SPE Distinguished Lecturer Program

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Near Surface External Casing Corrosion;
Cause, Remediation and Mitigation

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Society of Petroleum Engineers
Distinguished Lecturer Program
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Agenda

- Problem Description
- Corrosion Mechanism
- Repair Process
  - Excavation
  - Patch
- Mitigation Process
  - Sealant
- Summary and Conclusions

Kuparuk Operations

- Approximately 1200 wells
- Field startup in 1981
- First Surface Casing (SC) corrosion noted in 2000
- By 2005 over 25 wells with SC leaks

The Problem

- Escalating rate of SC failures
  - Holes near surface from 0 to 25'+
  - Detected by leaks at surface
- SC is a well barrier
  - Well integrity issues
  - Production impacts
- What is the cause and long term cost impact?

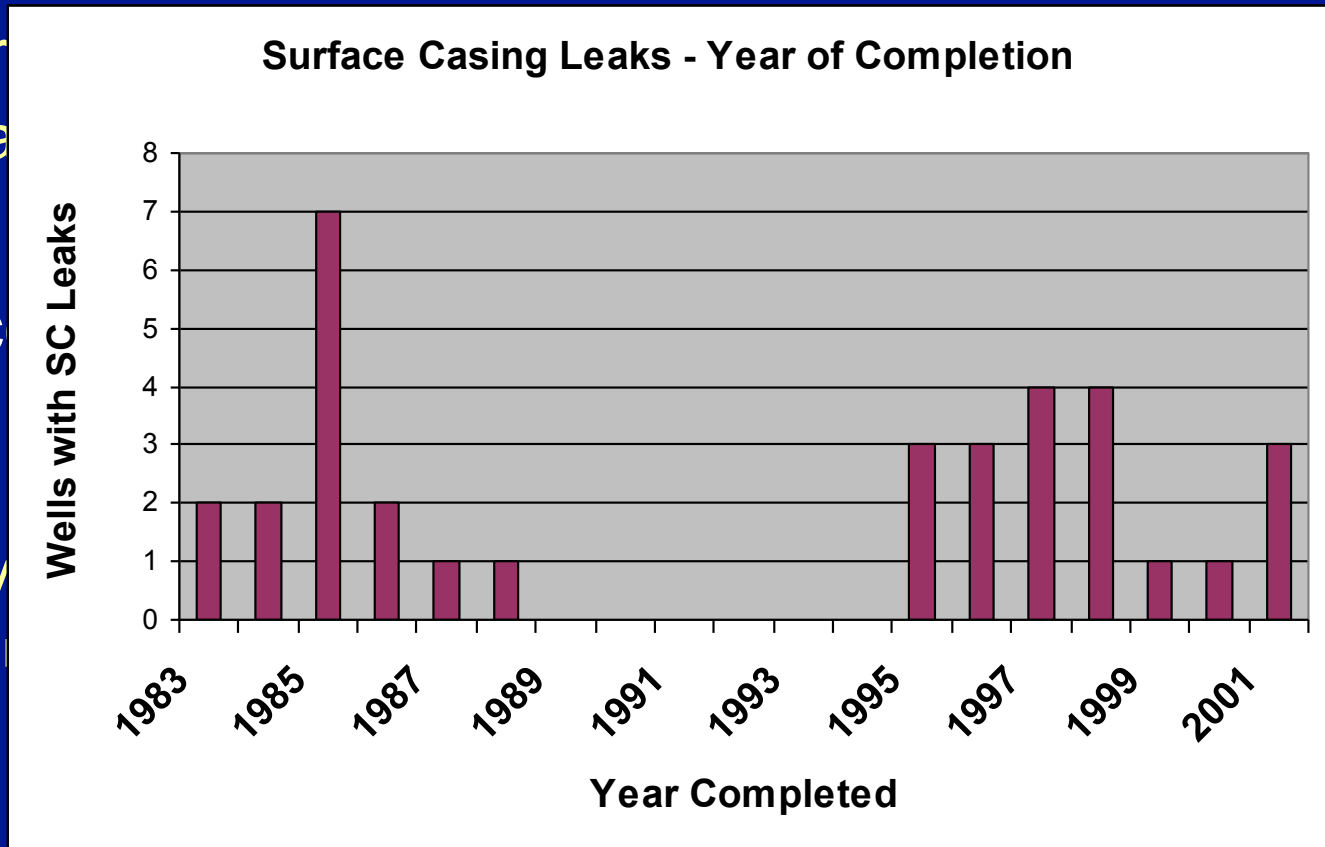
Surface Casing Corrosion

Investigation

SC corrosion NOT related to:

- Age of well
- Electrical str
- Surface loca

- There ARE c
  - Design
    - Number of
  - Type of serv
    - Temperatu



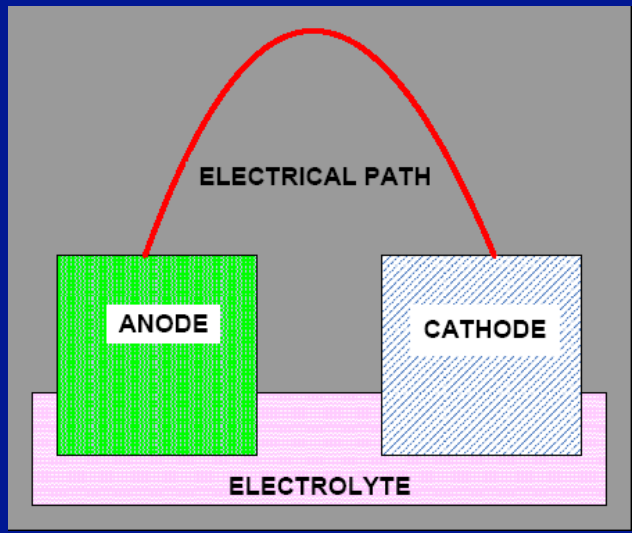
Findings

- Conducted field tests with corrosion consultant

- Root cause: Primary cement procedure combined with Arctic cement blends

Mechanism:

- Repeated wetting of cement with oxygenated water
- Cement breakdown = corrosive fluid
- Add heat from production
- Galvanic and thermo-galvanic cells
- SC becomes sacrificial anode
- Conductor becomes cathode



Corrosive Fluid

Oxygenated water becomes an electrolyte in the annulus due to components of degraded cement

Electrolyte Resistivity: The lower the resistance value, the easier it conducts electricity and is more corrosive.

