Residual No. 6 fuel oil (identified as Hazard ID F-3) was identified as posing the maximum heat flux exposure and is considered the bounding case. The elevation of the storage vault with respect to the fuel tank storage area (approximately 6 m [20 ft] elevation difference) protects the proposed storage vault from direct flame impingement. Because of the separation distance and the shielding offered by other structures on the site, thermal radiation is the only mechanism of heat transfer to the casks in the storage vault. The radiative heat transfer analysis was conducted using standard methodology and known view factors and a review of these procedures is presented in Section 6.1.5 of this SER. The analysis predicted that the casks stored in the vault will be able to withstand the exposure from the bounding fire (SAR Table 8.2-11) without exhibiting excessive surface temperatures, and all SSCs important to safety will maintain their intended safety functions during and after such an event.

Fuel Oil and Diesel Fuel Tanker Trucks

The delivery trucks supplying the storage tanks with diesel and fuel oil pose a fire hazard to the proposed ISFSI. The applicant states that administrative controls, as required by Technical Specification (TS) 5.1.5, "Cask Transportation Evaluation Program," will preclude the delivery of any fuels while onsite cask transfer and lowering activities are in progress. Any potential fire from diesel and fuel oil tanker trucks affecting the safety of the loaded casks during transportation and lowering into the storage vault, therefore, is not credible.

Additionally, the applicant states that although the delivery routes and the speed of trucks (limited to a maximum of 8 kmph [5 mph]) will be controlled by administrative procedures, a potential fire hazard to the casks in the storage vault does exist from these tanker trucks. The SAR states that the terrain slopes away from the storage vault, which makes it difficult for a fuel spill to collect close enough to the vault and in sufficient volume to result in a fire that would impact the storage vault directly.

Nevertheless, an accident scenario (Scenario F-14) assuming a stationary diesel pool fire congregated near the diesel storage tanks was analyzed by the applicant. The source of this pool fire is the entire 28,390 L [7,500 gal] of diesel oil spilled from a tanker truck. A reasonable distance of 24 m [80 ft] was selected as the exposure distance to the vault. The resulting nonengulfing fire scenario indicated that the vault covers will not experience a temperature that will compromise their performance and that other SSCs will be expected to maintain their intended safety functions during such an event.

Gasoline Tanker Truck and Gasoline Storage Tank

A gasoline tanker truck with a 11,356-L [3,000-gal] capacity periodically fills a 454-L [120-gal] storage tank on the east side of the HBPP site. As the HBPP Units 1 and 2 power blocks prevent a direct line of sight between the gasoline storage tank and the storage vault, a fire at the gasoline storage tank affecting the ISFSI vault during interim storage is not considered credible.

The applicant states that the gasoline tanker truck will be controlled by administrative procedures in the same way as fuel and diesel oil tankers inside the owner controlled area. Because the timing of delivery, delivery route, and vehicle speed will be controlled, potential fire from the gasoline tanker truck affecting safety of the loaded casks during transfer and lowering into the storage vault is not credible.

The only potential hazard to the storage vault during interim storage will be from a fire at the gasoline tanker truck while delivering to the storage tank. Consequently, the applicant provided an analysis on the potential effects from a tanker truck fire on the storage vault. As discussed previously, the downward slope surrounding the proposed vault site makes it difficult for a fuel spill to collect and for a fire to impact the vault directly. Results of this analysis are given in Table 8.2-12 of the SAR. The analysis indicates that the storage vault covers will not experience a temperature that will compromise their performance and that all SSCs important to safety will be expected to maintain their intended safety functions during such an event.

Propane Storage Tank

The SAR states that there is a 7,942 L [2,098 gal] propane storage tank approximately 34 m [113 ft] from the transporter route and 113 m [370 ft] from the storage vault. A deflagrating fire at the propane storage tank is considered a low probability event as explosion hazards are more commonly associated with the storage of propane. The slow release of propane from the tank and subsequent ignition of the vapor cloud will yield a high-temperature short-duration exposure for the transporter and the storage vault. Given the distance of the propane tank from the proposed storage vault and transporter route, the impact of such an event will be minimal. Additionally, administrative controls, which include inspecting for leaks before cask transfer is initiated, will limit the possibility of a propane tank fire.

The applicant's analysis assumed a fuel spill from the storage tank with a known pool area (i.e., the area covered by the fuel spill) and a view factor with respect to the cask vault. Although not a likely scenario, this assumption provides a fire duration that will produce a longer radiant exposure to the cask in the storage vault than the instantaneous release and ignition of a vapor cloud. The results indicate that the exposed SSCs important to safety will be able to maintain their intended safety functions during and after such an event.

Propane Tanker Truck

A 10,978 L [2,900 gal] propane tanker truck fills the propane storage tank approximately once a year. The truck is in the vicinity for less than 1 hour in a year. The applicant will control the time of delivery of propane, delivery route, and vehicle speed using administrative procedures. Consequently, a fire at the tanker truck affecting the onsite transportation of the loaded casks and cask lowering activities at the storage vault is not a credible scenario. A fire at the propane delivery truck, however, can potentially affect the casks in the vault during interim storage. The applicant has analyzed the potential effects on the storage vault from a nonengulfing fire originated at the propane tanker truck. The distance between the propane truck access and the storage vault is approximately 120 m [394 ft]. This distance is larger than the distance between the storage vault and the routes taken by the gasoline and diesel tanker trucks, which is approximately 24 m [80 ft]. The rise in vault temperature from the propane tanker truck fire, therefore, will be lower than those expected from the fires at the gasoline and diesel trucks, also considering the truck capacities and fuel types. As discussed previously, a potential fire at the gasoline and diesel trucks does not cause a sufficient rise of temperature at the storage vault to affect the cask safety functions. Consequently, all SSCs important to safety will maintain their intended safety functions during such an event.

Unit 3 Main Bank Transformer Oil

The SAR states that a fire in the Unit 3 main bank transformer oil could potentially affect the cask while it is being transferred to the storage vault. A significant increase in the storage vault temperatures due to a fire originating in the transformers is considered to be an incredible scenario, due to the separation distance and the shielding provided by the RFB.

The Unit 3 main bank transformers contain the dielectric oil Diala AX. The flash point of this oil is 146 °C [295 °F]. Based on the Fire Protection Association Handbook (National Fire Protection Association, 1997), the flash point of a liquid must be less than 37.8 °C [100 °F] to be classified as a flammable liquid. The maximum ambient temperature ever recorded at the HBPP site is 30.6 °C [87 °F] and the actual site temperature is generally less than 15.6 °C [60 °F]. The normal operating temperature of the oil in the transformers is approximately 40 °C [104 °F]. This oil, therefore, does not pose a credible fire hazard under normal operations; however, an electrical fault in the transformer could raise the oil temperature high enough to start an ignition. Although there is a very low probability of fire, the National Fire Protection Association rates this oil as having a "slight" probability of fire. Consequently, the applicant conducted an analysis of the potential fire hazards at the proposed facility from a fire in the Unit 3 main bank transformer oil (Holtec International, 2004d, HI-2033006).

The applicant states that during transfer to the storage vault, the casks are in proximity to the bank of transformers for only a fraction of total travel time, estimated to be less than 1 hour. The probability that a transformer fire will take place while the cask is in the immediate vicinity is, therefore, extremely low. The analysis results for this scenario (Scenario F-9 of Holtec International 2004d, HI-2033006) indicate that the expected temperature rise of the cask as a result of exposure to a transformer oil fire along the transfer route will be on the order of 94 °C [170 °F], which is within the safe limits for the cask. Therefore, the exposed SSCs important to safety will be able to maintain their intended safety functions.

Natural Gas Pipeline

The SAR states that a main supply line delivers natural gas to the site at high pressure. A pressure regulating station at the edge of the area controlled by the applicant reduces the pressure and feeds Humboldt Bay Units 1 and 2. The low pressure section of the natural gas line, which traverses the transporter route, will be isolated and depressurized prior to transferring casks to the storage vault and associated lowering activities, as stated in the SAR, in accordance with TS 5.1.5, "Cask Transportation Evaluation Program." A potential fire at the low pressure section of the pipeline, therefore, is not a credible hazard to the proposed facility during cask transfer; however, a fire at this low pressure side can be a potential hazard during interim storage. Additionally, a fire at the high pressure side of the pipeline is a potential hazard to the transporter with loaded casks. HBPP Units 1, 2, and 3 provide shielding to the storage vault from a fire at the high pressure side and, therefore, this fire is not considered a credible hazard to the proposed storage vault.

The applicant's analysis considered a fire originating at the high pressure side (upstream side) of the gas isolation valve (Scenario F-10 , Holtec International 2004d, HI-2033006). Similar to the propane storage tank analysis, the leakage and ignition of natural gas from the upstream side of the pipeline will likely produce a high-temperature and short-duration fireball. The analysis modeled the natural gas fire as a propane gas fire assuming a fixed pool fire located 123 m [409 ft] from the loaded casks. Results from this analysis indicate that this type of fire will not produce an unsafe condition for the storage casks, as the predicted temperature rise is less than 5 °C [9 °F].

Additionally, a fire at the gas distribution pipeline feeding Units 1 and 2 during interim storage may potentially affect the storage casks within the vault; however, the applicant estimated that the rise in temperature of the vault lid from this fire will be approximately 0.5 °C [1 °F], assuming a similar fire as for the upstream side of the pipeline. Casks in the storage vault, therefore, will be able to carry out their intended safety functions for this fire scenario.

Natural Vegetation

The SAR states that the restricted area surrounding the storage vault will be covered with 0.3-m [12-in]-thick crushed rock. A maintenance program will limit any significant growth of vegetation in the restricted area. The surface of the restricted area, therefore, will not have any combustible materials to sustain a potential fire. Additionally, the SAR states that the vegetation surrounding the storage vault is primarily grass with some small bushes. The applicant has proposed maintenance programs that will limit the uncontrolled growth of vegetation within a 15 m [50 ft] perimeter surrounding the restricted area fence of the proposed ISFSI site. Loaded casks will be transferred only after evaluating the weather conditions predicted, as stated in the SAR. Additionally, all other combustibles, including transient ones within the general area, and the transfer route will be controlled by administrative procedures, in accordance with TS 5.1.5. Therefore, a vegetation fire is not considered credible during onsite cask transfer and lowering of the casks into the vault because of the preventative measures and the fact that sufficient forewarning is generally available.

The limited availability of fuel in the surrounding vegetation will lead to a short duration fire. The applicant's analysis for this scenario assumed a steady-state heat transfer model. The analysis indicated that the vault cover will experience only a small temperature rise (approximately 54 °C

[97 °F]) as a result of such an exposure. This fire scenario, therefore, is bounded by the fire involving a 189 L [50 gal] capacity transporter fuel tank. Consequently, the applicant concluded that a vegetation wildfire will not affect the ability of any SSCs important to safety at the proposed facility to carry out their intended safety functions.

Barge in Bay Carrying Fuel

A barge with a maximum carrying capacity of 65,000 barrels of fuel transits the North Bay to the Chevron Fuel Terminal. The SAR states that administrative controls will ensure that no loaded cask transfer and lowering into the vault will take place while the barge is moving, as specified in TS 5.1.5. A fire at the barge, therefore, can only pose a hazard to the casks stored in the vault during interim storage.

The barge carries the fuel in 15 separate compartments, which hold approximately 65,866 L [17,400 gal] each, as stated in the SAR. These compartments are separated by steel walls. The barge generally carries diesel fuel in 5 compartments and gasoline in the remaining 10 compartments. The barge requires a tugboat for movement. Due to lack of onboard motive force, there are only a few ignition sources on the vessel. The barge movement will take place in good weather and low vessel traffic. The movement is controlled by the shipping company and the U.S. Coast Guard.

The barge in the North Bay may come as close as 1,372 m [4,500 ft] to the proposed site. The water depth at closer distance will not support moving the barge with the tugboats. A fire with the entire 65,000 barrels of fuel at a distance of 1,372 m [4,500 ft] will be bounded by the engulfing fire analysis. Additionally, the shoreline of the North Bay is approximately 66 m [200 ft] from the proposed facility. Portions of the fuel that leaked from the barge may be transported by wind or ocean currents near to the proposed facility and ignite. Alternatively, the fuel may ignite at the barge and the pool fire may be transported by wind or ocean current to the proposed facility. The SAR states that the compartments of the barge are constructed using U.S. Coast Guard standards and are equivalent to a double hull, which makes rupture and spill of cargo unlikely. Rupture of more than one or two compartments and a subsequent spill of the fuel, therefore, is not credible. In addition, if not ignited at the ship, the spilled fuel floating along the shoreline needs a suitable source of ignition. Thin fuel pools floating on water are generally difficult to ignite given the temperature of the water and enormous heat sink. These factors effectively keep the fuel well below its flash points. Moreover, as the movement of the barge is controlled by the shipping company and the U.S. Coast Guard, any potential rupture of the barge leading to a fuel spill will be detected early and be contained. Consequently, the applicant concludes that any spilled-fuel fire will have only limited effects on the SSCs important to safety at the proposed facility and the effects are bounded by the engulfing fire. The staff agrees with this conclusion and notes that the site geometry includes a vertical drop of over 12 m [40 ft] to sea level. This geometric configuration makes the proposed site naturally resistant to fires at the shoreline.

Conclusions

The staff has reviewed the information provided by the applicant regarding potential wildfires and onsite fires at the proposed facility. The staff finds the applicant's analysis acceptable because:

- Noncombustible and heat-resistant materials will be used to construct SSCs important to safety.

- A restricted area with designed fire barriers to prevent wildfires from affecting the proposed facility has been adequately described.

- The proposed storage casks are designed to withstand a fire from 189 L [50 gal] of diesel fuel from the fuel tank of the cask transporters based on the similarity of their design with the design of HI-STAR 100 casks.

- Fires in the immediate vicinity of the proposed facility are unlikely because of lack of suitable ignition sources.

- Administrative procedures to implement the requirements of Technical Specification 5.1.5, "Cask Transportation Evaluation Program," will prohibit or control movement of any transient fuel sources (e.g., supply tanker trucks, onsite vehicles), as appropriate, to minimize these hazards near the transfer route and storage vault during cask transfer and handling operations.

- The low pressure section of the natural gas pipeline will be isolated and depressurized prior to these operations by administrative procedures, in accordance with TS 5.1.5.

- HBPP Units 1, 2, and 3 provide shielding to this storage vault from a fire at the high-pressure side of the natural gas pipeline.

- Fuel storage tanks, including the propane tank, are sufficiently far away from the storage vault not to pose a fire hazard.

- Any fire hazard posed by the barge in the North Bay is bounded by the engulfing fire scenarios analyzed. The topography will minimize any potential effects of a fire at the barge. In addition, a potential fuel spill from the barge will not have sufficient heat load to affect the ISFSI, as a spill floating on water is very difficult to ignite. The shipping company and the U.S. Coast Guard control the movement of the barge in the bay, and will be able to detect any fuel leak quickly and take necessary steps to contain any spill.

Based on the applicant's assessment of the potential fire hazards and the fire protection measures to be applied at the Humboldt Bay ISFSI, the staff finds that there is reasonable assurance that the HI-STAR HB system will not be exposed to fires that exceed the design basis fire.

The applicant has assessed the site conditions, such as availability of vegetation, and ground topography near the proposed storage vault that may affect the safety of the proposed ISFSI. Additionally, the applicant has appropriately designed the SSCs important to safety and located them within the proposed facility so that they can continue to perform their intended safety functions under credible fire scenarios.

Based on the foregoing evaluation, the staff finds that there is reasonable assurance that onsite fires and vegetation fires will not create a significant hazard to the proposed facility. The staff finds that the proposed facility is sited, designed, and will be operated to minimize the potential for fires. The staff also finds that no onsite fires or vegetation fires will impair the ability of the SSCs important to safety to maintain the subcriticality, confinement, sufficient shielding, and retrievability of the stored fuel. The applicant's evaluation provides adequate assurance that the operations at the proposed Humboldt Bay ISFSI can be conducted without endangering the health and safety of the public.

15.1.2.6 Explosions

The staff has reviewed the information provided by the applicant on explosion hazards present at the proposed Humboldt Bay ISFSI. The review was performed to ensure that SSCs important to safety are designed and appropriately located so they can continue to perform their safety functions effectively under credible explosion events. This review included ensuring safety during both transfer and interim storage conditions. These accident events involve either offsite or onsite explosions that may damage SSCs important to safety. The staff reviewed the information presented in Section 8.2.6 of the SAR, the supplemental information presented in the applicant's risk assessment of explosion hazards (Pacific Gas and Electric Company, 2004d), and Holtec Report HI-2033041, "Evaluation of Explosions for the HBPP ISFSI" (Holtec International, 2004f).

An explosion may produce effects from reflected air overpressure, blast-induced ground motion, or blast-generated missiles. Regulatory Guide 1.91 (U.S. Nuclear Regulatory Commission, 1978) sets 6.9 kPa [1 psi] as the peak positive incident overpressure below which no significant damage to the structures will be expected to result from an explosion. Explosion-induced ground motions are bounded by the earthquake criteria. Similarly, effects of explosion-generated missiles will be bounded by those associated with the air overpressure levels if the threshold air overpressure from any explosion source is kept below 6.9 kPa [1 psi] (U.S. Nuclear Regulatory Commission, 1978).

Regulatory Guide 1.91 provides an acceptable methodology to estimate the minimum separation distance between an explosion source and a structure so that the peak positive incident overpressure will likely be less than 6.9 kPa [1 psi]. If the separation distance is not larger than the minimum separation distance calculated following the suggested methodology of Regulatory Guide 1.91, the peak positive incident overpressure will likely be more than 6.9 kPa [1 psi] from the explosion. Consequently, an analysis of the frequency of the explosion hazard will be necessary to show that the associated risk is sufficiently low. If the hazardous materials are shipped on more than one transportation mode, the frequency of exposure for the modes should be summed. Regulatory Guide 1.91 also states that potential explosion hazards can be screened out if, based on realistic or best estimate bases, an exposure rate less than 10^{-7} per year can be demonstrated. If conservative estimates are used, an exposure rate less than 10^{-6} per year is sufficiently low.

In general, the geometry of the proposed ISFSI makes it intrinsically resistant to explosion overpressure. The proposed ISFSI will be below grade with only concrete lids exposed. In this geometry, the targets (the vault lids) are parallel to the ground. Blasts occurring away from the proposed ISFSI will have significantly less impact on the lids because blast waves tend to travel parallel to the ground. This geometry reduces the consequence of offsite accidents, including those from any explosion-generated missiles.

The proposed ISFSI will be at an elevation of approximately 12 m [40 ft] above sea level and 6 m [20 ft] above adjacent areas, including the parking lot, fuel oil storage tanks, and other potential explosion sources. Explosions occurring in the bay or other lower elevations will have a reduced effect on the proposed ISFSI because the elevation difference will reduce the air overpressure significantly by absorbing and deflecting it. Additionally, prevailing wind directions are from west to east, away from the proposed storage vault site and transporter route. Consequently, prevailing wind conditions on Humboldt Bay and the elevated location of the proposed ISFSI, make it difficult for heavier-than-air hydrocarbon clouds to be organized and transported to the proposed ISFSI.

