Sustained Casing Pressure
What's working? and Why?

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A little about me...

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- **12 YRS**: Field | Operations | Management | Technical
- **LOCATIONS**: Multiple States and Regions in the US
Sustained Casing Pressure

WHAT IS SUSTAINED CASING PRESSURE (SCP)

• SCP is defined as any measurable casing pressure that rebuilds after being bled down, attributable to cause(s) other than artificially applied pressures or temperature fluctuations in the well.

FAILURE MECHANISMS

• Low Cement Top
• Channeling
• Micro annulus
• Gas Migration
• Cement Damage [Cyclic Loading]
Why should we care?

- Production and Financial Reasons
- Social License to Operate (SLO)
  - Our ability to operate as an industry is no longer decided by regulators, margins, or even the rock.
  - Industry wide… **Effects us all!**
Today’s Challenges… Tomorrow’s Problems

- Pre – Placement
- Cement Placement
- Post - Placement
Today’s Challenges… Tomorrow’s Problems

PRE - PLACEMENT
- Mud Conditioning
- Centralization
- Borehole Quality

CEMENT PLACEMENT
- Mud Removal
- Tight Pore & Frac Gradients
- Losses & Influx - Depleted Zones, Salt Water Formations, Gas Formations
- Water Wetting
- High temperature differentials for critical cement
- Extended Horizontal Laterals
Today’s Challenges… Tomorrow’s Problems

**CENTRALIZATION**
- Standoff vs placement

**SPACER FORMULATION**
- Volume for long lateral
- NAF Cleaning/ demulsifying
- Water Wetting

**PIPE ROTATION**
- Removal of mud pockets
- Improved fluid tops | Contamination
- Most impactful for reduction of lateral contamination

[Image showing comparison between rotation and no rotation]
Today’s Challenges… Tomorrow’s Problems

**POST PLACEMENT**
- Casing Corrosion Protection – Sulfates, CO2
- Gas Migration
- Stimulation
- Logging
- Cyclic Loads
- Cement failure is one of the leading causes of SCP

**Bumping the plug is just the beginning!!**

- Pressure or Temperature Increase
- Soft Formation
- Soft Formation
- Casing
- Cement
Who Dunnit?

- Loss zones?
- Field adherence to design?
- Inadequate Set Cement Properties?
- Gas Migration?
- Lack of Centralization?
- Poor Mud Removal?
- Poor well conditioning?

Microannuli

Cracks
Cement Job Evaluation

WHAT'S THE BIG IDEA?
• Cement job evaluation is analogous to detective work
• A combination of clues and evidence help to provide evidence and support for analysis
• The more data available, the more accurate the insight

WHAT CAN WE ANALYZE?
• Cement job data
• Rig data correlation
• Wireline logging data

WHY GO THROUGH THE TROUBLE?
• Identify design vs. actual discrepancies
• Determine failure points
• Optimize costs for over/under-engineered aspects
• Re-iterative process to continuously improve and advance
Pressure-matching – more than just plotting two lines on one chart

**TYPES OF PRESSURE-MATCHING**

- Quick analysis
  - Plot design and actual pressure data points
  - Rough comparison to identify any outstanding inconsistency
  - Rough TOC estimation in some cases
  - Complete in a few hours

- Detailed analysis
  - Plot design and actual pressure data points
  - Attain actual job data on parameters
  - Post-job testing for actual cement data
  - Analyze pressure-trends and pressure-signature down to 1-second data
  - Re-run advanced software simulation using pressure-matched data
  - Complete in a few hours to several days

**WHAT CAN THE RESULTS TELL US?**

- Identify potential points of failure
- Placement integrity of dynamic phase
Wireline Logging Evaluation

TYPES OF LOGS

• Cement bond log
  – Conventional
  – Heavy cement TOC
• Ultrasonic Imager
  – High resolution channel evaluation
  – 360 degrees impedance mapping
  – Medium to Heavy cement
• Isolation Scanner
  – Lightweight cement, partially set and/or contaminated cement
  – Flexural attenuation
  – Third Interface Echo
  – Casing centralization

WHAT CAN THE RESULTS TELL US?

