Durable Cement Systems For Long Term Zonal Isolation

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Agenda

• Objectives of primary cement job
• Some known challenges
• Causes
• Our approach
• Software simulation
• Fluid solution
• Summary
Primary Cementing Objectives

• Zonal isolation
  – Protect fresh water zones
  – Allow selective production or injection
  – Seal loose formations
  – Well control
  – Abandon a well or zone

• Protection of casing

• Protection of borehole
  – Prevent hole sloughing to allow for deeper drilling

• Change direction of well
**Challenge**

- **Sustained casing pressure**
  - Observed in more than 11,000 casing strings in 8,000 wells in OCS
  - Magnitude of leak rate is as important as magnitude of pressure when determining potential hazard

**Gulf of Mexico Wells**

(LSU Study, 2002)
Causes

- High-compressive strength vs. lower compressive strength compressible systems
- Poor cement bonding
  - Cement best practices
- Cement failure
  - Pressure changes
  - Temperature changes
  - Reservoir changes
What Do We Do Today

- Follow best practices
  - Centralization
  - Spacers
  - Displacement rates
  - Pipe movement

- Set for Life™ cementing system designs
  - DuraSet system
    - Low Young’s Modulus
    - Higher Poisson’s ratio
    - Improved tensile to compressive strength ratio
    - IsoVision™ software modeling application
Set Cement Properties for Long-term Well Integrity

Stresses due to:
- Pressure changes
- Temperature changes
- Mechanical impacts

Failure modes
- Tensile
- Compressive
- De-bonding

Set cement properties
- Tensile strength
- Young's modulus
- Poisson’s ratio
- Flexural strength
- Compressive strength
IsoVision Software Simulation
Fluid Solution: DuraSet System

- Provides improved tensile strength and elastic properties
- Enhanced mechanical properties
- Can be foamed
- Improved fracture toughness
- Used in wells that have a history of sustained casing pressure development after the cement sets
- Can be combined with other systems for multi-purpose benefits
  - CO2 resistance
- Enhanced with positive expansion:
  - Flexible expanding system
DuraSet Technical Specifications

<table>
<thead>
<tr>
<th>Typical Properties</th>
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<tbody>
<tr>
<td>Slurry Density Range</td>
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<tr>
<td>9 to 20 ppg (1078 to 2397 kg/m$^3$)</td>
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<tr>
<td>Temperature Range</td>
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<tr>
<td>70-450 deg F (21 -232 deg C) BHCT</td>
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Applications

- Critical primary cementing operations
- Fields with a history of sustained annular pressure
- Wells exposed to high-pressure fracturing operations
- Multilateral wellbore junctions
Industry Recognition & Case Histories

- 2013 World Oil Award for Best Drilling Technology
- SPE 150624, Kuwaits’ first Thermal Venture-Success with resilient cement
- Abu Dhabi, Fourteen wells successful campaign
Self Sealing Cement System

- What if assumptions are incorrect
- Self Sealing Cement System
  - More durable cement system to resist down hole fluctuations in temperature and pressure
  - Cracks self seal on contact with liquid hydrocarbon
  - Prevents flow through cement matrix or induced micro-annulli
  - Reduces risk of sustained casing pressure
  - Dormant in cement until needed
Test Apparatus

- Test apparatus designed and built
  - Cement cured under temperature and pressure
  - Adjustment of desired crack or microannulus width
  - Cement hydraulically cracked under temperature
  - Capable of controlling, measuring and recording developed crack size
  - Test through cracked cement matrix or induced microannulus
  - Measure and record flow and pressure
  - Capable of testing with gas, oil or other fluids
Self Sealing Cement Results

- Material easily mixed and blended in cement:
  - Hydrophilic
  - Passed slot testing
- No negative effects on cement properties
  - Enhanced mechanical properties

<table>
<thead>
<tr>
<th></th>
<th>Without Self Sealing Material</th>
<th>With Self Sealing Material</th>
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<tbody>
<tr>
<td>Compressive Strength</td>
<td>2300 psi</td>
<td>2350 psi</td>
</tr>
<tr>
<td>Tensile Strength</td>
<td>235 psi</td>
<td>350 psi</td>
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<tr>
<td>Young’s Modulus</td>
<td>$1.6 \times 10^6$</td>
<td>$7 \times 10^5$</td>
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<tr>
<td>Poisson’s Ratio</td>
<td>0.18</td>
<td>0.30</td>
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Self-Sealing Cement: Multiple sealing capability

Fracturing - Break and Seal test
Controlled crack width = 0.003", curing time = 96 hrs, Heal Time = 24 hrs, rm temp

Test Pressure (psi)

Ageing Time (days)
Self Sealing Cement: Specifications & Compatibility

- Recommended product loading will be between 6% and 12% BOWC, but it will depend on individual test.
- The specific gravity is 0.94.
- Compatible with all API and ASTM type cement, pozzolan, and lightweight cements and most cement additives.
- No negative effect on other cement properties.
- Future development of self-sealing product for dry gas and water.
Self Sealing Cement Applications

- **When**
  - Wells producing oil and or condensates – Oil Shales
  - Fields with occurrences of sustained casing pressure
  - Areas of high tectonic stress and or movement
  - Risk mitigation - Unable to follow all of best practices
    - Less than optimal centralization
    - No pipe movement
  - Plug and Abandonment

- **How**
  - At minimum upper 500 -1000 ft of cement column
  - Across areas where cross-flow could be an issue
  - In all cement plugs
  - Above areas to be hydraulically fractured
Summary

- Wells drilled today are more complex & have to withstand different levels of stress
- Sustained casing pressure is a concern
- Improvements have been made but there are still issues
- DuraSet cement system can help mitigate the risks if well conditions are known
- However, if well conditions are not fully known, a combination of DuraSet and Self-sealing cement
- Engineered approach a must to look at the complete picture ie good cementing practices