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Cement Spacer Technology Restores and Maintains Circulation in a Complex Casing Drilling Application

Cristian E. Aramayo and Carlos Martinez, Pan American Energy;
Mario D. Armella, Roberto J. Arroyo, and Walter R. Mamani, Servicios Especiales San Antonio S.A;
Francisco Bermudez and Jené Rockwood, Impact Fluid Solutions

Abstract

A critical component for extending the life of an oil or gas well is the cement sheath that creates zonal isolation. Before excellent zonal isolation can be achieved, the contact area for cement bonding must be prepared to provide a strong and stable cement bond. The primary goal is to completely remove all drilling fluid; this is crucial for establishing a strong cement bond and achieving complete zonal isolation.

To establish the desired cement bond, high-quality spacers with excellent rheological qualities must clear out the gelled residue created by drilling and deposit a cement-friendly filtercake.

While displacing the spacer with cement, the wellbore is exposed to the highest equivalent circulating density (ECD), which exacerbates any concerns created by earlier drilling losses and can, under these circumstances create additional induced losses as the ECD exceeds the rock's fracture gradient. It is difficult to accomplish top of cement (TOC) if losses occur. These concerns are handled by pumping a wellbore stabilization (WBS) spacer system ahead of the cement slurry; the WBS seals and isolates possible weak zones, allowing for complete cement placement.

A case history is presented where an operator chose to use a technique known as casing drilling due to wellbore instability and subsequently lost over 7,000 bbl of drilling fluid. The service provider suggested utilizing a WBS that can seal fractures up to 3,000 µm to increase the chance of a successful cementing job. The well was cemented without further lost circulation, and the TOC goal was met. The cement bond log (CBL) indicated a successful cement job.

Introduction – Wellbore Instability

Wellbore instability is a major drilling challenge that can cause several well problems during the drilling stage of a well such as lost circulation or borehole collapse.

Lost circulation refers to the uncontrolled loss of drilling fluid into the formation during drilling, cementing or completion operations. This occurs when the volume of the fluid returns is less than the volume of the drilling fluid that is pumped into the well (Metcalf et al., 2011). Lost circulation issues can be very serious and, depending on the severity of loss, must be resolved before drilling can resume. Lost circulation is associated with high cost and high risk. One quick solution is to reduce the density of the drilling fluid which can lead to other problems such as mechanical borehole collapse, or gas migration leading to well control issues. Other solutions typically look at plugging the fractures or strengthening the wellbore to control the losses.

Lost circulation is a major source of nonproductive time (NPT) when drilling a well. There are two types of losses: induced losses and natural losses.

Induced Losses

Induced losses occur when dense fluids are pumped into a wellbore with a low fracture gradient, causing the formation to fail under the load exerted by the fluid column. If the formation breaks down, the fluid will begin to flow into the formation instead of up the annular space. Engineers must plan the work to regulate static and dynamic pressures, and operations must always maintain the pressure of the hydrostatic column below the fracture limit of the formation to avoid induced losses.

Natural Losses

Natural losses occur in fractured rocks that have been fragmented naturally. Lost circulation materials (LCM) are introduced to the drilling fluid in order to fill or bridge the gaps created by natural fractures. In other cases, cement plugs are pumped into the well to compensate for natural losses before drilling can resume.

If any kind of wellbore instability problems are expected, drilling engineers must design the well to prevent or minimize these issues. There are many techniques to combat wellbore instability. In this paper, we will present a combination of two technologies that the operator used to solve problematic zones: casing while drilling and a specialized cement spacer system.

Casing While Drilling

Drillpipe is frequently used as a standard procedure while drilling a well. Other methods include casing while drilling (CwD), which includes screwing a bit into a joint of casing, drilling into the ground until total depth (TD) is reached, and then cementing the well through the bit.

The breakthrough in this technology was first implemented in the United States in the 1960s. However, because of its modest penetration rates compared to conventional drilling, this approach did not develop rapidly (Hahn et al., 2000).

Finally in the 1990s, the oil and gas industry began to utilize CwD technology when the conventional casing string was used to send rotary power to the bit and circulate drilling fluid into the well (Tessari and Madell, 1999). With the help of the plastering effect, CwD became used to address problems of traditional drilling procedures such as wellbore instability and lost circulation (Naveen and Babu, 2014).

Wellbore Stabilization Spacer

Many papers have confirmed (Metcalf et al., 2011; Kulakofsky et al., 2018; Jordan et al., 2019; Kulakofsky et al., 2020; Abad et al., 2020) that in wells where the fracture gradient has traditionally been a limiting factor for the design of cementing jobs and quality slurries, a wellbore stabilization (WBS) spacer has allowed service companies and operators to slightly increase the maximum fracture gradient during cementing, thus avoiding the invasion of fluids to the formation and allowing the correct cement placement without contamination, all while promoting the correct adhesion for casing-cement and cement-formation bonding.

