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 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 even. 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 EC [52 EF] and 16 EC [60 EF], respectively. The environmental temperature during the off-normal condition is elevated by 5 EC [8EF]. 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 EC [1,058 EF], 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 EC [!40 EF] 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 [3,600 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 [3,000-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 [3,600-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 with a steel-enclosed concrete lid. 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. The lid is approximately 55 cm [22 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 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 considered 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 Specification (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 pressures {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 review of the tsunami hazard assessment is given in Section 2.1.4.6 of this SER.

Based on the staff 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 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 analysis provides 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 EC [350 EF] 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.

<u>Fire Inside Storage Vault</u>

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 barrel]

(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 EC [100 EF] to be classified as a flammable liquid. The No. 6 fuel oil stored in these aboveground tanks has a flashpoint of 65.5 EC [150 EF] and has a high viscosity at the average ambient temperature encountered at Humboldt Bay. The fuel has an auto ignition temperature of 407 EC [765 EF], making it not readily ignitable. Similarly, the flash point of diesel oil is 51.7 EC [125 EF]. 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.

<u>Gasoline Tanker Truck and Gasoline Storage Tank</u>

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 restricted 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.

<u>Propane Storage Tank</u>

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 EC [295 EF]. Based on the Fire Protection Association Handbook (National Fire Protection Association, 1997), the flash point of a liquid must be less than 37.8 EC [100 EF] to be classified as a flammable liquid. The maximum ambient temperature ever recorded at the HBPP site is 30.6 EC [87 EF] and the actual site temperature is generally less than 15.6 EC [60 EF]. The normal operating temperature of the oil in the transformers is approximately 40 EC

[104 EF]. 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 at the Unit 3 main bank transformers 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 EC [170 EF], 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 purged of any natural gas 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 EC [9 EF].

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 EC [1 EF], 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 EC [97 EF]) 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 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.

<u>Conclusions</u>

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 design with 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 purged 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.

<u>Propane Storage Tank</u>

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 × 24.4 m × 12.2 m [20 ft × 80 ft × 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 cover will provide additional protection from the air overpressure and any explosion-generated missiles.

<u>Propane Tanker Truck</u>

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 cover will provide additional protection from any explosion-generated missiles.

Natural Gas Pipeline

A potential explosion of the natural gas pipeline upstream of the pressure regulatory 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 Pacific Gas and Electric Company-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 the 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-033041). 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 is below the design basis air overpressure of the HI-STAR HB cask. The vault cover will provide additional protection 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 cover 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 purged 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 cover will provide protection from any explosion-generated missiles.

Other Site Vehicle Fuel Tanks

The flash point of diesel fuel is 51.7 EC [125 EF]. Based on the Fire Protection Association Handbook (National Fire Protection Association, 1997), the flash point of a liquid must be less than 37.8 EC [100 EF] to be classified as a flammable liquid. Therefore, because of its properties, diesel 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, 20043f, 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 cover 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 lid 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.

<u>Barge in Bay Carrying Fuel</u>

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 688900 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 EC [125 EF]. Based on the Fire Protection Association Handbook (National Fire Protection Association, 1997), the flash point of a liquid must be less than 37.8 EC [100 EF] 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 vehicle. 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 from the ISFSI at which the peak incident air overpressure will be 6.9 kPa [1 psi] from an explosion of a compartment of the barge transporting 904,400 L [234,000 gal] of gasoline will be approximately 1,320 m [4,400 ft]. Because this distance is less than 1,350 m [4,500 ft], 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

$$r = n \cdot f \cdot s \qquad (15\text{-}1)$$

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.

<u>Conclusions</u>

The staff reviewed the information provided by the applicant regarding potential hazards from accidental onsite 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 purged prior to cask transfer operations by administrative procedures.

- Vault covers 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 onsite 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 confinement barrier and leakage of radioactive materials during onsite cask transfer, lowering of the cask into the vault, and 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 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 of approved contents provided in the 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 Specifications 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, 2003a, HI-2033033).

The maximum postulated extreme temperature at the Humboldt Bay ISFSI site, as given in SAR Table 3.2-3, is 32 EC [90 EF] and the average annual ambient temperature is 11 EC [52 EF]. The maximum extreme temperature given in SAR Table 3.2-3 bounds the maximum ambient temperature (30.5 EC [87 EF]) 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 EC [38 EF]. 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 EC [1,058 EF] (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 400EC [752EF] and the accident temperature limit of 570EC [1058EF], 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 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 on an average of 75 daily operations takes 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 very 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

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}

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.

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).

<u>Accidents</u>

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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