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CONTAINER LIFE AND SOURCE TERM

Presented by

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INTEGRATED SUBISSUES (ISIs) AND CLST KEY TECHNICAL SUBISSUES

- WP corrosion (humidity, chemistry, and temperature)
  - Effect of corrosion on container lifetime
- Mechanical disruption of WPs
  - Effect of materials stability and mechanical failure on container lifetime
- Quantity and chemistry of water contacting WPs and waste form
  - Effect of corrosion on container lifetime
  - Rate of degradation of SF and HLW glass
- Radionuclide releases rate and solubility limits
  - Rate of degradation of SF and radionuclide release from SF
  - Rate of degradation of HLW glass and radionuclide release from HLW glass

– criticality
– alternative design

RISK INSIGHTS FROM PERFORMANCE ASSESSMENT

- Importance of initial failures
- Effect of design changes
  - Improved performance due to alloy C-22
  - Importance of passive corrosion rate
  - VA design vs. alternate designs
- Effect of fabrication processes
- Importance of near-field chemistry
- Importance of penetration location on release
- Effect of cladding
- Effect of WP internal environment on release

INITIAL FAILURES TPA vs. TSPA-VA

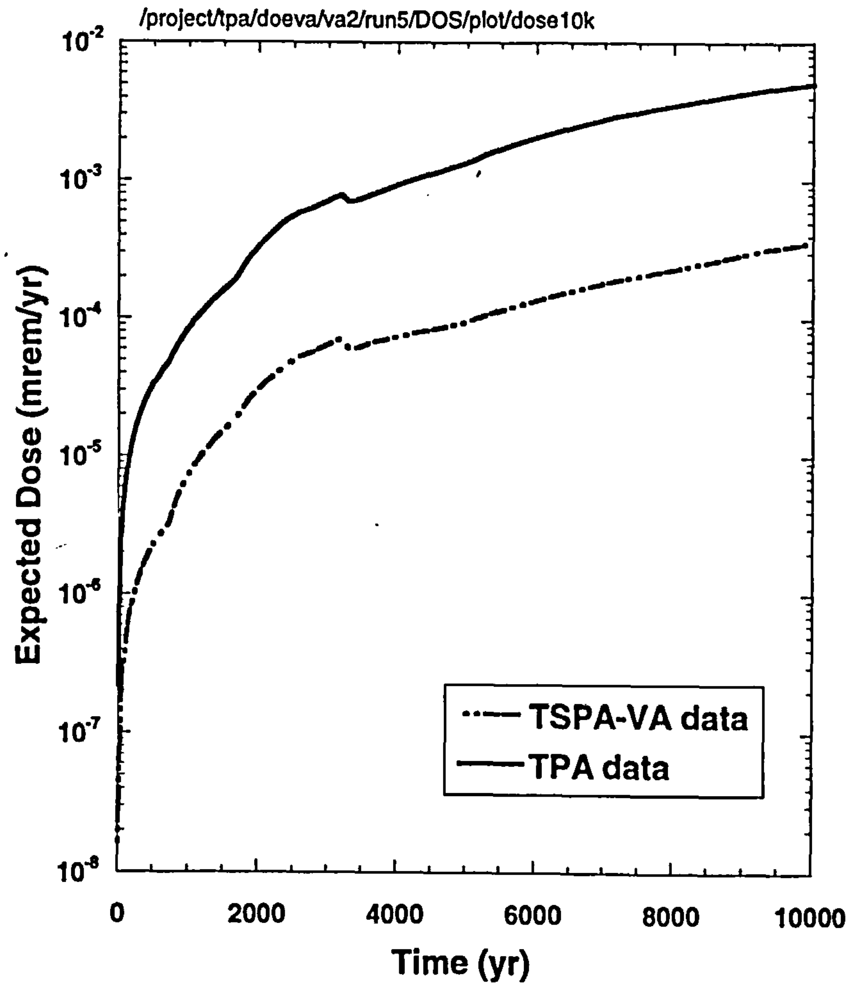
DOE TSPA-VA

- Subsumes a variety of processes and model uncertainties
  - Fabrication defects
  - Faulty emplacement
  - Faulting and seismic effects
- Assumed 1 in 10,500 waste packages (range of 1 to 10) with through-wall defect
- Assumed failure time to be 1000 years

