U.S. DEPARTMENT OF ENERGY
OFFICE OF CIVILIAN RADIOACTIVE WASTE MANAGEMENT

NUCLEAR WASTE TECHNICAL REVIEW BOARD FULL BOARD MEETING

SUBJECT: CORROSION ASPECTS UNDER VARIOUS THERMAL SCENARIOS

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Outline

- **Thermal factors in container materials performance**
- **Waste-package design considerations**
  - Configuration issues
  - Selection process (materials suitability)
  - Examples: SCP conceptual design
Overpacked multiple-purpose canister
- **Summary and conclusions**

Container Material Responses Categorized into Hydrothermal Regimes

	Container Surface Temperature		
	30-60°C*	60-120°C*	120-300°C*
Dry <70% relative humidity*	low temperature oxidation	low temperature oxidation	low temperature oxidation metallurgical changes
Wet	general corrosion localized corrosion stress corrosion	general corrosion localized corrosion stress corrosion usually more serious localized and stress corrosion	not applicable

- Rather arbitrary boundaries between thermal regimes
- Quantity and quality of water contacting container determine attack severity

* *approximate*

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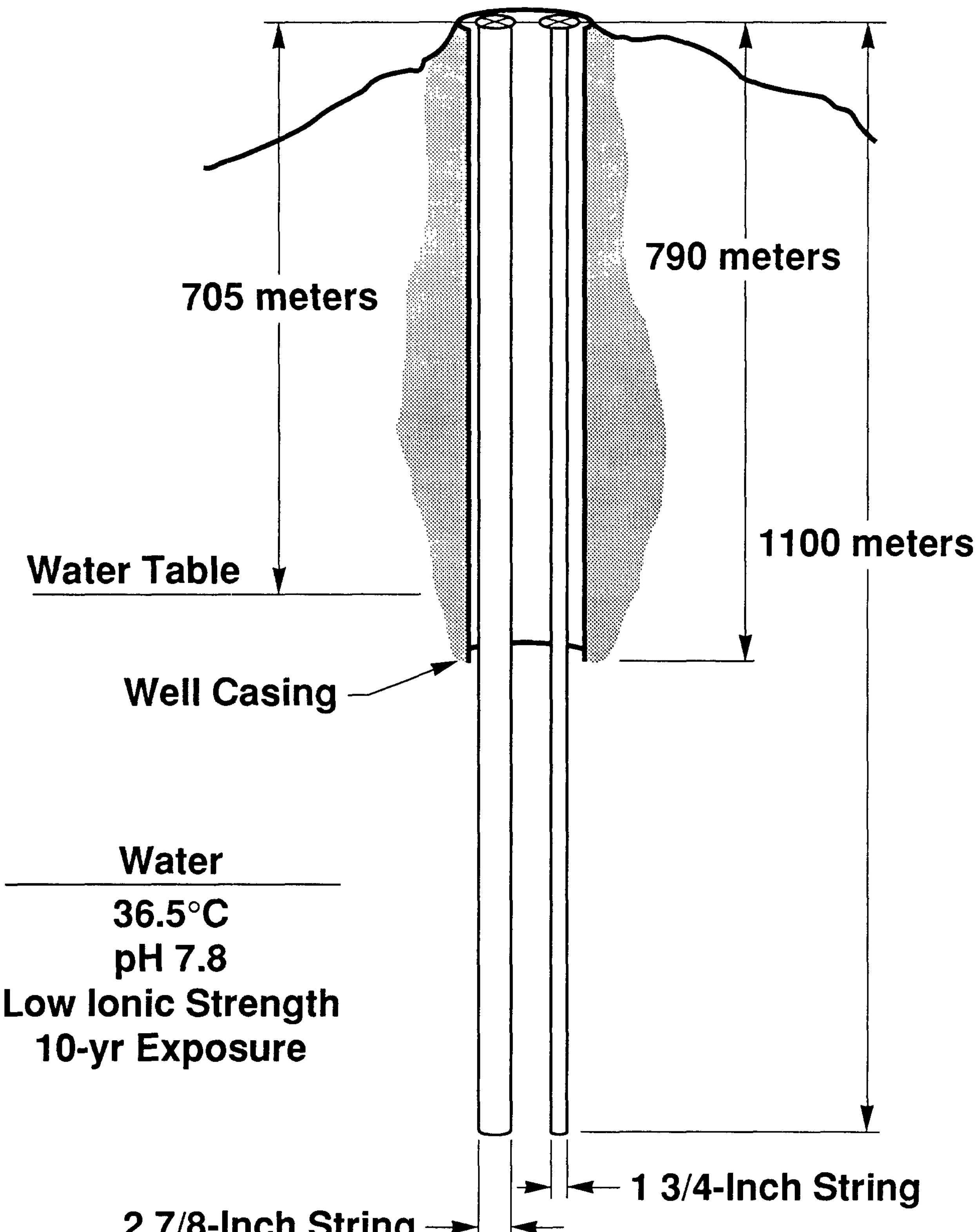
Photograph of tubing string pulled from WH-5 well

