An Overview of Dry Cask Storage

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Nuclear Energy Institute

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What is the Nuclear Energy Institute?

- Industry policy organization in place since 1953 (Atomic Industrial Forum)
- Formed in 1994 by merger of:
  - American Nuclear Energy Council (Legislative)
  - U.S. Council on Energy Awareness (Communications)
  - Nuclear Utility Management and Resources Council (Regulatory)
Approximately 350 Members in 19 Countries

- All U.S. nuclear utilities
- International nuclear utilities
- Reactor and major component suppliers
- Dry Cask Storage Vendors
- Architect/engineering firms
- Radiopharmaceutical manufacturers
- Fuel suppliers
- Universities
- Labor unions
- Law firms
Public Web Site

www.nei.org
Used Nuclear Fuel

- Solid ceramic pellets encased in metal clad rods
- 40 years of nuclear electricity have produced only a small amount
  - entire inventory would cover a single football field approximately 7 yards deep
Fuel Assemblies

15x15 PWR Fuel Assembly

Relative size of PWR and BWR fuel assemblies

Number of Operating Reactors
PWR – 69, BWR – 35

Assemblies in Reactor Core
PWR ~ 190, BWR ~ 750

~8.4 inches

~5.1 inches
Used Fuel Stored in Pool
Dry Cask Storage

Vertical Storage Cask

Horizontal Storage Module
Dual Purpose Canister (DPC)

On-site Transfer Cask

Transportation Cask

Vertical Storage Cask
Preparation of empty canister
Fuel Loading in Transfer Cask
Welding of Canister Lid
DPC Placement into Vertical Storage Cask
DPC Placement into Vertical Storage Cask

- Transfer cask is placed atop vertical storage cask
- DPC is lowered from transfer cask into vertical storage cask
Moving Vertical System to Storage Outside Plant
Moving Horizontal System to Storage Outside Plant
Loading Horizontal Storage Modules
Typical Independent Spent Fuel Storage Installation (ISFSI)

Surry Power Station in Virginia
ISFSIs with Vertical Storage Casks

Connecticut Yankee

Yankee Rowe
Typical Vertical DPC Dry Storage Systems

Holtec

NAC
Bare Fuel Storage Systems

Castor

Transnuclear
Horizontal Storage Systems at an ISFSI

Picnic Lunch Area

Southern California Edison – SONGS Units 1, 2, and 3
Typical Horizontal DPC Dry Storage Systems

Transnuclear
Dry Cask Storage at INL

Figure 2. Commercial Dry Storage casks used in SNF tests at the INL
Left to Right: REA 2023; VSC-17; TN 24P; V21; 125B; MC-10

Figure 3. The Below-grade Storage Facility CP-749 at the INL
Used to Dry Store Peachbottom Reactor SNF

Figure 2-9. NUHOMS Dry Storage Casks Emplaced in Concrete Horizontal Storage Modules at the Idaho National Laboratory Independent Spent Fuel Storage Installation
(Photos courtesy of Idaho National Laboratory)
Commercial Used Nuclear Fuel in Storage
June 2012

- **Used fuel inventory**
  - Approximately 69,000 MTU
  - Increases 2 - 2.4k MTU/year

- **Dry cask storage**
  - 67,691 assemblies
  - 19,000 MTU
  - 1,613 casks/modules loaded
  - 58 Operating ISFSIs
    - 1 pool ISFSI, 1 modular vault

- **Projections for 2020**
  - Estimating 88,000 MTU total
  - Estimating 31,000 MTU in dry storage
  - 3,000 casks/modules loaded
  - At 76 ISFSIs
    - All plant sites + Morris & INL
  - Fuel from 119 reactors

[Map showing spent nuclear fuel storage sites]
Historical Growth of Dry Cask Storage