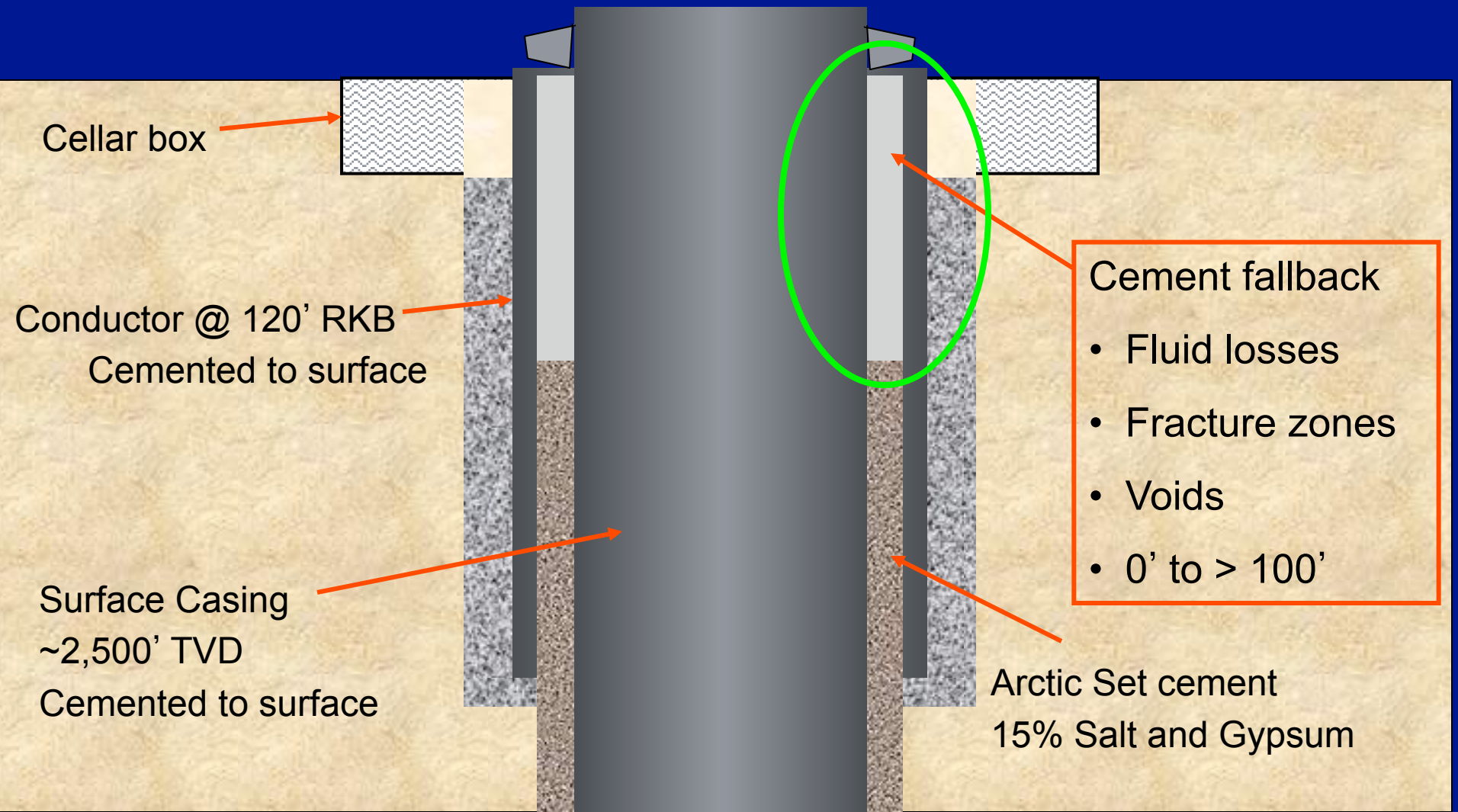
Resistivity (Ohm-cm)	General Category
Less than 500	**Extremely Corrosive**
501-1,000	Very Corrosive
1,001-5,000	Corrosive
5,001-10,000	Moderate-Mildly Corrosive
Above-10,000	Normally not significant

