Holtec International

Multi-Purpose Canisters for Long-Term Interim Storage

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Dry Storage & Transport Projects

Wet Storage Projects
Wet Storage Technology
Safe, but not an optimized long-term solution for fuel storage

- **Primary benefit of wet storage is efficient cooling**
  - Powered (active) water cooled heat exchangers
  - Required for discharged fuel due to high heat loads
  - Massive body of water provides efficient shielding

- **Wet storage pools generally not intended for long-term**
  - Storage of discharged fuel from reactor cores until...
  - Short-term holding prior to reprocessing
  - External fuel pools currently operating selected before dry storage was readily available (extensions of reactor pools)

- **Pools are safe, but recovery from “worst-case” scenarios may pose a challenge**
  - Severe seismic, Tsunami, Terrorist attack
  - Access to fuel for recovery may be impaired
    - Building access (stairs, elevators)
    - Crane and Fuel Handling Tool Damage
    - Debris blocking access to fuel
    - Potential for water leakage from cracks in pool
    - Damage to Pool/Building Structure
    - Loss of confinement structure if building is damaged
    - Debris in contact with fuel (Potential damage/corrosion mechanism)

- **Relatively expensive compared to canister-based storage**
  (capital investment, cash-flow structure, and O&M costs)
Dry Storage Technology
MPCs were designed for long-term storage

- Metal cask concept in Europe and Japan developed around reprocessing framework for short-term storage & transportation
  - Temporary storage and/or shipment before reprocessing (2-10 years)
  - Reuse of metal cask for multiple shipments
  - Bolted lids to allow easy access and reuse (seal failure during storage is a concern)
  - Relatively small number needed because of reuse (cost not a major consideration)

- Canister systems developed in U.S., and now used in United Kingdom, Spain, Ukraine, Mexico, and Taiwan (with others following) for long-term storage
  - Long-term storage (10 - 300+ years)
  - Welded lids to prevent leakage under long-term storage
  - Many systems needed since not reused (cost/cask is major consideration)
  - No reloading if transport cask license expires (e.g. from changing IAEA TS-R-1/SSR-6 regulations)
  - Lids are still removable with simple tools (performed during NRC dry-runs on mock-ups)
MPC Concept Developed by U.S. DOE (TAD) and Commercialized by Industry

- Over 750 Holtec systems loaded, over 80 units under contract worldwide
- Over 1550 MPC systems loaded in USA (all vendors)
Typical Canister-based Dry Storage Facility
Low Construction Costs

1. Jose Cabrera ISFSI in Spain

2. High Seismic Implementation at Diablo Canyon in USA

3. Underground Storage at Callaway in USA

4. Light weight metal building used to enclose storage pad for EDF Project at Sizewell B
Holtec’s International Projects

Holtec offers all available fuel storage technologies. Our client’s predominantly choose MPC-based systems.
Double Wall Canister (DWC) for Defense-in-Depth Security

- **Chernobyl Dry Storage Project**
  - DWC developed to provide two independent confinement boundaries during interim storage (required by Ukrainian regulations)
  - Over 230 DWCs on order for Chernobyl (production underway)

- **Ukraine Central Storage Project**
  - Signed in January 2015 for supply of all equipment for central storage of VVER fuel from 9 Reactors in Ukraine
  - Storage Facility Sited in the Chernobyl Exclusion Zone
  - Shipped to storage location in HI-STAR 190 transport casks from reactor units
  - DWCs will be supplied for compliance with Ukrainian regulations

- **EDF selected DWCs as Defense-in-Depth for Dry Storage at Sizewell B in United Kingdom**
  - Redundant barriers for long-term storage at coastal site
  - Over 140 DWCs to be stored (production underway)

- **DWCs are not used in the United States to date**
  (good experience with single-walled canisters)
Canister Welding is a Standard Process

- Welding of the primary lid and closure rings are performed using an automated welding machine
- Experienced Teams are available to perform the welding (e.g. Holtec’s site-services team)
- Leak-tightness assured by proven canister construction, welding, and testing
- Over 750 Canisters have been loaded – none have failed the testing and none have leaked
- *Holtec has patented technology to allow Volumetric Weld Examination (if desired)*
MPC Lid Welding is Performed Remotely Using Automatic Welding Equipment
Canister contents are retrievable using proven weld removal equipment

- Retrievably of contents is a requirement of US NRC and canister weld removal has been demonstrated numerous times

- Allows future reprocessing with weld removal station at reprocessing station (very small investment)
US NRC, DOE, and Industry: MPC Systems are Robust Against Aircraft Crash and Other BDBA

