Holtec International

Multi-Purpose Canisters for Long-Term Interim Storage

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Director of International Projects

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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

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- **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**)**

Wet Storage Pool

Dry Storage Technology

MPCs were designed for long-term storage

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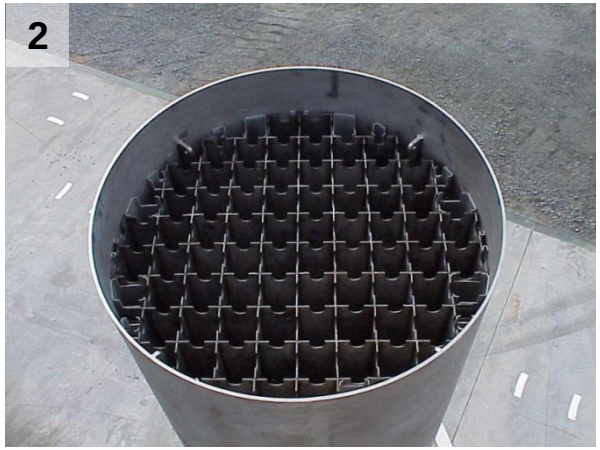
- **Metal cask concept in Europe and Japan developed around reprocessing framework for short-term storage & transportation**
  - Temporary storage and/or shipment before reprocessing (2-10 years)
  - Reuse of metal cask for multiple shipments
  - Bolted lids to allow easy access and reuse (seal failure 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)

Holtec Metal Cask



Holtec Canister

MPC Concept Developed by U.S. DOE (TAD) and Commercialized by Industry

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- **Over 750 Holtec systems loaded, over 80 units under contract worldwide**
- **Over 1550 MPC systems loaded in USA (all vendors)**

Used Fuel (Damaged, Intact, Debris)

Nuclear Material

Multi-Purpose Canister

Confinement, Reactivity Control, Heat Transfer

ASME NB Pressure Vessel

Storage Overpack

Shielding, Physical Protection, Passive Heat Removal

Typical Canister-based Dry Storage Facility

Low Construction Costs

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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.

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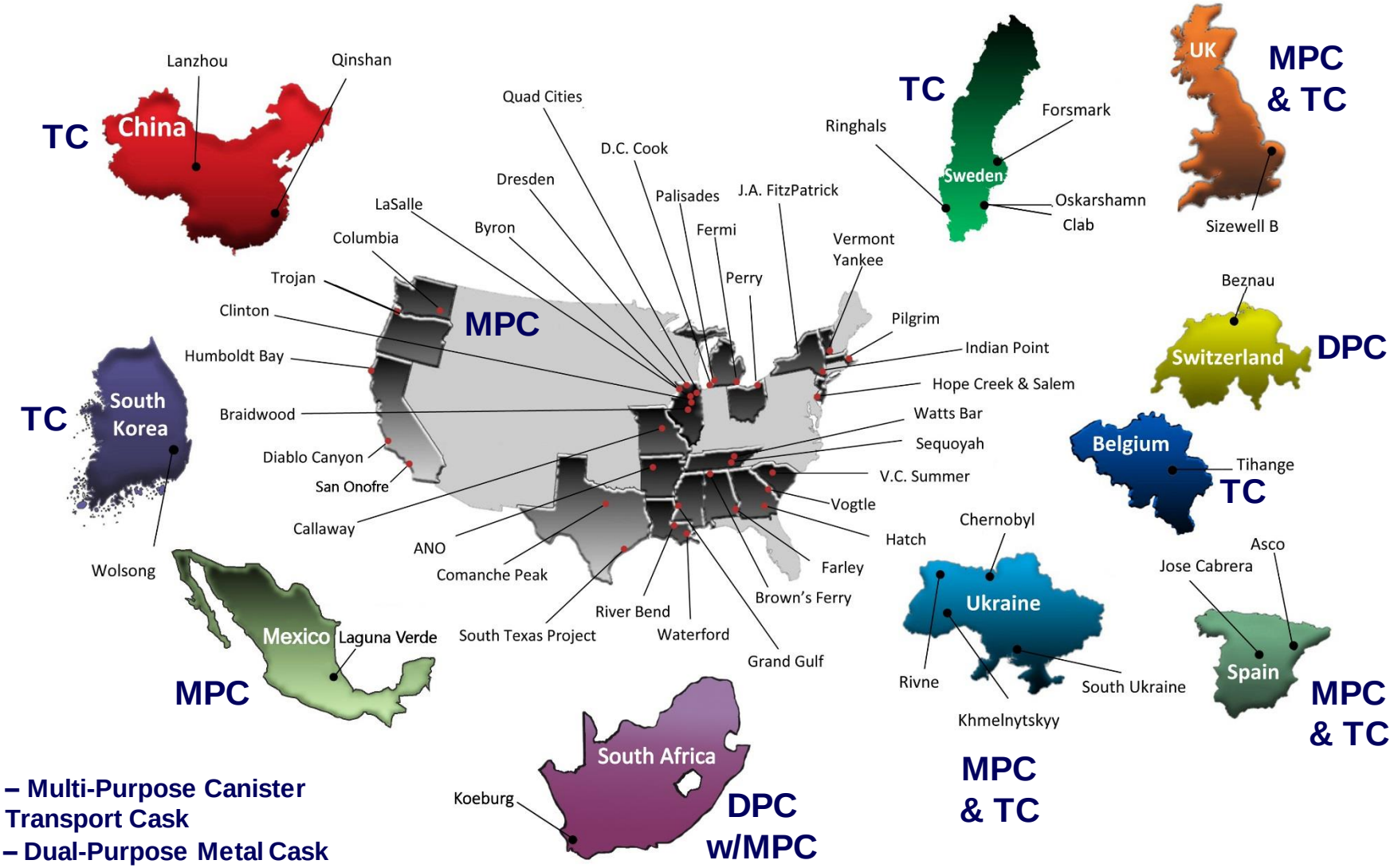