The potential explosion hazards that could affect the HI-STAR HB storage casks, the transporter, and the storage vault are identified in Section 8.2.6 of the SAR. These events are classified as either onsite or offsite explosion hazards.

Onsite Explosion Events

The onsite explosion hazards include flammable materials stored onsite as well as transient sources such as delivery trucks and other vehicles. Because all the accidents involve flammable gases, all accidents have to be initiated by a rupture, followed by an accumulation of flammable gases (a cloud), migration of the gases either to the transporter route or to the storage vault, and subsequent ignition. Onsite explosion scenarios include (i) a propane storage tank, (ii) a propane tanker truck, (iii) a natural gas pipeline, (iv) a gasoline tanker truck and storage tank, (v) other site vehicle fuel tanks, and (vi) a fossil power plant.

Propane Storage Tank

The site includes a 7,940-L [2,098-gal]-propane storage tank. The tank is located approximately 34.4 m [113 ft] from the nearest point on the transporter route and 126 m [414 ft] from the proposed ISFSI storage vault. Administrative procedures prohibit any vehicular traffic near the propane storage tank except for the tanker truck filling the tank periodically. This truck cannot come closer than 6 m [20 ft] from the propane storage tank. Additionally, there are barriers around the tank to prevent accidental impact from a rolling vehicle. A catastrophic rupture of the propane storage tank, therefore, is not credible. Moreover, the tank is located in an open area. Prevailing wind is from west to east, away from the transporter route and the storage vault. Therefore, significant accumulation and subsequent ignition of propane leaking from the tank is a very unlikely event.

Nevertheless, the applicant conducted an estimate of the air overpressure from accidental detonation of the entire 7,940 L [2,098 gal] of propane in the storage tank (Holtec International, 2004f, HI-2033041). In this scenario, a slow leak is assumed to have developed at the propane storage tank, due to faulty valves or other defects. The analysis (SAR Table 8.2-13) shows that the air overpressure resulting from an explosion of this volume of propane will not exceed the design limits of the cask. Additionally, any potential drop of the loaded cask from the transporter due to the incident air overpressure is bounded by the cask drop scenario reviewed in this chapter of the SER. Therefore, SSCs important to safety will maintain their intended safety functions.

The applicant will impose administrative controls, including a walk down of the transporter route and other pre-transfer requirements, as specified in TS 5.1.5, to identify any propane leak before transfer operations begin. Cask transfer activities will not be initiated if there is any indication of a propane leak. A propane gas vapor cloud explosion affecting the loaded cask while being transferred or lowered into the storage vault, therefore, is not credible.

The applicant also evaluated the potential for a vapor cloud of propane leaking from the storage tank to explode and affect the vault during interim storage. The applicant states that the propane storage tank is at a lower elevation than the vault. With the prevailing wind blowing in the opposite direction, it is quite unlikely that a vapor cloud will organize over the vault and detonate. The applicant analyzed the potential air overpressure from the detonation of a 61.0 m x 24.4 m x 12.2 m [20 ft x 80 ft x 40 ft] vapor cloud on the storage vault, as given in Table 8.2-13 of the SAR. The estimated air overpressure at the vault is lower than the design basis overpressure of the HI-STAR HB casks. The vault lids will provide additional protection from the air overpressure and any explosion-generated missiles.

Propane Tanker Truck

A delivery truck periodically supplies the storage tank with propane. Because administrative controls will restrict delivery during cask transfer and lowering operations, a potential impact on the storage casks during this phase of operation is not credible. An explosion of the tanker truck can pose a hazard to the vault during interim storage. The applicant conducted an analysis involving the 11,000 L [2,900 gal] propane tanker truck at its closest point to the vault on the delivery route {118 m [394 ft]}. The analysis assumed that propane leaks from the truck during delivery to the onsite storage tank and explodes.

The results of this analysis, given in Table 8.2-13 of the SAR, show that the estimated air overpressure on the vault will be too low to produce any significant damage to the storage casks. The vault lids will provide additional protection from any explosion-generated missiles.

Natural Gas Pipeline

A potential explosion of the natural gas pipeline upstream of the pressure regulating station may pose a hazard to the proposed ISFSI. The applicant did not consider a pipeline break in the upstream side of the natural gas pipeline because there is no vehicular traffic in the vicinity of the regulating station, which is located within the owner controlled area. Additionally, the applicant refers to a seismic study, which predicted that a pipeline break will potentially take place several miles away from this site. Consequently, the applicant concluded that a breakage of the natural gas pipeline in the upstream side leading to a detonation of the released gas is not a credible hazard to the proposed ISFSI during cask transfer, cask lowering activities, and interim storage of the casks inside the vault.

Additionally, the applicant states that a vapor cloud explosion of the natural gas released from the upstream side is not a credible hazard to the transfer and lowering operations because of (i) low potential for a pipeline break close to the HBPP facility; (ii) prevailing wind direction being from west to east, away from the transporter route and storage vault area; and (ii) short duration of the operations. Moreover, the applicant states that a vapor cloud explosion of natural gas released from the upstream side is not a credible hazard to the casks in storage because any such vapor cloud will be ignited before reaching the proposed ISFSI while floating across potential ignition sources of HBPP Units 1 and 2. For these reasons, the applicant concluded that a potential leak of natural gas at the upstream side of the pipeline will not pose a credible hazard to the proposed facility.

In order to confirm the applicant's conclusion, the staff conducted an independent analysis following the methodology presented in the applicant's analysis (Holtec International, 2004f, HI-2033041). The staff's analysis assumed the diameter of the pipe to be 91.4 cm [36 in] and the gas at a pressure of 2.8 MPa gauge [400 psig]. Additionally, it was assumed that the gas leak remains undetected for 30 minutes; the leaked gas floats close to Units 1 and 2 and organizes; and the vapor cloud detonates after finding an ignition source. Although the prevailing wind direction will drive the vapor cloud away from the operating units and the proposed storage vault site, no credit was taken for this effect. The staff's analysis estimated that a vapor cloud comprising 984,744 kg [2,166,437 lb] of natural gas will form from the postulated leak of the pipeline. The predicted air overpressure for this scenario is below the design basis air overpressure of the HI-STAR HB cask. The vault lids will provide additional protection to the casks from the air overpressure and any explosion-generated missiles.

The natural gas pipeline downstream of the regulating station (low pressure side) may rupture and pose an explosion hazard to cask transfer, cask lowering operations, and interim storage of the casks in the vault. The applicant states that administrative controls will require isolating and depressurizing the supply line during cask transfer and lowering operations. An explosion during cask transfer and lowering activities, therefore, is not a credible hazard to SSCs important to safety at the proposed ISFSI; however, an explosion at the downstream side of the gas pipeline can be a potential hazard to the casks stored in the vault. The applicant estimated the peak air overpressure at the vault to be 43.3 kPa [6.3 psi], as shown in Table 8.2-13 of the SAR. The cask is designed to withstand this pressure, and it will continue to perform its safety-related functions. Moreover, the vault lids will provide additional protection from any explosion-generated missiles.

The applicant estimated that an air overpressure close to the design pressure limit of the cask will develop if the center of the gas cloud explosion is approximately 19 m [62 ft] away from the cask (Holtec International 2003f, HI-2033041). Site geometry and prevailing wind conditions make it extremely unlikely for a gas cloud to remain within the flammable limits as it traverses the terrain and organizes close to the cask storage vault. Additionally, the applicant states that the gas pipeline on the downstream side of the pressure regulating station will be isolated and depressurized before any transfer and lowering operations will take place, as per the administrative procedures. A vapor cloud explosion of gas leaking from the downstream side of the pipeline affecting the casks during transfer and lowering operations, therefore, is not a credible hazard.

Underground gas pipelines generally leak before the rupture takes place. If there is a large leak or rupture of the downstream gas distribution pipeline, the applicant states that the operators of the Units 1 and 2 power plants will be able to recognize the leak immediately and will take necessary actions to locate and isolate the source of the leak. The applicant identifies that the likely rupture location will be where the gas supply lines enter the Unit 1 and 2 boilers. The applicant also states that being very close to the operating boilers, leaked gas, if any, will ignite easily before a large mass of gas is accumulated. Therefore, a large leak of the gas pipeline leading to a vapor cloud explosion affecting the casks stored in the vault is not a credible hazard. Additionally, the effects of any potential sympathetic explosion of the boilers due to a nearby vapor cloud explosion are bounded by the analysis of a boiler explosion presented by the applicant under "Fossil Power Plant Explosion" in this section of the SER.

Gasoline Tanker Truck and Storage Tank

The delivery truck having a capacity of 11,340 L [3,000 gal] supplies gasoline to the 454 L [120 gal] capacity storage tank. Both the tanker truck and storage tank can pose an explosion hazard to the proposed ISFSI.

Because administrative controls will prohibit the delivery of gasoline during cask transfer and lowering activities, a detonation of the tanker truck is not considered a credible hazard during these activities. Additionally, a line of sight is established between the transporter and the gasoline storage tank during onsite transfer of the loaded cask for a short period of time. In implementing the requirements of TS 5.1.5, administrative controls proposed by the applicant will include a requirement that a walkdown of the transporter route be conducted for all potential hazards before starting the transfer operation. The integrity of the gasoline storage tank will be checked in the walkdown process to detect any leak. The applicant concludes that the gasoline tanker truck and storage tank will not pose a credible hazard to cask transfer and lowering activities.

During interim storage, the explosion of the tanker truck and storage tank may pose a hazard to the casks in the vault. The tanker truck remains on the eastern side of the property and will not approach the vault area. Because of prevailing wind, a vapor cloud formed from rupture of either the tanker truck or the storage tank will float away from the storage vault. Additionally, when the tanker is filling the storage tank, there is no line of sight with the storage vault because of the structures of the Units 1 and 2 power blocks. Nevertheless, the applicant estimated the air overpressure on the vault from detonation of the tanker truck at a distance of 171 m [562 ft]. The estimated air overpressure is 15.2 kPa [2.21 psi], which exceeds the threshold 6.9 kPa [1 psi] criterion of Regulatory Guide 1.91 (U.S. Nuclear Regulatory Commission, 1978). The estimated overpressure will not cause any significant damage to the storage casks because the design basis external overpressure for the HI-STAR HB cask is 2 MPa gauge [300 psig], as stated in Section 3.3.1.6 of the SAR. Additionally, the vault lids will provide protection from any explosion-generated missiles.

Other Site Vehicle Fuel Tanks

The flash point of diesel fuel is 51.7 °C [125 °F]. Based on the Fire Protection Association Handbook (National Fire Protection Association, 1997), the flash point of a liquid must be less than 37.8 °C [100 °F] to be classified as a flammable liquid. Therefore, because of its properties, diesel fuel does not pose a credible explosion hazard. Consequently, only gasoline-powered vehicles need to be considered for potential explosion hazards.

The applicant assumed that the fuel capacity of all onsite gasoline-powered vehicles will be no more than 76 L [20 gal]. Based on the methodology of Regulatory Guide 1.91 (U.S. Nuclear Regulatory Commission, 1978), it is estimated that these vehicles should be at least 53 m [175 ft] away so that any accidental detonation of the vehicle will not generate a 6.9-kPa [1-psi] air overpressure. Based on this result, the applicant proposes using administrative controls to keep all gasoline-powered vehicles at least 53 m [175 ft] away from the transporter route while a cask is transferred or lowered into the vault.

The applicant states that all gasoline-powered vehicles will be kept at least 15 m [50 ft] away from the storage vault during interim storage operations through administrative controls that also limit the number of vehicles allowed at such distance. The applicant estimated the peak air overpressure from the detonation of a 75 L [20 gal] gasoline tank of a vehicle (Holtec International, 2004f, HI-2033041). The results are given in Table 8.2-13 of the SAR. Although the estimated air overpressure at the vault exceeds the 6.9-kPa [1-psi] criterion of Regulatory Guide 1.91, the estimated overpressure will not cause any significant damage to the storage casks because the design basis external overpressure for the HI-STAR HB cask is 2 MPa gauge [300 psig] (SAR Section 3.3.1.6). Additionally, the vault lids will provide protection from any explosion-generated missiles.

Fossil Power Plant Explosion

The applicant analyzed the effects of potential explosions at the fixed or mobile fossil units of the Humboldt Bay Power Plant (HBPP) on the proposed ISFSI. Both Units 1 and 2 of the HBPP, including the steam boilers and the mobile generators, are designed to prevent explosions, in accordance with governing codes and standards. However, boilers at other facilities have exploded and, therefore, the applicant has analyzed a boiler explosion of the fossil-fueled units (Holtec International 2004f, HI-2033041). Estimated air overpressures from this explosion, on the cask during transfer and on the storage vault, are given in Table 8.2-13 of the SAR. The cask is designed to withstand these estimated air overpressures without affecting the intended safety functions. Because the estimated air overpressures exceed 6.9 kPa [1 psi], potential missile impact from the exploding boilers is also considered. Cask exposure to any potential missiles from an explosion of a boiler of one of the fossil units, however, is highly unlikely because of the brief time the cask is being transported and placed in the storage vault. Although a missile generated from an exploding boiler may hit the storage vault, the lids will provide protection against any direct impact to the casks stored in the vault. A potential explosion of a boiler, therefore, will not affect any safety-related SSCs at the proposed facility.

Offsite Explosion Events

The applicant's evaluation of offsite accidents resulting in explosions mainly involved transient flammable solid or liquid materials near the site. The potential scenarios near the proposed ISFSI that can result in an offsite explosion include (i) an accident of a barge carrying flammable and combustible fuels, (ii) an accident on the Northwestern Pacific Railroad, and (iii) a transportation accident leading to an explosion of vehicles on Route 101.

Barge in Bay Carrying Fuel

A barge carrying a maximum of 10,334,000 L [65,000 barrels] of fuel in 15 compartments transits the North Bay to deliver its cargo to the Chevron Fuel terminal, which is approximately 3.2 km [2 mi] from the proposed ISFSI (SAR Section 8.2.6.2.8). At the closest point, the barge can be approximately 1,350 m [4,500 ft] from the proposed facility. Generally, the barge carries gasoline in 10 compartments, and diesel oil in the remaining 5 compartments. Each compartment of the barge can hold up to 688,900 L [4,333 barrels] of fuel. The barge requires a tugboat for movement and has only a limited number of ignition sources onboard. The most probable ignition source is collision with another vessel (Pacific Gas and Electric Company, 2004b). When the barge is moving through the bay, the U.S. Coast Guard and the shipping company control its motion and the motion of other nearby vessels. Good weather and low vessel traffic are required for the barge to be allowed to move through the bay (Pacific Gas and Electric Company, 2004a).

The flash point of diesel fuel is 51.7 °C [125 °F]. Based on the Fire Protection Association Handbook (National Fire Protection Association, 1997), the flash point of a liquid must be less than 37.8 °C [100 °F] to be classified as a flammable liquid. Diesel is classified as Class II combustible liquid and, therefore, does not pose a credible explosion hazard to the proposed ISFSI while being transported.

The barge design includes a very robust external bumper system near the water level. This bumper system will protect the barge cargo in case of a collision with another vessel. It is very unlikely that any vessel will be able to cause a direct impact to the barge hull. Additionally, the barge has the equivalent of a double hull. Construction of this hull meets the requirements of the U.S. Coast Guard and American Bureau of Shipping Standards (Pacific Gas and Electric Company, 2004b). It is therefore extremely unlikely that a vessel will be able to penetrate both hulls and ignite the barge cargo. Additionally, each compartment of the barge is separated from others by steel walls. These walls also meet the requirements of the U.S. Coast Guard and American Bureau of Shipping Standards. It is, therefore, unlikely that an accidental ignition of fuel in a compartment leading to explosion will be propagated to the adjoining compartments.

Using the TNT-equivalence methodology given in Regulatory Guide 1.91 with a 6-percent explosion yield, according to the Federal Emergency Management Agency (1989), the applicant estimated that 3.8 L [1 gal] of gasoline will be equivalent to 1.78 kg [3.91 lb] of TNT. However, using the Army Manual TM 5-1300 (U.S. Army, 1990) as the basis, the applicant estimated that the TNT-equivalent weight of 3.8 L [1 gal] of gasoline will be 1.33 kg [2.93 lb] (Pacific Gas and Electric Company, 2004d). Although information from both of these references is acceptable, the staff used the higher value in its confirmatory calculations. Using the higher conversion value, the distance at which the peak incident air overpressure will be 6.9 kPa [1 psi] from an explosion of a compartment of the barge containing 904,400 L [234,000 gal] of gasoline will be approximately 1,320 m [4,400 ft]. Because the ISFSI will be at least 1,350 m [4,500 ft] from the barge, and the quantity of fuel assumed in the calculation is conservative, SSCs important to safety will be able to carry out their intended functions in the event of an explosion of the barge.

Northwestern Pacific Railroad

The Northwestern Pacific Railroad is approximately 360 m [1,200 ft] from the proposed facility. Currently there is no passenger or freight traffic that uses this portion of the railroad. Although Northwestern Pacific Railroad has considered renovating this line for limited traffic, no definitive plans have been identified by the applicant. If rail service is restored, the applicant states that hazards will be evaluated based on Regulatory Guide 1.91 (U.S. Nuclear Regulatory Commission, 1978) to ensure that the risk will be acceptable. Additionally, several locomotives remain in the area and are used occasionally for moving heavy equipment locally. These locomotives operate on diesel and, consequently, will not pose a credible explosion hazard to the SSCs important to safety at the proposed ISFSI.

Vehicles on Route 101

U.S. Highway 101, the major land transportation route, is a four-lane highway that is approximately 667 m [2,000 ft] away from the proposed facility. Cars, light trucks, and major commercial vehicles, including a substantial number of lumber trucks, use this highway (Pacific Gas and Electric Company, 2004a).

Based on Regulatory Guide 1.91 criteria, the maximum probable hazardous cargo hauled by a single highway truck is assumed to be approximately 23,000 kg [50,000 lb] of TNT. The applicant calculated a minimum setback distance of 500 m [1,660 ft], such that the air overpressure on any SSCs important to safety at the proposed facility will be limited to 6.9 kPa [1 psi] from an accidental explosion of this cargo. Although the proposed ISFSI is beyond this limiting distance and an accidental explosion of a highway truck carrying explosive cargo will not pose a credible hazard to casks in the vault, a portion of the cask transfer route comes within approximately 290 m [965 ft] of the highway (Pacific Gas and Electric Company, 2004b). The applicant therefore conducted a probabilistic hazards analysis to show that the annual frequency of this hazard is insignificant (Pacific Gas and Electric Company, 2004d).

