Long Term Cement Integrity
– An Approach for Prevention of SCP Problem

- BK Gupta
Presentation Outline

- WHAT IS SCP
- ORIGINS OF SCP
- WORLDWIDE SCENARIO
- LONGTERM CEMENT INTEGRITY TO PREVENT SCP
- WELL EVENTS CAUSING STRESSES IN CEMENT SHEATH
- TYPES OF WELL SUBJECTED TO MAXIMUM STRESSES
- TRADITIONAL CEMENT DESIGN
- FACTORS EFFECTING CEMENT SHEATH ANNULAR SEAL
- CONCEPT FOR DURABLE CEMENT DESIGN
- CASE HISTORY
What is “sustained casing pressure”?

Any wellhead pressure that returns after one-hour bleed-off

Bleed-off through \( \frac{1}{2} " \) needle valve

24-hr build up

Stabilized flow

API RP 90 “Recommended Practice for Annular Casing Pressure Management of Offshore Wells”, 2006
SCP: Potential Pollution Source

Surface pollution:
- casing head failure;
- gas emission to atmosphere.

Subsurface pollution:
- casing shoe breaching;
- gas migration outside well;
- pollution of USDW, or
- gas emission to atmosphere.

Onshore Alberta: 14,175 of 315,000 onshore wells surveyed had surface casing exhibited gas migration (Watson, 2007).

MMS Report, 2004: 6717 of 14,927 wells had SCP: 2,215 of which linked to leaking cement. Cost of removal: $650 MM.
Origins of Sustained Casing Pressure

- Tensile crack in cement caused by temperature cycles
- Channel caused by flow after cementing
- Mud cake
- Casing leak
- Well-head leak
- Tubing leak
- Low pressure sand
- High pressure sand
- Sand
- Micro-annulus caused by casing contraction
A REVIEW OF SUSTAINED CASING PRESSURE OCCURRING ON THE OCS
ADAM T. BOURGOYNE, JR., LSU STUART L. SCOTT, LSU WOJCIECH MANOWSKI, DOWELL-SCHLUMBERGER
SCP STATISTICS

(11498 CASINGS IN 8122 WELLS ARE INCLUDED IN THIS GRAPH)
WHY NEED FOR DURABLE CEMENT

- Sustained casing pressure observed on a number of wells around the globe emphasizes the need of zonal isolation failure from well events.
- Seepage between the conductor and surface casing in deepwater wells after put on production

Main cause: Cement sheath failure due to stresses induced by well events.
CASING CEMENTATION OBJECTIVE TO PREVENT SCP

- Effective zonal isolation for life of well

Objective achieved if

- Drilling fluid removed from the wide and narrow side, filling the entire annulus with competent cement system.

- The set cement withstand the stresses induced by the well events and maintain its integrity during the life of the well.
STRESSES INDUCED BY WELL EVENTS

LARGE INCREASE OF WELLBORE PRESSURE

- Increase of mud weight
- Pressure integrity test
- Casing perforation
- Stimulation
- Gas production
STRESSES INDUCED BY WELL EVENTS

LARGE INCREASE OF WELLBORE TEMPERATURE

- Geothermal production
- Steam injection
- HT/HP wells
- Deepwater wells
WELLS SUSCEPTIBLE TO CEMENT SHEATH STRESS FAILURE

- Deep water wells
- HPHT wells
- Wells completed in weak unconsolidated formations
- Steam injection wells
- ISC wells
- Producing wells converted to injectors
- CBM/Shale gas wells
Traditionally cementing operations carried out by suitable design of

- The short term slurry properties
  - Historically focused on compressive strength
  - Effects of events during the well’s life not considered

- Proper slurry placement
CONCEPT FOR DURABLE CEMENT

Even if the slurry properly placed during the cementing job, and initially fulfills its isolation role

- Changes in down hole conditions induces sufficient stresses to destroy the integrity of the cement sheath

- Flexural and tensile strength more important form zonal prospective than compressive strength.
FACTORS EFFECTING CEMENT SHEATH LONG TERM DURABILITY

- Formation Type
- Set Cement Mechanical Properties
- Casing Physical Properties
ANNULAR SEAL TEST

