YUCCA
MOUNTAIN
PROJECT

Studies

Materials Testing-Program Status and Long-Term Plans

Presented to:
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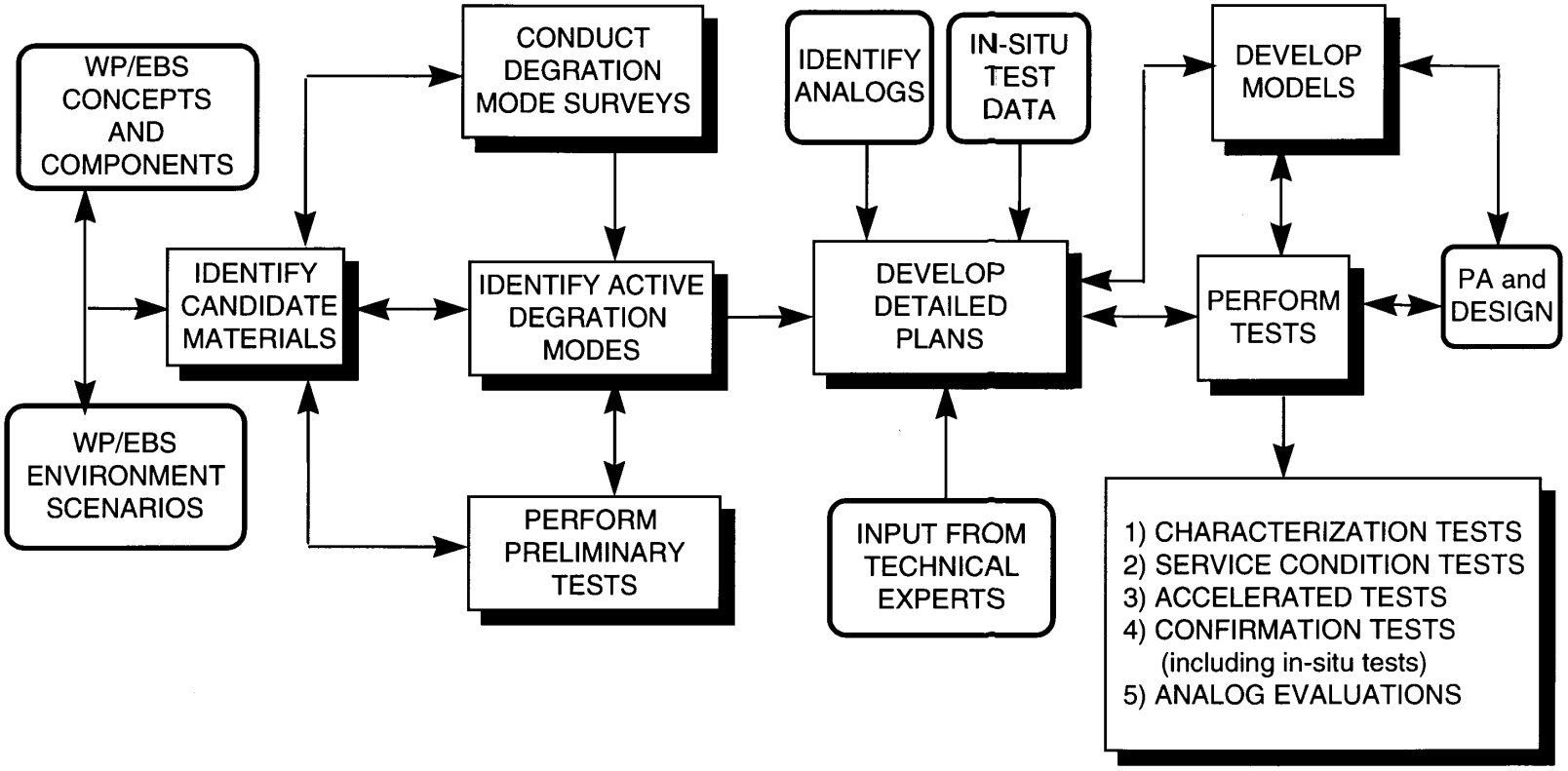
Outline

- **Objectives and Strategy**
- **Inputs to Materials Testing**
- **Material Selection**
- **Status of Materials Testing**
- **Summary**

Objectives

- **Provide the scientific basis for materials selection and performance for waste package and engineered barrier system design and performance assessment**
- **Follow the material testing and modeling strategy which parallels ASTM 1174 to provide timely input to TSPA-VA and TSPA-LA efforts**
  - **Includes support to Controlled Design Assumptions regarding waste package lifetime (3000 years) and keeping water from contacting the waste form (10,000 years)**

Waste Package Materials Test Strategy



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**
- **Test conditions (10X and 1000X J-13 water chemistry with pH range of 2 to 11 and temperatures of 60 and 90^0 C) have been established which bound expected conditions**
  - **Testing under concrete-modified conditions has been initiated while testing under saturated conditions is being evaluated**

Container Materials Under Test

- **Corrosion Allowance Materials:**
  - **Wrought carbon steel (A516)**
  - **Cast carbon steel (A27)**
  - **Low alloy (2.25 Cr-1 Mo) steel**
- **Intermediate Corrosion-Resistant Materials:**
  - **Copper-nickel (70/30) alloy**
  - **Nickel-copper (30/70 - Monel 400) alloy**

Container Materials Under Test
(Continued)

- **Corrosion Resistant Materials:**
  - **Nickel-rich alloys (Alloy G-3, G-30, 825)**
  - **Nickel-base alloys (Alloy 625, C-4, C-22)**
  - **Titanium alloys (Grades 7,12, 16)**
- **Other Materials:**
  - **Type 304(L)/316(L) stainless steel plus boron**
  - **Zircaloy (to support the Navy program)**
  - **Ceramic oxide coatings (Al, Ti, Mg, Zr, and mixtures)**