This analysis used the methodology given in Regulatory Guide 1.91 to estimate the annual frequency of potential transportation-related explosions at the proposed facility. Regulatory Guide 1.91 provides a methodology to estimate the exposure rate r per year as:

$$r = n \cdot f \cdot s \qquad (15\text{-}1)$$

where:

n = explosion rate (per mile)
f = frequency of shipment (per year)
s = exposure distance (mile)

The applicant used information from the National Highway Safety Administration and Federal Motor Carriers Safety Administration of the U.S. Department of Transportation to estimate the explosion rate (n) of tanker trucks in the vicinity of the proposed ISFSI. The analysis used statistics available for the year 2001 (Pacific Gas and Electric Company, 2004d).

The National Highway Traffic Safety Administration of the U.S. Department of Transportation (National Highway Traffic Safety Administration, 2004) reported accident statistics of large trucks in 2001. A total of 429,000 crashes involving large trucks took place that year. Additionally, based on Federal Motor Carrier Safety Administration data (2004), large trucks traveled approximately 333,000 million km [207,686 million mi] in 2001. Based on the information from 2001, the involvement rate for large trucks is 207 crashes per 160 million km [100 million mi] of travel.

The National Highway Traffic Safety Administration reports that 5.7 percent of all large truck crashes resulted in fires in 2001. The applicant assumed that 50 percent of all large truck fires result in explosions. Based on this assumption, the estimated annual frequency of explosions of large trucks, n, is 3.7×10^{-8} per km [5.9×10^{-8} per mi] of travel.

The staff obtained the information on large truck crashes for the years 2002 and 2003 available on the U.S. Department of Transportation websites (National Highway Traffic Safety Administration, 2004; Federal Motor Carrier Safety Administration, 2004). Although the number of crashes involving large trucks, distance traveled, and percentage of crashes in fatal and injury classes resulting in fire changed, the difference is not significant; therefore, the staff finds that the use of statistics from 2001 is acceptable.

The applicant estimated the exposure distance (s) to be 400 m [1,320 ft] based on Figure RAI 15-15-1 (Pacific Gas and Electric Company, 2004b). The presence of other structures, such as the Unit 3 fuel building, limits the exposure distance of the cask on the transfer route to the vault. In its analysis, the applicant assumed that all 6 transporter shipments would be done in a single year. The annual explosion rate (r), therefore, will be

$$r = 45.90 \times 10^{-10} \times 6 \times \frac{1320}{5280} = 8.85 \times 10^{-8} \qquad (15\text{-}2)$$

which is less than 1×10^{-6} per year. The assumption that 50 percent of accidents result in an explosion is conservative; however, assuming every accident leads to an explosion will not result in an annual exposure rate greater than 1×10^{-6}. Based on Regulatory Guide 1.91 criteria, the results of the analysis indicate that accidental explosions of large trucks while traveling on Route 101 will not pose a credible hazard to the proposed facility.

Conclusions

The staff reviewed the information provided by the applicant regarding potential hazards from accidental onsite and offsite explosions at the proposed facility. The staff finds the analysis acceptable because:

- Descriptions of potential explosion sources are adequate.

- Administrative procedures will control the movement of the propane tanker truck to keep the truck away from the transfer route and storage vault during cask transfer and handling operations. Similarly, administrative procedures will keep all gasoline-powered onsite vehicles at an acceptable distance away from the transfer route.

- Potential explosions of natural gas leaking from the low-pressure or high-pressure side of the pipeline will not affect any SSCs important to safety during transfer and handling activities at the storage vault and interim storage. Additionally, a vapor cloud explosion of the leaked gas is extremely unlikely to occur near the storage vault because of prevailing wind direction, topography, and presence of other structures, so that any such explosion will generate insufficient pressure to affect any SSCs important to safety.

- The low pressure section of the natural gas pipeline will be isolated and depressurized prior to cask transfer operations in accordance with administrative procedures.

- Vault covers (lids) will provide additional protection against air overpressure and explosion-generated missiles from the postulated explosion events.

- The barge at the North Bay has a robust design, and its movement is controlled by the shipping company and the U.S. Coast Guard. There is a lack of onboard ignition sources because the barge does not have any motive power.

- Based on the assessment of the proposed design of the HI-STAR HB cask system, there is reasonable assurance that the design will be adequate to withstand air overpressure limits similar to the HI-STAR 100 cask system.

The applicant has appropriately designed the SSCs important to safety and located them within the proposed facility so they can continue to perform their intended safety functions under potential onsite and offsite explosion scenarios. Based on the foregoing evaluation, the staff finds that potential explosions will not impair the ability of the SSCs important to safety to maintain the subcriticality, confinement, and sufficient shielding of the stored fuel. The applicant's evaluation provides adequate assurance that the operations at the proposed Humboldt Bay ISFSI can be conducted without endangering the health and safety of the public.

15.1.2.7 Drops and Tipover

The staff reviewed the information presented in Section 8.2.7 of the SAR. A potential drop of the HI-STAR HB cask during a seismic event is discussed in Section 15.1.2.1 of this SER. The applicant assessed potential drops and tipovers that may occur while the HI-STAR HB cask is on the rail dolly outside the RFB or on the cask transporter during the lowering of the cask into the vault.

While on the rail dolly outside the RFB a potential HI-STAR HB cask drop and tipover are not credible events. The rail dolly is a circular steel plate supported by two rows of heavy capacity rollers that travel along an existing rail system and elevate the HI-STAR HB approximately 23 cm [9 in]. As identified in a HBPP Unit 3 amendment request (Pacific Gas and Electric Company, 2004e), the rail dolly is designed in accordance with the American Institute of Steel Construction (AISC) Manual of Steel Construction (American Institute of Steel Construction, 2001). As identified in the license amendment request, the dolly and rail system have been analyzed to ensure that they will continue to retain and support the cask system in the appropriate position during a seismic event.

Potential HI-STAR HB cask drop and tipover events during the lowering operation in the storage vault are not considered credible by the applicant. The cask transporter load path components and HI-STAR HB overpack trunnion are designed to preclude a drop. As discussed in Section 15.1.1.4 of this SER, the staff finds that the cask transporter (lift links, connector pins, and lift beams) conforms to the requirements of the single-failure-proof design criteria in NUREG-0612 (U.S. Nuclear Regulatory Commission, 1980) and American National Standard Institute (ANSI) N14.6 (American National Standards Institute, 1993). The applicant stated the lifting trunnion of the HI-STAR HB cask also meets the single-failure-proof design criteria of NUREG-0612 (U.S. Nuclear Regulatory Commission, 1980) on the basis of the similarity of the trunnion design with that of the HI-STAR 100 cask. As discussed in Section 5.1.4.4 of this SER, the lifting trunnions and the flange at the trunnion/overpack interface region for the HI-STAR HB cask satisfy the single-failure-proof design criteria in accordance with NUREG-0612 and ANSI N14.6.

While in the storage vault, potential HI-STAR HB cask drop and tipover events are not considered credible. The HI-STAR HB cask rests on the vault floor and is encircled by the vault wall. The bottom support and the close proximity of the walls of the storage vault to the HI-STAR HB cask preclude any chance of a drop or tipover during interim storage.

The staff finds the information provided by the applicant acceptable and concludes that cask drop and tipover events will not occur, and thus will not impair the ability of SSCs important to safety to maintain subcriticality, confinement, and sufficient shielding. The applicant's evaluation provides adequate assurance that the operations at the Humboldt Bay ISFSI can be conducted without endangering the health and safety of the public.

15.1.2.8 Leakage from Confinement Boundary

The staff reviewed the information presented in Section 8.2.8 of the SAR. A potential breach of the confinement barrier and leakage of radioactive materials during onsite cask transfer, lowering of the cask into the vault, or interim cask storage is precluded by the design of the HI-STAR HB system. The structural integrity of the MPC-HB is solely relied on for confining the radioactive contents in the HI-STAR HB system. As discussed in Section 4.1.3.4 of this SER, the MPC-HB design bases and design criteria meet the applicable provisions of ISG-18 (U.S. Nuclear Regulatory Commission, 2003a), providing reasonable assurance that no credible leakage will occur and that the MPC-HB will maintain integrity of the confinement barrier under all off-normal and credible accident conditions.

Based on the design information provided, the staff concludes that leakage of radioactive material from the MPC-HB confinement boundary is not credible. The applicant's evaluation provides adequate assurance that operations at the proposed Humboldt Bay ISFSI can be conducted without endangering the health and safety of the public.

15.1.2.9 Misloading of a Damaged Fuel Assembly

The staff reviewed information presented in Section 8.2.9 of the SAR. The SAR states that misloading damaged fuel is a noncredible accident due to the administrative controls used to ensure that all fuel is correctly loaded into the MPC-HB.

Proposed Technical Specification 5.1.3 (Pacific Gas and Electric Company, 2004c, Attachment C, and 2005) states that the program for loading fuel and components into an MPC-HB at the Humboldt Bay ISFSI must comply with the requirements in Section 10.2 of the SAR. The controls used to ensure that each fuel assembly is correctly loaded are described in Section 10.2.1.1 of the SAR.

Based on the administrative controls provided in proposed Technical Specification 5.1.3 and the loading procedures for approved contents provided in proposed Technical Specification Section 2.1, loading an MPC-HB incorrectly is not considered a credible accident. If any of the fuel or loading conditions specified are violated, the applicant has committed to complete all the actions described in proposed Technical Specification 2.2 (Pacific Gas and Electric Company, 2004c, Attachment C). These actions include placing the affected fuel assemblies in a safe condition and reporting the event to NRC. Further evaluation of the Stored Material Specifications and the proposed Technical Specifications is provided in Section 8.1.2 of this SER.

Based on its review, the staff concludes that the applicant has provided adequate assurance that loading damaged fuel can be conducted at the proposed Humboldt Bay ISFSI without endangering the health and safety of the public.

15.1.2.10 Extreme Environmental Temperature

The staff reviewed the information presented in Section 8.1.10 of the SAR. The SAR evaluated the effects of extreme ambient temperature on the cask during interim storage in the vault. The staff also reviewed the thermal analysis presented in Section 4.2.3.3.5 of the SAR and in the supporting calculation package (Holtec International, 2004a, HI-2033033).

The maximum postulated extreme temperature at the Humboldt Bay ISFSI site, as given in SAR Table 3.2-3, is 32 °C [90 °F] and the average annual ambient temperature is 11 °C [52 °F]. The maximum extreme temperature given in SAR Table 3.2-3 bounds the maximum ambient temperature (30.5 °C [87 °F]) recorded at the HBPP site (SAR Table 3.4-1). As a result, the temperature increase due to the extreme environmental condition temperature is 21 °C [38 °F]. As discussed in Section 6.1.4 of this SER, the staff determined through confirmatory analysis that the temperature of all the materials of the SSCs important to safety will be within the applicable temperature limits under normal conditions. Based on this analysis, the staff concludes that the peak cladding temperature resulting from a rise in environmental temperatures will not exceed the maximum allowable accident temperature limit of 570 °C [1,058 °F] (U.S. Nuclear Regulatory Commission, 2003c). The temperature of all components (e.g., neutron shield material of the overpack, MPC-HB shell, and vault concrete) also will be below the accident temperature limits, as given in Table 8.2-14 of the SAR. In addition, the staff concludes that the MPC-HB internal pressure will be less than the accident design pressure given in Table 3.4-2 of the SAR. HI-STAR HB design criteria bound both the temperature and insolation values expected at the proposed Humboldt Bay ISFSI site. The integrity of the confinement and shielding capability of the HI-STAR HB cask system is not affected by this event because the fuel cladding and component temperatures, and the MPC-HB internal pressure are below the design limits.

Based on foregoing evaluation, the staff concludes that the extreme environmental temperature will not jeopardize the interim safe storage capability. The applicant's evaluation provides adequate assurance that operations at the proposed Humboldt Bay ISFSI can be conducted without endangering the health and safety of the public.

15.1.2.11 100-Percent Fuel Rod Rupture

The staff reviewed the information presented in Section 8.1.11 of the SAR. The applicant evaluated the potential consequences of a nonmechanistic 100-percent fuel rod failure within the MPC-HB. The potential effect from this postulated accident is an increase in MPC-HB internal pressure. The MPC-HB is a seal-welded pressure vessel designed in accordance with the criteria for no credible leakage that are provided in ISG-18 (U.S. Nuclear Regulatory Commission, 2003a) to withstand internal pressure from normal, and postulated off-normal and accident conditions. The applicant calculated internal pressures for this event (Holtec International, 2004a, HI-2033033) and provided a summary to the staff (Pacific Gas and Electric Company, 2004b). The applicant evaluated the maximum MPC-HB internal pressure to be 0.7 MPa gauge [101.1 psig] from the release of fill gas and fission product gas from the fuel rod into the MPC-HB cavity. The MPC-HB confinement boundary pressure from this accident is within the design basis MPC-HB internal pressure of 1.38 MPa gauge [200 psig] (SAR Table 4.3-2). The staff finds that the information provided is adequate to support the applicant's assessment and that the MPC-HB will maintain its confinement integrity, shielding performance, and criticality control functions if this event were to occur.

Based on the foregoing evaluation, the staff concludes that the internal pressure in the MPC-HB will not exceed the design basis internal pressure in the event of a 100-percent fuel rod rupture. The applicant's evaluation provides adequate assurance that operations at the proposed Humboldt Bay ISFSI can be conducted without endangering the health and safety of the public.

15.1.2.12 Lightning

As discussed in Section 8.2.12 of the SAR, the applicant analyzed the effects of a potential lightning strike on the HI-STAR HB cask system during its transfer from the RFB to the storage site. The gantry and rigging material of the transporter structure above the cask will protect the cask from a direct lightning strike and the current from a lightning strike will be conducted to the ground. The applicant stated that in the event of a lightning strike, the transporter will not be significantly damaged because of its massive steel structure. Thus, the ability of the transporter to hold the cask load will not be significantly impaired. In addition, the transporter is designed to shut down in fail safe condition if the operator is incapacitated or the controls and the drive systems are affected because of a lightning strike. The applicant stated that the thermal, structural, and shielding capabilities of the HI-STAR HB cask will not be affected by a lightning strike, based on the evaluation performed for the HI-STAR 100 cask system (Holtec International, 2002), because of similarity in design of the two casks.

The staff finds that the information provided by the applicant is sufficient to conclude that lightning will not impair the ability of SSCs important to safety to maintain subcriticality, confinement, and sufficient shielding. The applicant's evaluation provides adequate assurance that operations at the proposed Humboldt Bay ISFSI can be conducted without endangering the health and safety of the public.

15.1.2.13 Turbine Missiles

The staff reviewed the information presented in Section 8.2.13 of the SAR. The staff also reviewed the information presented in Sections 2.2.2.3 and 4.2.3.3.2.11 of the SAR and in the applicant's risk assessment of turbine missiles during cask transfer (Pacific Gas and Electric Company, 2003, PRA 03-12).

The applicant analyzed the potential for low-trajectory turbine missile strikes on the loaded HI-STAR HB cask while the cask is transferred from the RFB to the ISFSI. Missiles generated from the potential failure of turbines in HBPP Units 1 and 2 could strike the cask during loading of the cask onto the transporter outside the RFB, or during transit to the ISFSI site. The applicant conducted a risk assessment (Pacific Gas and Electric Company, 2003, PRA 03-12), and applied the methodology outlined in the Regulatory Guide 1.115 (U.S. Nuclear Regulatory Commission, 1977) to demonstrate adequate protection of essential systems against directly striking low-trajectory missiles ejected from turbines. The applicant evaluated the probability of a missile strike during the cask transfer operation to be below the acceptable risk rate defined in Regulatory Guide 1.115 as 10^{-7} per year for loss of an essential system from a single event. The applicant considered the probability of turbine failure resulting in a missile, the probability of damage to safety-related equipment due to a missile strike, and the time of exposure of the HI-STAR HB casks within the low-trajectory zone during loading and transfer. The staff accepts the applicant's approach to eliminate a turbine missile strike from further hazards analysis on the basis of its risk assessment, because the assessment is consistent with the guidance in Regulatory Guide 1.115. In addition, storage cask loading onto the transporter will be conducted on the east side of Unit 3, whereas the operative turbines are located on the south side of Units 1 and 2. Therefore, the Unit 3 building and structures will effectively shield the casks from potential missiles generated from these turbines during cask loading onto the transporter. The staff, therefore, considers a turbine missile strike during HI-STAR HB cask transfer from the RFB to the ISFSI site to be incredible. A potential turbine missile strike on the storage vault, as discussed in Section 2.2.2.3 of the SAR, is also precluded because the ISFSI site is not in the strike zone of the Unit 1 and 2 turbines, as defined in Regulatory Guide 1.115.

Based on the foregoing evaluation, the staff concludes that the turbine missile strike will not impair the ability of SSCs important to safety to maintain subcriticality, confinement, and sufficient shielding. The applicant's evaluation provides adequate assurance that operations at the proposed Humboldt Bay ISFSI can be conducted without endangering the health and safety of the public.

15.1.2.14 Blockage of Multi-Purpose Canister Vent Holes

The staff reviewed the information in Section 8.2.14 of the SAR. The elongated vent holes at the bottom of the MPC-HB fuel basket could potentially be blocked from fuel debris deposits. The vent hole blockage would prevent the circulation of helium gas inside the MPC-HB and restrict convective heat transfer.

The applicant determined that the vent holes could only be blocked by loose crud falling from the external surfaces of the fuel. Deposits of other materials (e.g., fuel cladding and fuel pellets) are not credible because fuel cladding is designed to preclude rupture. In addition, damaged fuel containers are built with screens to restrict the dispersal of particulates. The applicant evaluated the impact of complete blockage of the vent holes as a worst case scenario. The applicant relied on the HI-STAR 100 FSAR thermal analysis (Holtec International, 2002, Chapter 4) as a bounding case to justify the thermal consequence for the HI-STAR HB cask system in the event of complete blockage, because of the similarity in design between the two cask systems and the bounding fuel characteristics used in the HI-STAR 100 FSAR analysis. The HI-STAR 100 FSAR thermal analysis considers conduction and radiation as the primary means of heat transfer to remove heat generated by the fuel. The peak fuel cladding temperature determined from the generic analysis for this event is less than the normal temperature limit of 400°C [752°F] and the accident temperature limit of 570°C [1058°F], as given in ISG-11 (U.S. Nuclear Regulatory Commission, 2003c). This analysis was performed using the 18.5 kW [63,125 BTU/hr] maximum decay heat rate allowed for the generic HI-STAR 100 system, assuming complete blockage of the MPC vent holes. This decay heat rate is approximately one order of magnitude greater than the decay heat rate limit {2 kW [6,824 BTU/hr]} specified for the HI-STAR HB design. Although the HI-STAR HB decay heat rate will be much lower than that assumed in the generic analysis, the net rate of heat transfer from the surface of the HI-STAR HB cask is significantly reduced from that of the HI-STAR 100 design, as a result of its emplacement within the storage vault versus above-ground emplacement. However, the net effect of these differences is that the fuel cladding temperatures calculated for the previously approved HI-STAR 100 design for the postulated complete blockage of the MPC vent hole accident bound the partial blockage accident for the HI-STAR HB design.