<table>
<thead>
<tr>
<th>YEAR ENDING DECEMBER 31</th>
<th>NUMBER OF ISFSIs ADDED</th>
<th>TOTAL NUMBER OF ISFSIs</th>
<th>CASKS IN SERVICE</th>
<th>FUEL ASSEMBLIES IN DRY STORAGE</th>
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<td>9</td>
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<td>1998</td>
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<td>2001</td>
<td>3</td>
<td>17</td>
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<td>2002</td>
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<td>2003</td>
<td>4</td>
<td>27</td>
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<td>2004</td>
<td>1</td>
<td>28</td>
<td>664</td>
<td>22,644</td>
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<td>2005</td>
<td>5</td>
<td>33</td>
<td>763</td>
<td>26,531</td>
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<td>2006</td>
<td>3</td>
<td>36</td>
<td>848</td>
<td>30,032</td>
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<td>2007</td>
<td>1</td>
<td>37</td>
<td>924</td>
<td>33,281</td>
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<td>2008</td>
<td>8</td>
<td>45</td>
<td>1,073</td>
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<td>2009</td>
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<td>47</td>
<td>1,203</td>
<td>45,983</td>
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<td>2010</td>
<td>5</td>
<td>52</td>
<td>1,351</td>
<td>52,381</td>
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<td>2011</td>
<td>3</td>
<td>55</td>
<td>1,510</td>
<td>59,008</td>
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* Does not include fuel at Morris (wet ISFSI), Fort St. Vrain (modular vault), or INL.
# Used Fuel Storage Projections and Cask Transportability

<table>
<thead>
<tr>
<th>Year</th>
<th>Metric Tons Heavy Metal (MTHM) Total</th>
<th>MTHM Pools</th>
<th>MTHM Dry Storage</th>
<th>Dry Cask Systems</th>
<th>Total</th>
<th>Non-transportable</th>
<th>Transportable</th>
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<tr>
<td></td>
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<tr>
<td></td>
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<td></td>
<td></td>
<td></td>
<td>Bare fuel</td>
<td>Canister</td>
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<tr>
<td>2010</td>
<td>64,461</td>
<td>49,666</td>
<td>14,795</td>
<td>1,242</td>
<td>29</td>
<td>209</td>
<td>47</td>
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<tr>
<td>2020</td>
<td>87,721</td>
<td>57,611</td>
<td>30,110</td>
<td>2,231</td>
<td>29</td>
<td>259</td>
<td>176</td>
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<tr>
<td>2030</td>
<td>117,071</td>
<td>64,895</td>
<td>52,176</td>
<td>3,593</td>
<td>29</td>
<td>309</td>
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<td>2040</td>
<td>143,741</td>
<td>65,599</td>
<td>78,142</td>
<td>5,196</td>
<td>29</td>
<td>356</td>
<td>252</td>
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Used Nuclear Fuel Storage at ShutdownReactors

<table>
<thead>
<tr>
<th>Reactor Name</th>
<th>State</th>
<th>Shutdown Date</th>
<th>Storage Type</th>
<th>Decommissioning Status</th>
<th>Used Fuel Stored On Site (MTUs)</th>
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<tr>
<td>Indian Point 1*</td>
<td>NY</td>
<td>1974</td>
<td>Dry Cask</td>
<td>SAFSTOR</td>
<td>100</td>
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<td>Humboldt Bay</td>
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<td>1976</td>
<td>Dry Cask</td>
<td>SAFSTOR</td>
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<td>Dresden 1*</td>
<td>IL</td>
<td>1978</td>
<td>Dry Cask</td>
<td>SAFSTOR</td>
<td>69</td>
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<tr>
<td>LaCrosse</td>
<td>WI</td>
<td>1987</td>
<td>Pool</td>
<td>SAFSTOR</td>
<td>38</td>
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<tr>
<td>Rancho Seco</td>
<td>CA</td>
<td>1989</td>
<td>Dry Cask</td>
<td>SAFSTOR</td>
<td>228</td>
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<tr>
<td>Fort St. Vrain?</td>
<td>CO</td>
<td>1989</td>
<td>Dry Cask</td>
<td>SAFSTOR</td>
<td>25</td>
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<tr>
<td>Yankee Rowe</td>
<td>MA</td>
<td>1991</td>
<td>Dry Cask</td>
<td>SAFSTOR</td>
<td>122</td>
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<tr>
<td>Trojan</td>
<td>OR</td>
<td>1992</td>
<td>Dry Cask</td>
<td>SAFSTOR</td>
<td>345</td>
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<tr>
<td>San Onofre 1*</td>
<td>CA</td>
<td>1992</td>
<td>Dry Cask</td>
<td>SAFSTOR</td>
<td>146</td>
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<td>Haddam Neck</td>
<td>CT</td>
<td>1996</td>
<td>Dry Cask</td>
<td>SAFSTOR</td>
<td>422</td>
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<tr>
<td>Maine Yankee</td>
<td>ME</td>
<td>1996</td>
<td>Dry Cask</td>
<td>SAFSTOR</td>
<td>442</td>
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<tr>
<td>Zion 2</td>
<td>IL</td>
<td>1996</td>
<td>Pool</td>
<td>SAFSTOR</td>
<td>1.019 (combined pool)</td>
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<td>Zion 1</td>
<td>IL</td>
<td>1997</td>
<td>Pool</td>
<td>SAFSTOR</td>
<td>70</td>
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<tr>
<td>Big Rock Point</td>
<td>MI</td>
<td>1997</td>
<td>Dry Cask</td>
<td>SAFSTOR</td>
<td>522</td>
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<td>Millstone 1*</td>
<td>CT</td>
<td>1998</td>
<td>Pool</td>
<td>SAFSTOR</td>
<td>522</td>
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</table>