MPC – Multi-Purpose Canister
TC – Transport Cask
DPC – Dual-Purpose Metal Cask

Double Wall Canister (DWC) for Defense-in-Depth Security

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- **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)

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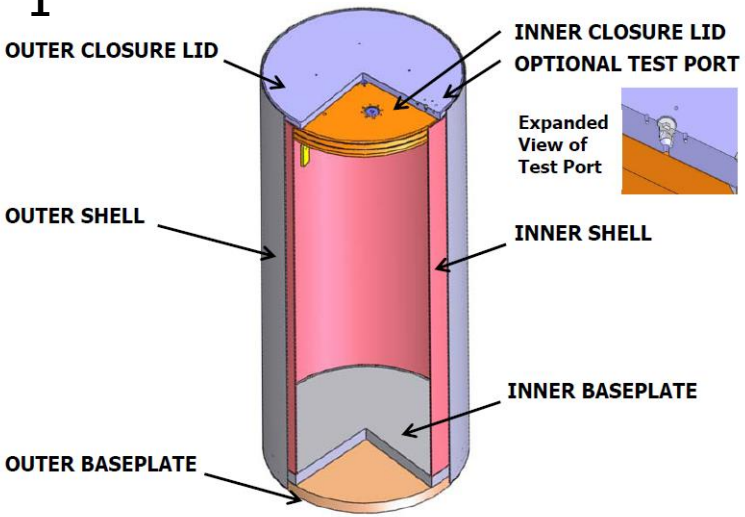

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Holtec Double Wall Canister (DWC)