The staff accepts that the thermal load used in the generic analysis bounds the licensing basis thermal load for the HI-STAR HB system and that the fuel cladding temperature will not exceed applicable limits in the event of a complete blockage of the MPC-HB vent holes. The MPC-HB basket vent hole blockage accident will not result in loss of confinement because the structural integrity is not affected by this event.

Based on its review, the staff concludes that radiological consequences and criticality concerns are precluded for the MPC-HB basket vent hole blockage accident, because the fuel cladding temperature will not exceed applicable limits. The applicant's evaluation provides adequate assurance that operations at the proposed Humboldt Bay ISFSI can be conducted without endangering the health and safety of the public.

15.1.2.15 Aircraft Crash Hazards

The staff reviewed the information presented in Section 2.2 of the SAR (Pacific Gas and Electric Company, 2004a) and the applicant's risk assessment of aircraft hazards (Pacific Gas and Electric Company, 2004f, PRA 03-14). In addition, the staff reviewed the information presented in the response to the staff's request for additional information (Pacific Gas and Electric Company, 2004b). This review determines whether the risk to the proposed spent fuel storage facility from aircraft hazards has been appropriately estimated and is acceptable.

The staff reviewed the aircraft crash hazard analysis in accordance with NUREG-0800, Section 3.5.1.6 (U.S. Nuclear Regulatory Commission, 1981c). This guidance is intended for use by the NRC staff in evaluating potential hazards at nuclear power plant sites; therefore, the staff finds the methodology conservative and acceptable for evaluating the aircraft crash hazards for the proposed ISFSI site. Section 3.5.1.6 of NUREG-0800 provides three screening criteria that must be satisfied to conclude that the aircraft crash hazard at a nuclear power plant is less than 1×10^{-7} per year for accidents that could result in radiological consequences greater than those specified in 10 CFR Part 100. The screening criteria are as follows:

(a) The plant-to-airport distance, D, is between 8 and 16 km [5 and 10 statute miles], and the projected annual number of operations is less than $500D^2$; or D is greater than 16 km [10 statute miles], and the projected annual number of operations is less than $1,000D^2$.

(b) The plant is at least 8 km [5 statute miles] from the edge of military training routes, including low-level training routes, except for those routes associated with a usage greater than 1,000 flights per year, or where activities (such as practice bombing) may create an unusual stress situation.

(c) The plant is at least 3.2 km [2 statute miles] beyond the nearest edge of a federal airway, holding pattern, or approach pattern.

The staff review indicates that the proposed facility site does not satisfy the proximity criterion (a) because the number of flights to the Eureka Municipal and Murray Field airports exceeds that given by $500D^2$ or $1,000D^2$. Additionally, federal flight corridors V-27, V-195, and V-494 are located almost directly over the proposed site; therefore, the proximity criterion (c) also is not satisfied. Consequently, based on NUREG-0800, Section 3.5.1.6 review guidance, a detailed analysis is needed to assess the aircraft crash hazard potential for the site, taking into consideration flight activities at all nearby airports and airways.

Estimating the total probability of an aircraft crash onto the proposed facility site requires an evaluation of crash probabilities from the following nearby sources:

- Aircraft taking off and landing at nearby airports, namely Eureka-Arcata Airport, Eureka Municipal Airport, Murray Field Airport, Kneeland Airport, and Rohnerville Airport
- Commercial aviation flying along federal flight corridors V-27, V-195, V-494, and V-607
- Flights at high altitude airways
- Military aircraft flying training route VR-1251 in addition to coastal surveillance and air-sea rescue missions by the U.S. Coast Guard

The applicant has examined flight activities in connection with potential hazards from the crash of civilian or military aircraft flying in the vicinity of the proposed ISFSI site. In addition to these sources, the applicant also included the contribution from flight training activities at the U.S. Coast Guard Reservation and Lifeboat Station and U.S. Coast Guard Air Station. The staff reviewed the data, information, and analyses presented along with additional referenced documents. In addition, the staff performed various sensitivity and confirmatory analyses to develop reasonable assurance that the annual frequency of accidental aircraft crashes onto the proposed ISFSI is low and will be acceptable.

The crash frequencies for aircraft are estimated on the basis of several elements that determine the overall likelihood that each specific type of aircraft operation may lead to an impact at the proposed facility. Typically, these include measures that reflect traffic density (e.g., flights per year), crash rate (e.g., crashes per mile, crashes per unit area per unit time), and effective target area using particular parameters pertaining to specific aircraft under consideration. Other factors, such as human errors in aircraft design, fabrication, or maintenance, also influence the estimated frequencies but have not been addressed explicitly since their effects are inherently taken into account through the use of historically established crash rate data.

Both the applicant and the staff used accepted methodologies given in Section 3.5.1.6 of NUREG-0800 and U.S. Department of Energy (DOE) DOE-STD-3014-96 Standard (U.S. Department of Energy, 1996). Some of the crash rate information was taken from Kimura, et al. (1996). Although the staff's approach is generally similar to that adopted by the applicant, there are some differences in the specific parameter values used in the estimation process. These differences mostly result from the specific assumption(s) and/or scenario(s) used in addition to differences in the importance assigned to each particular source of the aircraft crash hazard as discussed later in this section. Analyses conducted by both the applicant and the staff, however, resulted in an estimated cumulative aircraft crash probability at the proposed site below the accepted threshold of 10^{-6} crashes per year. As concluded later in this section, the annual crash frequencies at the proposed site estimated by both analyses are sufficiently low to conclude that an aircraft crash onto the proposed facility is not a credible hazard. Both analyses are discussed in this section. The estimated annual crash frequency values determined by these analyses are listed in Table 15-1 of this SER.

15.1.2.15.1 Aircraft Taking Off and Landing at Nearby Airports

Commercial airports near the proposed Humboldt Bay site include (i) Eureka-Arcata Airport, approximately 32 km [20 mi] away; (ii) Eureka Municipal Airport, located on the Samoa Peninsula, approximately 3.2 km [2 mi]; (iii) Murray Field Airport, approximately 10 km [6 mi] away; (iv) Kneeland Airport, approximately 22 km [14 mi] away; and (v) Rohnerville Airport near Fortuna, approximately 24 km [15 mi] away.

The applicant, in its aircraft crash risk assessment, (Pacific Gas and Electric Company, 2004f) stated that an average of 207 daily flight operations (takeoffs and landings) takes place at the Eureka-Arcata Airport (AirNav, LLC, 2004a). This gives an annual average of 75,500 flights. Approximately 32,000 and 21,000 of the annual flight operations are by local and itinerant general aviation aircraft, respectively, and 12,000 operations at this airport are by commercial aviation using commuter jet aircraft; 500 operations are by air taxis; and the remaining 10,000 operations are by military aircraft (Federal Aviation Administration, 2004a). Aircraft using this airport have an average weight of less than 5,700 kg [12,500 lb], as stated in the SAR. Additionally, the U.S. Coast Guard Air Station is located at this airport. Coastal surveillance and rescue missions at sea and training activities are conducted by this air station. These operations are conducted mostly by military helicopters and some small nonarmed training aircraft. Four helicopters and two military aircraft are based at this airport.

The applicant, in its aircraft crash risk assessment, further stated that Eureka Municipal Airport has an average of 96 weekly flights making a total of approximately 5,000 annual operations (AirNav, LLC, 2004b). Approximately 3,000 flights are by local general aviation aircraft, and the remaining 2,000 are by itinerant general aviation aircraft. Aircraft using this airport have an average weight of less than 5,700 kg [12,500 lb], as stated in the SAR.

The applicant reported that the Murray Field Airport has an average of 179 daily flight operations (AirNav, LLC, 2004c). The annual number of operations is approximately 65,450 (Federal Aviation Administration, 2004b). This airport has approximately 45,000 and 20,000 operations by local and itinerant general aviation aircraft, respectively; 150 operations by air taxis, and 300 operations by military aircraft. Aircraft using this airport have an average weight of less than 5,700 kg [12,500 lb], as described in the SAR.

The applicant reported that the Kneeland Airport has an average of 27 daily operations (AirNav, LLC, 2004d). Approximately 10,000 annual operations take place at this airport (Federal Aviation Administration, 2004c). Local and itinerant general aviation aircraft account for 1,000 and 9,000 annual operations, respectively. Aircraft using this airport have an average weight of less than 5,700 kg [12,500 lb], as given in the SAR.

The applicant reported that an average of 75 daily operations take place at Rohnerville Airport (AirNav, LLC, 2004e). Approximately 27,500 operations take place at this airport annually (Federal Aviation Administration, 2004d). Out of these 27,500 operations, approximately 16,500 were by local general aviation aircraft. The remaining 11,000 operations are by itinerant general aviation aircraft. Aircraft using this airport have an average weight of less than 5,700 kg [12,500 lb], as stated in the SAR.

The applicant concluded that, based on the distances from the proposed facility and the number of annual operations at the airports, aircraft taking off and landing at Eureka-Arcata Airport, Kneeland Airport, and Rohnerville Airport will not pose a credible hazard because each satisfy the proximity criterion (a) of Section 3.5.1.6 of NUREG-0800. Eureka Municipal and Murray Field airports are sufficiently close to the proposed ISFSI that they do not meet the proximity criterion (a). The applicant therefore calculated the annual frequency of aircraft crashing onto the proposed facility while landing or taking off at Eureka Municipal and Murray Field airports.

The applicant assumed that 50 percent of the aircraft using the Eureka Municipal Airport are turboprop type and that the remaining aircraft use piston engines, based on the type of aircraft maintained at this airport (Pacific Gas and Electric Company, 2004f). Because of differences in wingspan (21.9 m [73 ft] versus 15 m [50 ft]), the effective areas of the proposed facility for turboprop and piston engine general aviation aircraft are 0.001515 km^2 [0.000585 mi^2] and 0.001264 km^2 [0.000488 mi^2], respectively. The applicant estimated the probability of aircraft crashing onto the proposed ISFSI from aircraft operations at the Eureka Municipal Airport to be 1.02×10^{-7} per year. A crash probability of 3.8×10^{-8} crashes per 2.6 km^2 area per aircraft movement [3.8×10^{-8} crashes per mi^2 area per aircraft movement] was assumed based on Section 3.5.1.6 of NUREG-0800.

Traffic to Murray Field Airport consists of air taxi, general aviation, and military aircraft. The applicant combined air taxis and general aviation aircraft into one category. Additionally, the applicant assumed that 178 daily flights to this airport are by air taxi and general aviation aircraft; one military aircraft flies to this airport daily. Based on information from the Federal Aviation Administration (2004b), this assumption is reasonable. The applicant again assumed that 50 percent of general aviation and air taxi aircraft using this airport are turboprop type; the remainder are piston engine type. This assumption is also based on the type of aircraft maintained at this airport.

To calculate the annual crash probability, the applicant used a crash rate of general aviation aircraft at a distance of 11 km [7 mi] from the runway of 2.5×10^{-9} crashes per 2.6 km^2 area per aircraft movement [2.5×10^{-9} crashes per mi^2 area per aircraft movement]. Because NUREG-0800, Section 3.5.1.6 does not provide crash rate information for general aviation aircraft at or beyond 11 km [7 mi] from the runway, the applicant used the data given in NUREG-0800 for closer distances to estimate the crash rate. Similarly, the applicant used the crash information given in NUREG-0800 and estimated the crash rate for military aircraft at 11 km [7 mi] from the runway to be 3.6×10^{-9} crashes per 2.6 km^2 area per aircraft movement [3.6×10^{-9} crashes per mi^2 area per aircraft movement]. The estimated annual crash frequency onto the proposed facility by all aircraft operating at Murray Field Airport is 8.72×10^{-8} (Pacific Gas and Electric Company, 2004f).

Rohnerville Airport is approximately 24 km [15 mi] away, Kneeland Airport is approximately 22 km [14 mi] away, and Eureka-Arcata Airport is approximately 32 km [20 mi] away from the proposed ISFSI site. Based on Section 3.5.1.6, subsection III.3 of NUREG-0800, the staff concludes that the estimated annual frequency of aircraft crashing onto the proposed facility while landing or taking off from any of these 3 airports is negligible.

Eureka Municipal Airport is served by all general aviation traffic with approximately 5,000 annual operations. The end of the runway is more than 3.2 km [2 mi] from the proposed facility. The crash rate for general aviation aircraft attempting to land or take off from a runway is 6.2×10^{-9} crashes per 2.6 km^2 area per aircraft movement [6.2×10^{-8} per mi^2 area per aircraft movement]. The estimated effective area of the facility for a turboprop-type general aviation aircraft is 0.001515 km^2 [0.000585 mi^2] (Pacific Gas and Electric Company, 2004f). Because the estimated effective area for piston engine aircraft is smaller, the staff conservatively used the effective area for a turboprop-type general aviation aircraft, which has longer wingspan, in the confirmatory analysis described here. Using the crash rate for general aviation aircraft provided in NUREG-0800 Section 3.5.1.6, the staff estimates that the frequency of aircraft crashing onto the proposed facility while landing or taking off from Eureka Municipal Airport is 1.8×10^{-7} per year.

Murray Field Airport is approximately 11 km [7 mi] away from the proposed site. Based on Section 3.5.1.6, subsection III.3 of NUREG-0800, the estimated annual frequency of aircraft crashing onto the proposed facility while landing or taking off at this airport is negligible. The staff assumed in this analysis that the crash rate per mi^2 of area per aircraft movement is insignificant because no crash data are available at this distance for any general aviation aircraft. The annual frequency of both general aviation and military aircraft crashing onto the proposed facility while using the Murray Field Airport is negligible using the guidance provided in NUREG-0800.

Alternatively, DOE Standard DOE-STD-3014-96 (U.S. Department of Energy, 1996) may be used to obtain the crash rate of aircraft landing and taking off at the Murray Field Airport to estimate the annual crash frequency onto the proposed facility. The staff conducted an independent analysis to provide reasonable assurance that the lack of data in the NUREG-0800, Section 3.5.1.6 methodology does not underestimate the crash hazard at the proposed facility. Available Information (AirNav, LLC, 2004c), gives the orientation of runways 11 and 29 at the Murray Field Airport to be at 135° and 315° North, respectively. The proposed ISFSI will be located at a distance of approximately 11 km [7 mi] from the center of the runways in a direction almost perpendicular to the longer axis.

There is no crash information about general aviation aircraft at a distance of more than 10 km [6 mi] from the runway in a direction perpendicular to the longer axis in the DOE Standard DOE-STD-3014-96 (U.S. Department of Energy, 1996); which suggests that the annual crash frequency at the proposed facility will be negligible. However, the crash probability of general aviation aircraft at a distance of 8 to 10 km [5 to 6 mi] is 3.5×10^{-4} per 2.6 km^2 area [3.5×10^{-4} per mi^2 area], assuming that a crash has occurred. The staff has used this crash rate in the present analysis to be conservative. Assuming a fixed wing single reciprocating engine aircraft, the DOE Standard DOE-STD-3014-96 gives a crash rate of a representative general aviation aircraft to be 2.0×10^{-5} per landing. The crash rate for takeoffs is smaller and was not used by the staff. The staff calculates that a crash rate of general aviation aircraft, therefore, will be 7.0×10^{-9} crashes per 2.6 km^2 area per aircraft movement [7.0×10^{-9} crashes per mi^2 area per aircraft movement].

The structures in consideration at the proposed facility are the storage vault and storage casks, which are hardened structures designed to withstand all design-basis tornado generated missiles. It is expected that any general aviation crashes where the aircraft sustained only partial damage or the pilot was injured will not have sufficient impact forces to cause any substantial damage to these structures leading to a radioactive release. Consequently, it can be argued that only those crashes of general aviation aircraft in which a fatality occurred might conceivably have sufficient energy to cause any significant damage to these structures. Kimura, et al. (1996) reported a total of 2,783 crashes from 1986 through 1993. Out of 2,783 crashes, only 705 crashes (25.3 percent) resulted in fatalities. Therefore, it may be assumed that the pilot flying in a general aviation aircraft will be a casualty if the crash results in a significant impact. On this basis, the general aviation crash rate in cruise mode was estimated to be approximately 1.77×10^{-9} per 2.6 km^2 per aircraft movement [1.77×10^{-9} per mi^2 per aircraft movement]. Using crash rate information given in the DOE Standard DOE-STD-3014-96, the staff estimates that the annual crash frequency of general aviation aircraft onto the proposed facility while landing or taking off at the Murray Field Airport is 6.7×10^{-8}.

Information presented in DOE Standard DOE-STD-3014-96 shows that the probability of a small military aircraft crashing onto the proposed facility, which is in a direction almost perpendicular to the runways at the Murray Field Airport, will be insignificant. Therefore, the staff estimated that the annual crash frequency onto the proposed facility by all aircraft landing and taking off at Murray Field Airport will be 6.7×10^{-8}. The staff conservatively assumed all general aviation aircraft to be turboprop type, which gives a slightly higher effective area of the facility.

15.1.2.15.2 Flights Along Federal Routes V-27, V-195, and V-494

There are three federal aviation routes almost directly over the proposed site. These routes, V-27, V-195, and V-494, converge on the Fortuna transponder (Pacific Gas and Electric Company, 2004f). The applicant obtained information from the Federal Aviation Administration (FAA) Northwest Mountain Region about the usage of these routes. Approximately 15 commercial and 3 general aviation flights use these routes daily and 6,570 flights use these routes annually.

The applicant used a rate of 4×10^{-10} crashes per 1.6 km [4×10^{-10} crashes per mi] for all commercial aviation aircraft using these airways, based on NUREG-0800 Section 3.5.1.6. Additionally, as the flight corridors pass over the proposed facility site, the applicant has assumed the width of these airways to be 3.2 km [2 mi]. Using the DOE Standard DOE-STD-3014-96, the applicant estimated the effective area of the ISFSI for commercial aircraft crashes to be 0.0246 km^2 [0.0095 mi^2]. The estimated crash frequency of commercial aircraft while flying the routes V-27, V-195, and V-494 is 1.08×10^{-8} per year (Pacific Gas and Electric Company, 2004f).

The applicant also assumed that both piston engine and turboprop-type general aviation aircraft use these flight corridors in equal proportion. Assuming a rate of 1.510×10^{-7} crashes per 1.6 km [1.510×10^{-7} crashes per mile], representative of fixed wing aircraft (Kimura, et al., 1996), the applicant estimated the annual crash frequency of general aviation aircraft to be 4.44×10^{-8}. The width of the airways was assumed to be 3.2 km [2 mi]. The applicant therefore, has estimated the combined annual frequency of aircraft crashing onto the proposed facility while traversing these airways to be 5.48×10^{-8} (Pacific Gas and Electric Company, 2004f).

