SAND2015-2867C

Deep Borehole Disposal Engineering

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Unclassified, Unlimited Release (SAND2015-***)**
International High-Level Radioactive Waste Management Conference, "Real World Solutions for Integrated Management of Used Fuel and HLW," Charleston, SC, June 12-16, 2015.

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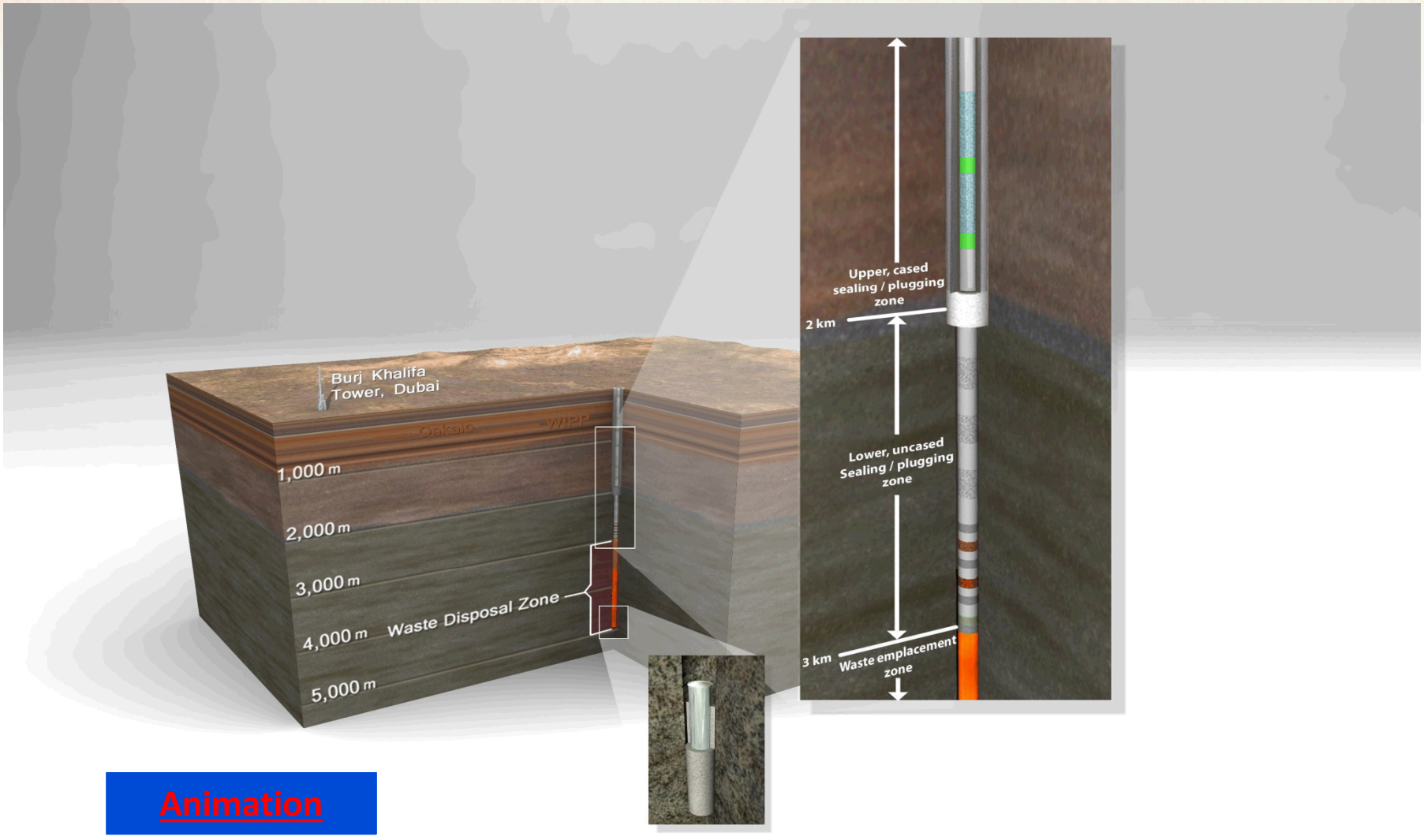
Outline