NRC/CNWRA TPA

- Assumes that initial failure occurs due to
  - Fabrication defects
  - Unknown failure mechanisms
- Assumed failure probability of 10^{-2} to 10^{-4} per subarea (Average of 35 out of 7000 containers)
- Assumed failure time at t=0

COMPARISON OF PERFORMANCE CALCULATIONS

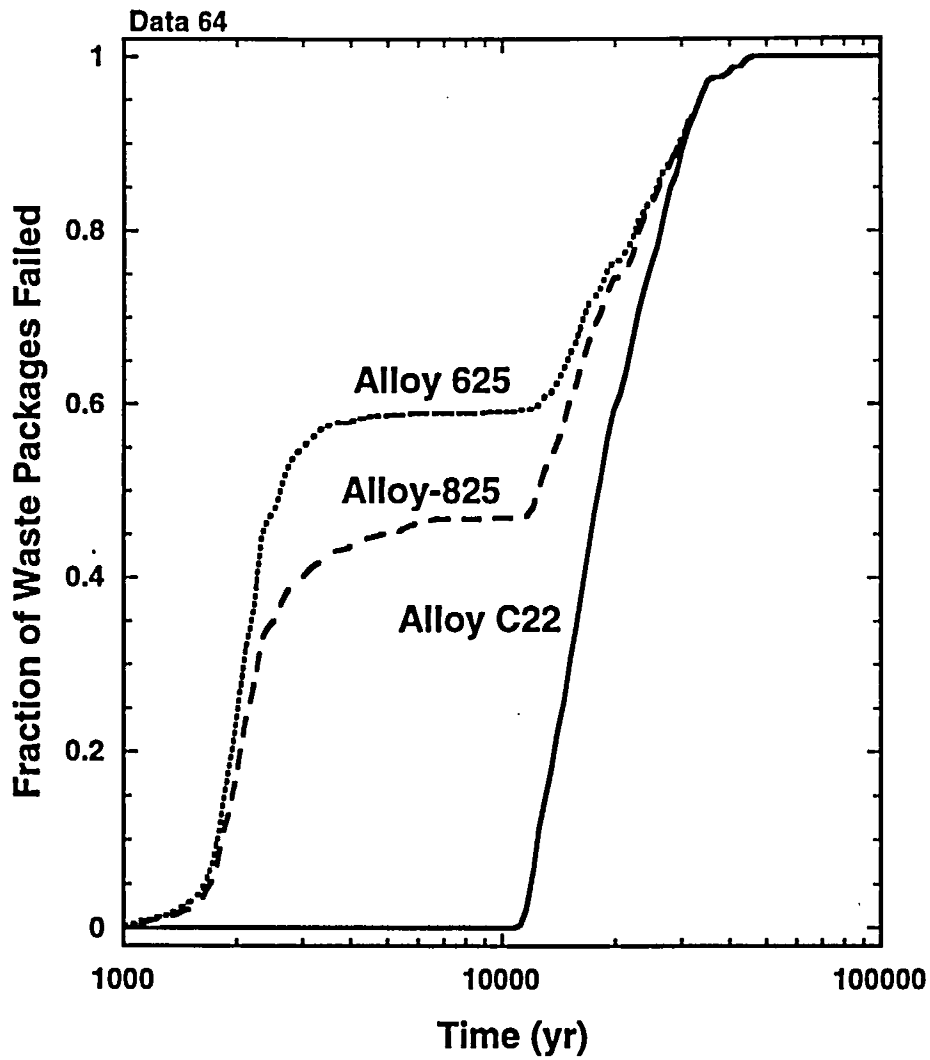


- TPA 3.2 calculation using DOE and NRC initial failure rates
- Time to initial failure was at 0 years for both TSPA-VA and TPA data