Conventional spacers are not designed to address pre-existing or induced losses and the risk of losses during a cementing job is greater once the heavier and thicker cement slurry enters the annular space. Consequently, pumping cement without addressing lost circulation increases the risk that the required top of cement (TOC) may not be achieved.

Treatments to cure losses typically include mixing high concentrations of fibrous LCM into the spacer or into the cement system, but this also presents several operational issues, from possible plugging of the cementing equipment or accessories, to compatibility challenges.

The WBS spacer system is a proprietary cellulosic formulation, engineered to create a flexible and strong membrane in the inside face of the formation when the spacer is pumped ahead of the cement slurry. The particles inside the spacer create an ultra-low-invasion fluid across a range of microfractures forming both a pressure and fluid barrier. If losses occurred during the drilling stage or before the initiation of the cementing process, the WBS should be enhanced with an LCM that is optimized to function in conjunction with the WBS to seal fractures up to 3,000 µm.

This spacer technology has been engineered with a simple approach for delivering any rheology required with a linearity between spacer concentration and yield point (YP) (Fig. 1).

While surface viscosity is easy to quantify and to achieve, when optimizing displacement efficiency, it is the rheological properties at downhole temperature that matter (Fig. 2).

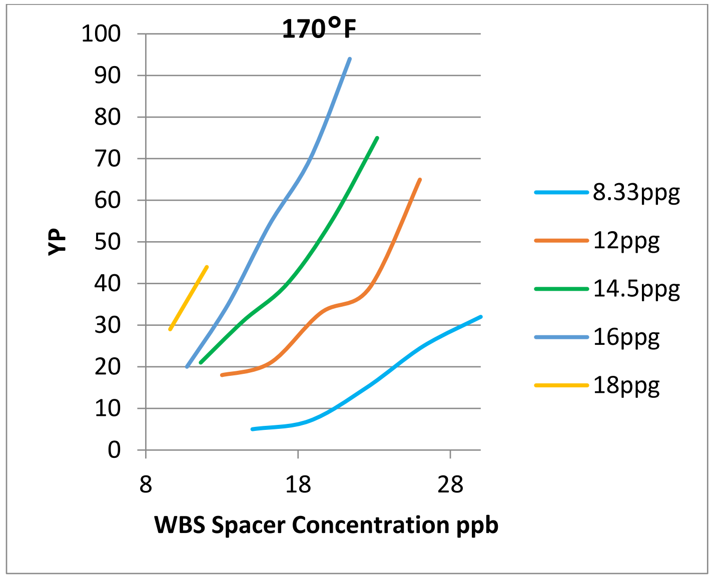

Figure 1 – WBS Spacer is designed to allow optimized hole cleaning with easily adjusted YP

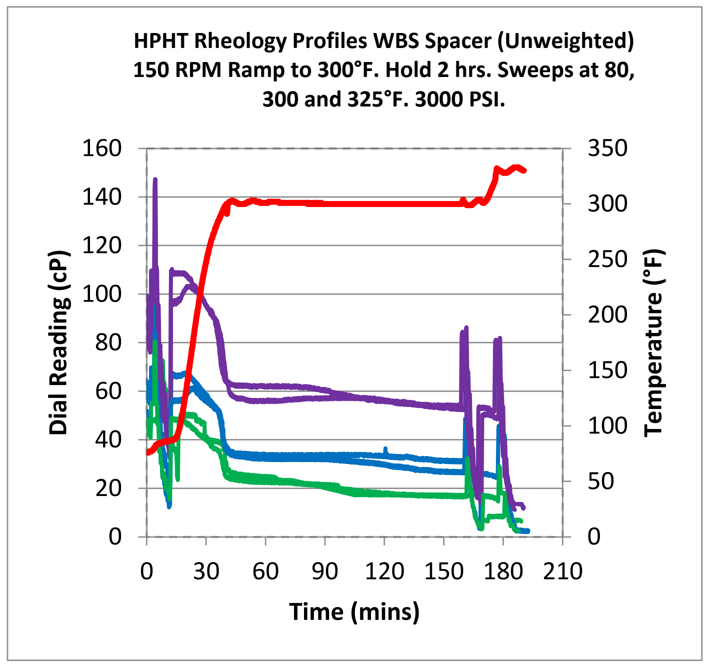

Figure 2 – WBS Spacer very stable up to 325 F. The spikes at the beginning and the end are the rheology measurements being taken.

