Waste Package and Repository Configuration

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Contents

- Location of Repository
- Repository Requirements
- Repository Layout
- Waste Package Requirements
- History of Waste Package Designs
- Waste Package Viability Design
- Alternative Designs
- Backup Information
LEGEND

1. water table
2. ramps and shafts
3. emplacement drifts
4. natural barrier

Subsurface Facility
Picture of Engineered Barrier Segment
The Reference VA Design

- Thermal Load 85 MTU/Acre
- Drift spacing 28 m
- Commercial and DOE glass-waste waste packages are alternated in drift
- Emplacement mode, horizontal in-drift
- Zeolite peak temperature of 90 °C at average 170 m below repository
- Drift wall peak temperature below 200 °C limit, current design 160 -180 °C
- Emplacement drifts ventilated, 5-10 m³/sec flow during emplacement
- An airflow of 0.1 m³/sec in filled drifts
Picture of Drift Handling
Major Design Goals

- Meet future NRC/EPA regulations, with objective evidence
- Containment of the waste for at least 3,000 years (program goal, 10 CFR 60 requires 300 to 1,000 years)
- Post containment release <1 part in $10^5$ per year of inventory of each radionuclide at 1000 years
- Protect waste from contact with seeping or dripping water for at least 10,000 years (program goal)
- Protect fuel rod cladding (temperature <350°C)
- Waste package containment barrier shielding to protect against radiolytically enhanced corrosion
- Criticality control
  - Preclosure: prevent criticality during operations
  - Postclosure: very low likelihood and insignificant consequences during isolation period
Waste Forms

- Commercial Spent Nuclear Fuel
  - PWR
  - BWR
- Vitrified Waste
  - Savannah River Site
  - West Valley
  - Hanford
- Other DOE Spent Nuclear Fuel
  - Approximately 250 waste forms compiled into categories
- Navy Fuel
- Plutonium
  - Commercial MOX
  - Immobilized
Design Basis Waste Package Environment

- High average thermal loading (80 to 100 MTU/Acre)
  - Waste container surface temperatures above boiling for thousands of years (about 3,000 years)
  - Relative low humidity initially, then as temperatures drop a slow return to initial ambient humidity
  - Some containers will see dripping water
  - Repository edge and fault avoidance effects will cause localized lower thermal loading

- Water in vicinity of waste packages
  - Bicarbonate water with pH 4.5 to 10.5
Scatter Plot of SNF
Licensing Considerations

- Waste package design(s) must have the intended contents specifically defined, similar to cask storage
  - SNF size, type, enrichment, burnup, cooling time, etc.
  - Bounding SNF defined by the Design Basis Fuel
- Each different segment of the waste stream must be addressed in the license, regardless if the same physical WP design was used
- Need to demonstrate regulatory compliance
- Identification of and compliance with industry consensus codes and standards
Progression of Design

- 1988: Thin-Walled; Borehole emplacement
- 1992: Definition of advanced conceptual design options: 7 design options
- 1992: Robust/Multi-Barrier; Drift emplacement
- 1993: Multi-Purpose Canister with Robust / Multi-Barrier Waste Package
- 1996: Advanced Conceptual Design
- 1998: Viability Assessment Design
- 2001: License Application Design
21 PWR UCF Waste Package Assembly

- Inner Barrier Lid (Alloy 625)
- Outer Barrier Lid (A516)
- Side Guide (A516)
- Interlocking Plates (Cutaway View) (Stainless Steel Boron)
- Inner Barrier Lid (Alloy 625)
- Outer Barrier Lid (A516)
- Corner Guide (A516)
- Corner Stiffener (A516)
- Side Cover (A516)
- Tube (A516)

Length = 5335 mm
Diameter = 1650 mm
Tare Weight = 34,039 kg
Loaded Weight = 50,423 kg
Waste Package Fabrication Process

- Barriers are rolled and seam welded
- Inner and outer barriers are assembled using shrink fit process
- Internal basket guides are installed in inner barrier
- Lower end plates are installed and then the assembly is stress relieved
- Basket components are assembled (tubes, stainless-steel boron plates, and thermal shunts) and then inserted into barriers
- After SNF is installed, inner and outer lids are welded using narrow gap process
- All welds and plates are 100% inspected
TSPA-VA Base-Case Waste Package Analysis Results
(NE area; SF WPs; no backfill; always dripping & 100% wetted)
Alternative/Design Options