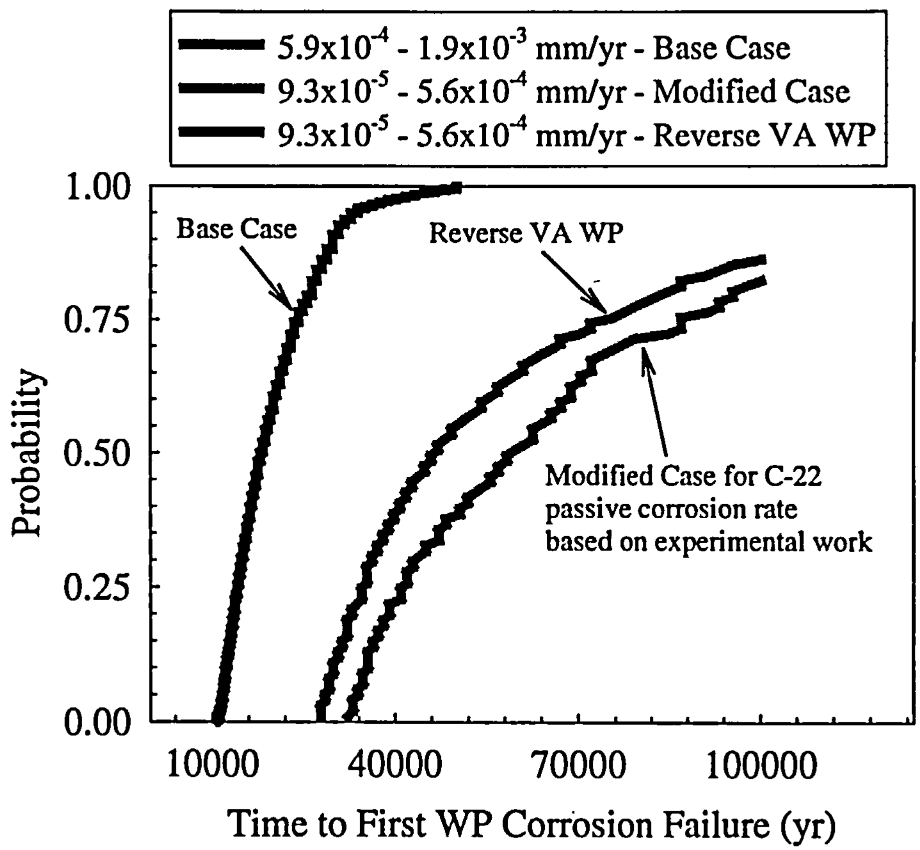
NEED FOR A BETTER TECHNICAL BASIS FOR INITIAL FAILURES

- Initial failures based on experience in unrelated systems and applications
- Difficulty in separating mechanisms of initial failures
- Relationship to detectability of defects unclear
- The effect of experience on initial failure rate not considered

EFFECT OF CONTAINER MATERIAL SELECTION ON SYSTEM PERFORMANCE

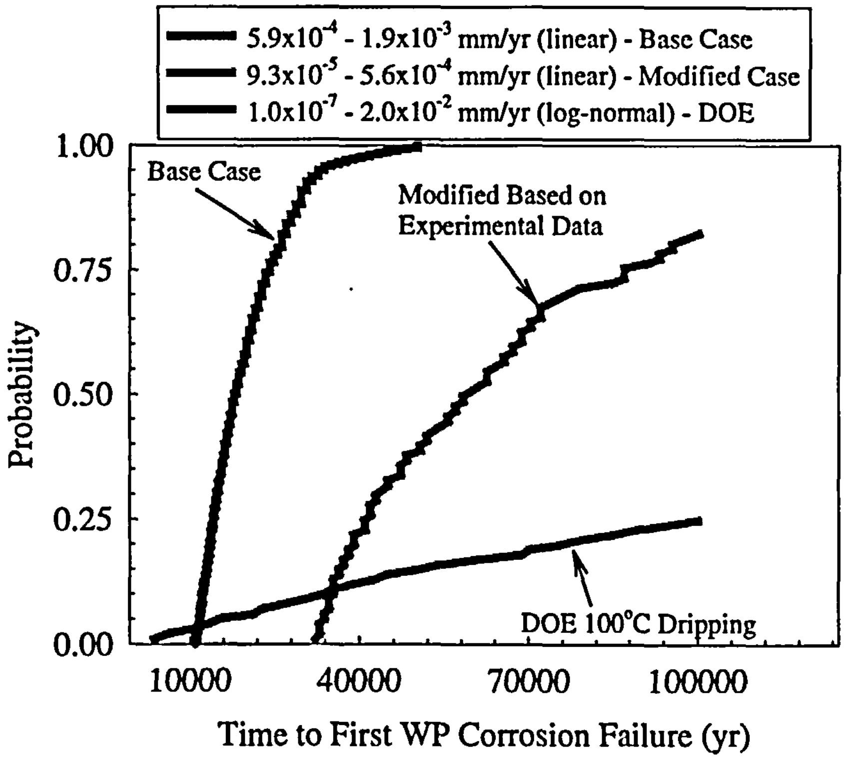


WASTE PACKAGE LIFETIME USING TPA 3.2 CALCULATIONS AND CNWRA DATA



- A median WP failure time of 17,920 yr is calculated for TPA 3.2 base case assuming no welds
- Using uniform corrosion rates of alloy C-22 obtained in CNWRA experiments the median WP failure time increases to 59,709 yr
- The reverse VA WP design exhibits a slightly lower median failure time of 46,990 yr