Canister Welding is a Standard Process

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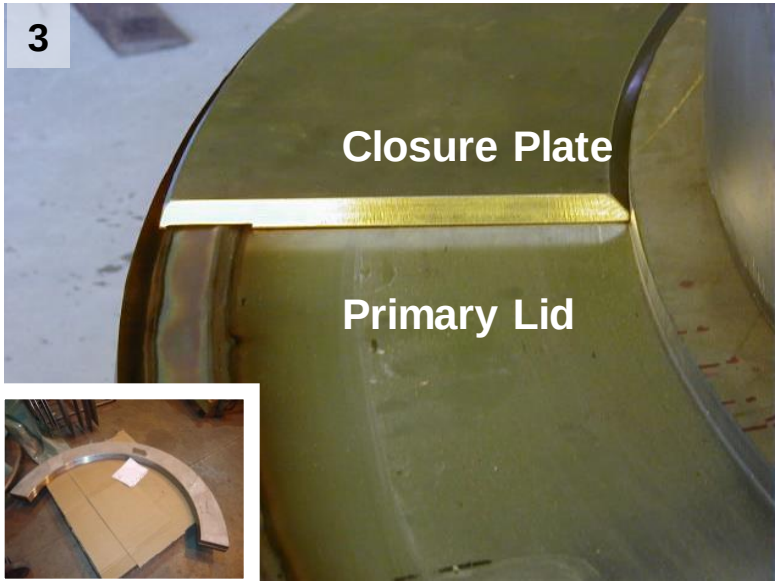
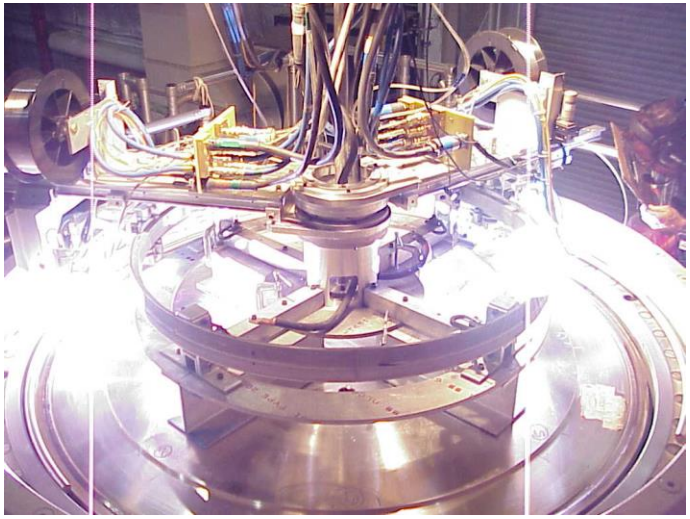
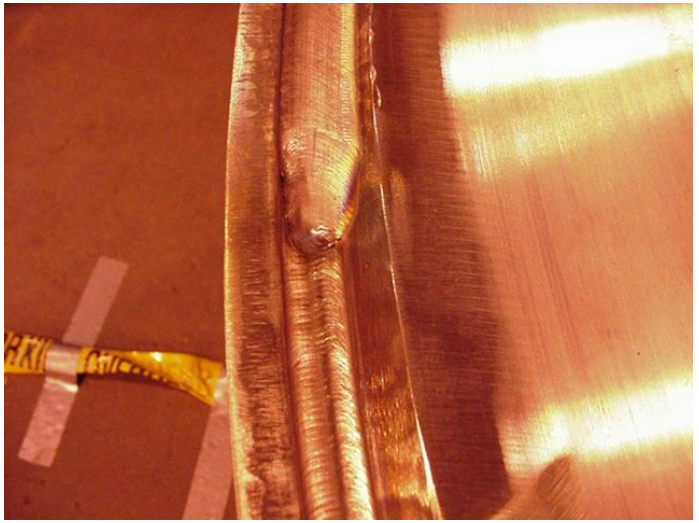
- Welding of the primary lid and closure rings are performed using an automated welding machine
- Experienced Teams are available to perform the welding (e.g. Holtec's site-services team)
- Leak-tightness assured by proven canister construction, welding, and testing
- Over 750 Canisters have been loaded – 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

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- 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)

Automated Weld Removal System

US NRC, DOE, and Industry: MPC Systems are Robust Against Aircraft Crash and Other BDBA

