NWTRB Workshop – Inventory

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This is a technical presentation that does not take into account the contractual limitations under the Standard Contract.

Under the provisions of the Standard Contract, DOE does not consider spent fuel in canisters to be an acceptable waste form, absent a mutually agreed to contract modification.
Outline

- Nuclear Power Reactors
- Current Inventory
  - By Reactor Type
  - By Storage Method
  - By Location
- Projected Inventory
  - Projected to 2021
  - Projected to 2060
- Implications
119 Nuclear Power Reactors (NPR) Built and Operated

100 in Operation as of November, 2013
- 2 Operating NPR have announced “Early Shutdown” dates of 2014 and 2019

2 NPR Nearing Completion (not shown)

4 New Build NPR (not shown)

10 NPR on 9 sites shutdown prior to 2000 with only fuel management activities on site and some decommissioning activities ongoing

1 NPR disabled and UNF owned by DOE (Three Mile Island unit 2)

3 NPR permanently shutdown on sites with continued nuclear operations

4 NPR on 3 sites ceased operations or restart activities in 2013
- 5 NPR total are shutdown on these sites
Projected Commercial Used Fuel Discharge and Dry Storage Inventory

Historical and Projected Commercial Used Nuclear Fuel Discharges

There are 100 Operating Reactors at 62 Sites
There are 14 Shutdown Reactors at 12 Sites

Assuming Transfer to Dry Storage at Reactor Shutdown

Source: *Based on actual discharge data as reported on RW-859s through 12/31/2002 and projected discharges, in this case for 100 license renewals.
Current Projected Commercial Inventory
December 31, 2012

- PWR Discharges ~45% by assemblies and ~66% by mass
- ~27% BWR UNF in Dry Storage
- ~29% PWR UNF in Dry Storage

- UNF discharged and stored at 118 NPR sites, excluding UNF at DOE sites:
  - TMI-unit 2 debris
  - Ft. St. Vrain
  - UNF transferred to INL and SRS

- Data Sources include the 2002 RW-859 database and DOE forecast discharges between 1/1/03 and 12/31/12
Used nuclear fuel assemblies are placed in canisters in spent fuel pool
- Canisters are removed from pool using transfer cask and placed in storage cask/overpacks for storage at ISFSI
- Canisters are removed from storage cask/overpacks and placed in transportation cask/overpacks for shipping
Current At Reactor Commercial Inventory
Dry Storage Systems

- **180 Bare Fuel Cask**
  - 7,826 Assemblies, 11.8% of Dry
  - Transnuclear TN-32

- **1,498 Welded Metal Canisters In Vented Concrete Overpacks**
  - 57,810 Assemblies, 86.9% of Dry
  - Transnuclear (38%)
  - Holtec (46%)
  - NAC (12%)
  - Holtec HiStar 100

- **12 Welded Metal Canisters in Transport Overpacks**
  - 866 Assemblies, 1.3% of Dry

- **57,810 Assemblies**

Pool
- **172,012, 72.1%**
- 49,475 MT
4 Vendors have provided bare fuel casks
- Westinghouse MC-10
- GNB Castor V21/V33 (cast iron body)
- NAC I-128
- Transnuclear TN-32, TN-40, TN-40HT and TN-68

TN-40 and TN-68 have a current transportation certificate of compliance (CoC)
- Prairie Island and Peach Bottom continue to load

Physical configuration varies
- Length from 175 to 215 inches
- OD from 94.8 to 110.25 inches
- Weight from 230,000 to 250,000 lbs
Metal Canisters Already in Transportation Overpacks

- Holtec Hi-Star 100 – generic overpack
  - Length: 203 in., 305 in. with impact limiters
  - OD: 96 in., 128 in. with impact limiters
  - Weight: 282,000 lbs. for heaviest configuration

- Specific design for Humboldt Bay
  - Approximately 78 in. shorter than generic

- Transportation-“ready” packages
  - Requires only impact limiters for transportation
  - 12 casks at Humboldt Bay, Dresden, and Hatch
  - Contents are licensed for transport
Above grade vented storage overpacks and modules are most widely deployed

Typical vertical cask at grade Holtec and NAC

Vendor specific transfer casks support fuel movement
- Pool to dry storage
- Storage to transportation cask
- Transportation to storage at ISF

Transnuclear
Horizontal Storage Module

Holtec HI-STORM
26 Different Welded Metal Canister Designs Have Been Licensed

Typical Configurations
- Right Circular Cylinder
  - Length 122.5 to 196 in.
  - Inner Diameter 60.5 to 68.75 in.
  - Weight 55,000 to 105,000 lbs.
  - Lifting configurations differ