WASTE PACKAGE LIFETIME USING TPA 3.2 CALCULATIONS AND DOE PARAMETERS



- Using the LLNL measured corrosion rates for alloy C-22 the median WP failure time is about 50,000 yr
- Using TSPA-VA range of uniform corrosion rates for alloy C-22, 80 percent of WPs exhibiting failure times longer than 100,000 yr

TECHNICAL APPROACH TO EVALUATE DOE WP DESIGNS AND MATERIALS

- Consider failure modes (corrosion, stress corrosion cracking, hydrogen embrittlement and mechanical failure) according to classes of materials (carbon and stainless steels, Ni-Cr-Mo alloys, Ti alloys)
- Evaluate a wide range of environmental conditions (i.e., anion concentrations, temperature, pH, redox potential) that can be expected for the water contacting WPs
- Develop abstracted models for performance assessment (PA) codes that can be supported by mechanistic models
- Gain confidence through focused laboratory measurements of important parameters

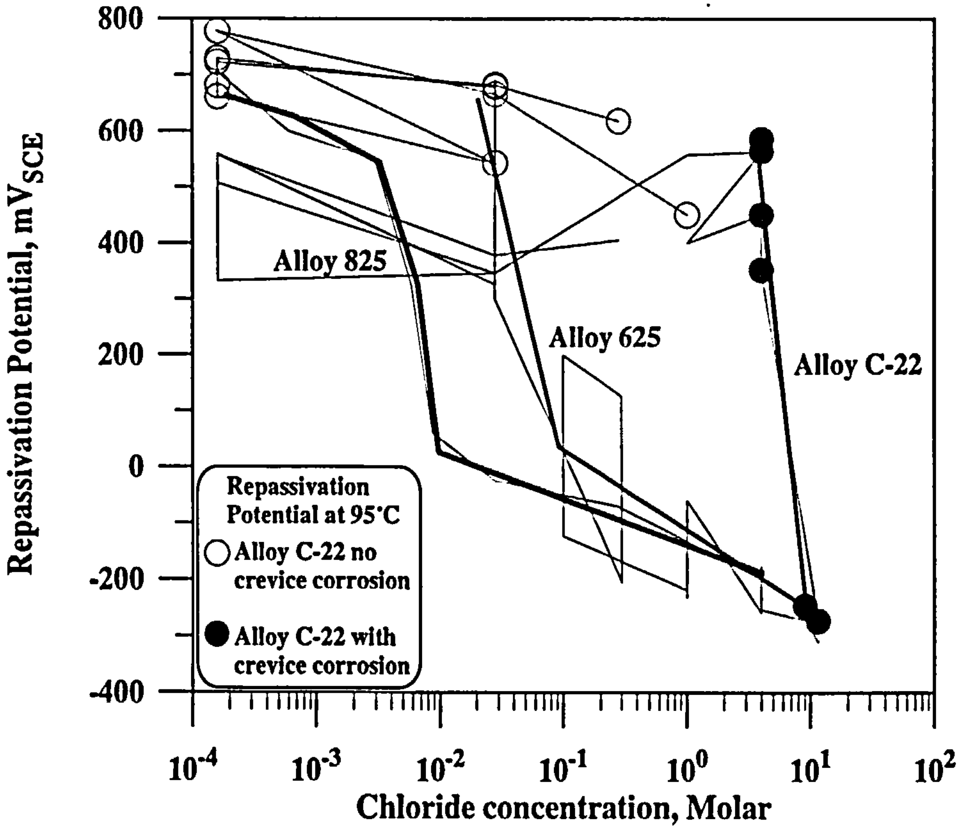
FACTORS AFFECTING THE PERFORMANCE OF CORROSION RESISTANT ALLOYS

- Temperature
  - What is the critical temperature for alloy C-22?
- Chemistry (especially chloride concentration)
  - What is the critical chloride concentration?
- Redox conditions (corrosion potential)
  - Does design change affect redox potential?
- Material microstructure (welding, heat treatment)
- Passive dissolution rate
- Active dissolution rate (pit growth rate)