The staff considers the applicant's assumption of 3-km [2-mi] wide airways extremely conservative. The regulation at 14 CFR §71.75(b)(1) states that the width of each federal airway is 13 km [8 mi] unless specified otherwise. In its analysis, the staff, therefore, assumed that airways are 13 km [8 mi] wide. The staff assumed a crash rate of 4×10^{-10} crashes per 1.6 km [4×10^{-10} crashes per mile] for all commercial aviation aircraft using these airways. Based on NUREG-0800 Section 3.5.1.6, this crash rate is appropriate because the number of daily flights in these airways is less than 100. Additionally, the staff used a crash rate of 1.788×10^{-7} crashes per 1.6 km [1.788×10^{-7} crashes per mile] from Kimura, et al. (1996), as representative for general aviation aircraft with turbine engines and rotary wing. Using a crash rate representative of general aviation fixed wing aircraft may also be appropriate here as low flight activities (3 daily flights) in these airways make only a small contribution to the cumulative annual crash frequency at the proposed facility. Using the same effective areas estimated by the applicant for commercial and general turboprop-type aircraft, the staff estimated the combined frequency of aircraft crashing onto the proposed facility while using these airways to be 1.7×10^{-8} crashes per year.

15.1.2.15.3 Flights Along Federal Route V-607

The normal approach and departure route to the Eureka-Arcata Airport is the airway V-607. The edge of this airway is 14 km [9 mi] away from the proposed site. The applicant has cited the proximity criterion (b) of NUREG-0800, Section 3.5.1.6, as the rationale for not estimating the potential crash hazard to the proposed facility from aircraft transiting airway V-607. There are, however, several secondary approach and departure patterns for this airport. Aircraft in these patterns will be either over the proposed site or within 3 km [2 mi] of the proposed site (Pacific Gas and Electric Company, 2004f).

The applicant has assumed, based on the configuration of the runways at the airport and prevailing wind directions, and normal weather patterns and instrument landing capabilities, that 5 percent (at most) of all commercial aircraft using this route will pose a hazard to the proposed facility because all commercial aircraft currently are required to fly under instrument (Pacific Gas and Electric Company, 2004f). The remaining 95 percent of commercial aircraft approaching or departing the Eureka-Arcata Airport will use airway V-607 and, therefore, do not pose any hazard to the proposed facility. Additionally, general aviation and military aircraft will not always use airway V-607 to land or depart the Eureka-Arcata Airport. The applicant argues that the secondary patterns used by the commercial aircraft also are not the likely approach and departure routes used by these aircraft. Based on discussions with a pilot, the applicant concluded that general aviation and military aircraft near the proposed facility will not be in these formal patterns. The applicant, therefore, assumed that only 5 percent of general aviation and military traffic to the Eureka-Arcata Airport will be in a position to pose a credible crash hazard to the proposed facility (Pacific Gas and Electric Company, 2004f). Additionally, the applicant assumed that the secondary approaches and departure patterns are 3.2 km [2 mi] wide, in contrast to the federal routes and airways, which are 13 km [8 mi] wide.

The applicant assumed that the number of flights by commercial aircraft through the airway that have a potential to crash onto the proposed facility will be 5 percent of 34 daily flights or 621 flights per year. Assuming the width of the airway to be 3 km [2 mi], effective facility area to be 0.0246 km^2 [0.0095 mi^2], and commercial aircraft crash rate to be 4×10^{-10} crashes per 1.6 km [4×10^{-10} crashes per mile], the applicant estimated the annual frequency of commercial aircraft crashes to be 1.18×10^{-9} (Pacific Gas and Electric Company, 2004f). Assuming 5 percent of general aviation aircraft will have a potential to crash onto the proposed facility, the applicant used 2,646 annual flights to estimate the crash hazard. The applicant further assumed that 50 percent of these aircraft are piston-driven and remaining 50 percent are turboprop-type aircraft.. The assumed crash rate for these aircraft is 1.51×10^{-7} crashes per 1.6 km [1.51×10^{-7} crashes per mile], representative of fixed wing aircraft (Kimura, et al., 1996). The applicant assumed the width of airway V-607 to be 3.2 km [2 mi] and estimated the annual frequency of crash to be 1.07×10^{-7} (Pacific Gas and Electric Company, 2004f).

Both military helicopters and air taxis use airway V-607. The applicant assumed all flights are by helicopters only. As the applicant could not obtain the crash rate for military helicopters, a value of 3.543×10^{-7} crashes per 1.6 km [3.543×10^{-7} crashes per mile], representative of rotary wing aircraft (Kimura, et al., 1996), was assumed (Pacific Gas and Electric Company, 2004f). Again, assuming 5 percent of the flights will have a crash potential at the proposed site, the applicant used 511 annual flights in the calculation. The applicant again assumed the width of airway V-607 to be 3 km [2 mi] and estimated the effective area of the proposed facility to be 0.00034 km^2 [0.00013 mi^2] for military helicopters. The estimated crash frequency is 1.18×10^{-8} per year. The estimated crash frequency onto the proposed facility from all aircraft using the airway V-607 is 1.2×10^{-7} per year (Pacific Gas and Electric Company, 2004f).

In its estimate, the staff considered the crash frequency of aircraft using airway V-607, following the methodology for airways suggested in NUREG-0800, Section 3.5.1.6. The staff estimated the annual crash frequency by separating the potential hazard originating from two sources or flight locations: (i) the aircraft is in airway V-607 and is at some distance away from the airport, which is 32 km [20 mi] from the proposed facility; or (ii) the aircraft is close to the airport so that it can be considered in the near-airport environment. Aircraft near the Eureka-Arcata Airport, including aircraft on all secondary approach and departure patterns, are considered to be in the near-airport environment because they are dependent on the orientation of the runways. The potential crash frequency of aircraft near the Eureka-Arcata Airport has been evaluated in Subsection 15.1.2.15.1 of this SER using the formula given in subsection III.3 of Section 3.5.1.6 of NUREG-0800. An evaluation of potential crash hazards while the aircraft is still in V-607 and outside the near-airport environment is given here. This portion of the crash frequency was estimated using the formula given in subsection III.2 of Section 3.5.1.6 of NUREG-0800.

Approximately 207 daily flights or 75,500 yearly flights use this airway. Out of these flights, 53,000 flights are by general aviation aircraft; 12,000 flights are by commuter aircraft (assumed to be commercial aircraft); and 10,000 flights are by military air taxi/transport aircraft (Federal Aviation Administration, 2004a). The staff assumed the width of this airway to be 13 km [8 mi], as per 14 CFR §71.75(b)(1). Because the proposed facility will be located outside the airway, the effective width of the airway for estimating the crash frequency will be 42 km [26 mi], per NUREG-0800, Section 3.5.1.6.

The staff assumed the facility effective area to be 0.0246 km^2 [0.0095 mi^2] for commercial aircraft, 0.00152 km^2 [0.000585 mi^2] for general aviation turboprop type aircraft, and 0.00058 km^2 [0.000224 mi^2] for military aircraft based on Pacific Gas and Electric Company (2004f). The staff assumed a crash rate of 4.0×10^{-10} crashes per 1.6 km [4.0×10^{-10} crashes per mile] for commercial aircraft, per NUREG-0800, Section 3.5.1.6. The crash rate for general aviation aircraft is conservatively assumed to be 1.788×10^{-7} crashes per 1.6 km [1.788×10^{-7} crashes per mile], representative of turbine engine, rotary wing type aircraft (Kimura, et al., 1996). The crash rate for military air taxis was assumed to be the same as general aviation aircraft.

The staff estimated the annual crash frequency for commercial, general aviation, and military aircraft to be 1.75×10^{-9}, 2.13×10^{-7}, and 4.02×10^{-8}, respectively. This independent analysis produced an estimated crash frequency onto the proposed facility by all aircraft while using the airway V-607 of 2.6×10^{-7} per year.

15.1.2.15.4 High Altitude Airspace

There are some high altitude airways, almost exclusively at 9,990 m [33,000 ft] that traverse the general area of the proposed facility. Approximately 52 flights use these airways daily (Pacific Gas and Electric Company, 2004f). Approximately 32 of these flights are by commercial jet aircraft transitioning from oceanic airspace to San Francisco. Approximately 16 military aircraft of unknown types use this high altitude airspace. Additionally, there are approximately four general aviation type aircraft using this airspace daily.

The applicant used a crash rate of 4.0×10^{-10} crashes per 1.6 km [4.0×10^{-10} crashes per mile] for commercial aircraft flying at high altitudes, per NUREG-0800, Section 3.5.1.6. The applicant again assumed that general aviation aircraft with both turboprop and piston engine use this corridor in equal proportion (Pacific Gas and Electric Company, 2004f). The crash rate for general aviation aircraft using this high altitude corridor was assumed to be 1.510×10^{-7} crashes per 1.6 km [1.510×10^{-7} crashes per mile], representative of fixed wing type aircraft (Kimura, et al., 1996). Because the types of military aircraft using this corridor are unknown, the applicant assumed them all to be F-16s with a crash rate of 2.736×10^{-8} crashes per 1.6 km [2.736×10^{-8} crashes per mile], as developed for the license application for the Private Fuel Storage Facility (2000). The assumption that military aircraft are F-16s, due to lack of any specific information on the aircraft type, is acceptable because F-16s have a relatively high crash rate among military aircraft (Kimura, et al., 1996).

The applicant estimated the annual crash frequency for commercial, general aviation, and military aircraft to be 2.22×10^{-8}, 5.91×10^{-8}, and 1.79×10^{-7}, respectively. The applicant's estimated crash frequency onto the proposed facility by all aircraft while flying the high altitude corridor, therefore, is 2.60×10^{-7} per year.

The staff assessed the annual crash frequency associated with flying the high altitude corridor assuming the crash rate for commercial, general aviation, and military aircraft to be 4.0×10^{-10} crashes per 1.6 km [4.0×10^{-10} crashes per mile], 1.788×10^{-7} crashes per 1.6 km [1.788×10^{-7} crashes per mile], and 2.736×10^{-8} crashes per 1.6 km [2.736×10^{-8} crashes per mile], respectively. The staff conservatively assumed that the general aviation aircraft flying this corridor are turbine engine, rotary wing type. Additionally, the staff assumed the width of the airway is 13 km [8 mi], as before. The staff followed DOE Standard DOE-STD-3014-96 to estimate the effective area of the proposed facility for military aircraft crashes. While flying this corridor, the aircraft will be in an inflight mode. Therefore, as suggested in the DOE Standard DOE-STD-3014-96, values appropriate for takeoff were used where available. The staff estimated the effective area of the proposed facility to be 0.0043 km^2 [0.00166 mi^2] for an F-16 aircraft. The estimated annual crash frequencies for commercial, general aviation, and military aircraft are 5.55×10^{-9}, 1.91×10^{-8}, and 3.32×10^{-8}, respectively. Therefore, the staff's estimated crash frequency onto the proposed facility by all aircraft types flying the high altitude corridor is 5.8×10^{-8} per year.

15.1.2.15.5 Military Aviation Along Route VR-1251

The military training route near the proposed ISFSI is VR-1251. It is approximately 29 km [18 mi] from the proposed facility. Its use is limited to transport through the area. There are no major military facilities within 80 km [50 mi] of the proposed facility. The U.S. Coast Guard Reservation and Lifeboat Station is located at the tip of Samoa Peninsula, approximately 2.4 km [1.5 mi] north of the proposed site. Training activities, as well as surveillance and sea rescue missions along the coastline, are conducted from this location and the U.S. Coast Guard Air Station located at the Eureka-Arcata Airport.

The applicant concluded, based on NUREG-0800, Section 3.5.1.6, that any flights by military aircraft in these training routes will have a negligible crash hazard to the proposed facility because the facility will be located at least 8 km [5 mi] beyond the nearest edge of a flight path. The staff agrees with this conclusion because route VR-1251 is a significant distance away from the proposed facility; therefore, an aircraft using that route will have negligible potential to crash on the proposed facility. Similarly, activities at the U.S. Coast Guard Air Station, located at the Eureka-Arcata Airport, will have an insignificant contribution to the total frequency of aircraft crash at the proposed facility due to significant distance. Additionally, coastal surveillance and air-sea rescue missions along the Humboldt County coastline are carried out from the U.S. Coast Guard Reservation and Lifeboat Station, located at the tip of Samoa Peninsula approximately 2.5 km [1.5 mi] from the proposed facility. Generally, these missions are carried out by helicopters. Based on DOE Standard DOE-STD-3014-96, the staff concludes that the helicopter flights will not pose a credible hazard to the proposed facility because the intended flight path is over the coastline and more than 0.4 km [0.25 mi] away from the proposed site.

15.1.2.15.6 Probability Acceptance Criterion for Aircraft Crash Hazards

NUREG-0800, Section 3.5.1.6, provides the methodology to estimate the probability of aircraft crashing onto a nuclear power plant. An operating nuclear power plant requires active systems to control the dynamic nuclear and thermal processes that occur in the conversion of nuclear reactions into thermal power. In the event of a mishap, there are large amounts of thermal energy within the reactor core. Emergency cooling systems are provided as part of a reactor facility design to avoid core damage or meltdown and the release of radioactive material into the environment.

Hazards that have the potential for initiating onsite accidents leading to loss of coolant at a reactor facility should have a sufficiently low probability of occurrence. NUREG-0800, Section 2.2.3 (U.S. Nuclear Regulatory Commission, 1981d), states a probability of occurrence of approximately 1×10^{-7} per year as the NRC staff objective, to screen out external events that may impact the nuclear reactor and have consequences on the safety of the facility and the potential for significant radiological impacts on public health and safety. However, data are often not available to permit an accurate estimation of the probabilities of occurrence of the postulated events. Accordingly, a probability of occurrence of potential radiation exposures in excess of the 10 CFR Part 100 dose guidelines of approximately 1×10^{-6} per year is acceptable for a nuclear power plant provided, when combined with qualitative arguments, the realistic probability can be shown to be lower. In its Policy Statement on Safety Goals, the Commission noted, "Consistent with the traditional defense-in-depth approach and the accident mitigation philosophy requiring performance of containment systems, the overall mean frequency of a large release of radioactive materials to the environment from a reactor accident should be less than 1 in 1,000,000 per year of reactor operation (U.S. Nuclear Regulatory Commission, 1986)." This translates to a probability of occurrence of 1×10^{-6} per year. In addition, the Commission has proposed an annual probability of occurrence of 1×10^{-6} for geologic repositories (U.S. Nuclear Regulatory Commission, 1999).

Compared to a nuclear reactor facility, an ISFSI is a relatively passive system that does not have complex control requirements and has contents with relatively low thermal energy. Consequently, potential fuel damage and the associated radioactive source terms from a potential accident at an ISFSI are significantly less than those expected from a potential accident at a nuclear reactor facility, and as a result, the estimated consequences are less severe. The staff, therefore, concludes that a probability of 1×10^{-6} crashes per year is an acceptable threshold probability criterion for evaluating aircraft crash hazards at the proposed ISFSI.

15.1.2.15.7 Summary of Aircraft Hazards Review

The applicant examined past and present activities in connection with potential hazards from the crash of civilian and military aircraft flying in the vicinity of the proposed facility. The activities examined include aircraft taking off and landing at nearby airports; aircraft flying Federal Airways V-27, V-195, V-494, and V-607; aircraft flying high altitude routes; and military aircraft flying in training route VR-1251. The staff reviewed the scenarios, data, information, and analyses presented by the applicant in connection with the proposed facility.

Summarizing the staff review, the crash probabilities for aircraft are given in Table 15-1. In addition, Table 15-1 gives the crash frequency estimates presented by the applicant (Pacific Gas and Electric Company, 2004f). These frequencies are estimated on the basis of several elements that determine the overall likelihood that each specific type of aircraft operation may lead to an impact at the proposed facility. Typically, these include measures that reflect traffic density (e.g., flights per year), crash rate (e.g., crashes per mile, crashes per unit area per unit time), and the effective target area.

The estimated crash probability values determined by the staff are different from those determined by the applicant because of different scenarios and assumptions made. However, both the staff's and the applicant's crash estimates fall below the acceptance criterion, and are in general agreement. Based on the information presented in Table 15-1 and the threshold probability criterion of 1×10^{-6} crashes per year, the staff concludes that the annual frequency of crashes for both civilian and military aircraft at the Humboldt Bay ISFSI is acceptable.

15.1.2.15.8 Future Developments

The SAR estimated the projected growth of civilian flights based on the Federal Aviation Administration long-range forecast (Federal Aviation Administration, 1999). Based on the FAA forecasts for the airports, the commercial and general aviation aircraft operations are projected to increase. Commercial aircraft operations include air carrier and commuter/air taxi takeoffs and landings at all United States towered and nontowered airports. Based on the FAA forecasts, the commercial aircraft operations are projected to increase from 28.6 million in 1998 to 36.6 million in 2010 and to 47.6 million in 2025. Commercial aviation operations in the United States, therefore, are projected to increase by 66 percent by 2025. The annual number of general aviation operations (takeoffs and landings) at all towered and nontowered airports in the United States are projected to increase from 87.4 million in 1998 to 92.8 million in 2010 and to 99.2 million in 2025 (Federal Aviation Administration, 1999). The FAA, therefore, projects an increase of general aviation traffic of 14 percent by 2025. The FAA predicts that the military air traffic will not increase appreciably, if at all, in the foreseeable future.

Table 15-1. Summary of Estimated Annual Aircraft Crash Hazard Frequency at the Proposed Humboldt Bay ISFSI

Source	Estimated Annual Frequency of Aircraft Crash Hazard	
	Pacific Gas and Electric Company	NRC
Eureka-Arcata Airport	0	~0
Eureka Municipal Airport	1.02×10^{-7}	1.8×10^{-7}
Murray Field Airport	8.72×10^{-8}	~0 to 6.7×10^{-8}
Kneeland Airport	0	~0
Rohnerville Airport	0	~0
Routes V27, V195, and V194	5.48×10^{-8}	1.7×10^{-8}
Route V607	1.27×10^{-7}	2.6×10^{-7}
High Altitude Routes	2.60×10^{-7}	5.8×10^{-8}
Military Aviation	0	~0
Helicopters.	0	~0
Cumulative	6.24×10^{-7}	5.2×10^{-7} to 5.8×10^{-7}

Based on the staff's independent annual crash frequency estimates listed in Table 15-1 and the increase of commercial and general aviation traffic projected by the FAA, the frequency of aircraft crashes per year onto the proposed facility will increase in 2025 from the estimated 5.2×10^{-7} to 5.8×10^{-7} to 5.9×10^{-7} to 6.6×10^{-7} per year. This remains below the threshold probability of 1×10^{-6} crashes per year, and is therefore acceptable to the staff.

15.2 Evaluation Findings

The applicant has provided acceptable analyses of the design and performance of SSCs important to safety under credible off-normal events and accident scenarios. The following summarizes the findings of the staff that pertain to the off-normal event and accident review.