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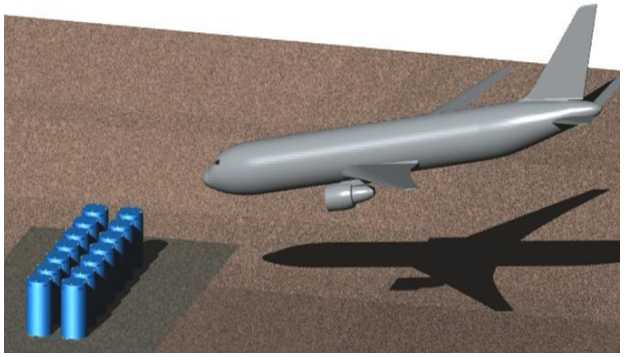
F-16 Military Crash Analysis (U.S. DOE Los Alamos Labs)



Boeing 767 Crash Analysis (U.S. Department of Energy)

- **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^{o} 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

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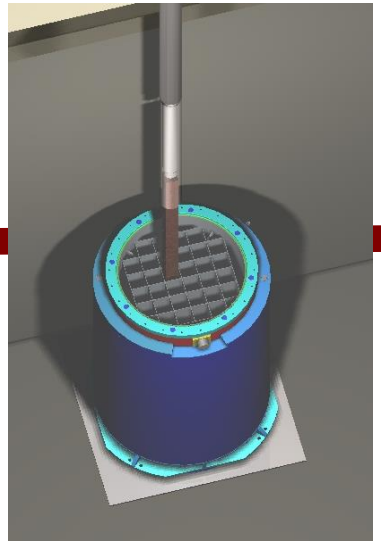
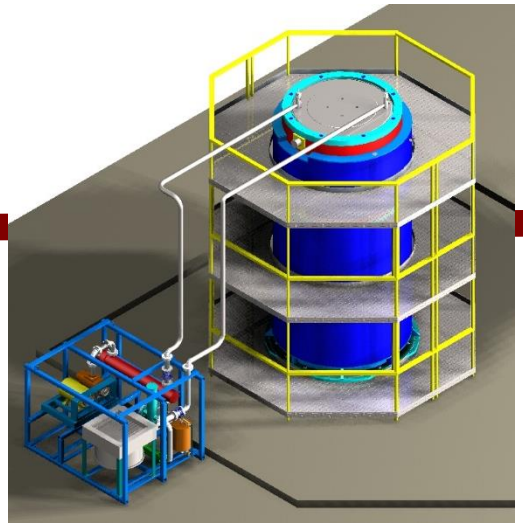
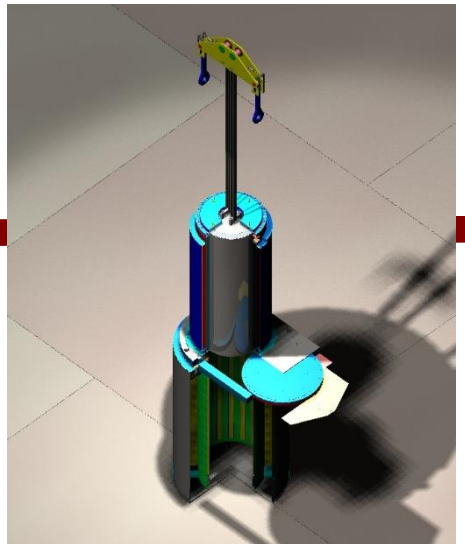
- HI-STORM loading is now performed routinely at over 60 plants (over 750 MPC's loaded)
  - Holtec is loading over 100 MPC's per year
  - BWR & PWR plants
  - Adaptable to just about any plant without plant modifications
- Typically loading duration is 5-7 days per cask (complete cycle)
- Total radiation 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

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- **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

