Cementing Strategies for Effective Zonal Isolation of CO₂ Wells

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OVERVIEW

• Review: Zonal Isolation of CO₂ wells (field studies)

What can we do ‘in addition’ to prevent leakage?

• Sealing Spacer improves cement placement

• Expanding cement system supporting bond

• CO₂ tolerable cement for long term bond
RESULTS FROM FIELD STUDIES

• Portland cement degradation due to CO$_2$: <10 mm / 30 yrs
  (J.W. Carey et al. 2007)

• Degradation mainly occurs along existing / induced pathways
  (B. Kutchko et al. 2009)

• Pozz/Portland cement inhibit CO$_2$ migration after carbonation
  (W. Crow et al. 2009)

⇒ Leakage only due to CO$_2$ attack very unlikely
⇒ Cements ability to resist CO$_2$ attack is secondary
⇒ Important: Good initial cement bond
## Overview

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**What can we do ‘in addition’ to prevent leakage?**

1. Sealing Spacer improves cement placement
2. Expanding cement system supporting bond
3. CO$_2$ tolerable cement for long term bond
SEALING SPACER - PURPOSE

Reducing lost circulation problems & damages
- Permeable, fragile, and weak formations
- (Natural) fractures
- Depleted reservoirs

Strengthening wellbore & Allowing cement placement
- Low frac gradients
- Narrow ECD margins (limit cement density)
SEALING SPACER - BENEFITS

- Prevents formation breakdown & fall back of cement tops
- Strengthens wellbore for improved cement slurry placement
STRENGTHENING OF WELLBORE

Before Sealing Spacer was applied:
• Cementing required a stage tool, since desired height exceeded max. ECD of 10.93 ppg

After using Sealing Spacer:
• Cementing in single stage at ECD 12.26 ppg
• No losses, top of cement found at desired top

=> Operator saved time & money with a high quality cement job
SEALING SPACER’s EFFICIENCY

Sealing Spacer

No flow

20/40 frac sand

Typical Spacer

Blow out

200 darcies

100 psi

No losses when Sealing Spacer is applied
MORE BENEFITS OF THE SEALING

- Sealing acts like a “condom”
- Potentially protects cement sheath towards corrosive fluids
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Expansion and Shrinkage Under Temperature and Pressure

- Patented BHI Molds (US 6,918,292)
- Placed in a modified HTHP curing chamber
- Measures shrinkage & expansion real time
- SPE/IADC 79911
Delayed hydration of MgO
+ Expansion after cement set
- Overdosage → cracking
Cement Additives for Expansion

Metallic aluminum powder as gas generator
- produces $\text{H}_2$ gas in alkaline environment (safety issue)
- difficult to control expansion
- gas generation occurs prior cement setting
Expanding Cement System

- 13.3 – 15.8 ppg
- HT polymeric extender
- Stable @ 465 F
- No gas generation
- No shrinkage
- Controlled Expansion

→ Supports bond
→ Reduces micro annuli
→ Field proven technology (SPE ATC 147012)
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CO₂ Attack in API Cement

I. unaltered set cement

III. carbonated cement

IV. porous silica (soft)

V. corrosive fluid

\[ \text{CO}_2 + \text{H}_2\text{O} \rightleftharpoons \text{H}_2\text{CO}_3 \rightleftharpoons \text{H}^+ + \text{HCO}_3^- \]

C-S-H phases dissolve

\[ \text{Ca(OH)}_2 \]

CaCO₃ precipitates dissolves

\[ \text{Ca}^{2+}_{aq} \quad \text{OH}^-_{aq} \]

\[ \text{CaCO}_3 \]

\[ \text{Ca}^{2+}_{aq} \quad \text{H}_2\text{CO}_3_{aq} \quad \text{H}^+ \quad \text{HCO}_3^- \]

SPE 132228-PA

Carbonation front

Leaching front
After 6 Months Exposure to CO$_2$

- Cement specimen flaked off (diameter $\Delta=-0.6$ mm)
- Cement bond failure / migration pathways
- Loss of zonal isolation
Exposed to 1 M HCl (24 hrs)

**CO₂ tolerable cement**

2 H⁺ + Ca(OH)₂ → Ca²⁺ + 2 H₂O

12 H⁺ + C₆-S₅-H₆ → 6 Ca²⁺ + 5 SiO₂ + 6 H₂O

Simulate: final of leaching step during CO₂ exposure
Durability in 1 M HCl (250 d)

Loss of mass (wt%)

-60% -50% -40% -30% -20% -10% 0%

Exposure time to 1 molar hydrochloric acid (days)

CO₂ tolerable cement

Conventional
After 250 d Exposure to 1 M HCl

$\text{CO}_2$ tolerable cement  Conventional

EDS analyses confirm complete Ca leaching for both
Durability in 1 M HCl (250 d)

- Conventional:
  -fell apart
  -no strength
  -squishy morph.

- CO$_2$ tolerable cement:
  -C.S. = 1,520 psi
  -W.P. = 0.00123 mD
0. Seal & Strengthen Formation

1. Follow good practices with API cement based systems (reliable, field proven & practical)

2. Improved cement bonding

3. Design a cement system:
   - with suitable mechanical properties
   - preventing strength retrogression
   - mitigating all corrosive attacks (Mg^{2+}, SO_4^{2-}, H_2S, CO_2, ...
Thank You for Your Interest

PERTH, AUSTRALIA