Off-Normal Events

The staff evaluated the information provided in Section 8.1 of the SAR on off-normal events. The potential events analyzed in the SAR, addressing Design Event I and II (American National Standards Institute/American Nuclear Society, 1992), relate to the nonmechanistic off-normal pressure, off-normal environmental temperature, and confinement boundary leakage during interim storage and cask drop from allowable design height during transfer operations. In addition, the SAR addressed loss of electric power and off-normal transporter operations caused by human error and component failure.

The staff finds the information provided by the applicant to preclude cask drop from less than design allowable drop height acceptable. The cask transporter will have redundant drop protection features and conform to the single-failure-proof requirements of NUREG-0612 (U.S. Nuclear Regulatory Commission, 1980) and ANSI N14.6 (American National Standards Institute, 1993). The staff concludes that the trunnion design and the top flange of the trunnion/overpack interface of the HI-STAR HB cask satisfy the single-failure-proof design criteria in accordance with NUREG-0612. As a result, an evaluation of a cask drop from less than the design allowable height is not required.

The staff finds that the off-normal pressure event will not exceed the design basis for MPC-HB off-normal pressure. The staff accepts that the fuel cladding temperature will not exceed the allowable temperature because of off-normal environmental temperature during interim storage of the cask in the storage vault. The MPC-HB confinement boundary meets the no credible leak design criterion in ISG-18 (U.S. Nuclear Regulatory Commission, 2003a), therefore, leakage of the confinement boundary as an off-normal event is not credible. The staff finds the applicant's evaluation that cask handling operations are not affected by the loss of electrical power acceptable. The off-normal cask transporter operations primarily result from operator error or failure of equipment. The design features of SSCs, operational controls, and actions by the support team accompanying the transporter will prevent the off-normal event. As a result, no consequences that affect the public health and safety are expected from these off-normal events so long as the fuel specifications in Chapter 7 and loading conditions as defined in the HI-STAR HB design bases, as discussed in Chapter 4 of this SER, are met.

The staff finds that the SAR adequately considered off-normal events that may result from facility operations. The information provided about the facility operations and design features of SSCs important to safety is sufficient to conclude that the Humboldt Bay ISFSI operations can be conducted without endangering the health and safety of the public during potential off-normal events.

In summary, the analyses in the SAR for off-normal events demonstrate that the proposed Humboldt Bay ISFSI will be designed, constructed, and operated so that during all credible off-normal events, public health and safety will be adequately protected. The staff finds that the proposed ISFSI will maintain subcriticality, confinement, and sufficient shielding for all credible off-normal events, consistent with the requirements of 10 CFR §72.106(b), §72.122(b), §72.122(c), §72.122(h)(1), §72.122(h)(4), §72.122(h)(5), §72.122(i), §72.122(l), §72.124(a), and §72.128(a)(2).

Accidents

The staff evaluated the information provided in Section 8.2 of the SAR regarding potential accidents addressing Design Events III and IV (American National Standards Institute/American Nuclear Society, 1992).

The potential events analyzed that relate to ISFSI operations include cask drops and tipover, leakage of the confinement boundary, misloading of damaged fuel assemblies, 100 percent fuel rod rupture, turbine missile strike, and blockage of MPC-HB vent holes. In addition, the applicant also evaluated fire and explosion hazards that could affect the ISFSI handling operations and interim storage. The applicant addressed the potential fire, explosions, and missiles generated by explosions initiated by onsite and offsite events. The applicant adequately demonstrated that these accident events are prevented or mitigated based on the design features of the SSCs and operational procedures; hence no increase in radiological dose is expected to result from these events. The applicant further evaluated the bounding radiological consequences for a hypothetical complete loss of HI-STAR HB overpack shielding as a postfire condition and demonstrated that the radiological dose will not exceed regulatory limits. The staff finds that the SAR adequately considered accident events that may occur during transfer and emplacement in the storage vault and during interim storage. The staff concludes that the cask drop and tipover accident is precluded because the load path components of the transporter, HI-STAR HB lifting trunnion, and top flange at the trunnion/overpack interface satisfy the single-failure-proof design criteria in accordance with NUREG-0612. The staff also considers that the applicant has demonstrated that adequate operating procedures will be in place in accordance with the Technical Specifications to preclude misloading of the damaged fuel assemblies. The staff accepts that the fuel cladding temperature will not exceed the allowable temperature limit due to extreme environmental temperature during interim storage of the cask in the storage vault. Radiological consequences are not expected to result from potential accident leakage of the confinement boundary, a 100-percent fuel rod rupture, a turbine missile strike, or blockage of MPC-HB vent holes, and the applicant's evaluations of these accidents are acceptable.

The applicant evaluated the impact of external events on the ISFSI, including earthquakes, tornadoes, missiles generated by natural phenomena, flood, extreme environmental temperatures, lightning, and aircraft impact. The SAR demonstrated that the SSCs important to safety at the proposed ISFSI are adequately protected against or designed to withstand the design basis flood, tsunami, tornado wind, and tornado missile strikes. The staff finds that the transporter design adequately protects the overpack against lightning strikes. The staff finds that the cumulative probability of occurrence of civilian and military aircraft crash accidents is below the threshold probability criterion of 1×10^{-6} crashes per year.

Based on the information provided on earthquakes as potential hazards, the staff finds the applicant's evaluations of tipover of the HI-STAR HB cask from the rail dolly at the RFB, stability of the cask transporter during transfer from RFB to the ISFSI site, lowering of the cask in the storage vault, and design of the seismic restraints in the storage vault acceptable. In addition, the applicant has provided sufficient documentation demonstrating adequate validation of the computer software, Visual Nastran, used in these analyses. The staff concludes that the applicant has demonstrated that the SSCs important to safety will be adequately protected from adverse impacts of potential earthquake events.

The staff finds that the SAR adequately considered accidents that may result from facility operations. The information provided about the facility operations and design features of SSCs is sufficient to conclude that the Humboldt Bay ISFSI operations can be conducted without endangering the health and safety of the public during potential accidents.

Based on the information provided, the staff finds that the proposed Humboldt Bay ISFSI will be designed, constructed, and operated so that during all credible accident events, public health and safety will be adequately protected. Based on the analyses submitted by the applicant and the staff's independent confirmatory analyses, the staff finds that the proposed ISFSI will maintain subcriticality, confinement, and sufficient shielding for all credible accident scenarios, consistent with the requirements of 10 CFR §72.90, §72.92, §72.94, §72.98(a), §72.98(c), §72.106(b), §72.122(b), §72.122(c), §72.122(h)(1), §72.122(h)(4), §72.122(h)(5), §72.122(i), §72.122(l), §72.124(a), and §72.128(a)(2).

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16 TECHNICAL SPECIFICATIONS

16.1 Conduct of Review

This chapter of the Safety Evaluation Report (SER) evaluates the proposed Technical Specifications (TS) for the Humboldt Bay Independent Spent Fuel Storage Installation (ISFSI). Attachment C, "Proposed Technical Specifications," of the License Application (Pacific Gas and Electric Company, 2004a) and Chapter 10, "Operating Controls and Limits," of the Safety Analysis Report (SAR) (Pacific Gas and Electric Company, 2004b) provide information about the proposed TSs, including their bases and justification. The Technical Specifications include functional and operating limits, monitoring instruments and limiting control settings, limiting conditions, surveillance requirements, design features, and administrative controls to ensure safe operation of the facility. The review objectives of this chapter are to ensure that the proposed Technical Specifications are complete, appropriately defined and justified, and supported by the technical disciplines reviewed in this SER.

The review considered how the SAR and related documents address the regulatory requirements of 10 CFR §72.26, §72.44(a), §72.44(c)(1–5), and §72.44(d)(1–3). Complete citations of these regulations are provided in the Appendix of this SER.

The storage system to be used at the Humboldt Bay ISFSI is the HI-STAR HB System. The HI-STAR HB system is a modified version of the HI-STAR 100 system, which is described in detail in the HI-STAR 100 system Final Safety Analysis Report (Holtec International, 2002). The Humboldt Bay ISFSI Technical Specifications are based on the approved Technical Specifications for the Holtec HI-STAR 100 system (U.S. Nuclear Regulatory Commission, 2001a, Appendices A and B). Where applicable, the staff relied on its findings from its previous review of the HI-STAR 100 system, as documented in the HI-STAR 100 Cask System SER (U.S. Nuclear Regulatory Commission, 2001b).

16.1.1 Functional/Operating Limits, Monitoring Instruments, and Limiting Control Settings

Functional and operating limits are those limits on fuel and waste handling and storage conditions necessary to protect the integrity of the stored fuel and waste container, to protect employees against occupational exposure, and to guard against the uncontrolled release of radioactive materials. The functional and operating limits that will be included in the Humboldt Bay ISFSI Technical Specifications, and the associated SAR sections, are listed in Table 16-1. The table also lists the sections of this SER that address each functional and operating limit.

Based on a review of the application, the staff confirms that the functional and operating limits listed in Table 16-1 to be placed on fuel and waste to be stored at the Humboldt Bay ISFSI are necessary to protect the integrity of the stored fuel, to protect employees against occupational exposure, and to guard against the uncontrolled release of radioactive materials. In addition, the staff confirms that because of the passive design features of the Humboldt Bay ISFSI, the applicant's proposal to not include technical specifications for monitoring instruments and limiting control settings is acceptable. The staff concludes that the proposed Technical Specifications for the Humboldt Bay ISFSI are in compliance with 10 CFR §72.26 and §72.44(c)(1).

Table 16-1. Functional/Operating Limits, Monitoring Instruments, and Limiting Control Settings			
Technical Specification Item	Functional/Operating Limit	Associated SAR Section(s)	Associated SER Section(s)
2.1.1	Spent Nuclear Fuel to be Stored	3.1.1, 10.2.1	4.1.1, 6.1.2, 7.1.1, 8.1.2
2.1.2	Greater than Class C Waste To Be Stored	3.1.1.4, 10.2.1.3	4.1.1, 7.1.1
2.2	Functional and Operating Limits Violations	10.2.1.4	8.1.2

16.1.2 Limiting Conditions/Surveillance Requirements

Limiting conditions for operation (LCOs) are the lowest functional capability or performance levels of equipment required for safe operation. Surveillance requirements (SRs) include inspection, test, and calibration activities to ensure that the necessary integrity of required systems is maintained, confirmation that operation of the ISFSI is within the required functional and operating limits, and confirmation that the limiting conditions required for safe storage are met. The LCOs and SRs that will be included in the Humboldt Bay ISFSI Technical Specifications and the associated SAR sections are listed in Table 16-2. The table also lists the sections of this SER that address each LCO and SR.

The staff confirmed that the LCOs listed in Table 16-2 specify the lowest functional capability for the equipment required for safe operation. In addition, the staff confirmed that the SRs listed in Table 16-2 provide for necessary inspection and testing, confirm operation within appropriate functional and operating limits, and confirm that LCOs for safe storage are met. The staff finds that the proposed Technical Specifications for the Humboldt Bay ISFSI are in compliance with 10 CFR §72.26, §72.44(c)(2), and §72.44(c)(3).

Table 16-2. Limiting Conditions for Operation and Surveillance Requirements				
Technical Specification Item	Limiting Condition for Operation	Associated Surveillance Requirements	Associated SAR Section(s)	Associated SER Section(s)
3.1.1	Multi-Purpose Canister (MPC-HB) - Drying, Helium Backfilling, and Leak Rate Limits	SR 3.1.1.1, 3.1.1.2, 3.1.1.3	4.4.1.2.3, 5.1.1.2, 10.2.2	4.1.3.3, 9.1.3
3.1.2	Overpack Heat Removal System - Drying, Helium Backfilling, and Leak Rate Limits	SR 3.1.2.1, 3.1.2.2, 3.1.2.3	4.4.1.2.3, 5.1.1.2, 10.2.4	4.1.3.3
3.1.3	MPC-HB Fuel Cool Down - Cavity Bulk Helium Temperature Limit	SR 3.1.3.1	4.4.1.2.6, 10.2.3	3.1.1

16.1.3 Design Features

The design features of the technical specifications include items that could have a significant effect on safety if altered or modified (e.g., materials of construction or geometric arrangements). The design features that will be included in the Humboldt Bay ISFSI Technical Specifications and the associated SAR sections are listed in Table 16-3. The table also lists the sections of this SER that address each design feature.

The staff confirmed that the design features listed in Table 16-3 are those which, if altered, could have a significant effect on safety. The staff finds the proposed Technical Specifications for the Humboldt Bay ISFSI are in compliance with 10 CFR §72.26 and §72.44(c)(4).

Table 16-3. Design Features

Technical Specification Item	Design Feature	Associated SAR Sections	Associated SER Sections
4.1.1	Criticality Control	3.3.1.4, 4.2.3.3.7	8.1.1.2
4.2	Codes and Standards	4.2.3.3	4.1.3.2, 5.1.1, 5.1.4, 9.1.1
4.2.1	Alternatives to Design Codes, Standards, and Criteria	3.4, Table 3.4-5	4.1.3.2
4.3.1	Cask Transporter	3.3.3, 4.3.2.1, Table 3.4-4	3.1.1, 4.1.3.2, 5.1.4.1
4.3.2	Storage Capacity	3.1	1.1.1, 4.1.1
4.3.3	Spent Fuel Storage Cask Load Handling Equipment	4.4.1	3.1.2

16.1.4 Administrative Controls

The administrative controls of the technical specifications include controls on the ISFSI organization and management, record keeping, review and audit, and reporting processes. The administrative controls included in the Humboldt Bay ISFSI Technical Specifications and the associated SAR sections are listed in Table 16-4. The table also lists the sections of this SER that address those administrative controls.

The staff confirmed that the administrative controls listed in Table 16-4 are those necessary to ensure that the operations involved in the storage of spent nuclear fuel (SNF) at the ISFSI are performed in a safe manner. The staff finds that the proposed Technical Specifications for the Humboldt Bay ISFSI are in compliance with 10 CFR §72.26, §72.44(c)(5), and §72.44(d)(1–3).

Table 16-4. Administrative Controls			
Technical Specification Item	Administrative Control	Associated SAR Sections	Associated SER Sections
5.1.1	Technical Specifications Bases Control Program	10.2.9	10.1.3.1
5.1.2	Radioactive Effluent Control Program	7.2.2, 7.3.4, 7.5.3	11.1.2.5, Chapter 14
5.1.3	MPC-HB and Spent Fuel Storage Cask Loading, Unloading, and Preparation Program	10.2	3.1.1, 8.1.2, 10.1.2.2, 10.1.3.1
5.1.4	ISFSI Operations Program	Chapter 5	Chapter 3
5.1.5	Cask Transportation Evaluation Program	8.2, 9.2.6, 10.2.9	10.1.3.1, 15.1.2
5.1.6	Greater than Class C Cask Loading and Preparation Program	3.1.1.4, 7.2.1.1. 10.2	7.1.1.1, 10.1.3.1

16.1.5 License Conditions

Section 10 CFR §72.44(a) requires that each license issued under 10 CFR Part 72 includes license conditions which pertain to design, construction, and operation, or which the U.S. Nuclear Regulatory Commission may include as it deems appropriate. In addition, 10 CFR §72.44(b) specifies whether certain license conditions which apply to each license issued under 10 CFR Part 72 are explicitly stated in the license. Those conditions are specified in 10 CFR §72.44(b)(1) through (b)(6) and are binding on the Humboldt Bay ISFSI license, but are not explicitly restated in the Humboldt Bay ISFSI license.

Table 16-5 lists the license conditions that the staff identified during its review of the Humboldt Bay ISFSI License Application and associated documents. These license conditions, related to the testing program for the neutron absorber materials and record keeping requirements, are discussed in Sections 8.1.3.2 and 10.1 of this SER, respectively. The staff finds that the proposed license conditions for the Humboldt Bay ISFSI are in compliance with 10 CFR §72.26 and §72.44(a).

Table 16-5. License Conditions	
License Condition Description	Associated SER Section
Testing of Neutron Absorber Materials	8.1.3.2
Record keeping requirements	10.1

16.2 Evaluation Findings

Based on its review of the information in the license application and SAR, the staff makes the following findings regarding the Technical Specifications for the Humboldt Bay ISFSI:

- The license application and SAR identify necessary technical specifications for the ISFSI to satisfy the requirements of 10 CFR §72.26, §72.44(a), §72.44(c)(1–5), and §72.44(d)(1–3).

- The proposed Humboldt bay ISFSI Technical Specifications provide reasonable assurance that the ISFSI will allow safe storage of spent nuclear fuel and Greater than Class C waste.

16.3 References

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APPENDIX

TITLE 10 CODE OF FEDERAL REGULATIONS APPLICABLE TO THE HUMBOLDT BAY INDEPENDENT SPENT FUEL STORAGE INSTALLATION

The following list identifies the primary regulations governing the licensing requirements for the Humboldt Bay Independent Spent Fuel Storage Installation. Individual regulations are cited throughout the staff's Safety Evaluation Report, as applicable.

10 CFR PART 20 - STANDARDS FOR PROTECTION AGAINST RADIATION

- 10 CFR §20.1101, "Radiation protection programs," states that: (a) Each licensee shall develop, document, and implement a radiation protection program commensurate with the scope and extent of licensed activities and sufficient to ensure compliance with the provisions of this part. (b) The licensee shall use, to the extent practical, procedures and engineering controls based upon sound radiation protection principles to achieve occupational doses and doses to members of the public that are as low as is reasonably achievable (ALARA). (c) The licensee shall periodically (at least annually) review the radiation protection program content and implementation. (d) To implement the ALARA requirements of §20.1101(b), and notwithstanding the requirements in §20.1301 of this part, a constraint on air emissions of radioactive material to the environment, excluding Radon-222 and its daughters, shall be established by licensees other than those subject to §50.34a, such that the individual member of the public likely to receive the highest dose will not be expected to receive a total effective dose equivalent in excess of 10 mrem (0.1 mSv) per year from these emissions. If a licensee subject to this requirement exceeds this dose constraint, the licensee shall report the exceedance as provided in §20.2203 and promptly take appropriate corrective action to ensure against recurrence.

- 10 CFR §20.1201, "Occupational dose limits for adults," paragraph(a), states that: The licensee shall control the occupational dose to individual adults, except for planned special exposures under §20.1206, to the following annual dose limits. (1) An annual limit, which is the more limiting of - (i) the total effective dose equivalent being equal to 5 rems (0.05 Sv); or (ii) The sum of the deep-dose equivalent and the committed dose equivalent to any individual organ or tissue other than the lens of the eye being equal to 50 rems (0.5 Sv). (2) The annual limits to the lens of the eye, to the skin of the whole body, and to the skin of the extremities, which are: (i) A lens does equivalent of 15 rems (0.15 Sv), and (ii) A shallow-dose equivalent of 50 rem (0.5 Sv) to the skin of the whole body or to the skin of any extremity.