- Deep Borehole Disposal Concept
- Borehole Emplacement Concepts
- Borehole Environment
- Disposal Overpack Design Questions
- Safety of Disposal Operations
- Disposal Borehole and Overpack Size Options
- System Concept for Packaging, Storage, Transportation & Geologic Disposal
- Deep Borehole Field Test Engineering Design
- Q&A

Deep Borehole Disposal Concept

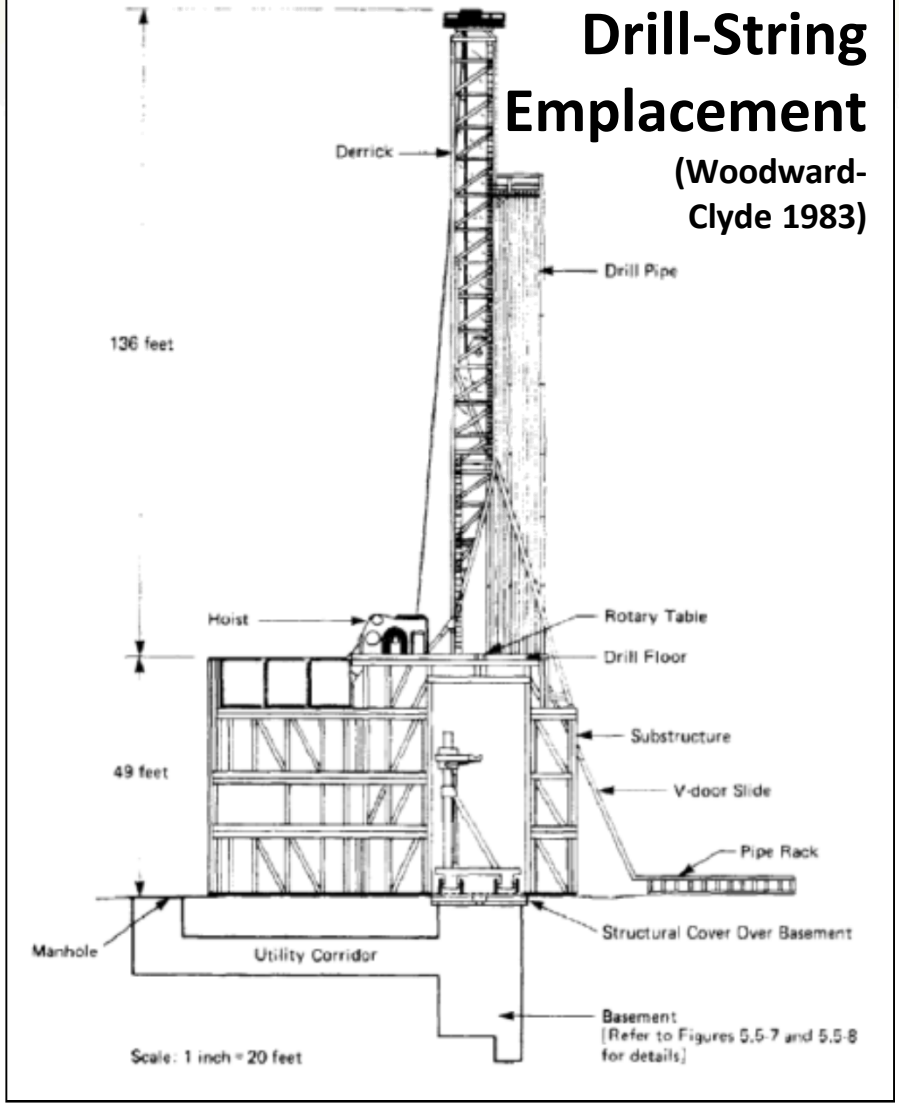


Animation

Deep Borehole Disposal Emplacement Concepts

Drill-String Emplacement

(Woodward-Clyde 1983)



