Well Integrity Master Class

Well Cementing

The most critical operation in achieving the ultimate well integrity

Keys to Successful Cementation

• Experience, Best practices, Technology, Job design and implementation

• Trained & Competent Personnel

• The right equipment for testing, mixing & pumping
Reasons for Cementing a Casing

- To assure Sufficient Structural Support
- To protect Fresh Water Formation
- To protect Casing from corrosion
- To protect Casing from shock loads (collapse) and formation stresses
- To prevent Blow Outs by installing BOP
- To assist in drilling across lost circulation zones, fractured & unconsolidated formations, sensitive clays
- To isolate permeable zones, to prevent fluid & gas migration, to provide controllable access to the Zone of interest
Challenges and Good Cementing Practices
Main cause of poor cement job....

POOR MUD REMOVAL

Compromises Cement Bonding,
Cement distribution and Cement Integrity
Well-Conditioned Drilling Fluid

Pre-job conditioning, circulation and thinning improve drilling fluid mobility

- Increases effectiveness of spacer in displacing the low mobility mud and filter cake
- Let cement fill up the entire annular space without leaving mud channels behind

Recommended Properties

<table>
<thead>
<tr>
<th>Property</th>
<th>Recommended</th>
<th>Preferred</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yield Point (YP)</td>
<td>10 or less</td>
<td>2</td>
</tr>
<tr>
<td>Plastic Viscosity (PV)</td>
<td>20 or less</td>
<td>15</td>
</tr>
<tr>
<td>Fluid Loss (FL)</td>
<td>15 cc/30 min or less</td>
<td>5</td>
</tr>
<tr>
<td>Gel Strength (GS)</td>
<td>10 sec/10 min</td>
<td>Flat profile (²/₅ not ²/₁₀)</td>
</tr>
</tbody>
</table>
Spacer and / or Flushes

As simple as water or
as complex as weighted, viscosified, saturated with cleaning agents and solvents fluid

Major functions

• Mud removal, cleaning the hole & water wetting surfaces for good cement bonding

• Separation of mud and cement, mitigation of fluid compatibility problems, reducing cement contamination

• Recommended to apply adequate volumes - 8-10 minutes of contact time or minimum 350m of spacer in the annulus lengthwise

Displace 3D Simulator optimises spacer design & volume
Spacer Volume → 50 barrels
Pipe Movement: Rotation or Reciprocation

Helps

• **Break up** gelled pockets of mud and loose cuttings accumulated within the pockets
• **Uniform** cement placement
• **Mitigate** the negative effects from poorly centralized pipe
Pipe Centralization

- **Good centralization** will equalize the distribution of forces exerted by cement slurry as it flows up the annulus.

- **Higher standoff** = higher displacement efficiency.

- **Poor centralization** will compromise well cleaning and circulation, cement tends to follow the path of least resistance – the wide side of the annulus.
Displacement Rates

- Best practice “pump as fast as you can without exceeding fracture gradient.”
- The higher rate provides higher displacement efficiency.
- High Annular Velocities help enhance removal of gelled pockets of drilling fluid

Pump Rate →

2-bpm  6-bpm  12-bpm

Same volume of spacer and cement pumped
Gas Migration through unset cement

- Initially cement behaves as a fluid and fully transmits hydrostatic pressure to the gas-bearing formation. This overbalance pressure prevents gas from percolating through cement.
- Gelation reduces the capability of the cement column to transmit hydrostatic pressure to the gas zone, causing loss of overbalance pressure which then allows gas to enter the annulus and percolate through the gelled cement.
- Gas percolation creates channels in cement. The channels can contribute unwanted gas & fluid flow in the annulus.

The shorter transition time the lesser chance for channelling.
Test cores of cement subjected to gas flow of 6 L/min before the slurry achieved adequate gel strength for resisting migration. SPE 24573
Operational loads during the life of a well

- Fluid Displacement / change of Fluid density
- Pressure Test
- Perforation
- Stimulation
- Production
- Injection
- Shut down

The operations create mechanical, pressure and thermal loads and stresses on the cement sheath. Over time it fails.
Common cement failures as the result of mechanical and thermal loads

Radial Cracking
Deformation and Deterioration
Debonding at cement faces

Rock  Cement  Casing

All these may result in radial or vertical migration of fluids & gases.
What Happens When \( \text{H}_2\text{S} \) Reacts With Portland Cement?

- \( \text{H}_2\text{S} \) has no significant affect on cement in the wellbore environment
- \( \text{H}_2\text{S} \) does have an effect on down hole tubulars, \( \text{H}_2\text{S} \) causes corrosion
What Happens When CO$_2$ Reacts With Portland Cement?

CO$_2$ Gas reacts with Portland cement to form an outer layer of carbonated material.

Carbonation is a chemical reaction in which calcium hydroxide (lime) reacts with carbon dioxide and forms calcium carbonate:

$$\text{Ca(OH)}_2 + \text{CO}_2 \rightarrow \text{CaCO}_3 + \text{H}_2\text{O}$$
Why Carbonation is bad for Portland Cement?

The carbonation reaction on its own will not destroy cement!

**CO₂ in water:** The potential danger comes if a solvent, an acidic liquid (pH ≤ 4) flows through carbonated cement, dissolving the calcium carbonate, eroding the mass and increasing a porosity/permeability.

Carbonic Acid

\[ \text{CO}₂ + \text{H₂O} \rightarrow \text{H₂CO₃} \]
used widely in soft drinks, destroys calcium carbonate

\[ \text{CaCO₃} + \text{CO₂} + \text{H₂O} = \text{Ca(HCO₃)₂} \]
becomes a solution containing dissolved reaction product

....calcium bicarbonate
How to prevent or mitigate the cement failures?

To Enhance cement mechanical properties, to design elastic cement resilient to wellbore stresses

- Foam
- Elastomers / Resin
- Fibres
- Epoxi like materials
Conventional cement Sheath with catastrophic failure.
Elastic Cement resiliently withstands load
How to prevent or mitigate the cement failures?

Prevent **shrinkage** of cement after its setting

- Reduce Free Fluid and Fluid Loss parameters
- Introduce Expansion Additives
- **Swell-able** materials

LifeCem™ cement expands when exposed to hydrocarbon flow re-establishing annular seal

- 1-2% expansion (100-250 microns)
Complementary Annular-Seal System

Strategically placed Swell Technology™ Systems
Questions?
Vladislav Konogorov

• Principal Technical Professional, Halliburton
• 8 + years of experience in cementing and acidizing services
• Kazakhstan, Canada, Libya and currently Western Australia

Education

• 1987-1993, Bachelor degree in Mechanical Engineering from Krasnoyarsk State Technical University, Krasnoyarsk, Russia
• 1994-1996, MBA degree from the Institute of Management, Economics and Strategic Research, Almaty, Kazakhstan