Configuration of US WH-5 Strings



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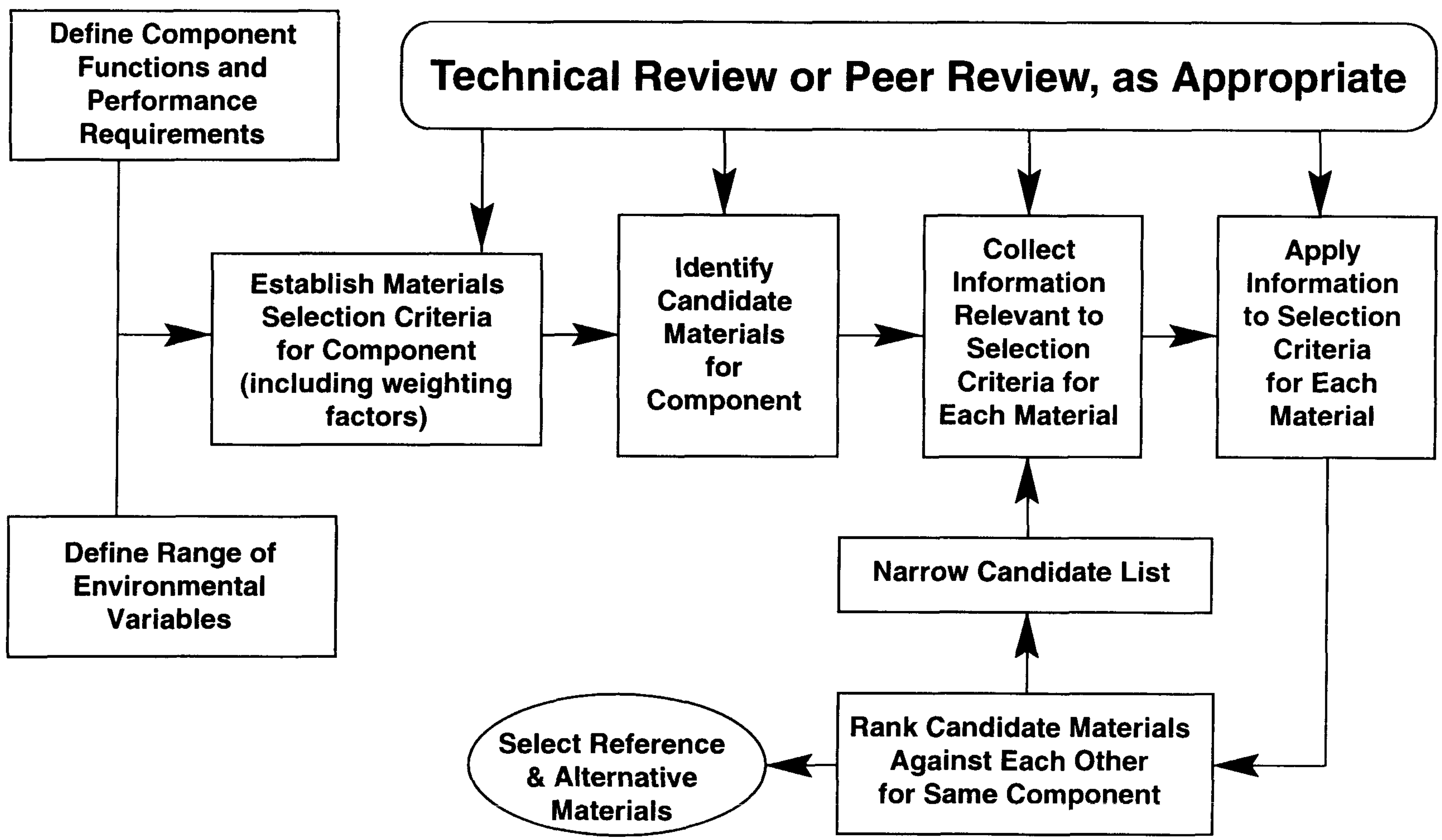
Issues in Waste-Package Configuration Govern Material Selection and Performance

