Closed-Loop Cementing - Offshore Well Construction

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Outline

• Cementing 101 – to get us on the same wavelength
• Typical challenges to getting a good cement job
• Origins and definition of Closed-Loop Cementing
• Key enablers - MPD Equipment & frequent Dynamic FIT’s
• How those technologies converge to facilitate:
  • More stable wellbore, hole cleaning & pre-conditioning
  • More precise mud displacement & slurry placement
  • Real-time detection of an induced fracture
  • More precise pressure management during pre-set & curing
  • Testing with MPD kit to reduce NPT
• Compliance with intent of API Recommended Practice 65 - *Isolating Potential Flow Zones During Well Construction*
Cementing 101

1. After casing is run into the well, a cementing head is fixed to the top of the wellhead to receive the slurry from the pumps. Two wiper plugs, or cementing plugs, that sweep the inside of the casing and prevent mixing: the bottom plug and the top plug.

2. Keeping the drilling fluids from mixing with the cement slurry, the bottom plug is introduced into the well, and cement slurry is pumped into the well behind it. The bottom plug is then caught just above the bottom of the wellbore by the float collar, which functions as a one-way valve allowing the cement slurry to enter the well.

3. Then the pressure on the cement being pumped into the well is increased until a diaphragm is broken within the bottom plug, permitting the slurry to flow through it and up the outside of the casing string.

4. After the proper volume of cement is pumped into the well, a top plug is pumped into the casing pushing the remaining slurry through the bottom plug. Once the top plug reaches the bottom plug, the pumps are turned off, and the cement is allowed to set.
Plato, Greek Philosopher, circa 340 BC

...was a pretty wise guy...

“One of the penalties for refusing to participate in politics is that you end up being governed by your inferiors.”

“Love is a serious mental disease.”

...but most applicable to this presentation:

“Necessity, who is the mother of invention”
Is there a “necessity” to find a better way?

• It is common knowledge that getting good cement job on a challenging offshore well construction program is sometimes a formidable task.

• HPHT adds to the complexity – fault segmented basins with rapid departures from more hydrostatic conditions to high overpressure, reservoir fluids tend to migrate to shallower depths, require non-conventional cement, etc.

• Data not accurately representing the actual down hole conditions used as input for modeling ECD, flow characteristics, open-hole gradients, u-tube risk...Routine wellbore strengthening, in/out control rate and ballooning characteristics...add uncertainty to cementation decision-making.

• With vintage (Spindletop, 1901) open-to-atmosphere returns systems, control and monitoring of the back-side fluid’s parameters falls short in optimizing placement and displacement procedures.

• Like of ability to detect in real-time an induced fracture during displacement.
Closed-Loop Cementing

“Involves the ability to verify formation containment capability prior to running casing, monitoring pre-flush effectiveness, more precise spacer & slurry displacement information for comparison with conventional calculations, Pp/Fp/MW/EMW inputs to cementing simulation models, and detection of an induced fracture during cementing sequences. Annulus backpressure is applied via the MPD automated choke or its backpressure pump; relaxed while displacing spacers & slurry into the annulus, tightened as slurry is pumped into a second portion of the annulus, etc., and held constant during curing.”

Ref: UT PETEX Drilling Hazard Mitigation Tools & Technology, Pub: Q3 2012
Closed-Loop System for CBHP MPD

1 – Rotating Control Device
2 – Dedicated PLC drilling choke system & mass-flow meter
3 – Remote Control and Display
• “Docking Station” RCD shown on a moored semisubmersible above marine riser tension ring & atop a surface annular BOP.

• The annular facilitates “docking & undocking” the RCD bearing & annular seal assembly & contributes to riser degassing, if needed.
“The MPD equipment was also successfully utilised during the P&A phase of the well. It is a known fact that placing balanced cement plugs at almost 6000m is very difficult and often no plug is found when running in to tag. On the “Mandarin East” well, the MPD equipment was utilised (with a solid float in the cement string) to keep approximately 50 psi of backpressure on the plugs when pulling out of the cement. This obviously helped in keeping the plugs in place as all the deep plugs were tagged at first attempt within reasonable depth from the theoretical top. Furthermore, the MPD equipment (good for 2,000 psi static pressure rating) was used to pressure test the cement plugs after tagging. This was significantly quicker than rigging up to the cement unit for testing.”