Interior Cell Dividers
- 7, 12, 24, 32, 37 PWR assemblies
- 52, 61, 68, 80, 87, 89 BWR assemblies
- Differing materials of construction, especially neutron absorber materials

NRC Licenses
- 5 designs (308 canisters) designated for “Storage Only”
- 21 designs are “Storage and Transportation”
- Vendor’s terminology varies
- None are licensed for disposal
- Allowable decay heat and fuel burnup varies by design
- Allowable failed fuel canisters varies by design from 4 upwards
Evolution of Dry Shielded Canisters for Pressurized Water Reactors (PWRs)

<table>
<thead>
<tr>
<th>YEAR</th>
<th>NUHOMS® Canister</th>
<th>Assemblies Capacity</th>
<th>Loaded Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>1985</td>
<td>7 P</td>
<td>7</td>
<td>10 tons</td>
</tr>
<tr>
<td>2000</td>
<td>24 PTH</td>
<td>24</td>
<td>40 tons</td>
</tr>
<tr>
<td>2003</td>
<td>32 PTH</td>
<td>32</td>
<td>55 Tons</td>
</tr>
<tr>
<td>2012</td>
<td>37 PTH</td>
<td>32</td>
<td>55 Tons</td>
</tr>
</tbody>
</table>

**NUHOMS® 24PTH**

**NUHOMS® 32PTH**

**NUHOMS® 37PTH**
UNF at Shutdown Nuclear Power Reactors

Permanently Shutdown Reactor Fuel
560 Fuel Casks, ~31 GTCC Casks
6,208 MT, 18,199 Assemblies

Shutdown Reactor Fuel Casks
62 Fuel Casks, ~6 GTCC Casks
647 MT, 3,933 Assemblies

Early Shutdown Reactor Fuel Cask
250 Fuel Casks, ~10 GTCC Casks,
2,747 MT, 6,617 Assemblies

Stranded Reactor Fuel Casks
248 Fuel Cask, 15 GTCC Casks,
2,813 MT, 7,649 Assemblies

Stranded UNF and Shutdown Reactor UNF based on RW-859 Database
Early Shutdown UNF based on DOE projections
Projected number of casks based on continued use of currently deployed systems
### Deployed Storage Systems at Shut-down Reactor Sites

12 shutdown plant sites use 17 different canister designs, 8 different storage overpack designs, and requires 8 different transport overpack designs.