- HI-STORM Storage Overpack and HI-STAR Transport Overpack have been analyzed by U.S. National Laboratories under Beyond-Design-Basis Accidents (BDBAs)
- U.S. Atomic Safety and Licensing Board concluded probability of F-16 crash breaching HI-Storm System not credible (ASLB Proceedings for Private Fuel Storage)
- U.S. Department of Energy Boeing 767 Analysis (Holtec has done our own analyses as well)
- Probability Risk Assessment on HI-STORM (NUREG-1864)
- Tunnel fire – HI-STAR sustained 7 hour 1500° fire (NUREG/CR 6886)
- HI-STORM Release Estimate after Impact from Armor-Piercing Missile (Spain)
- Terrorist truck bomb (results classified)
Loading Operations are Standard Process
Collective Dose Comparable to Dual-Purpose Casks

HI-STORM loading is now performed routinely at over 60 plants (over 750 MPC’s loaded)
  - Holtec is loading over 100 MPC’s per year
  - BWR & PWR plants
  - Adaptable to just about any plant without plant modifications

Typically loading duration is 5-7 days per cask (complete cycle)

Total radiation exposures during loading: ~1-2 mSv Total Crew Dose (well-trained crew)

Storage and maintenance radiation exposure less than dual-purpose metal casks

- Load MPC in Transfer Cask
- Dry and Weld MPC in Transfer Cask
- Transfer MPC to Storage Module
Holtec’s MPC’s are the Preferred Solution for Long-Term Storage of Used Fuel

- **Safety**
  - Proven single-wall canister designs
  - Double-wall canisters for enhanced safety
  - Preferred solution for Beyond-Design-Basis Accidents (burial, aircraft impact, fire, terrorist attack)

- **Risk Reduction**
  - Decouples transport and storage functions to avoid licensing complications of aging transport casks
  - Risk of leakage is reduced to essentially zero
  - Reprocessing option is preserved with weld-removal technology

- **Cost Effective (capital, cash-flow, and O&M)**

- **Experienced Project Implementation**
  - USA, Europe, Asia, and now South Africa
Holtec’s HI-STORM Overpack is Designed for Flood, Wind, and Long-Term Storage

- Provides physical protection and shielding of canisters
- Vertical, Ventilated cask with *steel exterior* (steel-concrete-steel)
  - Designed for all Plant Conditions and Accidents
  - Robust Under Flood and Wind Events (including “missile” impact)
  - Stable during earthquake
  - Concrete shielding material protected from environment
  - Minimal Maintenance
  - Vertical orientation provides for small footprint
- Passive Heat Removal (natural convection) up to 47 kW
- Robust Shielding

Dose from Metal Cask
Dose from HI-STORM

Passive Cooling
Storage, Transfer, and Transport Functions Performed by Separate, Optimized Casks

Purpose-specific casks allow for optimized transfer, storage, and transport of the canisterized spent fuel.
MPCs Provide a Robust Solution for Long-Term Confinement of Used Fuel

- Canisters provide containment of fuel, fuel debris, or non-fuel hardware and waste
- Canisters are protected by “Overpacks” during storage, onsite transfer, and offsite transport
- Designed as ASME NB Pressure Vessel (highest category of ASME III, Div. 1 Code)

Benefits of Canisters
- Welded lids provide highest level of protection of material
- Canisters are transportable without repackaging
- Fuel handled one time (minimizes chance for damage)
- Contents are retrievable using proven weld removal technology

Designed for Modern Fuel Cycles
- High Capacity: 37 PWR, 89 BWR, 31 VVER-1000, 85 VVER-440
- Max. Heat Load – up to 46 kW
- Max. Burn-up – 68 GWD/MTU
- Max. Initial Enrichment – 5 %U$_{235}$
- Min. Cooling Time – 3 years
The “Backend” of the Fuel Cycle
Long-term interim dry storage

Confidential Information

- **Nuclear reactors contain approximately 150 – 250 fuel assemblies**
  - Refueling on ~12 – 24 month outage cycles
  - Replace ~1/3 of the core during each outage
  - After shutdown fuel must remain in reactor for 3 - 5 days due to high heat-loads (exponential decay)
  - Fuel is then moved (underwater) from reactor to wet storage pool using fuel transfer equipment

- **Spent fuel pools provide effective radiation shielding and heat transfer (water is efficient in both regards)**

- **Modern reactors are designed with 10 - 20 years of storage capacity in the wet storage pools**
  - The spent fuel pool must contain enough space to unload an entire core from the reactor under emergency conditions
  - The plant cannot operate without this spare capacity

- **What happens to the fuel after interim storage in the spent fuel pool?**
  - Interim Wet Storage Facilities
  - Dry Storage in Dual-Purpose Metal Casks & Multi-Purpose Canisters (MPCs)
  - Geological Repositories (not discussed since none operating for commercial fuel & why rush?)
  - Reprocessing (not discussed here since is on decline due to economics)