END

Holtec's HI-STORM Overpack is Designed for Flood, Wind, and Long-Term Storage

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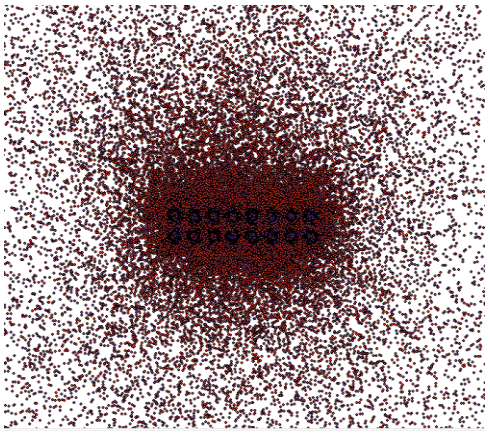
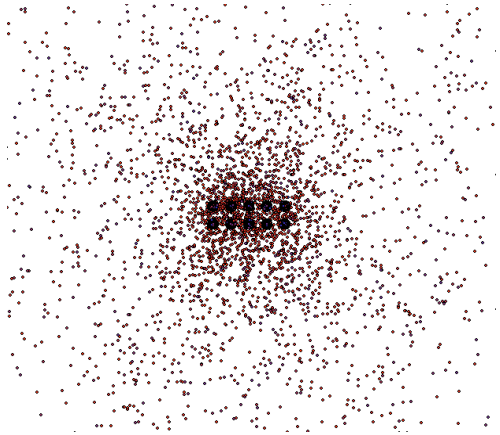
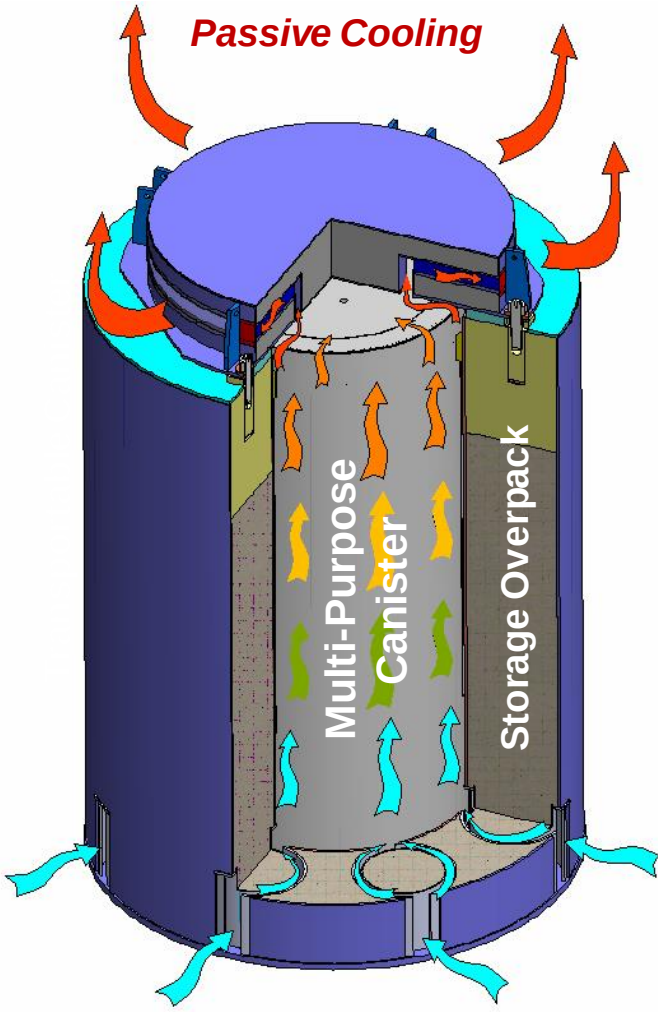
- **Provides physical protection and shielding of canisters**
- **Vertrical, Ventilated cask with *steel exterior* (steel-concrete-steel)**
  - Designed for all Plant Conditions and Accidents
  - Robust Under Flood and Wind Events (including "missile" impact)
  - Stable during earthquake
  - Concrete 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