Degradation Modes

- **Container materials:**
  - **Humid air corrosion**
  - **General aqueous corrosion**
  - **Pitting and crevice corrosion**
  - **Stress corrosion cracking**
  - **Environmentally assisted corrosion**
  - **Galvanic corrosion**
  - **Microbiologically influenced corrosion**
  - **Thermal instability**
  - **Radiolysis-enhanced corrosion**

Selection of Alloy C-22 for Inner Barrier

- **Alloy C-22 is much more resistant to crevice/pitting corrosion than Alloy 625**
- **Alloy C-22 has excellent phase stability under low temperature (~450^0 C) aging while Alloy 625 suffers from embrittlement**
- **Alloy C-22 is more resistant to stress corrosion cracking than 625 under similar conditions**
- **Weldability of Alloy C-22 is not significantly different than Alloy 625**

Container Materials Corrosion Testing

- **24 Long-Term Corrosion Test Vessels are Operational**
  - **18 vessels evaluate weight loss, crevice and U-bend specimens and 6 vessels evaluate galvanic couples**
  - **Conditions span those expected at Yucca Mountain including those modified by concrete**
  - **One year test results for carbon steel confirm predicted rates while one year test results for corrosion-resistant materials show no attack (on Alloys 625, C-22, Titanium-Grade 12, 16) except for Alloy 825 crevice specimens**

Container Materials Corrosion Testing

(Continued)

- **Crevice corrosion fiber optic probe is being developed to determine crevice chemistry (pH, chloride ion, ferric ion, etc.) as corrosion proceeds as input to localized corrosion model**
- **Drip testing onto heated surfaces has been initiated to study electrolyte chemistry and follow corrosion processes**
- **Long-term relative humidity tests are underway with carbon steel specimens and other samples with salted and unsalted surfaces to provide input to corrosion models**

Container Materials Corrosion Testing

(Continued)

- **Short-term and long-term electrochemical tests and crack growth tests are being performed with Alloy C-22 and other corrosion-resistant materials as input to corrosion models**

- **Microbiologically influenced corrosion tests are underway to evaluate nutrient requirements, biofilm generation, and corrosion of carbon steel and the corrosion-resistant materials including Alloy C-22**

Container Materials Corrosion Testing

(Continued)

- **Ceramic coatings on carbon steel are being evaluated to achieve dense, impermeable coatings which resist corrosion and handling loads**
- **Concrete materials are being tested to determine changes in structure and pH, due to aging and carbonation, which could impact the chemistry of water contacting the waste packages**
- **Models that describe the performance of the candidate container materials have been developed and provided to Performance Assessment for TSPA-VA**

Planned Work at University of Virginia

- **The University of Virginia program has two phases**
- **Work this fiscal year will focus on the determination of model parameters such as pit birth and death rates, stabilization criteria and pitting rates for corrosion-resistant materials**
- **Work next fiscal year will focus on the determination of stifling parameters for pit growth**
- **Studies will be performed as a function of pH, chloride concentration, electrochemical potential and temperature (25 to 90^0 C)**

Performance Confirmation Waste Package-Materials Monitoring and Testing Plan

- **Continue off-site laboratory testing (long-term corrosion test facility, relative humidity chamber tests, etc.)**
- **Conduct in-situ waste package monitoring (remote sensing and visual examination)**
- **Examine in-situ witness specimens**
- **Examine dummy waste packages (destructive exam only if needed)**

Waste Form Testing and Modeling

- **Oxidation testing continues with existing spent fuel Approved Test Materials to evaluate oxidation state thresholds and new ATMs will be added**
- **Flow-through, alteration and unsaturated drip condition tests continue with existing glass and spent fuel ATMs to provide input to models and new ATMs are being added**
- **Colloid tests and cladding integrity tests (with rod segments) that provide input on radionuclide release are starting up**

Waste Form Testing and Modeling
(Continued)

- **Glass parameter tests are underway to determine effects of iron and magnesium on glass performance**
- **Degradation and release models have been upgraded and provided to Performance Assessment for TSPA-VA**
  - **Models for cladding degradation have been provided to Performance Assessment to permit cladding credit to be assumed for the base case**
  - **Literature survey on Zircaloy performance has been initiated and long-term localized corrosion tests have been proposed**

Summary

- **Long-term (service condition) and short-term (aggressive condition) tests and model development have provided inputs to design and TSPA-VA and will be conducted following our testing strategy to meet TSPA-LA needs**
- **Data, models and model abstractions are provided as they are generated and are followed by transmittal via a formal documentation process including the Waste Form Characteristics Report and the Engineered Barrier Characteristics Report**

Backup Viewgraphs

Status of Model Development

- **Corrosion-Allowance Materials:**
  - **Oxidation** — **Model provided**
  - **Humid Air** — **TSPA-95 model updated**
  - **General Aqueous** — **TSPA-95 model updated**
  - **Pitting** — **Expert Panel model utilized**
  - **Microbiological** — **Preliminary model provided**
  - **Galvanic** — **Preliminary model provided**

All models will be finalized for TSPA-LA

Status of Model Development

(Continued)

- **Corrosion-Resistant Materials:**
  - **Humid Air** — **Preliminary model provided**
  - **General Aqueous** — **Preliminary model provided**
  - **Pitting/Crevice** — **Updated model provided**
  - **H_2 Embrittlement** — **Preliminary model provided**
  - **Stress Corrosion Cracking** — **Preliminary model provided**
  - **Microbiological** — **Preliminary model provided**

All models will be finalized for TSPA-LA