- 10 CFR §20.1301, "Dose limits for individual members of the public," paragraph (a), states that: Each licensee shall conduct operations so that - (1) The total effective dose equivalent to individual members of the public from the licensed operation does not exceed 0.1 rem (1 mSv) in a year, exclusive of the dose contributions from background radiation, from any medical administration the individual has received, from exposure to individuals administered radioactive material and released under §35.75, from voluntary participation in medical research programs, and from the licensee's disposal of radioactive material into sanitary sewerage in accordance with §20.2003, and (2) The dose in any unrestricted area from external sources, exclusive of the dose contributions from patients administered radioactive material released in accordance with §35.75, does not exceed 0.002 rem (0.02 mSv) in any one hour.

- 10 CFR §20.1301, paragraph (b), states that: If the licensee permits members of the public to have access to controlled areas, the limits for members of the public continue to apply to those individuals.

- 10 CFR §20.1301, paragraph (e), states that: In addition to the requirements of this part, a licensee subject to the provisions of EPA's generally applicable environmental radiation standards in 40 CFR Part 190 shall comply with those standards.

- 10 CFR §20.1302, "Compliance with dose limits for individual members of the public," states that: (a) The licensee shall make or cause to be made, as appropriate, surveys of radiation levels in unrestricted and controlled areas and radioactive materials in effluents released to unrestricted and controlled areas to demonstrate compliance with the dose limits for individual members of the public in §20.1301. (b) A licensee shall show compliance with the annual dose limit in §20.1301 by - (1) Demonstrating by measurement or calculation that the total effective dose equivalent to the individual likely to receive the highest dose from the licensed operation does not exceed the annual dose limit; or (2) Demonstrating that - (i) The annual average concentrations of radioactive material released in gaseous and liquid effluents at the boundary of the unrestricted area do not exceed the values specified in table 2 of appendix B to part 20; and (ii) If an individual were continuously present in an unrestricted area, the dose from external sources would not exceed 0.002 rem (0.02 mSv) in an hour and 0.05 rem (0.5 mSv) in a year.

- 10 CFR §20.1406, "Minimization of contamination," states that: Applicants for licenses, other than renewals, after August 20, 1997, shall describe in the application how facility design and procedures for operation will minimize, to the extent practicable, contamination of the facility and the environment, facilitate eventual decommissioning, and minimize, to the extent practicable, the generation of radioactive waste.

- 10 CFR §20.1501, regarding surveys and monitoring, paragraph (a)(1), states that: Each licensee shall make or cause to be made, surveys that may be necessary for the licensee to comply with the regulations in this part.

- 10 CFR §20.1701, "Use of process or other engineering controls," states that: The licensee shall use, to the extent practical, process or other engineering controls (e.g., containment, decontamination, or ventilation) to control the concentration of radioactive material in air.

- 10 CFR §20.1702, "Use of other controls," paragraph (a), states that: When it is not practical to apply process or other engineering controls to control the concentrations of radioactive material in the air to values below those that define an airborne radioactivity area, the licensee shall, consistent with maintaining the total effective dose equivalent ALARA, increase monitoring and limit intakes by one or more of the following means - (1) Control of access; (2) Limitation of exposure times; (3) Use of respiratory protection equipment; or (4) Other controls.

10 CFR PART 72 - LICENSING REQUIREMENTS FOR THE INDEPENDENT STORAGE OF SPENT NUCLEAR FUEL, HIGH-LEVEL RADIOACTIVE WASTE, AND REACTOR-RELATED GREATER THAN CLASS C WASTE

- 10 CFR §72.2, "Scope," paragraph (a)(1), states that: Except as provided in §72.6(b), licenses issued under this part are limited to the receipt, transfer, packaging, and possession of power reactor spent fuel to be stored in a complex that is designed and constructed specifically for storage of power reactor spent fuel aged for at least one year, other radioactive materials associated with spent fuel storage, and power reactor-related GTCC waste in a solid form in an independent spent fuel storage installation (ISFSI).

- 10 CFR §72.24, "Contents of application: Technical information," states that: Each application for a license under this part must include a Safety Analysis Report describing the proposed ISFSI or MRS for the receipt, handling, packaging, and storage of spent fuel, high-level radioactive waste, and/or reactor-related GTCC waste as appropriate, including how the ISFSI or MRS will be operated. The minimum information to be included in this report must consist of the following: (a) A description and safety assessment of the site on which the ISFSI or MRS is to be located, with appropriate attention to the design bases for external events. Such assessment must contain an analysis and evaluation of the major structures, systems, and components of the ISFSI or MRS that bear on the suitability of the site when the ISFSI or MRS is operated at its design capacity. If the proposed ISFSI or MRS is to be located on the site of a nuclear power plant or other licensed facility, the potential interactions between the ISFSI or MRS and such other facility - including shared common utilities and services - must be evaluated. (b) A description and discussion of the ISFSI or MRS structures with special attention to design and operating characteristics, unusual or novel design features, and principal safety considerations. (c) The design of the ISFSI or MRS in sufficient detail to support the findings in §72.40, including: (1) The design criteria for the ISFSI or MRS pursuant to subpart F of this part, with identification and justification for any additions to or departures from the general design criteria; (2) The design bases and the relation of the design bases to the design criteria; (3) Information relative to materials of construction, general arrangement, dimensions of principal structures, and descriptions of all structures, systems, and components important to safety, in sufficient detail to support a finding that the ISFSI or MRS will satisfy the design bases with an adequate margin for safety; and (4) Applicable codes and standards. (d) An analysis and evaluation of the design and performance of structures, systems, and components important to safety, with the objective of assessing the impact on public health and safety resulting from operation of the ISFSI or MRS and including determination of: (1) The margins of safety during normal operations and expected operational occurrences during the life of the ISFSI or MRS; and (2) The adequacy of structures, systems, and components provided for the prevention of accidents and the mitigation of the consequences of accidents, including natural and manmade phenomena and events. (e) The means for controlling and limiting occupational radiation exposures within the limits given in part 20 of this chapter, and for meeting the objective of maintaining exposures as low as is reasonably achievable. (f) The features of ISFSI or MRS design and operating modes to reduce to the extent practicable radioactive waste volumes generated at the installation. (g) An identification and justification for the selection of those subjects that will be probable license conditions and technical specifications. These subjects must cover the design, construction, preoperational testing, operation, and decommissioning of the ISFSI or MRS. (h) A plan for the conduct of operations, including the planned managerial and administrative controls system, and the applicant's organization, and program for training of personnel pursuant to subpart I. (i) If the proposed ISFSI or MRS incorporates structures, systems, or components important to safety whose functional adequacy or reliability have not been demonstrated by prior use for that purpose or cannot be demonstrated by reference to performance data in related applications or to widely accepted engineering principles, an identification of these structures, systems, or components along with a schedule showing how safety questions will be resolved prior to the initial receipt of spent fuel, high-level radioactive waste, and/or reactor-related GTCC waste as appropriate for storage at the ISFSI or MRS. (j) The technical qualifications of the applicant to engage in the proposed activities, as required by §72.28. (k) A description of the applicant's plans for coping with emergencies, as required by §72.32. (l) A description of the equipment to be installed to maintain control over radioactive materials in gaseous and liquid effluents produced during normal operations and expected operational occurrences. The description must identify the design objectives and the means to be used for keeping levels of radioactive material in effluents to the environment as low as is reasonably achievable and within the exposure limits stated in §72.104. The description must include: (1) An estimate of the quantity of each of the principal radionuclides expected to be released annually to the environment in liquid and gaseous effluents produced during normal ISFSI or MRS operations; (2) A description of the equipment and processes used in radioactive waste systems; and (3) A general description of the provisions for packaging, storage, and disposal of solid wastes containing radioactive materials resulting from treatment of gaseous and liquid effluents and from other sources. (m) An analysis of the potential dose equivalent or committed dose equivalent to an individual outside the controlled area from accidents or natural phenomena events that result in the release of radioactive material to the environment or direct radiation from the ISFSI or MRS. The calculations of individual dose equivalent or committed dose equivalent must be performed for direct exposure, inhalation, and ingestion occurring as a result of the postulated design basis event. (n) A description of the quality assurance program that satisfies the requirements of subpart G to be applied to the design, fabrication, construction, testing, operation, modification, and decommissioning of the structures, systems, and components of the ISFSI or MRS important to safety. The description must identify the structures, systems, and components important to safety. The program must also apply to managerial and administrative controls used to ensure safe operation of the ISFSI or MRS. (o) A description of the detailed security measures for physical protection, including design features and the plans required by subpart H. (p) A description of the program covering preoperational testing and initial operations. (q) A description of the decommissioning plan required under §72.30.

- 10 CFR §72.26, "Contents of application: Technical specifications," states that: Each application under this part shall include proposed technical specifications in accordance with the requirements of §72.44 and a summary statement of the bases and justifications for these technical specifications.

- 10 CFR §72.28, "Contents of application: Applicant's technical qualifications," states that: Each application under this part must include: (a) The technical qualifications, including training and experience, of the applicant to engage in the proposed activities; (b) A description of the personnel training program required under subpart I; (c) A description of the applicant's operating organization, delegations of responsibility and authority and the minimum skills and experience qualifications relevant to the various levels of responsibility and authority; and (d) A commitment by the applicant to have and maintain an adequate complement of trained and certified installation personnel prior to the receipt of spent fuel, high-level radioactive waste, and/or reactor-related GTCC waste as appropriate for storage.

- 10 CFR §72.40, "Issuance of license," paragraph (a), states that: Except as provided in paragraph (c) of this section, the Commission will issue a license under this part upon a determination that the application for a license meets the standards and requirements of the [Atomic Energy] Act and the regulations of the Commission, and upon finding that: (1) The applicant's proposed ISFSI or MRS design complies with subpart F; (2) The proposed site complies with the criteria in subpart E; (3) If on the site of a nuclear power plant or other licensed activity or facility, the proposed ISFSI would not pose an undue risk to the safe operation of such nuclear power plant or other licensed activity or facility; (4) The applicant is qualified by reason of training and experience to conduct the operation covered by the regulations in this part; (5) The applicant's proposed operating procedures to protect health and to minimize danger to life or property are adequate; (6) Except for DOE, the applicant for an ISFSI or MRS is financially qualified to engage in the proposed activities in accordance with the regulations in this part; (7) The applicant's quality assurance plan complies with subpart G; (8) The applicant's physical protection provisions comply with subpart H. DOE has complied with the safeguards and physical security provisions identified in §72.24(o); (9) The applicant's personnel training program complies with subpart I; (10) Except for DOE, the applicant's decommissioning plan and its financing pursuant to §72.30 provide reasonable assurance that the decontamination and decommissioning of the ISFSI or MRS at the end of its useful life will provide adequate protection to the health and safety of the public; (11) The applicant's emergency plan complies with §72.32; (12) The applicable provisions of part 170 of this chapter have been satisfied; (13) 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; and (14) The issuance of the license will not be inimical to the common defense and security.

- 10 CFR §72.40, paragraph (c) states that: For facilities that have been covered under previous licensing actions including the issuance of a construction permit under part 50 of this chapter, a reevaluation of the site is not required except where new information is discovered which could alter the original site evaluation findings. In this case, the site evaluation factors involved will be reevaluated.

- 10 CFR §72.44, "License conditions," paragraph (a), states that: Each license issued under this part shall include license conditions. The license conditions may be derived from the analyses and evaluations included in the Safety Analysis Report and amendments thereto submitted pursuant to §72.24. License conditions pertain to design, construction and operation. The Commission may also include additional license conditions as it finds appropriate.

- 10 CFR §72.44, paragraph (c), states that: Each license issued under this part must include technical specifications. Technical specifications must include requirements in the following categories: (1) *Functional and operating limits and monitoring instruments and limiting control settings.* (i) Functional and operating limits for an ISFSI or MRS are limits on fuel or waste handling and storage conditions that are found to be necessary to protect the integrity of the stored fuel or waste container, to protect employees against occupational exposures and to guard against the uncontrolled release of radioactive materials; and (ii) Monitoring instruments and limiting control settings for an ISFSI or MRS are those related to fuel or waste handling and storage conditions having significant safety functions. (2) *Limiting conditions.* Limiting conditions are the lowest functional capability or performance levels of equipment required for safe operation. (3) *Surveillance requirements.* Surveillance requirements include: (i) Inspection and monitoring of spent fuel, high-level radioactive waste, or reactor-related GTCC waste in storage; (ii) Inspection, test and calibration activities to ensure that the necessary integrity of required systems and components is maintained; (iii) Confirmation that operation of the ISFSI or MRS is within the required functional and operating limits; and (iv) Confirmation that the limiting conditions required for safe storage are met. (4) *Design features.* Design features include items that would have a significant effect on safety if altered or modified, such as materials of construction and geometric arrangements. (5) *Administrative controls.* Administrative controls include the organization and management procedures, recordkeeping, review and audit, and reporting requirements necessary to assure that the operations involved in the storage of spent fuel and reactor-related GTCC waste in an ISFSI are performed in a safe manner.

- 10 CFR §72.44, paragraph (d), states that: Each license authorizing the receipt, handling, and storage of spent fuel, high-level radioactive waste, and/or reactor-related GTCC waste under this part must include technical specifications that, in addition to stating the limits on the release of radioactive materials for compliance with limits of part 20 of this chapter and the "as low as is reasonably achievable" objectives for effluents, require that: (1) Operating procedures for control of effluents be established and followed, and equipment in the radioactive waste treatment systems be maintained and used, to meet the requirements of §72.104; (2) An environmental monitoring program be established to ensure compliance with the technical specifications for effluents; and (3) An annual report be submitted to the Commission in accordance with§72.4, specifying the quantity of each of the principal radionuclides released to the environment in liquid and in gaseous effluents during the previous 12 months of operation and such other information as may be required by the Commission to estimate maximum potential radiation dose commitment to the public resulting from effluent releases. On the basis of this report and any additional information that the Commission may obtain from the licensee or others, the Commission may from time to time require the licensee to take such action as the Commission deems appropriate. The report must be submitted within 60 days after the end of the 12-month monitoring period.

- 10 CFR §72.72, "Material balance, inventory, and records requirements for stored materials," paragraph (d), states that: Records of spent fuel, high-level radioactive waste, and reactor-related GTCC waste containing special nuclear material meeting the requirements in paragraph (a) of this section must be kept in duplicate. The duplicate set of records must be kept at a separate location sufficiently remote from the original records that a single event would not destroy both sets of records. Records of spent fuel or reactor-related GTCC waste containing special nuclear material transferred out of an ISFSI must be preserved for a period of five years after the date of transfer.

- 10 CFR §72.90, "Siting Evaluation Factors, General considerations," states that: (a) Site characteristics that may directly affect the safety or environmental impact of the ISFSI or MRS must be investigated and assessed. (b) Proposed sites for the ISFSI or MRS must be examined with respect to the frequency and the severity of external natural and man-induced events that could affect the safe operation of the ISFSI or MRS. (c) Design basis external events must be determined for each combination of proposed site and proposed ISFSI or MRS design. (d) Proposed sites with design basis external events for which adequate protection cannot be provided through ISFSI or MRS design shall be deemed unsuitable for the location of the ISFSI or MRS. (e) Pursuant to subpart A of part 51 of this chapter for each proposed site for an ISFSI.... the potential for radiological and other environmental impacts on the region must be evaluated with due consideration of the characteristics of the population, including its distribution, and of the regional environs, including its historical and esthetic values. (f) The facility must be sited so as to avoid to the extent possible the long-term and short-term adverse impacts associated with the occupancy and modification of floodplains.

- 10 CFR §72.92, "Design basis external natural events," states that: (a) Natural phenomena that may exist or that can occur in the region of a proposed site must be identified and assessed according to their potential effects on the safe operation of the ISFSI or MRS. The important natural phenomena that affect the ISFSI or MRS design must be identified. (b) Records of the occurrence and severity of those important natural phenomena must be collected for the region and evaluated for reliability, accuracy, and completeness. The applicant shall retain these records until the license is issued. (c) Appropriate methods must be adopted for evaluating the design basis external natural events based on the characteristics of the region and the current state of knowledge about such events.

- 10 CFR §72.94, "Design basis external man-induced events," states that: (a) The region must be examined for both past and present man-made facilities and activities that might endanger the proposed ISFSI or MRS. The important potential man-induced events that affect the ISFSI or MRS design must be identified. (b) Information concerning the potential occurrence and severity of such events must be collected and evaluated for reliability, accuracy, and completeness. (c) Appropriate methods must be adopted for evaluating the design basis external man-induced events, based on the current state of knowledge about such events.

- 10 CFR §72.98, "Identifying regions around an ISFSI or MRS site," states that: (a) The regional extent of external phenomena, man-made or natural, that are used as a basis for the design of the ISFSI or MRS must be identified. (b) The potential regional impact due to the construction, operation or decommissioning of the ISFSI or MRS must be identified. The extent of regional impacts must be determined on the basis of potential measurable effects on the population or the environment from ISFSI or MRS activities.

(c) Those regions identified pursuant to paragraphs (a) and (b) of this section must be investigated as appropriate with respect to: (1) The present and future character and the distribution of population, (2) Consideration of present and projected future uses of land and water within the region, and (3) Any special characteristics that may influence the potential consequences of a release of radioactive material during the operational lifetime of the ISFSI or MRS.

- 10 CFR §72.100, "Defining potential effects of the ISFSI or MRS on the region," states that: (a) The proposed site must be evaluated with respect to the effects on populations in the region resulting from the release of radioactive materials under normal and accident conditions during operation and decommissioning of the ISFSI or MRS; in this evaluation both usual and unusual regional and site characteristics shall be taken into account. (b) Each site must be evaluated with respect to the effects on the regional environment resulting from construction, operation, and decommissioning for the ISFSI or MRS; in this evaluation both usual and unusual regional and site characteristics must be taken into account.

