Dry Cask Storage

Pacific Gas & Electric – Humboldt Bay Power Plant - 10217

Tawni Hardwick, Lawrence Pulley, E. Don Strassman
Pacific Gas & Electric, Humboldt Bay Power Plant, Eureka, Ca

ABSTRACT

This paper presents the unique design features of the Dry Cask Storage facility at the Pacific Gas and Electric (PG&E) Humboldt Bay Power Plant (HBPP).

The nuclear unit at HBPP is a very small (65 MW) BWR which became operational in 1963. The reactor was shutdown in 1976 for seismic upgrades as well as upgrades as a result of the Three Mile Island accident in 1979. After significant geologic studies and major plant upgrades, the unit was placed in SAFSTOR in 1984 when it became obvious that it would not be economically feasible to restart it.

After a significant period of storing the spent fuel in the spent fuel pool (SFP), it was clear that the initial step in decommissioning the unit was to place the fuel into dry storage. The design and licensing of an Independent Spent Fuel Storage Installation (ISFSI) presented many challenges. The plant, as well as the site, is small, is in a high seismic area, and the standard cask systems were not readily suitable for use due to shorter fuel bundles used in the HBPP reactor. PG&E, in partnership with Holtec International, developed a unique approach to solve the problem. A shortened version of the generically licensed HI-STAR 100 system was selected and an underground concrete vault was designed to contain the specialized HI-STAR HB casks. This resolved several issues, namely the lack of suitable rock foundation and close proximity of the vault to the site boundary fence. The underground vault provided lateral support for the cask system, shielding to minimize site boundary dose, and alleviated various security concerns.

Another unique aspect of the HBPP Dry Cask Storage Project was that the main refueling building crane was not of sufficient capacity for handling the cask system and was not single-failure-proof. As the refueling building also was not qualified for the new seismic requirements, it became obvious that an alternate solution was required. This led to the design of a special one-of-a-kind, single-failure-proof, davit crane for handling the casks during fuel loading in the SFP.

To transport the casks from the refueling building to the storage facility, a single-failure-proof cask transporter was developed. The transporter was designed and built such that it could carry the casks up a 10% slope, and be suitable for sharing with our company's other nuclear units, Diablo Canyon Units 1 & 2.

All fuel has been stored successfully in the storage facility as of the end of 2008. The ISFSI was designed with a separate security area to separate it from the plant proper to allow for ease of decommissioning the unit where the security requirements are not as stringent with fuel removed.

DRY CASK STORAGE – PACIFIC GAS & ELECTRIC – HUMBOLDT BAY POWER PLANT

When observed in its current complete and loaded state, the Humboldt Bay Independent Spent Fuel Storage Installation (ISFSI) is quite unassuming and unimpressive. The unknowing passerby would never guess the years and countless man-hours that went into planning for, designing, licensing, constructing and loading this ISFSI. One would never know that, because of a unique combination of site and plant characteristics, this ISFSI has many unique design and operational features and characteristics.

Figure 1 - Humboldt Bay Power Plant with ISFSI Site Highlighted

SITE CHARACTERISTICS

The Humboldt Bay ISFSI site is located in an area that poses many potential hazards and therefore many unique challenges for the design and construction of a dry cask storage facility. The Humboldt Bay Power Plant (HBPP) site is in an area of very high seismicity in Northern California. The site is located near the intersection of numerous major tectonic features. In fact, the Humboldt Bay ISFSI is built practically on top of the Bay Entrance Fault and the Buhne Point Fault. Other major features in the area include the Little Salmon Fault Zone and the Cascadia Subduction Zone. Extensive research and analysis of the regional and site tectonic setting and seismic hazards was performed prior to design of the ISFSI. This information, as well as earth sciences data, earthquake hazards assessments and other geotechnical analyses can be found in the Humboldt Bay ISFSI Final Safety Analysis Report (FSAR). The results of the analyses were used in the design of the ISFSI Vault.