- Two CRM design
  - Capacity: 21/12 PWR and 44/24 BWR
  - Drift emplaced

- Shielded waste package
  - Shield material: (carbon steel, concrete, DU, composite)

- Ceramic coated waste package

- VA design with thicker CRM
  - Inner barrier: 40 mm of C-22
  - Outer barrier: 100 mm of A516
  - Capacity: 21/12 PWR and 44/24 BWR
  - Drift emplaced
Backup / Additional Information
Waste Package Transportation Operation

- Shielded transporter and manually driven locomotive to the mouth of the emplacement drift
- A remote controlled gantry picks up the waste package, travels a maximum of 600 m
- Emplacement from both ends of emplacement drift
- Waste packages are placed from center of the drift towards the entrance of drift. No leap-frogging
Waste Package Requirements

- Requirements are stated in the CFRs
  - 10 CFR 20 Standards for Protection Against Radiation
  - 10 CFR 60 Disposal of High-Level Radioactive Waste in Geological Repository
  - 10 CFR 960 General Guidelines for Recommendation of Sites for Nuclear Waste Repositories

- Program requirement documents:
  - Engineered Barrier Design Requirements Document (EBDRD)
  - Control Design Assumptions (CDA)
  - System Description Document (SDD) - New requirements documentation, under development
SCP Concept

- **1988: Thin-Walled, Borehole Design**
  - Proposed Material: Stainless steel 304L or Inconel 825
  - Thickness: 10mm
  - Emplacement: Vertical boreholes spaced every 15 feet
  - Fixed Thermal Load of 57 kW/Acre, Cladding Temperature Exceeded 350 C (380 C)
  - 4-PWR and 3-BWR
  - No Criticality Control Method Specified

- Little or no performance allocated to waste package
Robust Concepts/Designs

- **1992:** Robust/Multi-Barrier, Drift Emplaced
- **1993:** Multi-Purpose Canister/ Robust/Multi-Barrier
  - “A Preliminary Evaluation of Using Multi-Purpose Canisters Within the Civilian Radioactive Waste Management System” issued March 1993
- **1996:** Advanced Conceptual Design
  - Workable concept
  - Handle over 90% Commercial Spent Nuclear Fuel in basic design
  - Inner barrier alloy 825; outer barrier carbon steel, high and low thermal load designs
- **1998:** Viability Assessment Design
  - Handle 100% of All Specified waste Forms
  - Incorporate Scientific Studies, corrosion, site, Performance Assessment
  - Inner barrier C-22; outer barrier AS16
Advanced Conceptual Concepts

- 1992: Definition of Advanced Conceptual Design Options
  - Metallic Multi-Barrier, Drift Emplaced
  - Metallic Personnel Shielded
  - Small Metallic Multi-Barrier
  - Non-Metallic Multi-Barrier
  - Multi-Purpose Waste Package
  - Universal Cask - Waste Package
  - SCP-CDR (thin walled container)

- Waste package containment/release important to performance
Waste Stream Considerations

- Commercial SNF waste stream projections indicate a wide distribution in characteristics
  - For example, the heat output of the 90th percentile can be more than twice the average heat output

- Projected SNF was sorted by assembly characteristics important to design
  - Physical size and weight of assembly
  - Heat output at time of emplacement
  - Criticality potential (k-infinity)
Waste Package Designs

- Uncanistered Spent Nuclear Fuel
- Canistered Spent Nuclear Fuel
- Defense High Level Waste
- DOE-owned Spent Nuclear Fuel
- Canistered Navy Fuel
Waste Package Materials

- Dual barrier design provides two independent failure mechanisms
  - Corrosion-Allowance Barrier
    - Subject to general corrosion
    - Permits performance prediction; thickness governs time to failure
    - Relatively low cost
    - Current design 100 mm A516 carbon steel
  - Corrosion-Resistant Barrier
    - Corrosion resistance in wide range of pH
    - Localized corrosion is stifled
    - Initiation of corrosion and failure random
    - Current design 20 mm high-nickel Alloy C-22
Waste Package Basket Design/Materials

- Defense-in-depth
  - Basket structure, carbon steel tubes
    - Load bearing
    - Heat removal
    - Long term performance, as it degrades,
      - Moderator displacement (reduces probability of criticality)
      - Retards radionuclides
  - Performance based neutron absorbing material
    - Corrosion resistant, Stainless steel-boron
    - Non-structural, in compliance with NRC guidance
  - Thermal shunt, ensures cladding temperature is met
Waste Package Thermal Restraints