METHODOLOGY APPLIED TO EVALUATE CORROSION OF WASTE PACKAGE MATERIALS

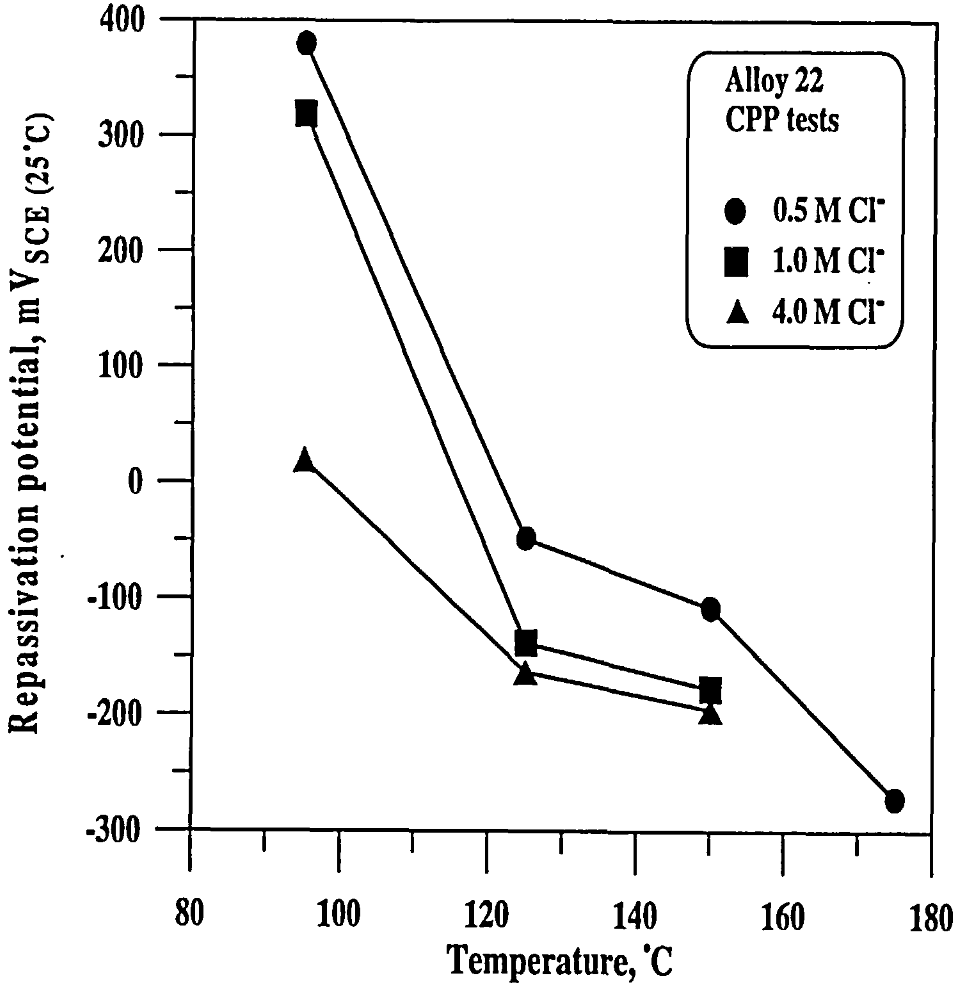
- Calculation of corrosion potential (E_{corr}) based on electrochemical kinetics laws and verify by experiments
- Experimental determination of repassivation potentials (E_{rp}) as a function of temperature (T), pH, and [Cl^-] with [Cl^-]> [Cl^-]$_{crit}$
- Experimental determination of stress corrosion cracking (SCC) susceptibility in terms of E_{rp} and critical stress intensity for SCC (K_{Iscc})
- Experimental determination of uniform and localized corrosion rates and crack growth rates
- Experimental evaluation of the effect of welding or thermal treatments on some critical PA parameters (i.e., E_{rp}, K_{Iscc}, corrosion rates)
- Fundamental modeling of passivity and localized corrosion processes