Figure 2 – Some of the Tectonic Features Near the HBPP ISFSI

Fortunately, it was determined that, due to the subsurface soil conditions as well as other geologic factors of the ISFSI site, the ISFSI is not susceptible to liquefaction or landslides.
In addition, the location along the Cascadia Subduction zone increases the potential for significant tsunami effects. Tsunami hazards along the coast of northern California have been recognized for many decades, especially after the 1964 Alaska earthquake caused a tsunami that devastated the northern California town of Crescent City and caused a minor run-up at the Humboldt Bay site. The HBPP and ISFSI sites are situated along the eastern shore of Humboldt Bay, in line with the Bay entrance. Extensive evaluations were performed based on past earthquake and tsunami information and evidence found in the field. It was concluded that the maximum runup at the bay entrance for a tsunami triggered by the design basis seismic event would be 30 to 40 feet above mean lower lower water level (MLLW). Taking tidal action into consideration, runup from the design basis tsunami could reach 43 feet above MLLW. The top of the ISFSI Vault is located at elevation 44 feet above MLLW and therefore will be unaffected by the design basis event.

Figure 3 - Aerial Photo of the Entrance to Humboldt Bay Showing the ISFSI Site

The ISFSI site is located in close proximity to public roadways, waterways and local communities, including a public trail between the ISFSI and Humboldt Bay. This means that the public is capable of getting in close proximity to the ISFSI site, at some points even within 100 yards of the ISFSI. Therefore, an underground vault system was selected to provide shielding to meet dose to the public limitations and to provide for additional security protection.

WHY DRY CASK STORAGE AND WHY NOW?

The nuclear unit (Unit 3) at HBPP is a very small (65 MW) Boiling Water Reactor (BWR) which became commercially operational in 1963. The reactor was shutdown in 1976 for NRC-required seismic upgrades since new seismic studies indicated that ground motions generated by the local earthquake faults were of greater magnitude than those used in the plant's original design. After performing significant geologic studies and major plant upgrades, and considering the additional upgrades required as a result of the Three Mile Island accident in 1979, as well as the continuing seismic upgrade studies, it became obvious that it would not be economically feasible to restart the unit. The decision was made to pursue decommissioning of the unit which was placed in SAFSTOR (possess but not operate) in 1984. The Unit 3 license (DPR-7) will expire on November 9, 2015.

In addition to Unit 3, there are two conventional fossil units onsite capable of operating on either natural gas or fuel oil and producing 53 megawatts-electric (MWe) each. These fossil units are beyond their design life and they will be decommissioned concurrently with Unit 3. The fossil units are being replaced by a new power plant, Humboldt Bay Generating Station, which will be located on the HBPP site and will consist of ten reciprocation engines capable of running on natural gas or diesel.

The first step in the decommissioning of Unit 3 was to remove the spent fuel from the spent fuel pool (SFP) located in the Refueling Building. Dry cask storage has many advantages to SFP storage and it is considered a safer option. Dry cask storage in an Independent Spent Fuel Storage Installation such as the one at HBPP helps to facilitate decommissioning because, once the fuel is out of the unit, the security measures in the unit can be lessened. Prior to fuel transfer, there were 390 spent fuel assemblies in the SFP. The fuel assemblies were located in racks for support and restraint and the water in the pool provided shielding.

THE ISFSI VAULT

Prior to transferring the fuel from the SFP, a storage vault was constructed in which the storage casks are placed. Because of the age of the HBPP fuel and the low decay heat associated with it, the ISFSI storage casks do not require the normal atmospheric cooling. Subsequently, the casks may be stored underground without fear of overheating. The ISFSI Vault was designed as an I-shaped, subterranean concrete vault with six cylindrical vault liners poured in place. Each liner with its surrounding concrete is considered a separate “cell” within the vault.