- 10 CFR §72.103, "Geological and seismological characteristics for applications for dry cask modes of storage on or after October 16, 2003," paragraph (b), states that: West of the Rocky Mountain Front (west of approximately 104° west longitude), and in other areas of known potential seismic activity east of the Rocky Mountain Front, seismicity must be evaluated by the techniques presented in paragraph (f) of this section. If an ISFSI or MRS is located on an NPP [nuclear power plant] site, the existing geological and seismological design criteria for the NPP may be used. If the existing design criteria for the NPP is used and the site has multiple NPPs, then the criteria for the most recent NPP must be used. (c) Sites other than bedrock sites must be evaluated for their liquefaction potential or other soil instability due to vibratory ground motion.
(d) Site-specific investigations and laboratory analyses must show that soil conditions are adequate for the proposed foundation. (e) In an evaluation of alternative sites, those which require a minimum of engineered provisions to correct site deficiencies are preferred. Sites with unstable geologic characteristics should be avoided. (f) Except as provided in paragraphs (a)(2) and (b) of this section, the design earthquake ground motion (DE) for use in the design of structures, systems, and components must be determined as follows: (1) *Geological, seismological, and engineering characteristics.* The geological, seismological, and engineering characteristics of a site and its environs must be investigated in sufficient scope and detail to permit an adequate evaluation of the proposed site, to provide sufficient information to support evaluations performed to arrive at estimates of the DE, and to permit adequate engineering solutions to actual or potential geologic and seismic effects at the proposed site. The size of the region to be investigated and the type of data pertinent to the investigations must be determined based on the nature of the region surrounding the proposed site. Data on the vibratory ground motion, tectonic surface deformation, nontectonic deformation, earthquake recurrence rates, fault geometry and slip rates, site foundation material, and seismically induced floods and water waves must be obtained by reviewing pertinent literature and carrying out field investigations. However, each applicant shall investigate all geologic and seismic factors (for example, volcanic activity) that may affect the design and operation of the proposed ISFSI facility irrespective of whether these factors are explicitly included in this section. (2) *Geologic and seismic siting factors.* The geologic and seismic siting factors considered for design must include a determination of the DE

for the site, the potential for surface tectonic and nontectonic deformations, the design bases for seismically induced floods and water waves, and other design conditions as stated in paragraph (f)(2)(iv) of this section. (i) Determination of the Design Earthquake Ground Motion (DE). The DE for the site is characterized by both horizontal and vertical free-field ground motion response spectra at the free ground surface. In view of the limited data available on vibratory ground motions for strong earthquakes, it usually will be appropriate that the design response spectra be smoothed spectra. The DE for the site is determined considering the results of the investigations required by paragraph (f)(1) of this section. Uncertainties are inherent in these estimates and must be addressed through an appropriate analysis, such as a probabilistic seismic hazard analysis (PSHA) or suitable sensitivity analyses. (ii) Determination of the potential for surface tectonic and nontectonic deformations. Sufficient geological, seismological, and geophysical data must be provided to clearly establish if there is a potential for surface deformation. (iii) Determination of design bases for seismically induced floods and water waves. The size of seismically induced floods and water waves that could affect a site from either locally or distantly generated seismic activity must be determined. (iv) Determination of siting factors for other design conditions. Siting factors for other design conditions that must be evaluated include soil and rock stability, liquefaction potential, and natural and artificial slope stability. Each applicant shall evaluate all siting factors and potential causes of failure, such as, the physical properties of the materials underlying the site, ground disruption, and the effects of vibratory ground motion that may affect the design and operation of the proposed ISFSI. (3) Regardless of the results of the investigations anywhere in the continental U.S., the DE must have a value for the horizontal ground motion of no less than 0.10 g with the appropriate response spectrum.

- 10 CFR §72.104, "Criteria for radioactive materials in effluents and direct radiation from an ISFSI or MRS," states that: (a) During normal operations and anticipated occurrences, the annual dose equivalent to any real individual who is located beyond the controlled area must not exceed 0.25 mSv (25 mrem) to the whole body, 0.75 mSv (75 mrem) to the thyroid and 0.25 mSv (25 mrem) to any other critical organ as a result of exposure to: (1) Planned discharges of radioactive materials, radon and its decay products excepted, to the general environment, (2) Direct radiation from ISFSI or MRS operations, and (3) Any other radiation from uranium fuel cycle operations within the region. (b) Operational restrictions must be established to meet as low as is reasonably achievable objectives for radioactive materials in effluents and direct radiation levels associated with ISFSI or MRS operations. (c) Operational limits must be established for radioactive materials in effluents and direct radiation levels associated with ISFSI or MRS operations to meet the limits given in paragraph (a) of this section.

- 10 CFR §72.106, "Controlled area of an ISFSI or MRS," states that: (a) For each ISFSI or MRS site, a controlled area must be established. (b) Any individual located on or beyond the nearest boundary of the controlled area may not receive from any design basis accident the more limiting of a total effective dose equivalent of 0.05 Sv (5 rem), or the sum of the deep-dose equivalent and the committed dose equivalent to any individual organ or tissue (other than the lens of the eye) of 0.5 Sv (50 rem). The lens dose equivalent may not exceed 0.15 Sv (15 rem) and the shallow dose equivalent to skin or any extremity may not exceed 0.5 Sv (50 rem). The minimum distance from the spent fuel, high-level radioactive waste, or reactor-related GTCC waste handling and storage facilities to the nearest boundary of the controlled area must be at least 100 meters. (c) The controlled area may be traversed by a highway, railroad or waterway, so long as appropriate and effective arrangements are made to control traffic and to protect public health and safety.

- 10 CFR §72.120, "General Design Criteria, General considerations," paragraph (a), states that: As required by §72.24, an application to store spent fuel or reactor-related GTCC waste in an ISFSI... must include the design criteria for the proposed storage installation. These design criteria establish the design, fabrication, construction, testing, maintenance and performance requirements for structures, systems, and components important to safety as defined in §72.3. The general design criteria identified in this subpart establish minimum requirements for the design criteria for an ISFSI or an MRS. Any omissions in these general design criteria do not relieve the applicant from the requirement of providing the necessary safety features in the design of the ISFSI or MRS. (b) The ISFSI must be designed to store spent fuel and/or solid reactor-related GTCC waste. (1) Reactor-related GTCC waste may not be stored in a cask that also contains spent fuel. This restriction does not include radioactive materials that are associated with fuel assemblies (e.g., control rod blades or assemblies, thimble plugs, burnable poison rod assemblies, or fuel channels); (2) Liquid reactor-related GTCC wastes may not be received or stored in an ISFSI.

- 10 CFR §72.122, "Overall requirements," states that: (a) *Quality Standards.* Structures, systems, and components important to safety must be designed, fabricated, erected, and tested to quality standards commensurate with the importance to safety of the function to be performed. (b) *Protection against environmental conditions and natural phenomena.* (1) Structures, systems, and components important to safety must be designed to accommodate the effects of, and to be compatible with, site characteristics and environmental conditions associated with normal operation, maintenance, and testing of the ISFSI or MRS and to withstand postulated accidents. (2)(i) Structures, systems, and components important to safety must be designed to withstand the effects of natural phenomena such as earthquakes, tornadoes, lighting, hurricanes, floods, tsunami, and seiches, without impairing their capability to perform their intended design functions. The design bases for these structures, systems, and components must reflect: (A) Appropriate consideration of the most severe of the natural phenomena reported for the site and surrounding area, with appropriate margins to take into account the limitations of the data and the period of time in which the data have accumulated, and (B) Appropriate combinations of the effects of normal and accident conditions and the effects of natural phenomena. (ii) The ISFSI or MRS also should be designed to prevent massive collapse of building structures or the dropping of heavy objects as a result of building structural failure on the spent fuel, high-level radioactive waste, or reactor-related GTCC waste or on to structures, systems, and components important to safety. (3) Capability must be provided for determining the intensity of natural phenomena that may occur for comparison with design bases of structures, systems, and components important to safety. (4) If the ISFSI or MRS is located over an aquifer which is a major water resource, measures must be taken to preclude the transport of radioactive materials to the environment through this potential pathway. (c) *Protection against fires and explosions.* Structures, systems, and components important to safety must be designed and located so that they can continue to perform their safety functions effectively under credible fire and explosion exposure conditions. Noncombustible and heat-resistant materials must be used wherever practical throughout the ISFSI or MRS, particularly in locations vital to the control of radioactive materials and to the maintenance of safety control functions. Explosion and fire detection, alarm, and suppression systems shall be designed and provided with sufficient capacity and capability to minimize the adverse effects of fires and explosions on structures, systems, and components important to safety. The design of the ISFSI or MRS must include provisions to protect against adverse effects that might result from either the operation or the failure of the fire suppression system. (d) *Sharing of structures, systems, and components.* Structures, systems, and components important to safety must not be shared between an ISFSI or MRS and other facilities unless it is shown that such sharing will not impair the capability of either facility to perform its safety functions, including the ability to return to a safe condition in the event of an accident. (e) *Proximity of sites.* An ISFSI or MRS located near other nuclear facilities must be designed and operated to ensure that the cumulative effects of their combined operations will not constitute an unreasonable risk to the health and safety of the public. (f) *Testing and maintenance of systems and components.* Systems and components that are important to safety must be designed to permit inspection, maintenance, and testing. (g) *Emergency capability.* Structures, systems, and components important to safety must be designed for emergencies. The design must provide for accessibility to the equipment of onsite and available offsite emergency facilities and services such as hospitals, fire and police departments, ambulance service, and other emergency agencies. (h) *Confinement barriers and systems.* (1) The spent fuel cladding must be protected during storage against degradation that leads to gross ruptures or the fuel must be otherwise confined such that degradation of the fuel during storage will not pose operational safety problems with respect to its removal from storage. This may be accomplished by canning of consolidated fuel rods or unconsolidated assemblies or other means as appropriate..... (4) Storage confinement systems must have the capability for continuous monitoring in a manner such that the licensee will be able to determine when corrective action needs to be taken to maintain safe storage conditions. For dry spent fuel storage, periodic monitoring is sufficient provided that periodic monitoring is consistent with the dry spent fuel storage cask design requirements. The monitoring period must be based upon the spent fuel storage cask design requirements. (5) The high-level radioactive waste and reactor-related GTCC waste must be packaged in a manner that allows handling and retrievability without the release of radioactive materials to the environment or radiation exposures in excess of part 20 limits. The package must be designed to confine the high-level radioactive waste for the duration of the license. (i) *Instrumentation and control systems.* Instrumentation and control systems for wet spent fuel and reactor-related GTCC waste storage must be provided to monitor systems that are important to safety over anticipated ranges for normal operation and off-normal operation. Those instruments and control systems that must remain operational under accident conditions must be identified in the Safety Analysis Report. Instrumentation systems for dry storage casks must be provided in accordance with cask design requirements to monitor conditions that are important to safety over anticipated ranges for normal conditions and off-normal conditions. Systems that are required under accident conditions must be identified in the Safety Analysis Report. (j) *Control room or control area.* A control room or control area, if appropriate for the ISFSI or MRS design, must be designed to permit occupancy and actions to be taken to monitor the ISFSI safely under normal conditions, and to provide safe control of the

ISFSI or MRS under off-normal or accident conditions. (k) *Utility or other services.* (1) Each utility service system must be designed to meet emergency conditions. The design of utility services and distribution systems that are important to safety must include redundant systems to the extent necessary to maintain, with adequate capacity, the ability to perform safety functions assuming a single failure. (2) Emergency utility services must be designed to permit testing of the functional operability and capacity, including the full operational sequence, of each system for transfer between normal and emergency supply sources; and to permit the operation of associated safety systems. (3) Provisions must be made so that, in the event of a loss of the primary electric power source or circuit, reliable and timely emergency power will be provided to instruments, utility service systems, the central security alarm station, and operating systems, in amounts sufficient to allow safe storage conditions to be maintained and to permit continued functioning of all systems essential to safe storage. (4) An ISFSI or MRS which is located on the site of another facility may share common utilities and services with such a facility and be physically connected with the other facility; however, the sharing of utilities and services or the physical connection must not significantly: (i) Increase the probability or consequences of an accident or malfunction of components, structures, or systems that are important to safety; or (ii) Reduce the margin of safety as defined in the basis for any technical specifications of either facility. (l) *Retrievability.* Storage systems must be designed to allow ready retrieval of spent fuel, high-level radioactive waste, and reactor-related GTCC waste for further processing or disposal.

- 10 CFR §72.124, "Criteria for nuclear criticality safety," states that: (a) *Design for criticality safety.* 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 have occurred 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. (b) *Methods of criticality control.* When practicable, the design of an ISFSI or MRS 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. (c) *Criticality Monitoring.* 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. Underwater monitoring is not required when special nuclear material is handled or stored beneath water shielding. 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.

- 10 CFR §72.126, "Criteria for radiological protection," states that: (a) *Exposure control.* Radiation protection systems must be provided for all areas and operations where onsite personnel may be exposed to radiation or airborne radioactive materials. Structures, systems, and components for which operation, maintenance, and required inspections may involve occupational exposure must be designed, fabricated, located, shielded, controlled, and tested so as to control external and internal radiation exposures to personnel. The design must include means to: (1) Prevent the accumulation of radioactive material in those systems requiring access; (2) Decontaminate those systems to which access is required; (3) Control access to areas of potential contamination or high radiation within the ISFSI or MRS; (4) Measure and control contamination of areas requiring access; (5) Minimize the time required to perform work in the vicinity of radioactive components; for example, by providing sufficient space for ease of operation and designing equipment for ease of repair and replacement; and (6) Shield personnel from radiation exposure. (b) *Radiological alarm systems.* Radiological alarm systems must be provided in accessible work areas as appropriate to warn operating personnel of radiation and airborne radioactive material concentrations above a given setpoint and of concentrations of radioactive material in effluents above control limits. Radiation alarm systems must be designed with provisions for calibration and testing their operability. (c) *Effluent and direct radiation monitoring.* (1) As appropriate for the handling and storage system, effluent systems must be provided. Means for measuring the amount of radionuclides in effluents during normal operations and under accident conditions must be provided for these systems. A means of measuring the flow of the diluting medium, either air or water, must also be provided. (2) Areas containing radioactive materials must be provided with systems for measuring the direct radiation levels in and around these areas. (d) *Effluent control.* The ISFSI or MRS must be designed to provide means to limit to levels as low as is reasonably achievable the release of radioactive materials in effluents during normal operations; and control the release of radioactive materials under accident conditions. Analyses must be made to show that releases to the general environment during normal operations and anticipated occurrences will be within the exposure limit given in §72.104. Analyses of design basis accidents must be made to show that releases to the general environment will be within the exposure limits given in §72.106. Systems designed to monitor the release of radioactive materials must have means for calibration and testing their operability.

- 10 CFR §72.128, "Criteria for spent fuel, high-level radioactive waste, reactor-related greater than Class C waste, and other radioactive waste storage and handling," states that: (a) *Spent fuel, high-level radioactive waste, and reactor-related GTCC waste storage and handling systems.* Spent fuel storage, high-level radioactive waste storage, reactor-related GTCC waste storage and other systems that might contain or handle radioactive materials associated with spent fuel, high-level radioactive waste, or reactor-related GTCC waste, must be designed to ensure adequate safety under normal and accident conditions. These systems must be designed with - (1) A capability to test and monitor components important to safety, (2) Suitable shielding for radioactive protection under normal and accident conditions, (3) Confinement structures and systems, (4) A heat-removal capability having testability and reliability consistent with its importance to safety, and (5) means to minimize the quantity of radioactive wastes generated. (b) *Waste treatment.* Radioactive waste treatment facilities must be provided. Provisions must be made for the packing of site-generated low-level wastes in a form suitable for storage onsite awaiting transfer to disposal sites.

- 10 CFR §72.144, "Quality assurance program," paragraph (a), states that: The licensee, applicant for a license, certificate holder, and applicant for a CoC shall establish, at the earliest practicable time consistent with the schedule for accomplishing the activities, a quality assurance program which complies with the requirements of this subpart. The licensee, applicant for a license, certificate holder, and applicant for a CoC shall document the quality assurance program by written procedures or instructions and shall carry out the program in accordance with these procedures throughout the period during which the ISFSI or MRS is licensed or the spent fuel storage cask is certified. The licensee, applicant for a license, certificate holder, and applicant for a CoC shall identify the structures, systems, and components to be covered by the quality assurance program, the major organizations participating in the program, and the designated functions of these organizations....(c) The licensee, applicant for a license, certificate holder, and applicant for a CoC shall base the requirements and procedures of their quality assurance program(s) on the following considerations concerning the complexity and proposed use of the structures, systems, or components: (1) The impact of malfunction or failure of the item on safety; (2) The design and fabrication complexity or uniqueness of the item; (3) The need for special controls and surveillance over processes and equipment; (4) The degree to which functional compliance can be demonstrated by inspection or test; and (5) The quality history and degree of standardization of the item.

- 10 CFR §72.150, "Instructions, procedures, and drawings," states that: The licensee, applicant for a license, certificate holder, and applicant for a CoC shall prescribe activities affecting quality by documented instructions, procedures, or drawings of a type appropriate to the circumstances and shall require that these instructions, procedures, and drawings be followed. The instructions, procedures, and drawings must include appropriate quantitative or qualitative acceptance criteria for determining that important activities have been satisfactorily accomplished.

- 10 CFR §72.166, "Handling, storage, and shipping control," states that: The licensee, applicant for a license, certificate holder, and applicant for a CoC shall establish measures to control, in accordance with work and inspection instructions, the handling, storage, shipping, cleaning, and preservation of materials and equipment to prevent damage or deterioration. When necessary for particular products, special protective environments, such as inert gas atmosphere, and specific moisture content and temperature levels must be specified and provided.

- 10 CFR §72.180, "Physical protection plan," states that: The licensee shall establish, maintain, and follow a detailed plan for physical protection as described in §73.51 of this chapter. The licensee shall retain a copy of the current plan as a record until the Commission terminates the license for which the procedures were developed and, if any portion of the plan is superseded, retain the superseded material for 3 years after each change or until termination of the license. The plan must describe how the applicant will meet the requirements of §73.51 of this chapter and provide physical protection during on-site transportation to and from the proposed ISFSI or MRS and include within the plan the design for physical protection, the licensee's safeguards contingency plan, and the security organization personnel training and qualification plan. The plan must list tests, inspections, audits, and other means to be used to demonstrate compliance with such requirements.

- 10 CFR §72.184, "Safeguards contingency plan," states that: (a) The requirements of the licensee's safeguards contingency plan for responding to threats and radiological sabotage must be as defined in appendix C to part 73 of this chapter. This plan must include Background, Generic Planning Base, Licensee Planning Base, and Responsibility Matrix, the first four categories of information relating to nuclear facilities licensed under part 50 of this chapter.... (b) The licensee shall prepare and maintain safeguards contingency plan procedures in accordance with appendix C to 10 CFR part 73 for effecting the actions and decisions contained in the Responsibility Matrix of the licensee's safeguards contingency plan. The licensee shall retain a copy of the current procedures as a record until the Commission terminates the license for which the procedures were developed and, if any portion of the procedures is superseded, retain the superseded material for three years after each change.

- 10 CFR §72.190, "Operator requirements," states that: Operation of equipment and controls that have been identified as important to safety in the Safety Analysis Report and in the license must be limited to trained and certified personnel or be under the direct visual supervision of an individual with training and certification in the operation. Supervisory personnel who personally direct the operation of equipment and controls that are important to safety must also be certified in such operations.

- 10 CFR §72.192, "Operator training and certification program," states that: The applicant for a license under this part shall establish a program for training, proficiency testing, and certification of ISFSI or MRS personnel. This program must be submitted to the Commission for approval with the license application.

- 10 CFR §72.194, Physical requirements," states that: The physical condition and the general health of personnel certified for the operation of equipment and controls that are important to safety must not be such as might cause operational errors that could endanger other in-plant personnel or the public health and safety. Any condition that might cause impaired judgment or motor coordination must be considered in the selection of personnel for activities that are important to safety. These conditions need not categorically disqualify a person, if appropriate provisions are made to accommodate such defect.

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