- Single vs. multiple barrier
- Corrosion-allowance vs. corrosion-resistant metals/alloys
- Radiation shielded vs. non-shielded (thick vs. thin)
- All metal vs. metal/ceramic
- Packing materials vs. air gap

Waste-Package Materials Selection Process



Features of the SCP Waste Package Conceptual Design (1991)

- Single metal barrier (approximately 1-3 cm thick) functions as the disposal container
- Disposal container surrounds spent fuel assemblies or vitrified waste in stainless steel pour canister
- Not radiation shielded
- Vertical emplacement
- No packing material
- Peak disposal container temperatures
  - ~ 220°C (spent fuel packages)
  - ~ 140°C (vitrified waste packages)

Container Material Selection Process for SCP Conceptual Design

- Weighting factors
  - 70 points for performance considerations (corrosion, compatibility, mechanical properties)
  - 30 points for engineering considerations (fabricability, cost, experience base)

- Recommended materials
  - Nickel-rich Alloy 825 (UNS N08825)
  - Nickel-base Alloy C-4 (UNS N06455)
  - Titanium Grade 12 (UNS R53400)

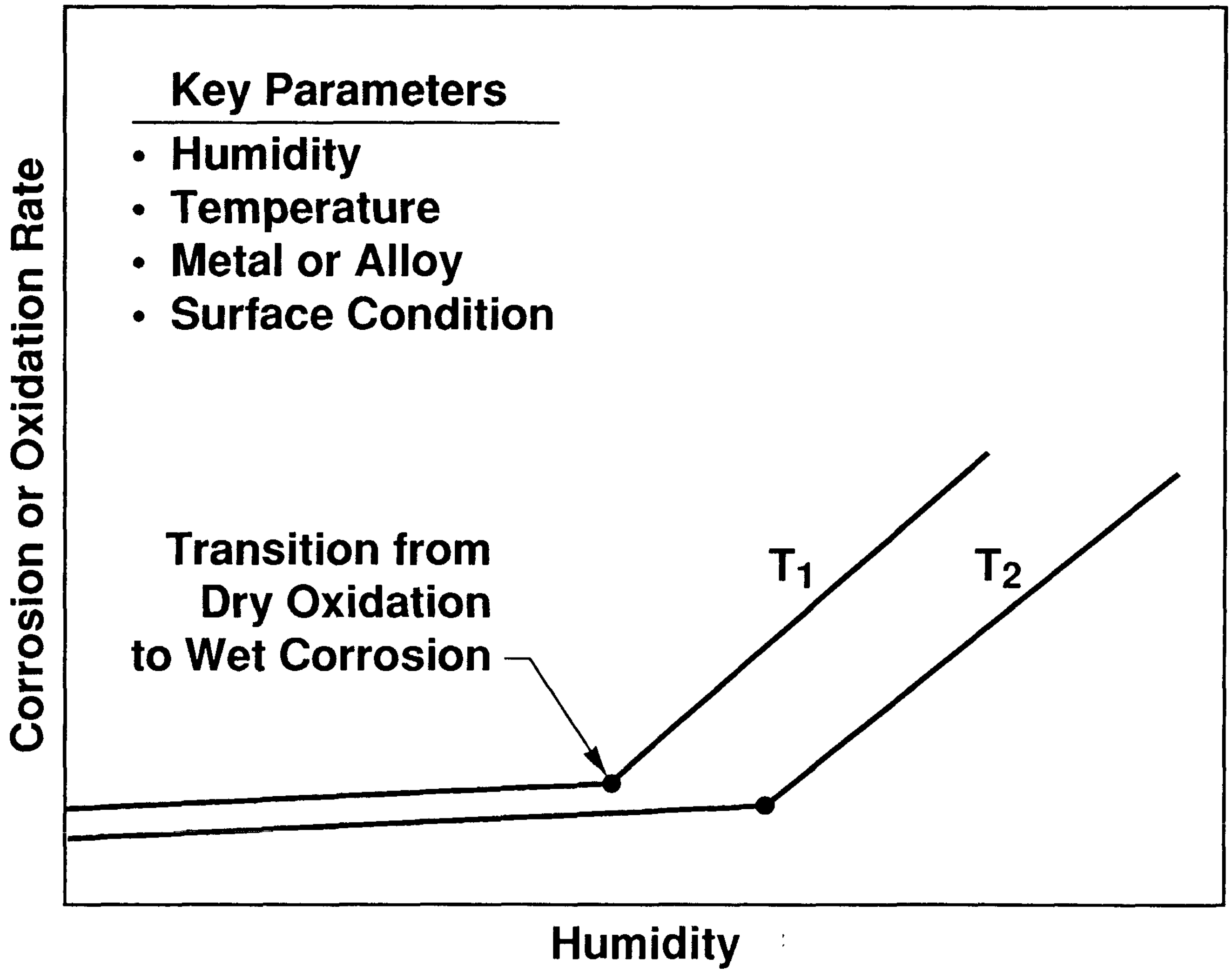
One Multiple-Barrier Waste-Package Design Concept is a Corrosion-Resistant Container Overpacked with a Corrosion-Allowance Material

- **Example:** Alloy 825 inner barrier, carbon steel outer barrier
- **Principle:** Outer barrier slowly oxidizes and corrodes to protect inner barrier
- Applicable to multiple-purpose canister proposal
- Applicable to "extended dry" thermal strategy