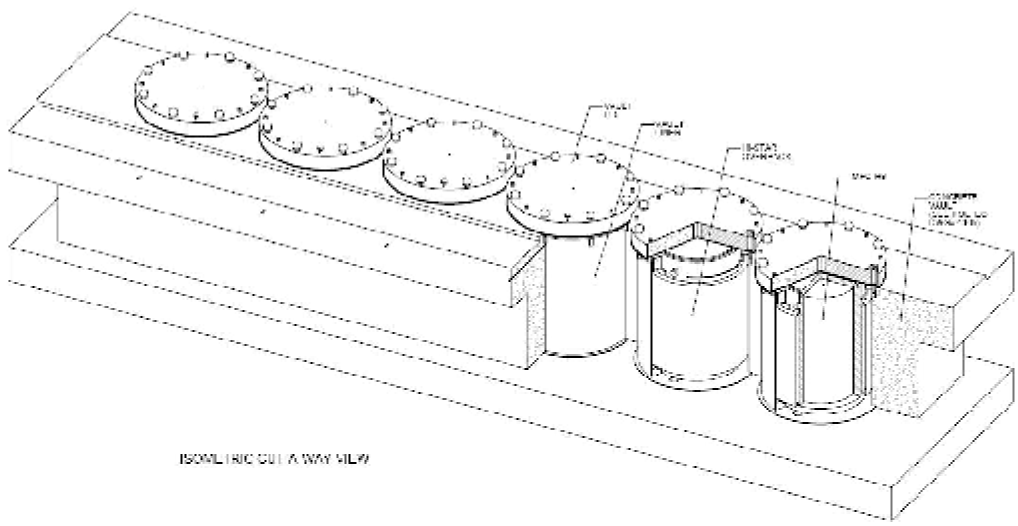

Figure 4 - Isometric View of ISFSI Vault

The concrete vault provides structural stability as well as lateral restraint to resist seismic forces. The concrete vault also provides radiation shielding to lower the potential dose to the public in close proximity to the vault (i.e. along the public trail between the ISFSI and Humboldt Bay.) The vault liners are equipped with lids that consist of 18-inches of concrete encased in carbon steel for additional shielding. The vault liners are also equipped with seismic restraints at the top and bottom to provide seismic restraint of the casks once inserted into the liners. The vault also provides security protection, protection from the environment, and defense-in-depth protection from tornado and explosion generated missiles.

Figure 5 - Bluff Site Prior to ISFSI

Figure 6 - Excavation for ISFSI Vault

The ISFSI Vault is considered to be an Important-to-Safety structure in order to provide the appropriate level of quality assurance in the design and construction. All concrete construction was in accordance with the American Concrete Institute's ACI 349, Code Requirements for Nuclear Safety Related Concrete Structures, and other codes and standards, as applicable. In addition, site specific procedures were written to control all concrete and reinforcing steel construction. An on-site batch plant was used in order to closely control the mixing of the concrete.

Figure 7 - Vault Liners in Place and Prep for Second Concrete Pour

THE HOLTEC HI-STAR HB STORAGE AND TRANSPORTATION CASKS

HBPP Unit 3 was one of the first commercially operational BWR's in the country. As such, the fuel that was used in the Unit 3 reactor is different from conventional fuel today. The fuel used in the HBPP reactor is significantly shorter and smaller in cross-section than modern fuel is. While the Holtec HI-STAR 100 system licensed under 72-1008 was suitable for the HBPP fuel, the size and weight of standard casks would not fit in the HBPP Refueling Building or the SFP. To rectify this problem, a modified version was developed under a site specific license. This modified cask system is called the HI-STAR HB, and is a shorter cask with a fuel basket sized to accept 80 fuel assemblies, including up to 40 damaged fuel assemblies. This feature is especially important as there were significant fuel cladding failures during operation 130 assemblies out of the total of 390 were classified as damaged.

The HI-STAR HB system is a self-contained, independent, passive system that does not rely on any mechanical systems for normal storage operations. The HI-STAR HB system is designed to store spent nuclear fuel from HBPP under all normal, off-normal, and accident conditions of service applicable to the Humboldt Bay site, including the most severe design-basis natural phenomena in accordance with 10 CFR 72. This cask system is also licensed to transport under 10 CFR 71, and requires no on-site transfer activities.

The HI-STAR HB system is comprised of an all-welded multipurpose canister (MPC-HB) designed to store up to 80 HBPP fuel assemblies inside a bolted-lid steel overpack that provides physical protection of the MPC and provisions for handling. The HI-STAR HB system uses METAMIC® neutron absorbers as an alternative to BORAL® in the MPC-HB fuel basket.

The HI-STAR HB system is designed to ensure that fuel criticality is prevented, fuel cladding and confinement integrity are maintained, the fuel remains retrievable, and radiation shielding is maintained under all Humboldt Bay site-specific design basis loadings due to environmental conditions and natural phenomena. The ISFSI Vault is designed to accommodate a total of six casks with five containing spent fuel assemblies and the sixth containing HBPP reactor-related greater than Class C (GTCC) waste. The GTCC cask will be designed to accept the specific GTCC waste to be stored at the ISFSI and be compatible with all HI-STAR HB lifting and handling equipment.