Note: “plug” in this case refers to cement placement for zonal isolation...and not the wiper plugs themselves.
“The 12 ¼” hole section (critical zone) started few days ago, a dynamic FIT was conducted showing a lower limit than expected. Petrobras is re-logging the hole drilled, also running a CBL and maybe will drill another 30m to find a marker and set a liner prematurely due to the fact that we have just 100 psi + 100 psi safety factor from the actual FIT value.”
Merging two MPD-related capabilities

Constant Bottom Hole Pressure variation of MPD – An adaptive drilling process used to precisely control the annular pressure profile throughout the wellbore. The objectives are to ascertain the downhole pressure environment limits and to manage the annular hydraulic pressure profile accordingly.

PLUS

Conducting dynamic formation integrity tests frequently, perhaps after each stand, while drilling the uncased hole to be assured it will handle the pressures of the planned cementing operation.
Constant Bottom Hole Pressure (CBHP) variation of MPD (swapping circulating AFP with shut-in backpressure = Constant EMW)
Dynamic Formation Integrity Test

FIT – “the ability of the formations to withstand applied pressure” and not to be confused with LOT – “a test used to determine the amount of pressure required to cause a formation to fracture”. Ref: BOEMRE Glossary of Terms

Dynamic FIT’s are performed with rig pumps, through the bit and while rotating the drill string. Surface backpressure is applied by the MPD system, eliminating the need to use the BOP in the process. The ease of dynamic FIT’s support the practice of being conducted in critical zones after each stand is drilled, rather than making the usual assumption that the weakest point coincides with the casing shoe depth, reducing risk of an underground blowout. Also conducted to assure a stable wellbore prior to cementing operations.

Ref: UT PETEX Drilling Hazard Mitigation Tools & Technology, Pub: Q3 2012
+25 psi SBP/minute to FIT value or losses (LOT)

(noting previous mud compressibility and/or ballooning fingerprints)
Displacing the 1st Plug

Cement is injected in to the well, SBP applied to keep a constant BHP.

An increase in Flow Out is visible.

Flow In/Out increases at the bottom of the screenshot, showing the cement being displaced on to bottom.

SBP is reduced to compensate.
1st Plug on bottom

When the cement “turns the corner” the annular fluid is displaced with greater momentum.

Once the entire plug reaches the bottom of the well, flow ceases in preparation to pull out of hole.

SBP increases to 300psi to replace annular friction pressure.
Setting the 1st plug

PLC choke system can ascertain the integrity of the plug once the BHA has been lifted above it.

Flow in restores partial annular pressure and allows returns monitoring.

SBP decreases to 125psi to ascertain constant annular conditions.

Mass balance monitoring enables the detection of leaks or gas migration/infiltration.
Displacing the 2\textsuperscript{nd} plug

The procedure for displacing the first plug is repeated to displace the second plug.
After displacing the BHA is POOH to wait on the cement setting.

The return flow pattern here indicates swabbing.

As before the system can be used to monitor the annulus.

Integrity tests can then be performed upon the annulus, and in this case...

Leak-Off Test and a 1600psi pressure test
Closed-Loop Cementing in relation to API RP 65
“Isolating potential flow zones during well construction”

“A stable wellbore - no gains or losses” Optimize MW, flow rates using CBHP MPD tools & technology, conduct frequent dynamic FIT’s drilling the open hole

“Proper mud conditioning and hole cleaning prior to cementing” Better understanding of margins between PP/FG & EMW’s - more efficient hole prep

“Spacer Design” Use info to adjust density/rheology as necessary to manage ECD, effect positive displacement of mud, etc

“Proper fluid dynamics during circulation and placement of cement to achieve mud removal” Real-time mass flow in/out measurements, Δbackpressure

“Tripping requirements” Manage surge/swab

“Drilling techniques” Data acquisition that can be applied to subsequent casing running and cementing

“Well monitoring” DAQ in real-time, onsite & offsite monitoring

“Sustained hydrostatic pressure during cement curing” Without exercising rigs BOP & compensating for heave induced pressure fluctuations
Questions?

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