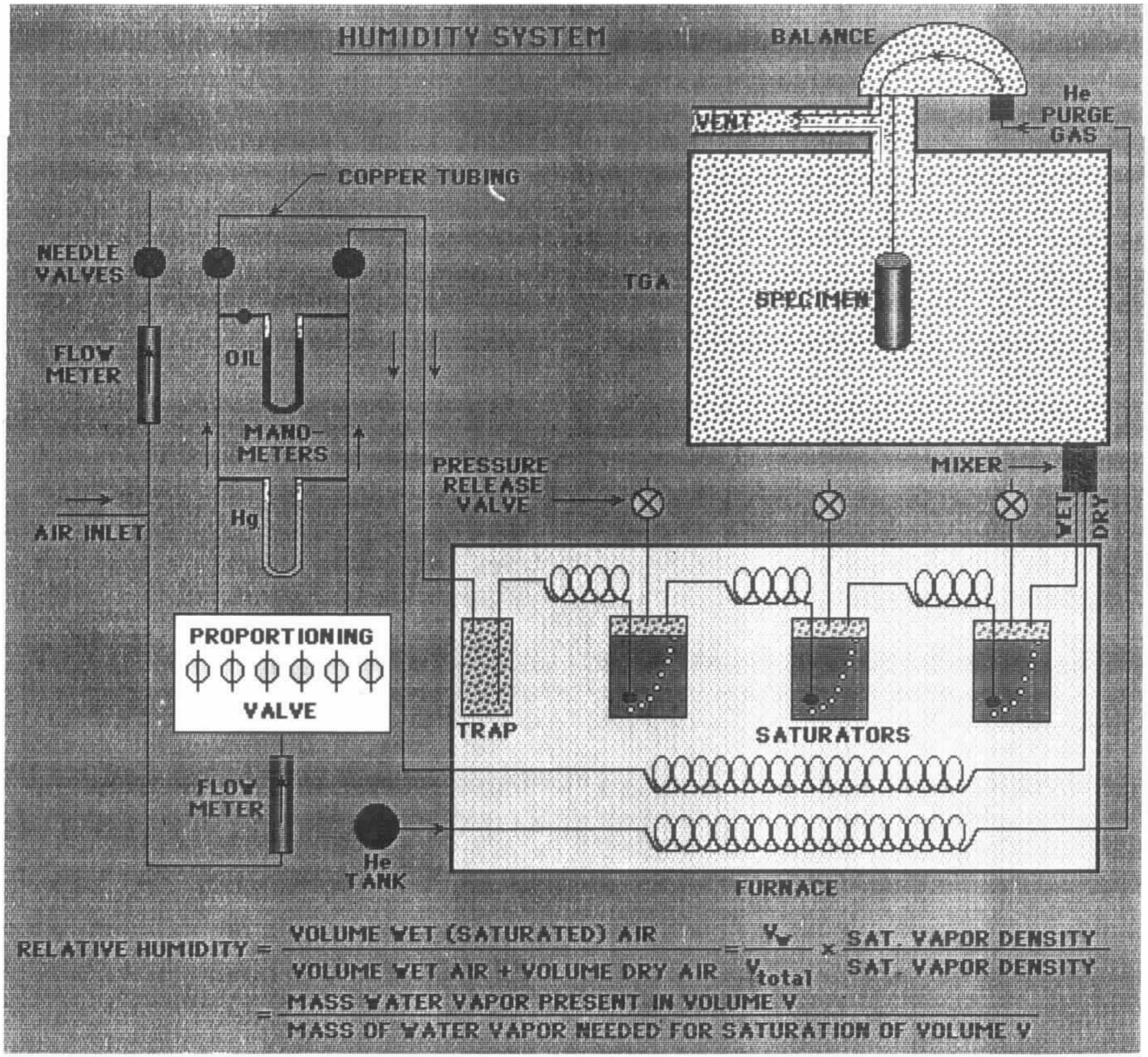
Performance of Steel Barrier is very Sensitive to Moisture

- **Oxidation of carbon steel is slow**
  - Extrapolations from high temperature data indicate rates of 0.002-0.1 mm/yr in repository thermal environment
  - Thick overpack would endure for more than 10,000 years
- **Corrosion of carbon steel is more rapid**
  - Measured rates of 0.01-0.5 mm/yr
  - Localized corrosion factor (2-4 times general corrosion rate)
  - Overpack *could* be penetrated in several decades