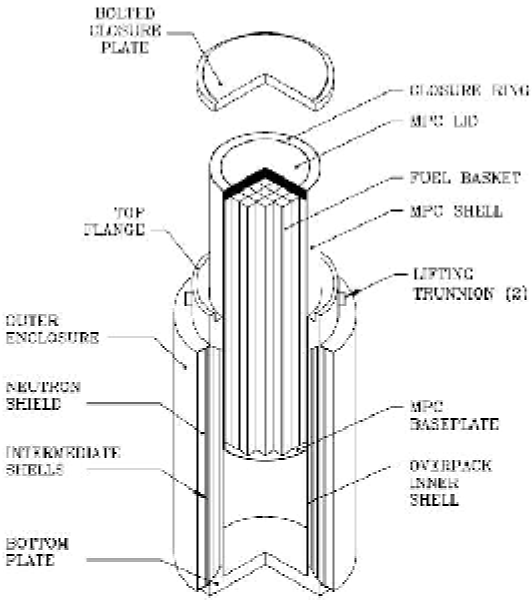

Figure 8 - HI-STAR HB with MPC Partially Inserted

THE DAVIT CRANE

The fuel handling activities added per Amendment 37 to the HBPP license included the installation of a first-of-its-kind, single-failure proof Davit Crane in the Unit 3 Refueling Building. The Davit Crane was installed because the Refueling Building crane was not of sufficient capacity to handle the 85-ton, loaded HI-STAR HB casks, nor was it single-failure proof per NUREG-0554, "Single-Failure-Proof Cranes for Nuclear Power Plants." The Davit Crane was designed and installed in accordance with the requirements of NUREG-0554 and NUREG-0612, "Control of Heavy Loads at Nuclear Power Plants," as well as other applicable codes and standards.

The Davit Crane is mounted directly on top of the wall of the SFP and to the adjacent truck bay wall such that the inverted U-frame (booms plus top beam) can pivot to reach both the cask loading area in the SFP and the truck bay. Sections of the main floor beam are removable to allow the HI-STAR HB system to be rolled into or out of the davit crane on a rail dolly. The HI-STAR HB system is supported from the top beam of the U-frame via a 235-ton strand jack connected to the lift yoke. The lift yoke is a special lifting device designed in accordance with ANSI N14.6. Cask raising and lowering are performed by the use of the hydraulic strand jack located on the top beam of the U-frame. The strand jack is controlled locally at the hydraulic power unit or via a remote control station. The strand jack has one main cylinder that controls the raising and lowering of the load, and two smaller cylinders that control the locking mechanism that locks the strands in place during lifting and lowering.

Figure 9 - Davit Crane Lowering HI-STAR HB into SFP

The Davit Crane was assembled in the Refueling Building with very limited space. A mobile crane in conjunction with the overhead Refueling Building crane (when possible) were used to assist in the assembly of the Davit Crane. The Davit Crane was then tested at 125% of its rated capacity of 190,000 lbs. using certified crane counter weights brought into the small building space using a special hydraulic rail system.

Figure 10 - Assembly of the Davit Crane in the Refueling Building

Figure 11 - Post-Installation Load Test of the Davit Crane

FUEL LOADING AND PROCESSING OF THE CASKS

The HI-STAR HB system design features were evaluated in detail for fuel handling activities in the HBPP 10 CFR 50 facilities in License Amendment Request (LAR) 04-02, submitted to the NRC in July 2004. The LAR describes MPC fuel loading in the spent fuel pool, draining, drying, sealing, helium filling, and helium leak testing the MPC while inside the HI-STAR cask; and loading the cask onto the cask transporter for onsite transfer to the ISFSI. The NRC issued HBPP License Amendment 37 to allow implementation of LAR 04-02.

Figure 12 - Loading Fuel into an MPC

Figure 13 - Inserting a Fuel Assembly into a Submerged MPC

Once the cask was loaded and removed from the SFP, the cask was put through a series of processes including removal of water from the MPC and overpack, welding the MPC lid onto the top of the MPC using an automatic welding machine, vacuum drying, helium backfill and bolting the HI-STAR lid onto the cask.