• Competency of cement sheath and weak points yielding to SCP potential
• Problem areas that may develop throughout the lift of the well

Example of CBL blind to lightweight cement, but visible on Isolation Scanner
Wireline Logging – Examples of Channeling

Low Side Channeling (Dynamic Phase)
- Poorly centralized casing resulting in mud channel left behind
- Pathway created for pressure communication

Post-Placement Channeling (Static Phase)
- Inadequate gas migration control during cement setting
- Can occur independent of dynamic placement quality

Casing contact with outer wall
Not all gray matter is created equal

Flexible cement
Multi-modal blend
High SVF
- Improve mud removal
- Higher compressive strength
- Decrease porosity and permeability

Low Young’s Modulus

<table>
<thead>
<tr>
<th>Pressure</th>
<th>Conventional</th>
</tr>
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<tbody>
<tr>
<td>3,000 psi</td>
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Self-healing cement
- All benefits of flexible cement
- Effectively heals when exposed to liquid and gas!

hydrocarbons
Evolution of US Land Lateral Cementing Solutions (actual used)

There are an abundance of novel ideas and solutions out there, but what are the fit-for-purpose solutions actual operators use with field-proven results?

2000s – Conventional Cement
- Neat Cement
- Poz/Cement combos
- Centralization

2013 – Mechanically engineered cement
- Lowered-Young' modulus
- Flexible
- Expansion & sealing
- Pipe rotation wide spread use

2016 – Mechanically engineered + Self-healing
- Reaction to hydrocarbon
- Enhanced resilience to higher pressure formation or stimulation environments
Wells are outgrowing their conventional cement designs

- **PRESSURE LIMITATIONS**
  - Lowered pump rates
  - ECD management heightened

- **CENTRALIZATION & Pipe Movement**
  - Lateral centralization minimal or non-existent
  - Pipe rotation becoming increasingly more difficult/impossible

- **SPACER FORMULATION**
  - Insufficient volumes
  - Inadequate density & rheological hierarchy
  - Fluid contamination exposure increased
Same Cement Design, Different Lateral Lengths

**ORIGINAL LATERAL LENGTH – 5k ft**
- Optimized cement design
- Robust azimuthal cement coverage above productive zone
- Slurry contamination minimized in design

**EXTENDED LATERAL LENGTH – 10k ft**
- Same cement design no longer optimal
- Significantly reduced azimuthal cement coverage above productive zone
- Slurry contamination worsened

2 to 3 mile laterals are more and more common today!
What can we do to improve the cement job?

**DYNAMIC PHASE**

**WELL CONDITIONING**
- Cure losses
- Condition mud prior to cementing

**CENTRALIZATION**
- Optimized cement design
- Robust azimuthal cement coverage above productive zone
- Focus the vertical section where a “cap” can be achieved

**FLUID INFLUX**
- Manage hydrostatics & ECDs to reduce fluid inflow/outflow
- Address gas migration w/ adequate preventive & mitigative measures

**ENGINEERED CEMENT DESIGN**
- Optimize mud removal and spacer design
- Run hydraulic simulations with advanced fluid instability simulation software to minimize contamination and optimize placement to meet zonal isolation targets

**STATIC PHASE**

**SET CEMENT PROPERTIES**
- Optimize cement for expected performance conditions
- Determine if conventional cement performance is adequate for post-job well activity
- Cement cracking due to well stresses
- Micro-annular development due to cement shrinkage or stresses

**GAS MIGRATION PREVENTION**
- Optimized cement design
- Robust azimuthal cement coverage above productive zone

**EVALUATION**
- Wireline logging combine with cement job pressure-matching can provide insights to further improve.
- Determine whether design is over-engineered and need to step back on costs, or whether under-engineered and additional investment is needed to effectively prevent SCP.
What’s on the Horizon?

OPTIMIZE FOR LONG-LATERALS
- Revisit the vertical section
- Re-establish the “cap”

DECOUPLE THICKENING-TIME FROM SLURRY STRENGTH DEVELOPMENT
- Static gel-strength enhancers
- Enable long working time, without compromising slurry strength development

UTILIZING MUD CHANNELS
- If you can’t fight it join it—turn left behind mud into competent well barriers

IMPROVE BOND LOGS
- Next generation expansion additives
Key Takeaways

**AS DRILLING TECHNIQUES ADVANCE, CEMENT DESIGNS NEED TO ADVANCE AS WELL**
- Conventional designs no longer fit the bill
- Advanced cement formulations improve placement and long-term resilience
- Lateral lengths can and do have drastic affects on zonal isolation and SCP

**THERE IS NO “I” IN “TEAM”**
- SCP can result from one or a combination of the many aspects involved in the life of the well
- A collaborative effort in addressing all aspects is key to eliminating SCP

**AN OUNCE OF PREVENTION IS WORTH A POUND OF CURE**
- Advanced remediation technology can cure SCP, but comes at a hefty cost
- Doing it right from the start enables financially beneficial and socially responsible outcomes for a sustainable hydrocarbon energy future.

**TODAY’S CHALLENGES **CAN** **BE TOMORROW’S SOLUTIONS!**