Case History: Golfo San Jorge Basin

The Golfo San Jorge, Argentina's first oil producing region, is a challenging basin to drill due to depletion as a result of over 50 years of production (Clavijo et al., 2007). Responding to the worldwide increased demand for oil, the operator opted to increase production levels by drilling more wells and optimizing existing wells.

It is well known that the Golfo San Jorge Basin suffers from severe to total lost circulation problems throughout the drilling stage and, therefore, especially during the cementing stage.

Studying the data in Table 1, it is clear that this formation has a very tight window between the pore pressure and frac gradient over an extended section. If the frac gradient is exceeded, this results in uncontrolled fluid losses, which makes cementing jobs more difficult to complete.

Table 1 – Pore Pressure and Fracture Gradient Window

Depth (m)	Pore Pressure		Fracture Gradient	
	psi/ft	psi	psi/ft	psi
730	0.45	1084	0.70	1686
1074	0.45	1595	0.70	2481
1320	0.45	1960	0.70	3049
1520	0.45	2257	0.70	3511
1600	0.46	2429	0.70	3696
1667	0.46	2531	0.70	3851
2385	0.46	3620	0.70	5509
2490	0.46	3780	0.70	5752

Due to wellbore instability and lost circulation, the operator decided to use the CwD technique, whereby casing is run simultaneously during the drilling stage (Fig.3). CwD allows the operator to drill across problematic zones with lost circulation, but it does not guarantee a good cementing job.

At 1,600 m (5,249 ft), a severe loss of 95 to 125 bbl/hr was encountered which dramatically increased to significantly higher range of 180 to 220 bbl/hr while drilling the next 15 m (50 ft). During the drilling stage several lost circulation pills were pumped at different depths with little success. It was determined that 7,235 bbl of drilling fluid was lost in reaching the programmed total depth (TD) of 2,490 m (8,169 ft).

In order for the cementing operation to be effective, it was necessary to maintain pressure control and mitigate wellbore instability during the process. For the cementing job, there were additional obstacles, such as using a fluid that was heavier than the drilling fluid (and would result in a higher ECD downhole than the drilling fluid) and which would be pumped passed the same unstable wellbore areas which caused lost circulation during drilling. Pumping cement must be achieved without losing circulation to accomplish the programmed top of cement.

Pumping the WBS spacer to cure losses ahead of the cement was advised by the service company as a way to boost the likelihood of a successful cement project in spite of the fact that more than 7,200 bbl of drilling fluid was lost during the drilling process.

The WBS was designed using the spacer design program, and comprehensive lab testing, including sand bed tests (SBT) and slot tests, were carried out to verify the sealing capabilities of the spacer (Fig. 4).

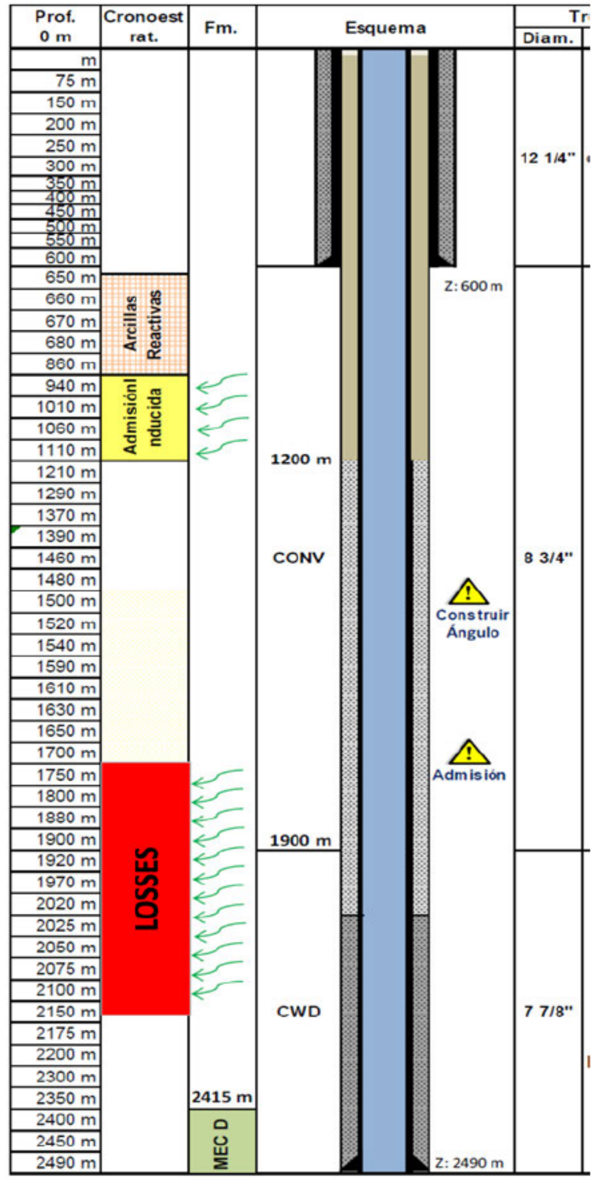

Figure 3 – Wellbore schematic indicating where losses are expected in the production stage (CwD).