For ALARA purposes during cask loading and processing, the Vacuum Drying System could be monitored and the Davit Crane and Automatic Welding Machine could be operated from a remote control station located on top of the Reactor Shield Plug. A platform was built over the top of the Shield Plug to provide an area suitable for these purposes. The Reactor Shield Plug area was chosen as the remote control area because this location had good visibility of the SFP, and facilitated an overall dose of approximately 100 mrem per cask for cask loading and processing.

Figure 14 - Welding the Closure Lid onto the MPC Using the Automatic Welding Device

For the purposes of moving the casks into and out of the Refueling Building, the existing rail system in the truck bay of the Refueling Building was extended out of the building and into the Unit 3 yard. The cask was loaded onto a low profile transfer dolly that used Hillman rollers in conjunction with the rail system, and then pushed/pulled into/out of the Refueling Building with the use of an airplane tugger.

Figure 15 – Removing a Loaded HI-STAR HB from the Refueling Building Using the Airplane Tugger

THE VERTICAL CASK TRANSPORTER

The Vertical Cask Transporter (VCT) is a self-propelled, open-front, tracked vehicle used for handling and onsite transport of a loaded HI-STAR HB overpack. It is nominally 29 feet long, 19 feet wide, and weighs approximately 95 tons, unloaded. It is designed with two steel tracks to spread out the load on the transport route surface. These tracks also provide the means to maneuver the cask transporter around the site. This good maneuverability was important for negotiating the tight spaces at HBPP. On top of the main structure is a lifting beam supported by two lifting towers that use hydraulic cylinders to provide the lifting force. The industrial grade hydraulic cylinders are made of carbon steel to ensure high strength and ductility for all service conditions. The VCT is diesel powered and is limited to a fuel volume of 50 gallons to ensure the assumptions in the fire analysis are bounding. The same VCT used at the Humboldt Bay ISFSI is also licensed for use at Pacific Gas & Electric's Diablo Canyon Power Plant ISFSI.

Figure 16 - Maneuvering the VCT out of the Radiological Controlled Area with a Loaded HI-STAR HB

Figure 17 - The VCT Entering the ISFSI Security Area with a Loaded HI-STAR HB

The VCT design is suitable for all conditions at the Humboldt Bay ISFSI site, including the transport route with a maximum grade of approximately 8.5 percent. The VCT is designed and used to safely lift, handle, and transport a HI-STAR HB overpack, loaded with spent fuel or a cask loaded with GTCC waste, between the HBPP Refueling Building and the ISFSI. The movement is conducted exclusively on the HBPP site. The cask transporter is designed to withstand all credible design-basis, natural-phenomena events while lifting, handling, and moving the loaded transfer cask or overpack without leaving the transport route or impairing its ability to safely hold the load.

Figure 18 - VCT Preparing to Lower a HI-STAR HB into the ISFSI Vault

CURRENT STATUS AND FUTURE ACTIVITY

All spent fuel has been stored successfully in the storage facility as of the end of 2008. The ISFSI was designed with a separate security area to separate it from the plant proper to allow for ease of decommissioning the unit where the security requirements are not as stringent with fuel removed. HBPP is now in the beginning phases of design approval and fabrication of the HI-STAR GTCC and MPC GTCC for placement in the sixth and final vault location. As art of the reactor vessel (RPV) removal project, a portion of the RPV internals will be segmented into sizes that will fit into the GTCC cask, which is identical to the fuel casks in size and materials. This RPV material, as well as other potential GTCC waste, will be placed into the GTCC cask and processed similarly to the fuel casks and then transported to the ISFSI for storage.

CONCLUSION

In summary, the small spaces around the HBPP site, high seismic conditions of the area and close proximity of the ISFSI site to the public necessitated some unique solutions including a subterranean vault design and a first-of-its-kind Davit Crane installed in the HBPP Refueling Building for cask handling.

REFERENCES

"Humboldt Bay ISFSI Final Safety Analysis Report." Humboldt Bay ISFSI Manual. Volume 4. Section I L-9. Revision 0. July 10, 2008.

"Specification for Construction of an Independent Spent Fuel Storage Installation (ISFSI)." HBPP Specification HBPP-2006-01. Revision 2. November 9, 2006.