Simulated Hard or Intermediate Formation

Simulated Soft Formation

Plastisol Sleeve
ANNULAR SEAL TEST MODEL

N₂ Out

N₂ In

Seal for Confining Pressure

Confining Pressure

Rubber Sleeve
ANNULAR SEAL FAILURE FOR PRESSURE - CYCLED

Comparison of Cumulative Energy in Joules at Failure

- Hard
- Intermediate
- Soft

- Type 1
- Foam
- Bead
- Latex

Joules

0 4,000 8,000 12,000 16,000 20,000 24,000 28,000

Formation
Comparison of Cumulative Energy in Joules at Failure

Types:
- Type 1
- Foam
- Bead
- Latex

Formation:
- Hard
- Intermediate
- Soft
BEST DURABLE CEMENTS

- Cements with high tensile strength to young’s modulus ratio

- Low young’s modulus value compared to that of rock

- Higher value of poison's ratio of set cement

- Young’s modulus and tensile strength greatly affect cement sheath’s ability to withstand cyclic stresses loading during the life of the well
# MECHANICAL PROPERTIES

<table>
<thead>
<tr>
<th>Slurry</th>
<th>Tensile Strength (psi)</th>
<th>Young’s Modulus</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type I</td>
<td>394/213</td>
<td>19.15 E 4</td>
</tr>
<tr>
<td>Type I with Fibers</td>
<td>1071</td>
<td>9.6 E 4</td>
</tr>
<tr>
<td>Latex</td>
<td>539</td>
<td>5.32 E 4</td>
</tr>
<tr>
<td>Latex with Fibers</td>
<td>902</td>
<td>4.5 E 4</td>
</tr>
</tbody>
</table>
DESIGN CRITERIA

Cement designs to maintain seal in the wellbore throughout the life of the well.

- Decision Support System to predict the cement’s mechanical properties requirement to withstand the stresses in the well throughout the full productive life
- Cement designs custom fit to individual wellbore stress environments that changes during the life time of the well
CASE HISTORY
Cementing - ISC Wells

Conventional Completion

Charged Aquifer

Injector Well

Producer Well
Thermal Cycling

Ignition
Air Injection
Effect of Thermal Cycling

Moulds No-1, 2, 3 Thermal cycled upto 300 deg C
Moulds No-4, 5, 6 Thermal cycled upto 400 deg C
Slurry Properties:

Composition: Portland Cement along with Metakaolin and Carbon fiber

Parameters: S.G. - 1.78, Thickening time - 210 min, Free fluid - Nil, API Fluid loss - 230ml/ 30 min,

Resistant to Thermal cycling upto 650 Deg C.

Liquid permeability is retained
## Thermal Properties of Tail Slurry

<table>
<thead>
<tr>
<th>Temp (Deg C)</th>
<th>Duration of Curing (hrs)</th>
<th>Cumulative Duration of Curing (days)</th>
<th>Comp. Strength (psi)</th>
<th>Liquid Permeability (md)</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>70</td>
<td>24</td>
<td>1</td>
<td>2945</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>70</td>
<td>96</td>
<td>4</td>
<td>3125</td>
<td>0.03</td>
<td>--</td>
</tr>
<tr>
<td>70→350→70</td>
<td>72 (3 cycle)</td>
<td>7</td>
<td>--</td>
<td>--</td>
<td>Thermal cycling</td>
</tr>
<tr>
<td>70→650→70</td>
<td>72 (3 cycle)</td>
<td>10</td>
<td>2930</td>
<td>0.06</td>
<td>Thermal cycling</td>
</tr>
</tbody>
</table>

Remarks indicate thermal cycling conditions.
Cementing - ISC Wells

Ideal Completion

Injector Well

Producer Well
THANKS
### SHORT AND LONG-TERM PROPERTIES

<table>
<thead>
<tr>
<th>CEMENT SLURRY:</th>
<th>CEMENT SHEATH:</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Short-term properties</strong></td>
<td><strong>Long-term properties</strong></td>
</tr>
<tr>
<td>Desired density</td>
<td>Thermally stable</td>
</tr>
<tr>
<td>Mixable at the surface</td>
<td>Resists down hole chemicals</td>
</tr>
<tr>
<td>Stable at bottom hole</td>
<td></td>
</tr>
<tr>
<td>Desired free water</td>
<td></td>
</tr>
<tr>
<td>Desired thickening time</td>
<td></td>
</tr>
<tr>
<td>Desired fluid loss</td>
<td>Mechanical properties to withstand stresses from various well events and provide zonal isolation during entire life of the well</td>
</tr>
<tr>
<td>Desired comp. strength</td>
<td></td>
</tr>
<tr>
<td>100% placement</td>
<td></td>
</tr>
<tr>
<td>Resists fluid influx</td>
<td></td>
</tr>
</tbody>
</table>
CHALLENGES IN DEEPWATER

• Unconsolidated Formation over a few thousand feet below the mud line

• The weaker the formation, the worst the condition as formation unable to support cement deformation

• Reservoir temperature several times higher than the sea bed temperature

• Temperature differential becomes even higher in ultra deepwater and ultra high temperature environments