HI-STORM Storage Cask

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

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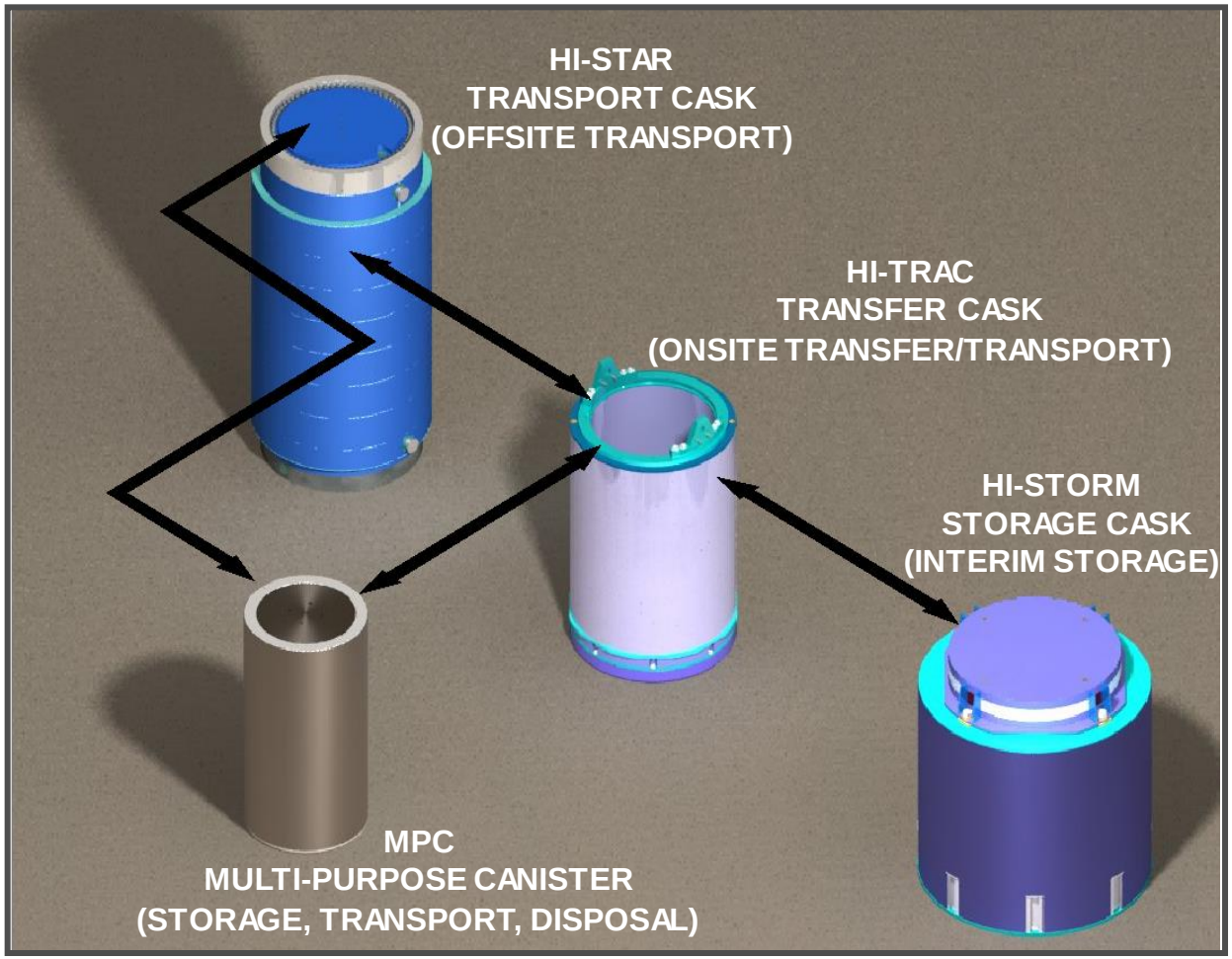
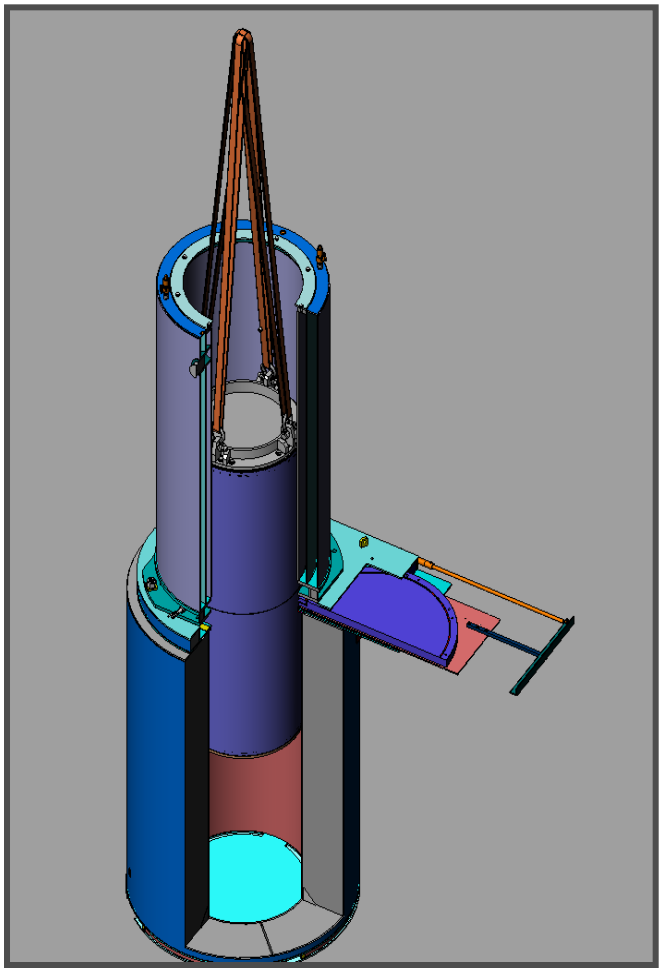