<table>
<thead>
<tr>
<th>Reactor</th>
<th>Shutdown Date</th>
<th>Assby</th>
<th>Initial Uranium (MT)</th>
<th>Storage System/Canisters</th>
<th>Transport Cask Status</th>
<th>Number of Canisters Fuels/GTCC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Big Rock Point</td>
<td>8/29/1997</td>
<td>441</td>
<td>58.05</td>
<td>Fuel Solutions W150 Storage Overpack / W74 Canister</td>
<td>TS-125 (Docket No. 71-9276); Certificate expires 10/31/2017. None fabricated</td>
<td>7/1</td>
</tr>
<tr>
<td>Haddam Neck</td>
<td>12/5/1996</td>
<td>1,019</td>
<td>412.29</td>
<td>NAC-MPC / MPC-26 and MPC-24 canisters</td>
<td>NAC-STC (Docket No. 71-9236); Certificate expires 5/31/2014. Foreign use versions fabricated</td>
<td>40/3</td>
</tr>
<tr>
<td>Humboldt Bay 3</td>
<td>7/2/1976</td>
<td>390</td>
<td>28.94</td>
<td>Holtec Hi-STAR HB / MPC-HB canister</td>
<td>Hi-STAR HB (Docket No. 71-9261); Certificate expires 3/31/2014. Fuel in canisters in fabricated casks. No impact limiters.</td>
<td>5/1</td>
</tr>
<tr>
<td>Maine Yankee</td>
<td>12/6/1996</td>
<td>1,434</td>
<td>542.26</td>
<td>NAC-UMS/UMS-24 canister</td>
<td>NAC-UMS (Docket No. 71-9270); Certificate expires 10/31/2017. None fabricated</td>
<td>60/4</td>
</tr>
<tr>
<td>Rancho Seco</td>
<td>6/7/1989</td>
<td>493</td>
<td>228.38</td>
<td>TN NUHOMS / FO-DSC, FC-DSC, and FF DSC</td>
<td>NUHOMS MP187 (Docket No. 71-9255); Certificate expires 11/30/2013. One cask fabricated. No impact limiters.</td>
<td>21/1</td>
</tr>
<tr>
<td>Trojan</td>
<td>11/9/1992</td>
<td>760</td>
<td>358.85</td>
<td>TranStor Storage Overpack / Holtec MPC-24E and MPC-24EF canisters</td>
<td>Hi-STAR 100 (Docket No. 71-9261); Certificate expires 3/31/2014. Units fabricated but dedicated to storage at other sites. No impact limiters.</td>
<td>34/0</td>
</tr>
<tr>
<td>Yankee Rowe</td>
<td>10/1/1991</td>
<td>533</td>
<td>127.13</td>
<td>NAC-MPC / MPC-36 canister</td>
<td>NAC-STC (Docket No. 71-9236); Certificate expires 05/31/2014. Foreign use versions fabricated</td>
<td>15/1</td>
</tr>
<tr>
<td>Zion 2</td>
<td>2/21/1997</td>
<td>1,143</td>
<td>523.95</td>
<td>NAC MAGNASTOR / TSC 37 canister</td>
<td>NAC MAGNATRAN (Docket No. 71-9356); License under review. None fabricated</td>
<td>61/4</td>
</tr>
<tr>
<td>Zion 1</td>
<td>9/16/1996</td>
<td>1,063</td>
<td>496.49</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stranded</td>
<td></td>
<td>7,649</td>
<td>2,813</td>
<td>Does not have a licensed ISFSI, early selection TransNuclear. NUHOMS 32PTH1 storage canister, in a Horizontal Concrete Overpack</td>
<td>TN MP197/B (Docket No. 71-9302); This cask is not currently licensed for the 32PTH1 payload. One in fabrication</td>
<td>248/15</td>
</tr>
<tr>
<td>Crystal River</td>
<td>2009</td>
<td>1,319</td>
<td>611.98</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Kawaunee</td>
<td>2013</td>
<td>1,335</td>
<td>513.33</td>
<td>TransNuclear. NUHOMS 32PT storage canister, in a Horizontal Concrete Overpack</td>
<td>TN MP197/B (Docket No. 71-9302); This cask is not currently licensed for the 32PT payload. One in fabrication</td>
<td>42/2</td>
</tr>
<tr>
<td>Songs 1,2,3</td>
<td>2012</td>
<td>3,963</td>
<td>1,622.17</td>
<td>TransNuclear. NUHOMS 24PT and 24PT1 storage canister, in a Horizontal Concrete Overpack</td>
<td>TN MP197/B (Docket No. 71-9302); This cask is not currently licensed for the 24PT or 24PT1 payloads. One in fabrication</td>
<td>166/6</td>
</tr>
<tr>
<td><strong>Recent Shutdown Reactor Plants Total</strong></td>
<td><strong>6,617</strong></td>
<td><strong>2,747</strong></td>
<td></td>
<td></td>
<td></td>
<td><strong>250/10</strong></td>
</tr>
</tbody>
</table>
No Replacement NPR Scenario Potential Inventory Includes:

- Shutdown reactor UNF
- Announced “early shutdown” reactor UNF for NPR not planning to operate 60 years
- Remaining NPR assumed to get a single license extension and operate for 60 years
- New builds are not included
### Potential New Build NPR Inventory

#### Forecast Discharges 1/1/13 to 12/31/60

<table>
<thead>
<tr>
<th>Reactor Type</th>
<th>Assemblies</th>
<th>Initial Uranium (MT)</th>
<th>Assemblies</th>
<th>Initial Uranium (MT)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Watts Bar 2</td>
<td>2,242</td>
<td>1,031.32</td>
<td>2,242</td>
<td>1,031.32</td>
</tr>
<tr>
<td>Bellefonte 1</td>
<td>2,614</td>
<td>1,202.44</td>
<td>2,614</td>
<td>1,202.44</td>
</tr>
<tr>
<td>Vogtle 3</td>
<td>2,506</td>
<td>1,060.04</td>
<td>2,506</td>
<td>1,060.04</td>
</tr>
<tr>
<td>Vogtle 4</td>
<td>2,504</td>
<td>1,059.19</td>
<td>2,504</td>
<td>1,059.19</td>
</tr>
<tr>
<td>Summer 2</td>
<td>2,351</td>
<td>980.37</td>
<td>2,351</td>
<td>980.37</td>
</tr>
<tr>
<td>Summer 3</td>
<td>2,326</td>
<td>969.94</td>
<td>2,326</td>
<td>969.94</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>14,543</strong></td>
<td><strong>6,303</strong></td>
<td><strong>14,543</strong></td>
<td><strong>6,303</strong></td>
</tr>
</tbody>
</table>
NRC 10 CRF Part 72 storage licenses and CoCs have been amended to meet plant needs, including storage of high burnup, high heat load fuel.

