YUCCA MOUNTAIN PROJECT

Studies

Waste Package Design and Materials

Presented to:
Nuclear Waste Technical Review Board

Presented by:
David Stahl, Ph.D.
Manager, Waste Package Materials Department
Management and Operating Contractor

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U.S. Department of Energy
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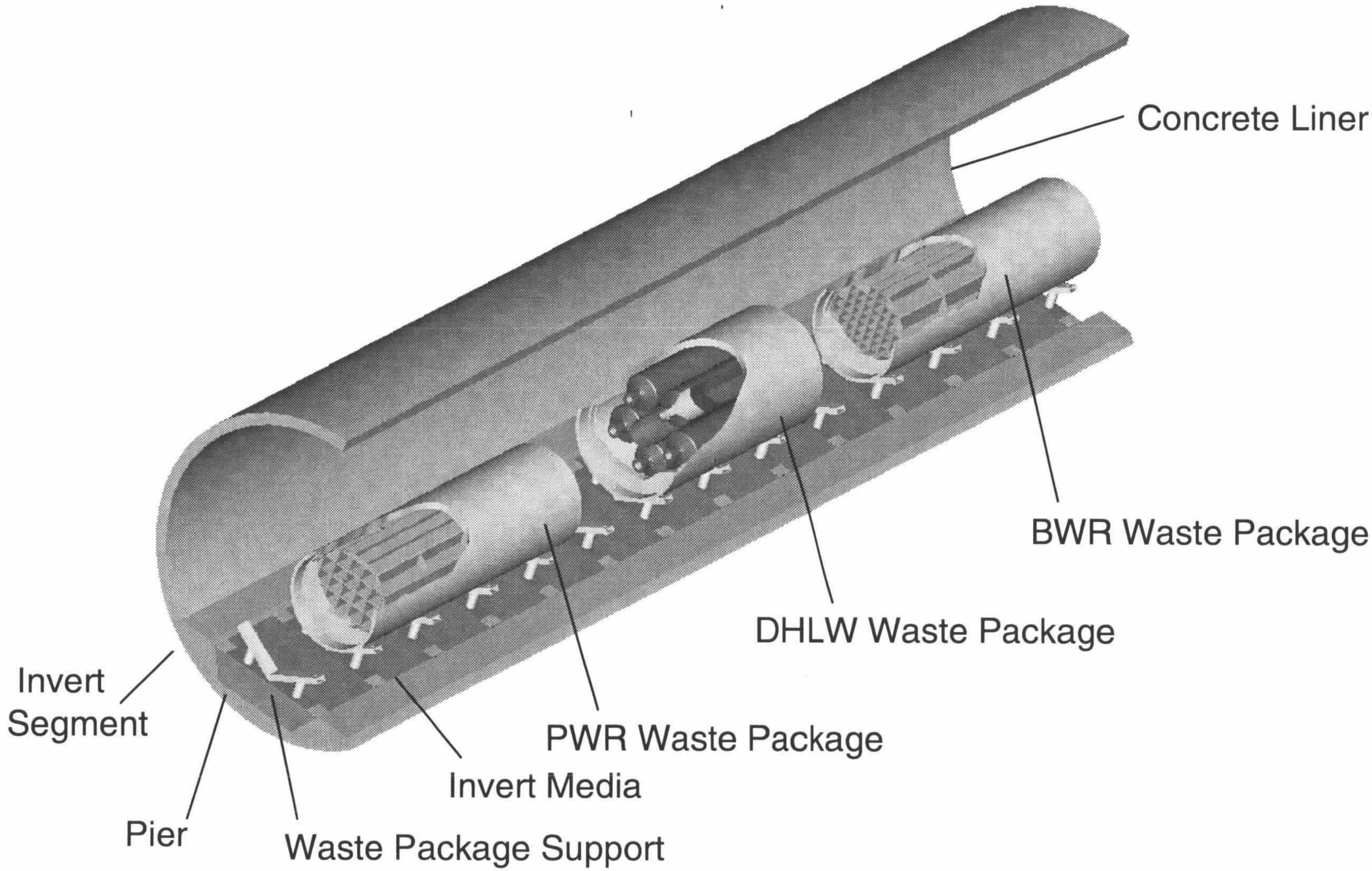
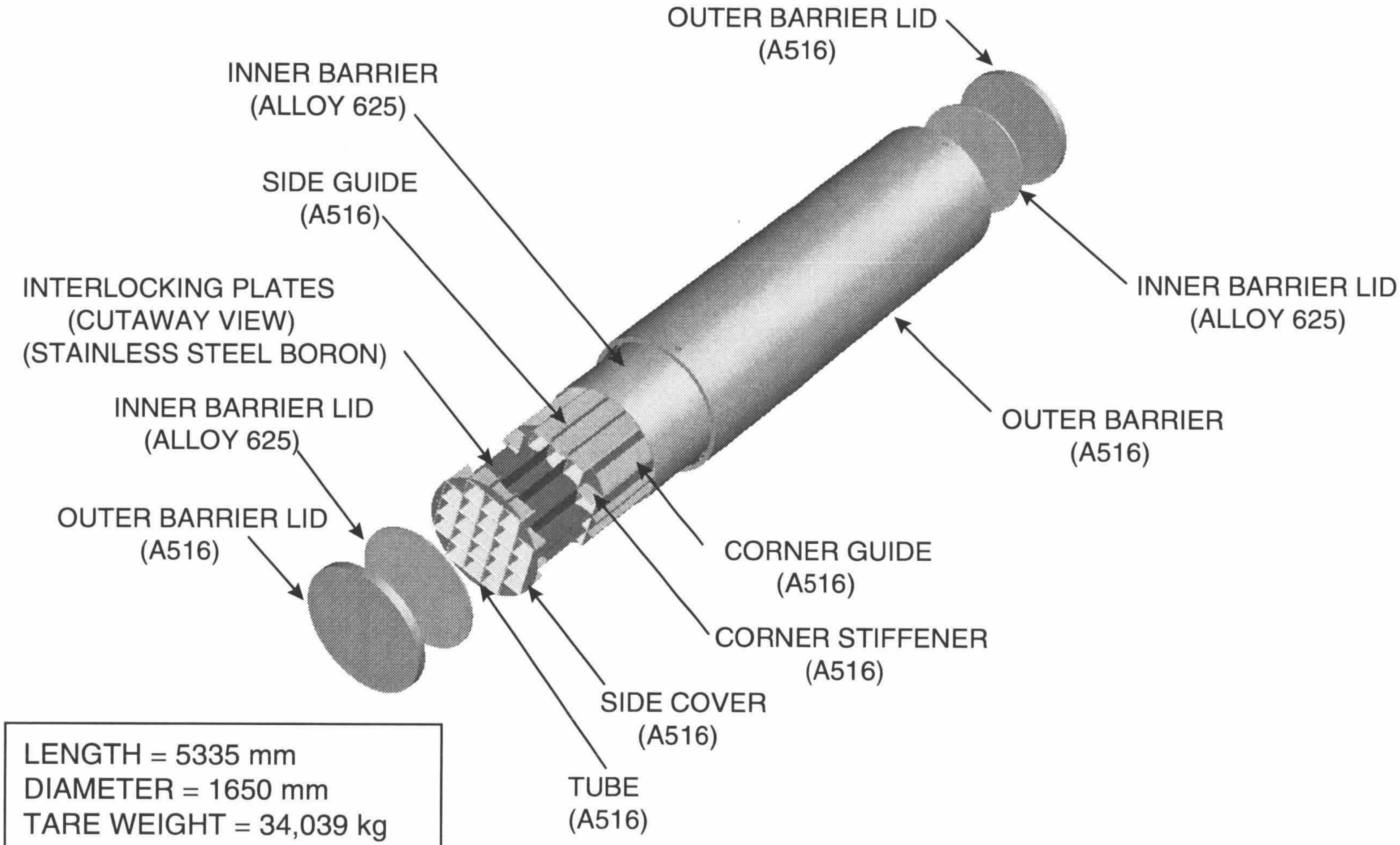
Waste Management