Purpose-specific casks allow for optimized transfer, storage, and transport of the canisterized spent fuel



Canister Transfer

MPCs Provide a Robust Solution for Long-Term Confinement of Used Fuel

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- **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

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Holtec's Single-Wall Canister

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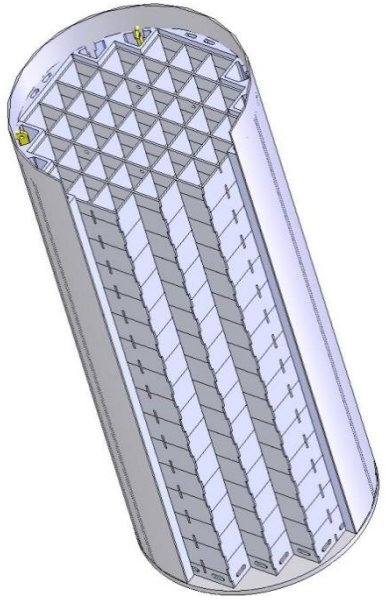

MPC-37

The "Backend" of the Fuel Cycle

Long-term interim dry storage

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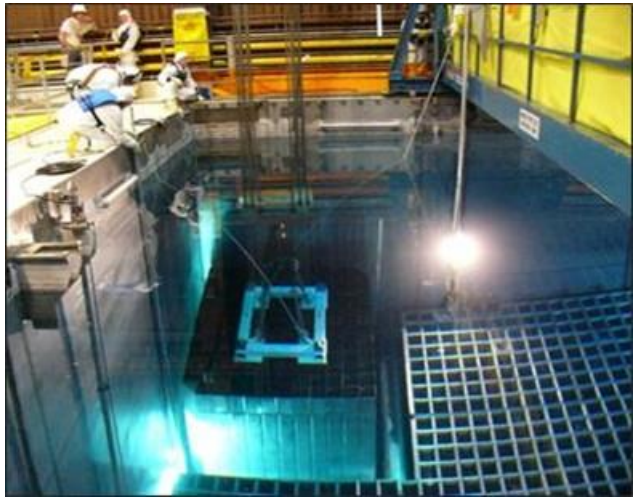
- **Nuclear reactors contain approximately 150 – 250 fuel assemblies**
  - Refueling on ~12 – 24 month outage cycles
  - Replace ~1/3 of the core during each outage
  - After shutdown fuel must remain in reactor for 3 - 5 days due to high heat-loads (exponential decay)
  - Fuel is then moved (underwater)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



Holtec pioneered the "high-density" spent fuel storage rack in 1990's to expand capacity of reactor fuel storage pools. Holtec has supplied racks for over 100 NPPs in 7 countries totaling over 170,000 SFAs and performed the design for most modern reactors (AP-1000, ABWR, APWR, APR-1400)

- **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)