6 THERMAL EVALUATION

6.1 Conduct of Review

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

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

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

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

6.1.1 Decay Heat Removal Systems

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

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

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

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

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

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

6.1.2 Material Temperature Limits

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

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

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

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

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

The applicant indicated in responses to the NRC request for additional information (Pacific Gas and Electric Company, 2004b) that the reinforced concrete storage vault would be constructed using Type II cement and fine and coarse aggregates that satisfy the requirements of ASTM C33-03 (ASTM International, 2003). Therefore, if the reinforced concrete storage vault temperatures of general or local areas exceed 93 EC [200 EF] but do not exceed 149 EC [300 EF], no tests to prove capability for elevated temperatures and no reduction of concrete strength are required (U.S. Nuclear Regulatory Commission, 2000). The 177 EC [350 EF] short term accident temperature limit for the reinforced concrete is consistent with guidance provided by the American Concrete Institute (2001, Appendix A.4). The applicant has committed to revise SAR Table 4.2-10 to reflect a higher allowable concrete temperature of 149 EC [350 EF] (Pacific Gas and Electric Company, 2005).

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

- The short- and long-term temperature limits for the HI-STAR HB cask structural materials are acceptable because their structural strengths will not be adversely affected for all potential off-normal and accident scenarios if these limits are not exceeded.

- The short- and long-term temperature limits for the HBPP SNF to be stored within the proposed ISFSI conform to ISG-11 (U.S. Nuclear Regulatory Commission, 2003a).

- The temperature limits for the reinforced concrete vault are acceptable because the structural strength of the concrete will not be adversely affected for all potential off-normal and accident scenarios if these limits are not exceeded.

- The short and long term temperature limits for the HI-STAR HB cask shielding materials are acceptable because their performance characteristics will not be adversely affected for all potential off-normal and accident scenarios if these limits are not exceeded.

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

6.1.3 Thermal Loads and Environmental Conditions

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

The meteorological conditions for the HBPP ISFSI site are documented in Section 2.3 of the SAR. The minimum, maximum, and average ambient temperatures for the proposed ISFSI site are derived from data recorded within the Eureka, California, region for a period of more than

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

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

- The methodology used to establish the decay heat rates of the SNF (Holtec International, 2004, HI-2033023) to be stored at the Humboldt Bay ISFSI is acceptable.
- Reliable sources have been used to obtain temperature and insolation data at nearby sites that are applicable to the proposed ISFSI location.
- The temperatures and solar loads at the HBPP ISFSI site are bounded by, or equal to, the HI-STAR HB cask and the reinforced concrete storage vault system design parameters (Table 3.2-3 of the SAR).

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

6.1.4 Analytical Methods, Models, and Calculations

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

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

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

6.1.5 Fire and Explosion Protection

6.1.5.1 Fire

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

6.1.5.1.1 Bounding Events

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

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

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

6.1.5.1.2 Engulfing Fire Thermal Evaluation

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

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

6.1.5.1.3 Nonengulfing Fire Thermal Evaluation

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

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

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

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

- The HI-STAR HB cask has been evaluated for a bounding, fully engulfing fire caused by a 190-L [50-gal] spill from the transporter fuel tank. The analysis indicated that the engulfing fire will result in temperatures that are below the design basis component temperatures of the cask.

- Both the HI-STAR HB cask and the ISFSI vault geometry have been evaluated for a bounding, radiant fire exposure caused by the spill and containment of 10,448,000-L [2,760,169-gal] of fuel oil. The analysis indicated that the radiant exposure will not induce temperatures in excess of the design basis temperatures for the cask or the ISFSI storage vault cavity cover lid.

- Based on the assessment of the potential fire hazards and the fire protection measures established for the Humboldt Bay ISFSI, there is reasonable assurance that the HI-STAR HB system will not be exposed to fires that exceed the design basis fire conditions.

- SSCs important to safety are designed and located so that they can continue to perform their safety functions effectively under credible fire exposure conditions.

- Noncombustible and heat-resistant materials are used wherever practical throughout the ISFSI.

- The design of the ISFSI includes provisions to protect against adverse effects that might result from fire.

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

6.1.5.2 Explosion

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

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

6.1.5.2.1 In-Transit Explosions

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

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

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

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

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

6.1.5.2.2 Explosions Affecting the ISFSI in a Storage Configuration

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

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

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

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

- Descriptions of potential explosion sources are sufficient.

- Sufficient administrative controls will be imposed to reduce the likelihood of in-transit explosions.

- Site geometry is such that an off-site explosion overpressure will have a reduced effect on the HI-STAR HB cask while in-transit to the storage vault and after emplacement within it.

- None of the explosion scenarios considered will be of sufficient duration to cause the allowable short-term accident temperatures of the HI-STAR HB cask or storage vault to be exceeded.

- The potential consequences attributable to the credible explosion hazards, including overpressures and explosion generated missiles, are conservatively estimated and the relevant design criteria for the confinement structures are not exceeded.

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

6.2 Evaluation Findings

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

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

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

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

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

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

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

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

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

6.3 References

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