Engineered Barrier System



21-PWR UCF Disposal Container



LENGTH = 5335 mm
DIAMETER = 1650 mm
TARE WEIGHT = 34,039 kg
LOADED WEIGHT = 50,423 kg

Materials Considerations in Waste Package Designs

- Corrosion-allowance outer barrier materials
  - Predictable slow degradation
  - Tolerant to handling and service loads
  - Radiolysis protection
  - Galvanic protection
  - Acceptable strength
  - Fabricability
- Corrosion-resistant inner barrier materials
  - Long-term corrosion resistance
  - Predictable performance
  - Acceptable strength
  - Fabricability

Materials Considerations in Waste Package Designs

(Continued)

- Basket Materials
  - Long-term performance of neutron absorber material
  - Predictable performance of structural materials
  - Acceptable thermal conductivity
  - Fabricability
- EBS Materials
  - Compatible with other waste package materials
  - Ability to retard radionuclide migration in the long term when the waste package has degraded

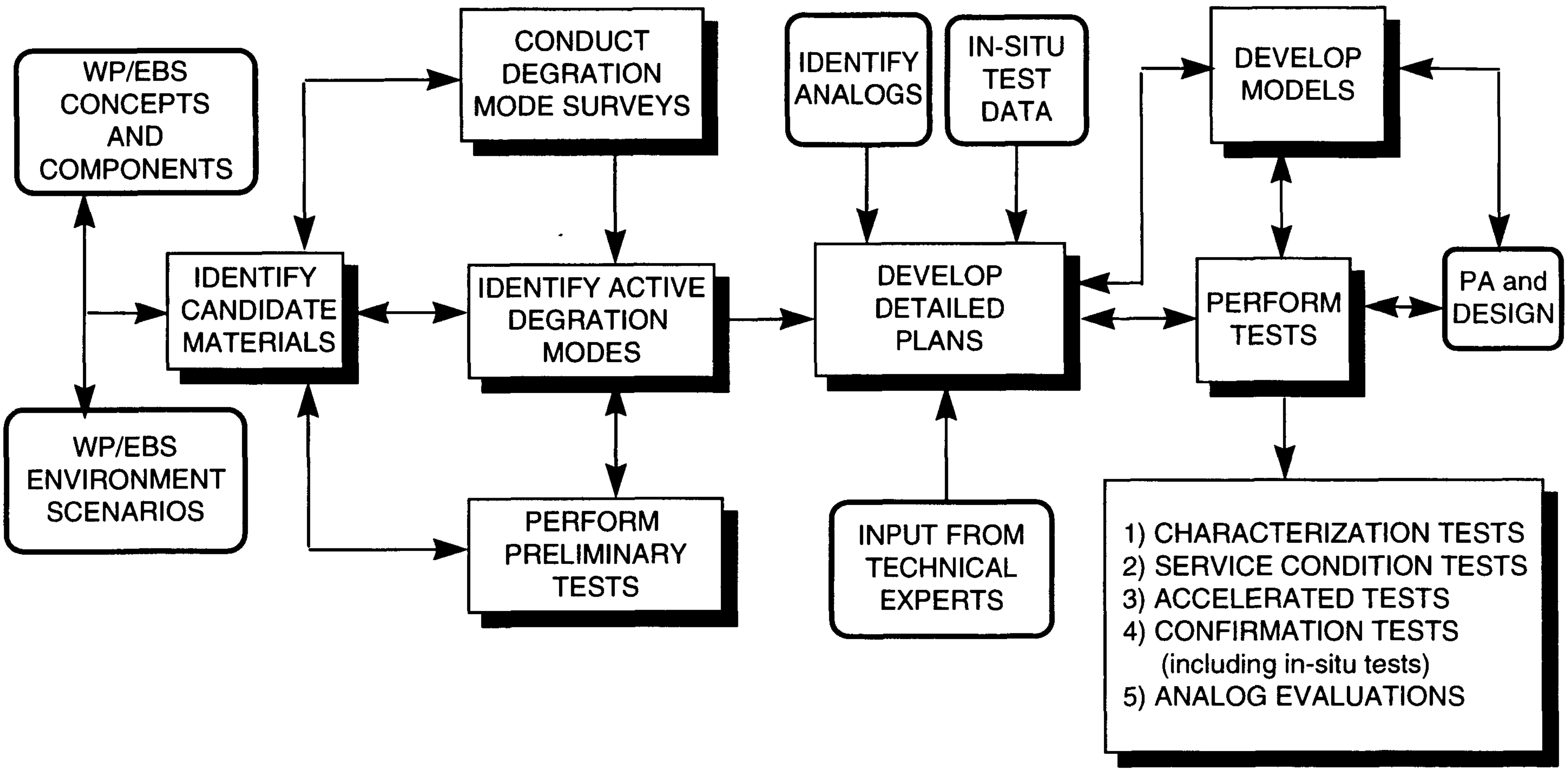
Environment Assumptions for Waste Package Materials Testing

- Assumed Water Contact Mode Scenario:
  - Early hot, dry conditions followed by cooler, more humid conditions with potential for dripping of concentrated groundwater onto waste packages
- Existing test conditions include water chemistry which ranges from 10X to 1000X J-13 and pH ranges from 2 to 12 and temperatures of 60 and 90°C
- Higher water seepage flux may reduce concentration of ionic species of water contacting the packages
  - However corrosion degradation is more closely coupled to local conditions at the surface of the waste package
- Test environments include controlled and equilibrated relative humidity, water line and complete submersion
  - Drip testing is scheduled to begin in FY 1998