Coiled Tubing

(www.stewartandstevenson.com)

Electric Wireline

(www.wellservicingmagazine.com)

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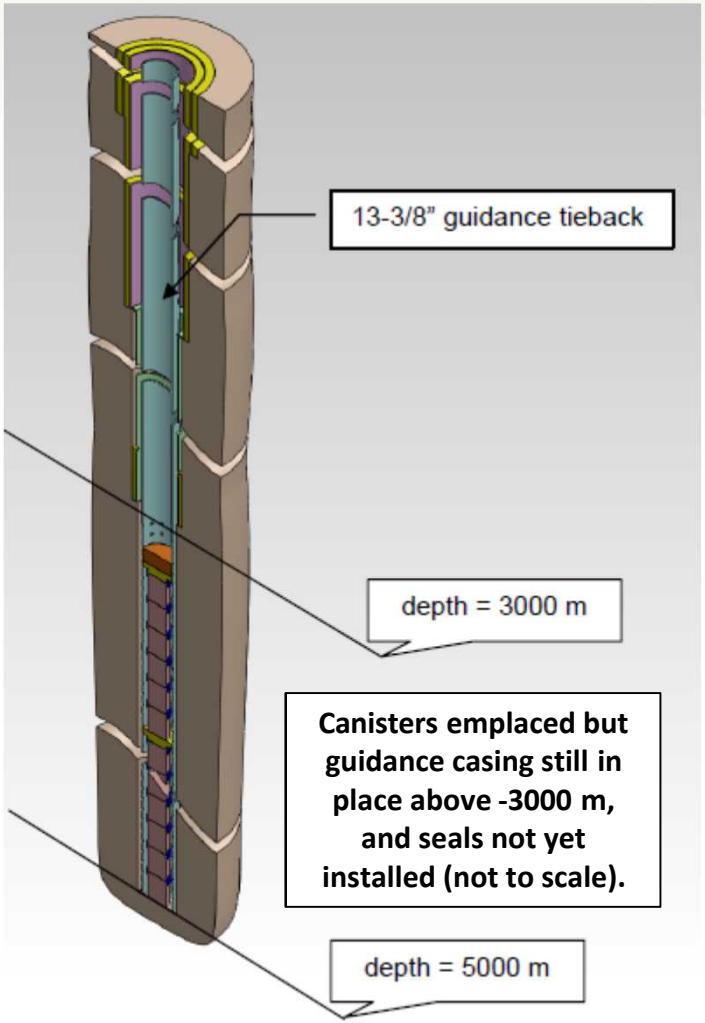
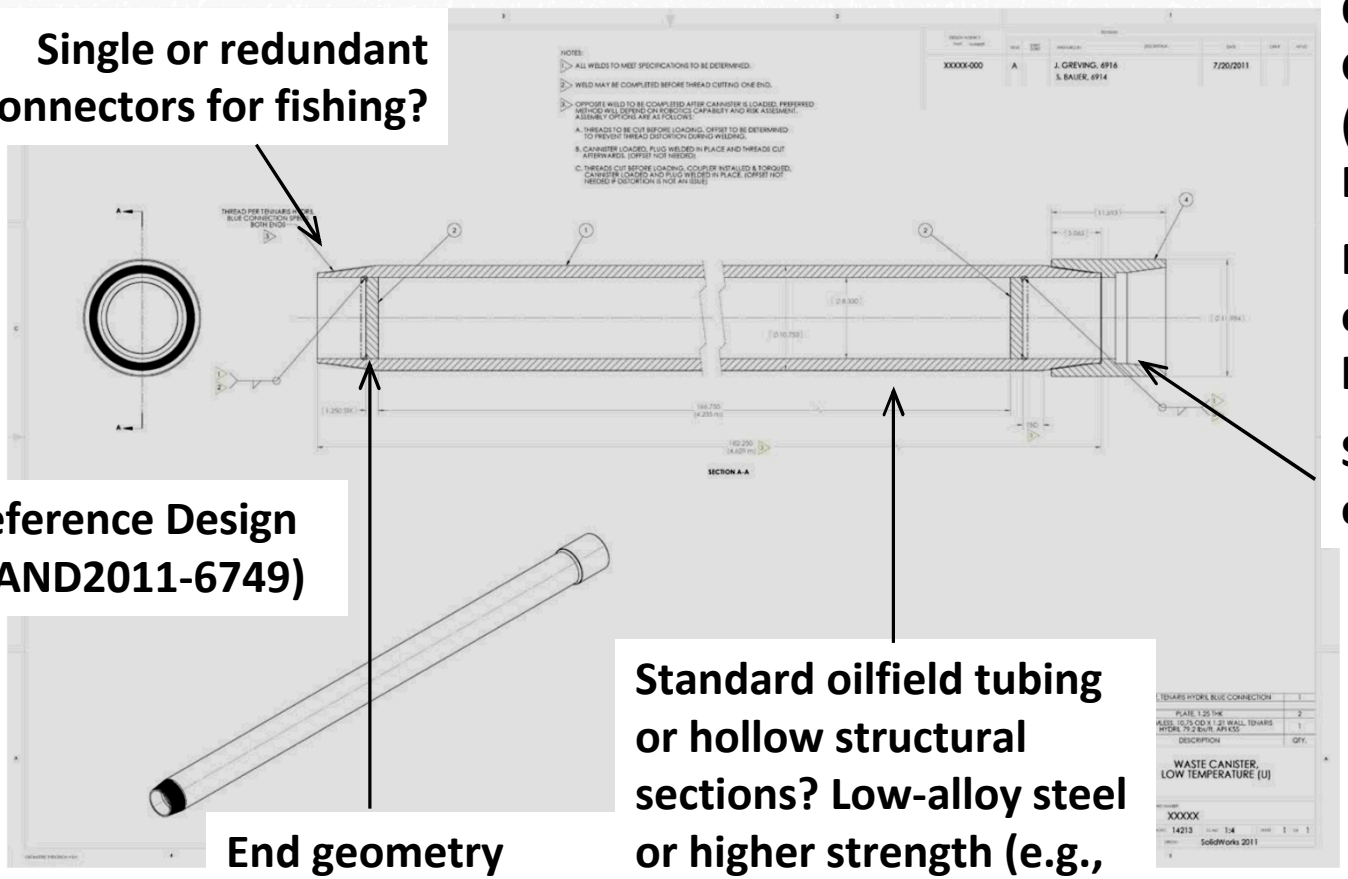
Borehole Environment