Source: Farwest Corrosion Control Report 6731, J. Bollinger

Test Samples From One Well

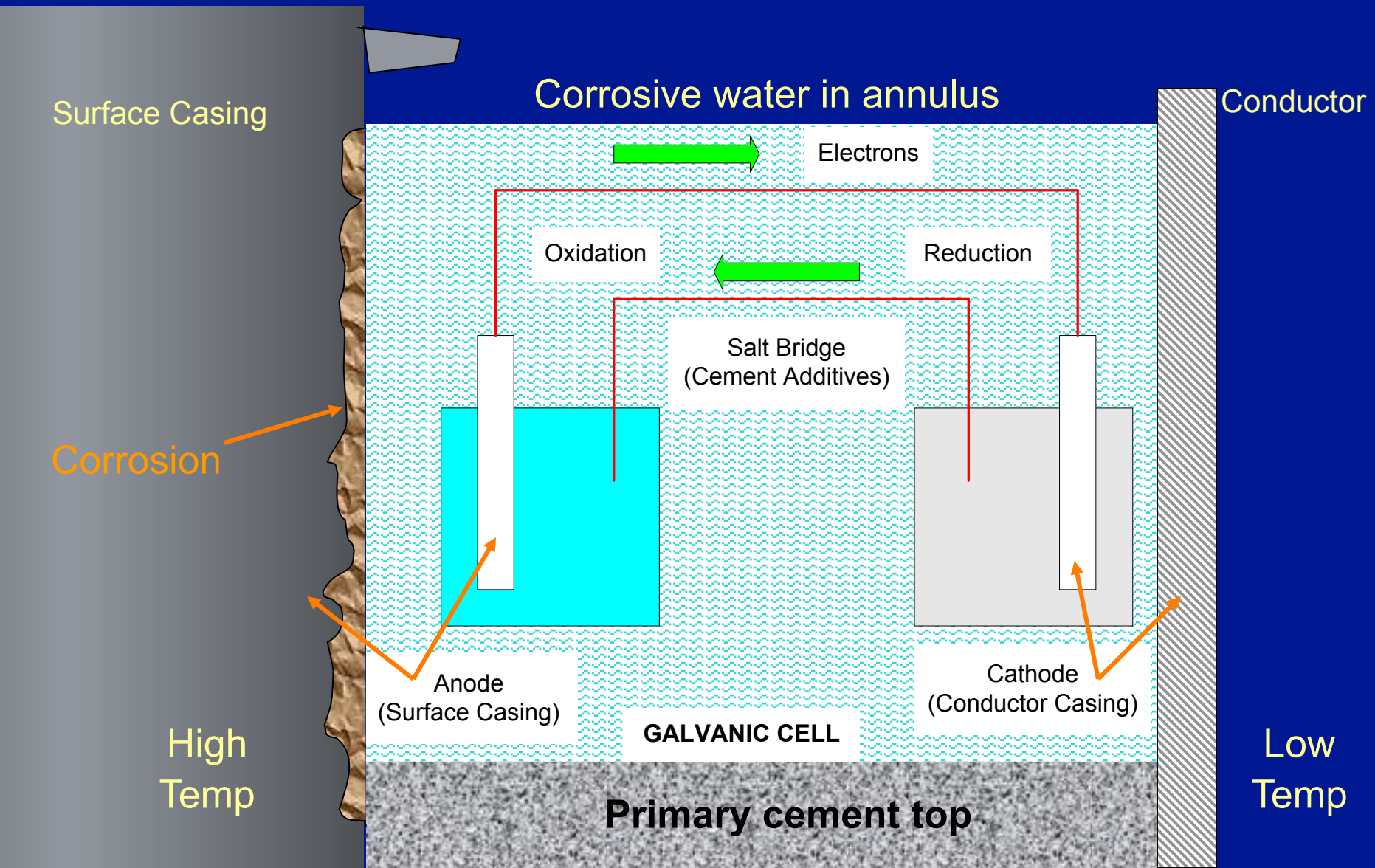
Material & Source	Resistivity	Classification
Cellar Water	1,020	Corrosive
Cement (Dry)	400,000	Not significant
Cement (Saturated)	**38**	**Extremely Corrosive**
Soil Adjacent cellar (Dry)	58,000	Not significant
Soil Adjacent cellar (Sat)	3,700	Corrosive

Well Construction



Galvanic Cell in Annulus

(Cross Section)



Heat Increases Corrosion Rate

Single Casing Completion with Hot Water Injection*

- One less annulus to insulate from permafrost
- Higher Temperature Gradient = Faster Thermo-Galvanic Corrosion

Thermo-Galvanic Corrosion

- Caused by thermal gradient
- Similar effect as galvanic corrosion
- Anodic and cathodic areas are formed
- Corrosion attack will develop

*'A' annulus and conductor; no 'B' annulus

Source: Farwest Corrosion Control Report 6731, J. Bollinger

Primary Cement Blend

Surface Casing Cement

- Good cement minimizes corrosion
- Light weight cement to reduce hydrostatic head
- Designed to set prior to freezing in permafrost zone

Additives = Complications

- +/- 15% Salt for Freeze Point Depression
  - Salt Water = Higher Corrosion Rates
- Gypsum for Heat of Hydration
  - Gypsum = Plaster of Paris
    - Degrades Rapidly in Water
- Lead slurry contaminated during displacement

To Initiate Corrosion:

Just add oxygenated water from snow melt or rain--
And repeat year after year!