CONDITIONS FOR LOCALIZED CORROSION OF THREE CANDIDATE ALLOYS



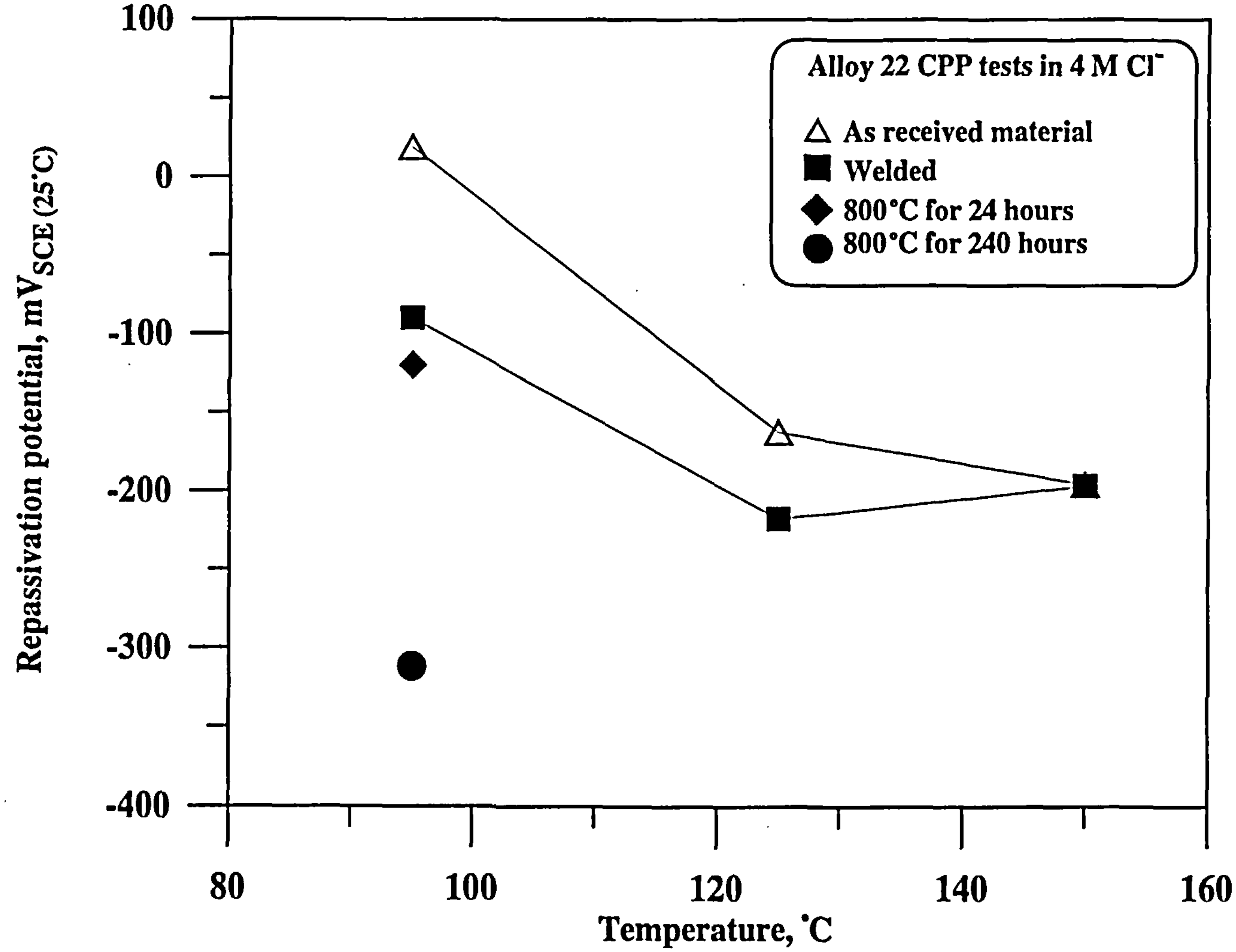
- Repassivation potential (E_{rcrev}) used as a critical potential for the initiation of localized (crevice) corrosion in TPA 3.2 code
- Improved corrosion resistance in the order 825<625<C-22
- Critical chloride close to saturation of NaCl