NRC 10 CFR Part 71 transportation CoCs have not kept pace:
- With one small exception, no HBU fuel is licensed for transportation.
- Even canisters limited to 45 GWd per assembly require extended cool time to transport.

**Storage:**
- Burnups up to 65 GWd
- Heat loads up to 40 kW

**Transport**
- Burnups to 45 GWd
- Heat loads in mid-20s kW

Plants continue to load dozens of HBU fuel and high heat load canisters each year that will require licensing actions, and or CoC amendments to transport.
Effect of Thermal Constraints on Large DPCs

- Thermal constraints are more stringent on transportation overpacks than on dry storage canisters/overpacks
  - Utilities loading recently discharged higher burn-up UNF
  - Approaching storage canister/overpack limits
  - Vendors developing canisters with higher thermal limits
    - Holtec Hi-Storm FW: ~47 Kw/canister

<table>
<thead>
<tr>
<th>Canister</th>
<th>Storage Heat Limit</th>
<th>Transport Heat Limit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Holtec MPC-68</td>
<td>34kW</td>
<td>18.5kW</td>
</tr>
<tr>
<td>Holtec MPC-32</td>
<td>34kW</td>
<td>20kW</td>
</tr>
<tr>
<td>NUHOMS 32P</td>
<td>40.8kW</td>
<td>24kW</td>
</tr>
<tr>
<td>NUHOMS 61B</td>
<td>31.2kW</td>
<td>24kW</td>
</tr>
<tr>
<td>NAC UMS 24</td>
<td>23kW</td>
<td>20kW</td>
</tr>
</tbody>
</table>

- Large dry storage canisters loaded to storage thermal limit would have to stay on-site for an extended period of time
  - Perhaps decades between loading and when canister could be transported off-site
Effect of Thermal Constraints on Potential UNF Acceptance Strategies

- Evaluated acceptance of UNF from reactors for two different strategies
  1. All UNF shipped in large DPCs
  2. UNF from pools shipped in re-useable bare fuel transportation casks

- Canister-Only acceptance strategies have an irreducible “tail”
  - Due to need to decay-store DPCs to meet thermal limits

- Acceptance of bare fuel in re-useable transportation casks that could accommodate higher heat loads could allow for earlier and faster UNF transport
  - Bare fuel rail transportation casks have not been certified for most fuel types
Repackaging Requires a Substantial Effort

- Potentially package or re-package ~206,000 BWR and ~277,000 PWR fuel assemblies
- Canisters that would have to be opened depends on UNF management strategy, acceptance rates, and start dates

<table>
<thead>
<tr>
<th>Acceptance Rate</th>
<th>Acceptance Start Data</th>
<th>Management Strategy</th>
<th>Dry Storage Canisters at Reactors</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dry Storage Only</td>
<td>3,000 MT/yr</td>
<td>2021</td>
<td>Oldest Fuel First</td>
</tr>
<tr>
<td>Dry and Bare Fuel Transport</td>
<td>3,000 MT/yr</td>
<td>2021</td>
<td>Oldest Fuel First</td>
</tr>
<tr>
<td>Dry and Bare Fuel Transport</td>
<td>4,500 MT/yr</td>
<td>2021</td>
<td>Oldest Fuel First</td>
</tr>
<tr>
<td>Dry and Bare Fuel Transport</td>
<td>~4,300 MT/yr</td>
<td>2021</td>
<td>Eliminate Additional Dry Storage Canister Production</td>
</tr>
</tbody>
</table>

- Waste Disposal Canisters to be produced depends upon geologic repository considerations

<table>
<thead>
<tr>
<th></th>
<th>4-PWR/9-BWR</th>
<th>12-PWR/24-BWR</th>
<th>21-PWR/44-BWR</th>
</tr>
</thead>
<tbody>
<tr>
<td>PWR Waste Packages</td>
<td>52,250</td>
<td>17,417</td>
<td>9,952</td>
</tr>
<tr>
<td>BWR Waste Packages</td>
<td>30,333</td>
<td>11,375</td>
<td>6,205</td>
</tr>
<tr>
<td>Total Waste Packages</td>
<td>82,583</td>
<td>28,792</td>
<td>16,157</td>
</tr>
</tbody>
</table>

Discussion

Discussion