Remediation Process

- Excavation
- Preparation
- Patch
- Important:
  - Perform risk assessment
  - Wells require safe-out
  - Follow HSE guidelines

Excavation Methods

Shallow – Vacuum Removal

Excavation Methods

Moderate – Backhoe & Scaffold

Excavation Methods

Deep – Backhoe & Trench Box

Multiple Well Excavation

Current Approach

- Minimal cellar
- Up to 8’ deep
- Low cost option

Conductor Removal Methods

Torch

Conductor Removal Methods

Casing Window Cutter

Cement Sheath Removal

Conductor

Shallow Repair Sequence

- Buff or sandblast SC
- Ultrasonic Thickness (UT) inspection
- Engineered patch

Shallow Repair Sequence

Install SC sleeve – typically split casing

Shallow Repair Sequence

Sleeve installed and welded

Shallow Repair Sequence

Corrosion protection installed over sleeve

Shallow Repair Sequence

Re-install Conductor
Fill with cement and top with sealant

Corrosion Mitigation Process

- Existing wells:
  - Seal water entrance paths
    - Weld or plug conductor holes
    - Top-fill with cement to near surface
    - Top with dielectric sealant
- New wells - Drilling
  - Improve cementing practice
    - Cement to near surface
    - Top with dielectric sealant

Job of Sealants

- Seal annulus from water and oxygen
  - Even if completely submersed
- Suitable for wide temperature fluctuations
- Environmentally benign
- Should be removable
- Should remain in place
  - No “Projectile” with deeper Leak
- Should be replenishable

Sealant Properties

- "Grease-like" product
- Dielectric properties
- Non hardening co-polymer
- Excellent corrosion performance
- Provides protective film
- Densified with zinc dust
  - Heavier than water
- Best performance