CRITICAL TEMPERATURES FOR LOCALIZED CORROSION OF ALLOY C-22

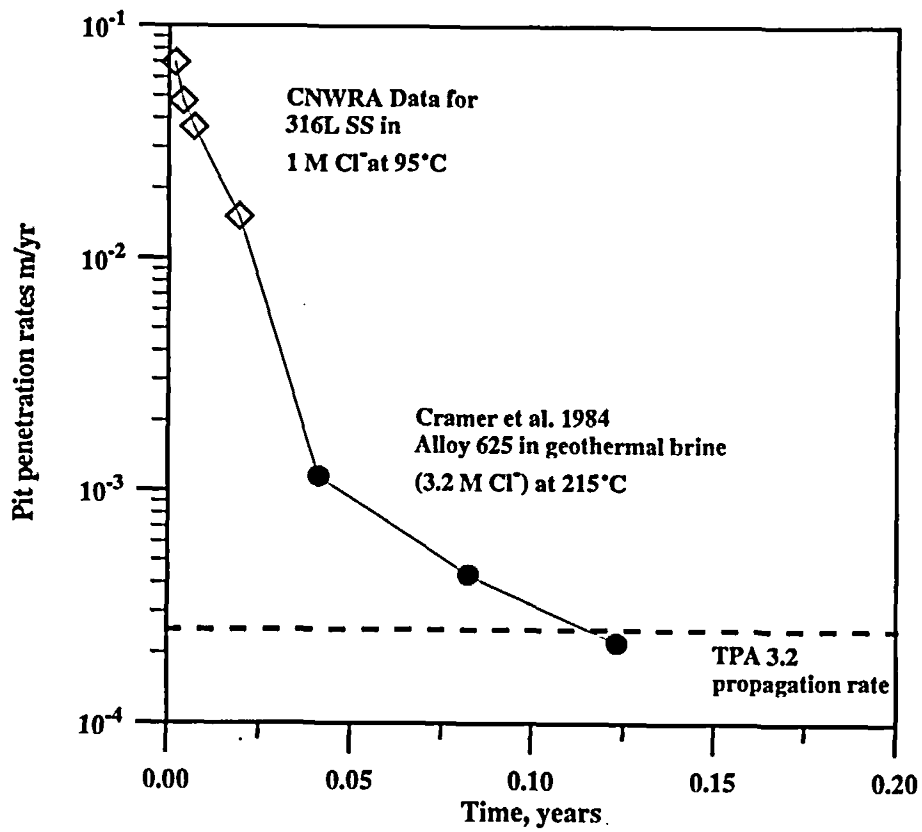


- Tests performed using autoclaves to identify ranges of susceptibility below and above boiling point
- Sharp decrease in E_{rp} above 95°C
- Crevice corrosion observed in all environmental conditions except in 0.5 M NaCl at 95°C

EFFECT OF FABRICATION ON CORROSION OF ALLOY C-22



Localized Corrosion Propagation Rate for Corrosion Resistant Ni-Cr-Mo Alloys



- Pit growth rate controlled by diffusion
- A time-independent growth rate is currently used in TPA 3.2
- Assumed growth rate is not more conservative than observed rates
- In TSPA-VA the highest value of corrosion rate is $2x10^{-5}$ m/yr, but the median rate is $4x10^{-8}$ m/yr

UNIFORM CORROSION RATE OF ALLOY C-22 AND VALUES USED IN TPA 3.2

Starting Condition of Alloy C-22	$[Cl^-]$, molar	pH	Temp, °C	Potential, mV_{SCE}	Anodic Current Density, A/cm^2	Corrosion Rate, mm/yr	Lifetime of 20 mm Thick WP Barrier, Years
As-received	0.028	8	20	200	2×10^{-9}	2×10^{-5}	1,007,455
As-received	0.028	8	95	200	3×10^{-8}	3×10^{-4}	67,163
As-received	0.028	0.7	95	200	7×10^{-8}	7×10^{-4}	28,784
As-received	4	8	95	200	3×10^{-8}	3×10^{-4}	67,163
As-received	4	8	95	400	4×10^{-8}	4×10^{-4}	50,372
TPA 3.2 Calculation Low Dissolution Rate					6×10^{-8}	7×10^{-4}	33,581
TPA 3.2 Calculation High Dissolution Rate					2×10^{-7}	2×10^{-3}	10,074

SUMMARY

- The approach used by NRC/CNWRA is flexible
  - Has accommodated DOE design changes
  - Has allowed for laboratory data to update models
  - Has allowed placing all experiences on a "performance map"
  - Is being adopted by DOE
- The sensitivity analyses have focused the detailed studies
- The assumptions made in container modeling are not unduly conservative

PATH FORWARD

- Complete study of fabrication effects
- Study the most important of alternative designs
- Help better define near-field environmental conditions on WP surface (integrated activity with TEF and ENFE)
- Identify tools, techniques, and areas of performance confirmation testing