- Thermal restraints are governed by temperature limits for:
  - Cladding
  - Drift wall
  - Zeolites

- Repository thermal loading 80-100 metric tons uranium per acre

- Waste Package maximum thermal output limit is 18kW
Structural Restraints

- Preclosure Analyses
  - Handling Load
    - SNF loading and container closure
    - Waste container lifting and moving
    - Emplacement/Retrieval
  - Design Basis Events
    - Drops (vertical, horizontal, oblique)
    - Tip-over
    - Impacts (missile from failure of pressurized component, rock fall, etc.)

- Postclosure Analyses
  - Drift Liner Collapse/Rock Fall
  - Seismic Event
Parametric

- Thicker Corrosion-Resistant Material (CRM) extends waste package life
- Worst case: Constant water drip on waste packages
  - 20mm: ~ 8,000 years to initial breach
  - 30 mm: ~ 25,000 years to initial breach
  - 40 mm: ~ 40,000 years to initial breach
## Baseline and Shielded WP Designs

<table>
<thead>
<tr>
<th>WP Capacity</th>
<th>Diameter x Length</th>
<th>WP Mass</th>
<th>Diameter x Length</th>
<th>WP Mass</th>
</tr>
</thead>
<tbody>
<tr>
<td>21 PWR</td>
<td>1.7 m x 5.3 m</td>
<td>51,000 kg</td>
<td>A 516</td>
<td>3.8 m x 7.5 m</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>DU</td>
<td>2.9 m x 6.6 m</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>Concrete</td>
<td>2.8 m x 6.5 m</td>
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<tr>
<td>12 PWR</td>
<td>1.3 m x 5.3 m</td>
<td>34,000 kg</td>
<td>A 516</td>
<td>3.5 m x 7.5 m</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>DU</td>
<td>2.5 m x 6.6 m</td>
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<td></td>
<td></td>
<td></td>
<td>Concrete</td>
<td>2.5 m x 6.5 m</td>
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<tr>
<td>5 PWR</td>
<td>1.0 m x 5.3 m</td>
<td>20,000 kg</td>
<td>A 516</td>
<td>3.1 m x 7.4 m</td>
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<td>DU</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>Concrete</td>
<td>2.1 m x 6.5 m</td>
</tr>
</tbody>
</table>
Cost for Options

- **Extended Life with Personnel Shielding**
  - **For 12 PWR size waste package**

<table>
<thead>
<tr>
<th>Material</th>
<th>2.5 mrem/hr</th>
<th>100 mrem/hr</th>
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<tbody>
<tr>
<td>A516</td>
<td>$356,000</td>
<td>$210,000</td>
</tr>
<tr>
<td>C-22</td>
<td>$3,626,000</td>
<td>$1,688,000</td>
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<tr>
<td>A516/C-22</td>
<td>$1,992,000</td>
<td>$949,000</td>
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</tbody>
</table>
## Comparison Table

<table>
<thead>
<tr>
<th>Type Package</th>
<th>21 PWR A516/ C-22 Baseline</th>
<th>21 PWR C-22/Ti-7 Extended</th>
<th>21 PWR C-22/Ti-7 Extended with A516 Shield</th>
<th>21 PWR C-22/Ti-7 Extended with C-22 Shield</th>
<th>12 PWR A516/ C22 Baseline</th>
<th>12 PWR C-22/Ti-7 Extended with A516 Shield</th>
<th>12 PWR C-22/Ti-7 Extended with C-22 Shield</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weight</td>
<td>51 metric tons</td>
<td>40 metric tons</td>
<td>205 metric tons</td>
<td>222 metric tons</td>
<td>34 metric tons</td>
<td>25 metric tons</td>
<td>140 metric tons</td>
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<tr>
<td>Diameter</td>
<td>1663 mm</td>
<td>1573 mm</td>
<td>2609 mm</td>
<td>2609 mm</td>
<td>1320 mm</td>
<td>1230 mm</td>
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</tr>
<tr>
<td>Length</td>
<td>5335 mm</td>
<td>5230 mm</td>
<td>6276 mm</td>
<td>6276 mm</td>
<td>5335 mm</td>
<td>5230 mm</td>
<td>6164 mm</td>
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