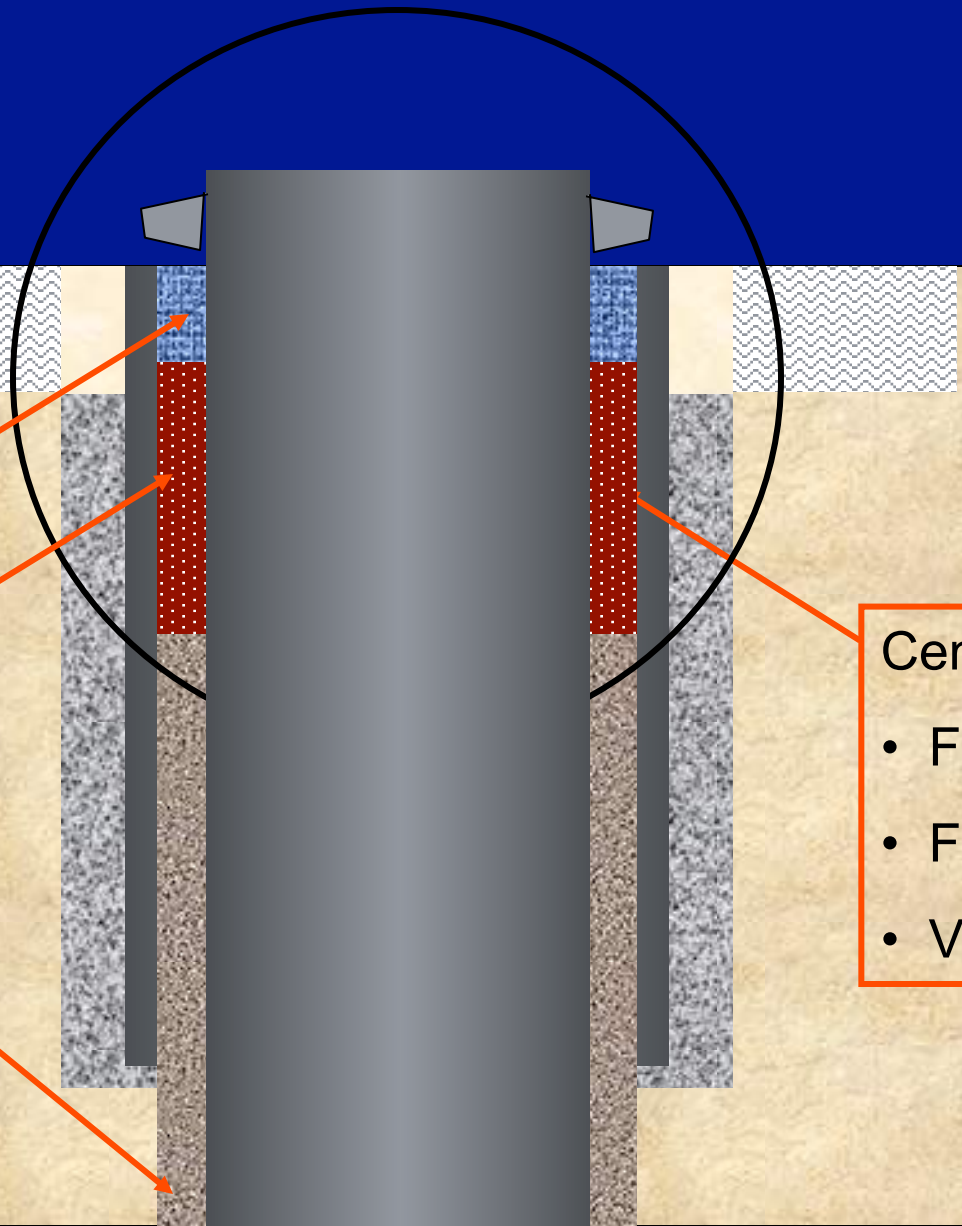
Pipe immersed in aerated salt solution covering insulation for 2 Years

Treatment Temperature

- Sealant 115 to 130 F
- Will not burn workers
- Sufficient to self level

- Will not overflow when at operating temperature

Treatment Overview



Top with sealant

(1-2' typical)