- **Thermal**
  - 170°C background (+/-)
- **Hydrologic**
  - 11 ksi downhole pressure with heavy bentonite mud
- **Mechanical**
  - Steel liner from surface
- **Chemical**
  - Chloride brine
- **Longevity of Construction and Packaging Materials**
  - Nominally ≤ 10 years



Deep Borehole Disposal
Disposal Overpack Design Questions

Single or redundant connectors for fishing?



Reference Design (SAND2011-6749)

End geometry pressure-limiting? Flat or convex?

Standard oilfield tubing or hollow structural sections? Low-alloy steel or higher strength (e.g., forged, smaller t/D) for more disposal volume?

Factor of safety?
Oilfield tubulars ≤ 1.66
Gas pipelines ≤ 2.0 (49CFR192)
Hydraulics = up to ~4

Post-closure containment lifetime?

Separate connectors or welded?

Safety of Disposal Operations

- **DB Field Test vs. Potential Future Disposal System**
  - DBFT will have zero radiological risk
- **Accident/Off-Normal Prevention**
  - Focus of DBFT engineering: downhole safety, highest risks for disposal system
- **Downhole Failure Modes/Accidents (disposal system)**
  - Pipe string + canister(s) drop in borehole
  - Pipe string drop onto canister(s)
  - Canister leak/crush
  - Fishing operations (pipe string or wireline)
  - Single canister drop in borehole (zero consequence?)
  - Seismic events, and other hazards potentially significant to the choice of waste package emplacement mode

Disposal Borehole and Overpack Size Options

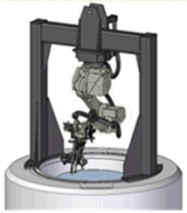
Borehole and Canister Sizes >>>>	Small	Medium	Reference	Large
Waste per Canister >>>>	2 to 8 capsules end-to-end	3-capsule groups stacked ≤ 8 high	Bulk	Bulk
Disposal Zone Hole Diameter	8.5”	12.3”	17”	22”
Disposal Zone Casing ID	6.4”	9.8”	12.6”	17.4”
Disposal Overpack OD	5”	8.5”	11”	16”
Disposal Overpack ID	4”	6.5”	8.5”	12”
Avail. Disposal Volume/Borehole (ft^3)	460	1220	2,090	4,170
Disposal Canister Length (ft)	3.9 to 15.6	3.9 to 15.6	16.7	16.7
Canister Capacity	2 to 8 capsules	6 to 24 capsules	5.2 $ft.^3$	10.4 $ft.^3$
# Waste Packages/Disposal Zone	968 to 242	323 to 81	400	400
Capsule Disposal Interval Height	~4,500 ft *	~1,500 ft *		
Drilling/Completion Costs ($M)	< 20 *	< 25 *	40	60
Borehole Cost/Disposal Vol. ($k/$ft^3$)	< 40 *	< 26 *	19	15
($/$in^3$)	< 23 *	< 15 *	11	8

* Capsule disposal intervals are less than the length of 2 km (6,560 ft) used for borehole cost estimation, so borehole costs would be less.

System Concept for Packaging, Storage, Transportation & Geologic Disposal

Bulk waste

Canister loading/sealing

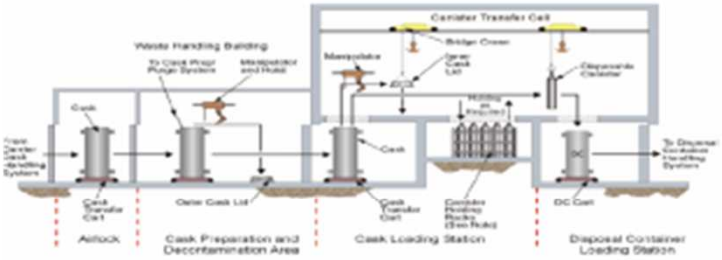


Multi-canister overpack

Multi-canister transport cask

Storage casks on pad

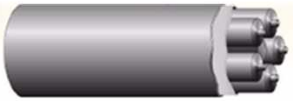
DBD packaging (hot cell, welding)



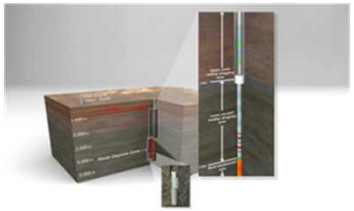
Mined repository packaging

Transport to DBD location

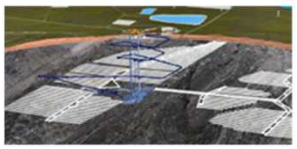
Multi-canister waste package



Deep borehole disposal (DBD)



Mined geologic repository



Deep Borehole Field Test Engineering Design

- **Conceptual Design FY15**
  - Conceptual Design Report
- **Final Design FY16**
  - Design Package
    - Design/Fabrication Specs.
    - Safety Manual
    - Procedures
    - Testing Specs.
- **Fabrication/Testing FY17**
  - Transport Cask Integration
- **Field Implementation FY18-19**

Engineering Services Contractor Support

Bid Contract(s)