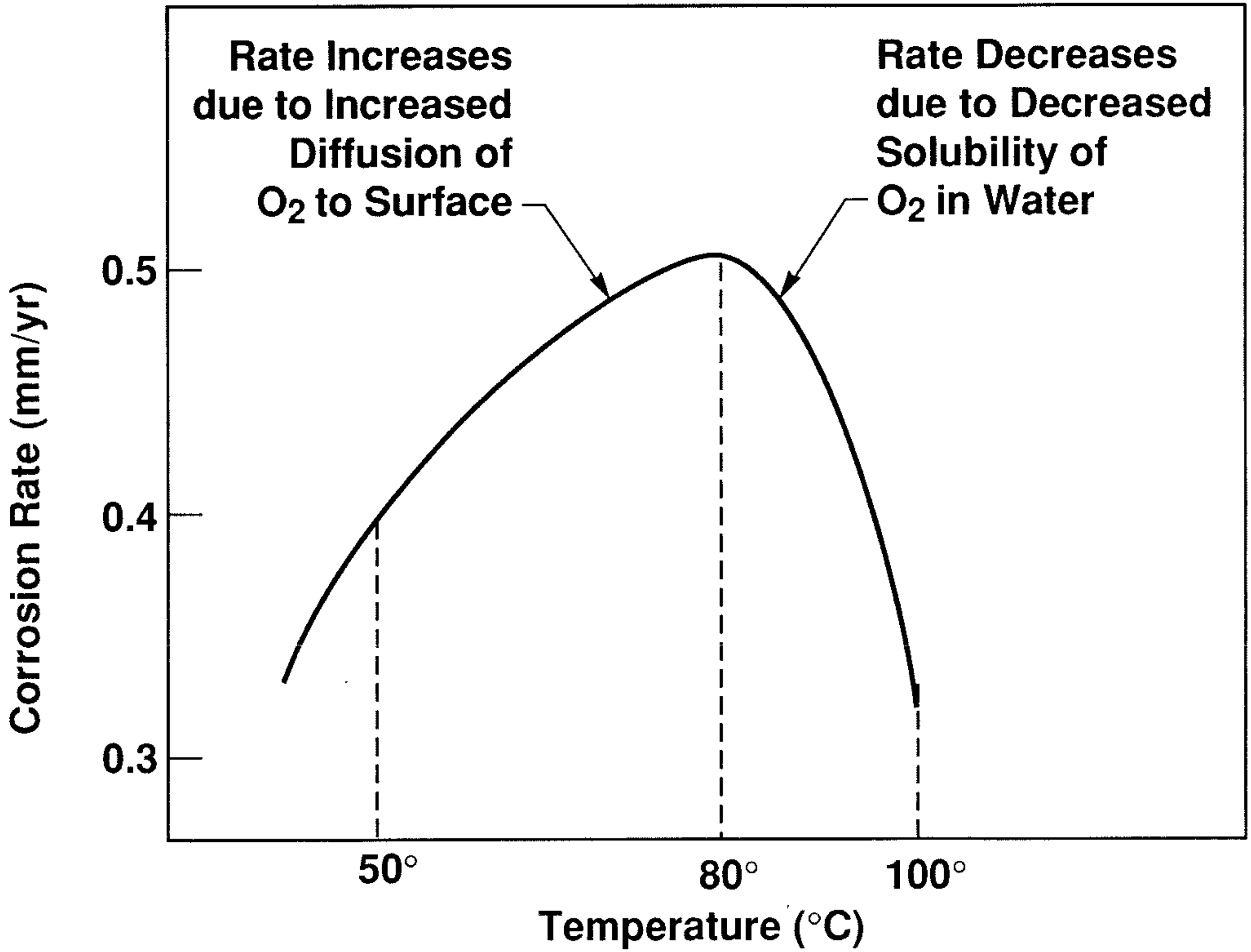
Atmospheric Exposure of Metals Indicates Transition from Oxidation to Corrosion