* Collocated with operating reactors
† Transferred to the U.S. Department of Energy on June 4, 1999

Source: Gutherman Technical Services
Dry Storage Safety

- **Dry Casks are robust systems with no moving parts**

- **Defense in depth designs provide long-term protection**
  - NRC rulemaking increasing license and renewal terms from 20 to 40 years concluded “This increase is consistent with the NRC staff’s findings regarding the safety of spent fuel storage as documented in the renewal exemptions issued to the Surry and H.B. Robinson ISFSIs” 76 Fed. Reg. 8874 2/16/2011
  - NRC Waste Confidence findings stated “studies performed to date have not identified any major issues with long-term use of dry storage” 75 Fed. Reg. 81072, 12/23/2010

- **Risk studies affirm high confidence in safety**
  - 2007 EPRI and NRC Probabilistic Risk Assessments determined annual cancer risk due to dry storage between $1.8 \times 10^{-12}$ and $3.2 \times 10^{-14}$ *

- **Characterization project confirmed performance**
  - In 2000, INL opened a cask after 14 yrs., finding “long-term storage has not caused detectable degradation of the spent fuel cladding or the release of gaseous fission products”
  - Opportunities to further verify performance being pursued

* Compares to 2E-6 LCF/yr. public & 1E-5 LCF/yr. worker thresholds of negligible risk from NRC’s framework for “Risk-Informed Decision-making for Nuclear Material and Waste Applications”, Revision 1, February 2008
Regulatory Dose Rate Limits

- **Storage:** at the controlled area boundary
  - Normal condition: 25 mrem/yr
  - Accident condition: 5 rem

- **Transportation:**
  - Normal Condition: 10 mrem/hr at 2 meters, 200 mrem/hr on contact
  - Accident Condition: 1 Rem/hr at 1 meter

Annual U.S. Estimated Radiation Dose Per Person, all natural & man made sources = 622 mrem (0.62 Rem)
Transportation of Used Nuclear Fuel

- Used nuclear fuel is transported in robust containers designed to withstand severe accidents
  - Truck containers weigh 25 to 40 tons
  - Rail containers weigh 75 to 125 tons
- Four decades of safety - over 3,000 shipments in US.
  - 78% by truck and 22% by rail.
  - Transported over 1.7 million miles
- Over 24,000 shipments internationally.
  - More than 73,000 MTHM SNF/HLW transported
- No release of the radioactive contents from the transport cask; no injury due to radioactive contents.
Transportation Cask
Testing of Transportation Cask
Conclusion

- Dry cask storage is a proven and widely used solution to accumulating inventories of used nuclear fuel at reactor sites
- The safety of dry cask storage is well established
- Industry is committed to continue to build on this success