Raise cement top

"Top Job" with hose &

low pressure pump

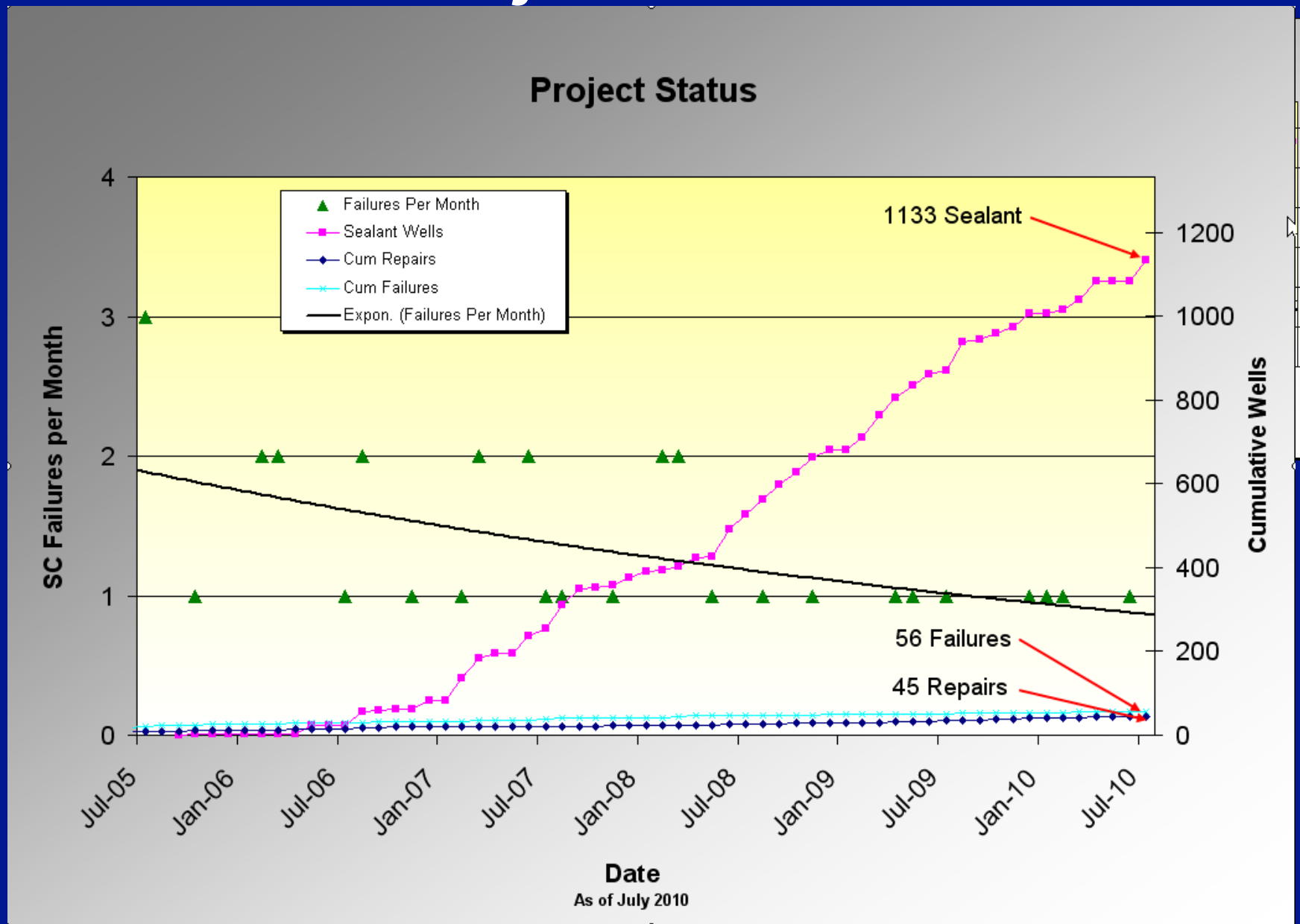
SC ~ 2,500' TVD

Cement fallback

- Fluid losses
- Fracture zones
- Voids

What Sealant Looks Like

Project Status



Patch Economics

- Cost < 6% of rig workover repairs
- Savings > $65,000,000
  - Over 8-year period compared to using rotary rig
  - Assuming 50% of wells were “economic” to repair
- More wells remain in service due to robust patch economics

Sealant Mitigation

- Treat remaining wells in Kuparuk and satellite fields
- New wells treated after release by Drilling
- Other North Slope Operators adopting program
- Applicable in many global locations

Conclusion

- SC corrosion cause identified
- SC repairs on-going
- Mitigation in progress

- Improved cement procedures for new wells
- A non-traditional, non-rig repair can be a safe, cost-effective alternative

Application

- Offshore locations
  - Saltwater exposure
- Onshore
  - Cement additives
  - Shallow surface water sources
  - Production fluids release
  - Well servicing fluid exposure

Thank you!

Questions?

Based on:
SPE-100432-PP Near Surface Casing Corrosion in Alaska; Cause and Mitigation

Jerry Dethlefs, Curtis Blount, ConocoPhillips and

John Bollinger, Farwest Corrosion Company

Contributions by ConocoPhillips Alaska Wells Group

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  - SPE Drilling & Completion Journal, December 2008, Volume 23, Number 4
- Reference:
  - SPE 50967 Corrosion Problems in Below-Grade Wellhead Equipment and Surface Casings
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