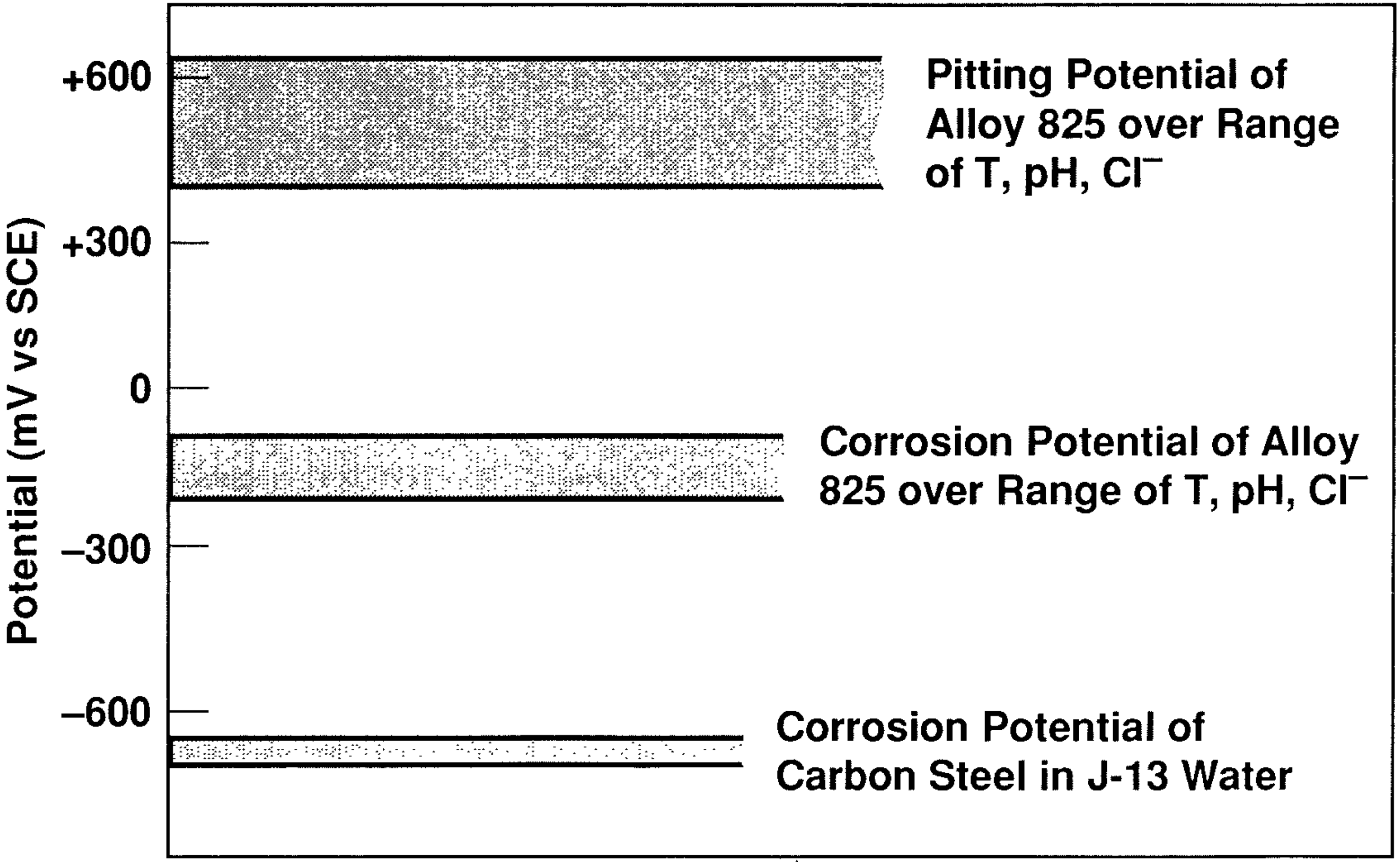
Color Schematic of Humidity System



Corrosion of Carbon Steel in Neutral-pH Water Shows a Maximum



Carbon Steel will Protect Alloy 825 from General and Pitting Corrosion



Corrosion-Related Aspects of Packing Materials

- **Purpose**

  Use "tailored" packing around container to minimize corrosion (kinetically or thermodynamically)

  - Redox buffer
  - pH buffer
  - Diffusion barrier

- **Issues**

  - Will the backfill function as intended in the unsaturated zone?
  - Will the backfill undergo chemical change to alter its buffering properties?
  - Will there be undesirable thermal effects?

Waste-Package Cost Aspects of Thermal Loading

- Materials-related factors
  - As-fabricated materials cost ($/cm³)
  - Dimensions of waste packages
  - Number of waste packages
- May be more economical to make fewer but more robust waste packages

Summary and Conclusions

- Thermal strategies used in repository and waste package designs have materials implications (selection and performance)
  - Thermal and hydrological regimes
  - Waste package configuration
- Many "trade-offs" are possible between materials selection and performance expectations
- "Extended dry" thermal strategy appears to generate fewer materials performance considerations
- Transition from dry oxidation to wet corrosion is a key performance issue
  - Experimental work
  - Characterization work