Container Materials in Corrosion Test Program

- Corrosion-Allowance Materials
  - Carbon steel - cast (ASTM A27) and wrought (ASTM A516)
  - Low alloy (2.25 Cr - 1 Mo) steel
- Intermediate Corrosion-Resistant Materials
  - Copper-nickel (70/30) alloy
  - Nickel-copper (70/30 - Monel 400) alloy
- Corrosion-Resistant Materials
  - Nickel-rich alloys (Alloy G-3, G-30, 825)
  - Nickel-base alloys (Alloy 625, C-4, C-22)
  - Titanium alloys (Ti-Grade 12, Ti-Grade 16)
- Other Materials
  - Type 304/316 stainless steel with and without boron
  - Zircaloy (to be added to support Navy testing)
  - Ceramic coatings (alumina, titania, alumina-magnesia)

Waste Package Materials Test Strategy



Waste Package Materials Studies

- Engineered Barrier Materials
  - Container materials testing
    - » Long-term corrosion
    - » Humid air corrosion
    - » Crack growth
    - » Electrochemical potential
    - » Microbiologically-influenced corrosion
- Basket materials corrosion
  - Ceramic materials testing
  - Other engineered barrier materials testing
  - Degradation and abstraction modeling
- Waste Form Materials
  - Spent fuel testing
  - High-level waste glass testing
  - Degradation and abstraction modeling

Results of Near-Term Materials Studies

- **Long-Term Corrosion Test Facility**
  - First six-month test completed March 1997 and preliminary analysis of specimens indicated that aqueous corrosion rates are in the range of expected values, 80-110 mm/yr (3-4 mpy)
- **Humid Air Corrosion Tests**
  - For clean surfaces the critical RH is greater than 85% while that for surfaces with oxide or salt films is significantly reduced
- **Crack Growth Testing**
  - Cracking confirmed in Alloy 825 under broad range of environmental conditions while only limited cracking found in Alloy C-4
- **Electrochemical Potential Testing**
  - Alloys 825, G-3, G-30 and C-4 suffered pitting/crevice corrosion in acidic brines while C-22 and titanium did not

Results of Near-Term Materials Studies

(Continued)

- Microbiologically Influenced Corrosion
  - Tests with carbon steel at room temperature in a range of microbes showed that corrosion rate was about five times that of the abiotic case
- Basket Material Testing
  - Examination of boron-stainless steel from the scoping tests indicated that the metal borides were more corrosion resistant than the stainless steel matrix which will be confirmed utilizing ongoing electrochemical tests
- Ceramic Material Testing
  - Drops testing of coated steel at up to 2 m using a 100 kg simulated tuff rock did not produce visible coating damage while greater loads produced some flaking of the coating

Results of Near-Term Materials Studies

(Continued)

- Engineered Barrier System Materials Testing
  - Short-term (1 mo) concrete tests revealed that significant chemical and microstructural alteration occurred
- Waste Form Testing
  - Thermogravimetric spent fuel oxidation tests to establish oxidation kinetics and spent fuel and HLW glass unsaturated drip condition tests are ongoing to establish dissolution and release information for PA
  - Scoping tests are underway to establish the geometry and conditions for colloid and rodlet unsaturated tests
- Materials Modeling
  - Significant progress has been made in both container materials, particularly in describing the interaction between the inner and outer containers, and waste form modeling, and interaction meetings were held with PA

Uncertainties in Materials Performance

- Durability of corrosion-allowance material including pitting and microbiologically influenced corrosion
- Preferential attack of welds
- Effectiveness of galvanic protection
- Durability of corrosion-resistant material including localized and microbiologically influenced corrosion
- Extrapolation of degradation rates to long times

Methods of Treating Uncertainties

Uncertainties	Samples in long-term tests	Bounding environments	Various temperatures	Mechanistic models	Analogs
Durability of corrosion-allowance material	X	X	X		X
Preferential attack at welds	X	X	X		
Effectiveness of galvanic protection	X	X	X		
Durability of corrosion-resistant material	X	X	X	X	
Extrapolation of degradation rates to long times				X	X

Interactions of Program Activities

- Frequent interface meetings with the design team on material test results and latest design considerations
- Frequent meetings with performance assessment on model inputs and the test results during the model abstraction process
- Input from the experts on the Nuclear Waste Technical Review Board, the Repository Consulting Board, the TSPA Peer Review Panel and the Waste Package Degradation Expert Elicitation Panel
- The overall objective of these interactions is to ensure that the testing and modeling efforts are consistent with design and performance assessment needs