Figure 4 – Sand Bed Test used to test WBS Spacer using pea gravel. A strong seal is formed at the top of the gravel and no leak off was observed at the bottom valve

Verification is provided by a pressure match based on the final pressure measurements (Fig. 5) and validated further by the cement bond log (CBL) (Fig. 6), both of which indicate a successful cement job.

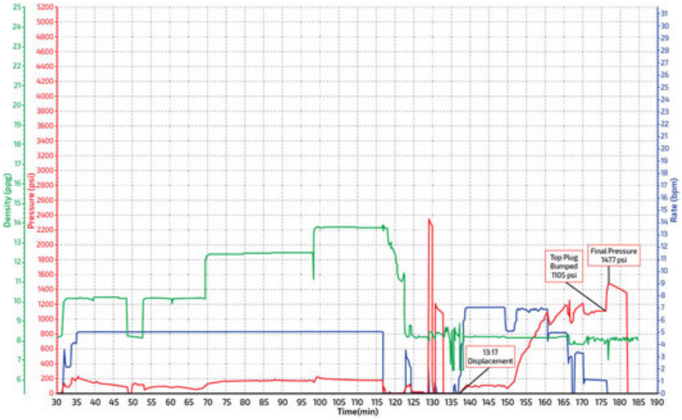

Figure 5 – Pressure increase is observed at the end of displacement indicating that the cement column is being lifted. The green line is density (lb/gal); the red line is pressure (psi) and the blue line is pump rate (bbl/min).

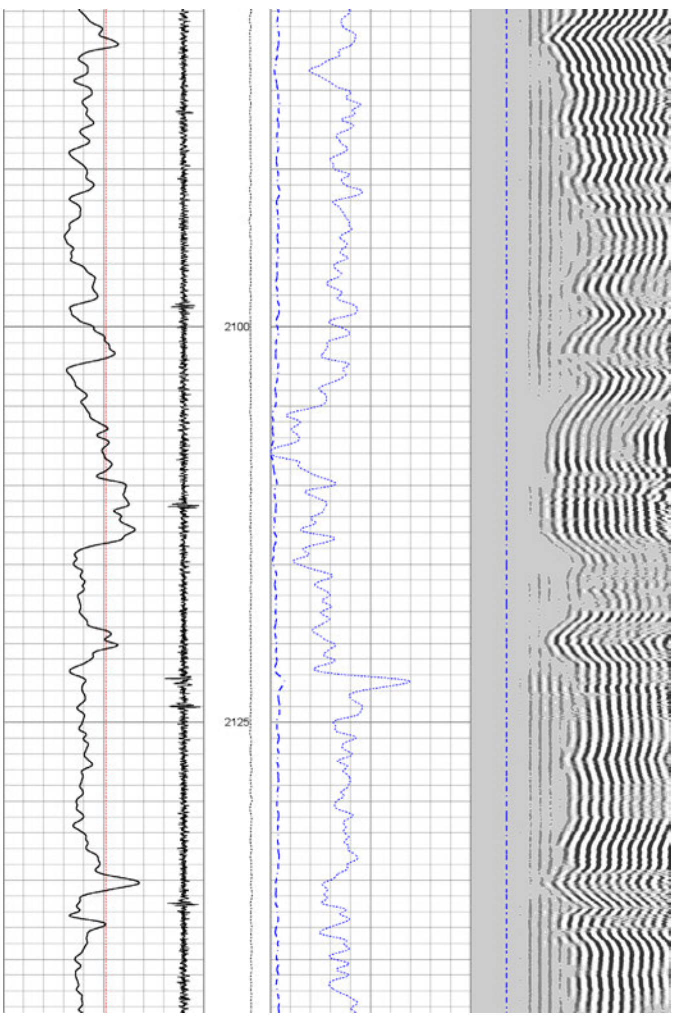

Figure 6 – CBL/VDL shows good hydraulic seal.

After this experience, the operator adopted the use of WBS spacer as part of their cementing program, achieving excellent results and eliminating the additional expenses that are associated with remedial jobs.

The first job combining CwD and WBS for this operator was the subject of this paper's case study. There have already been 18 cases in which these two technologies have been used in conjunction to ensure that effective primary cement has been achieved without the loss of circulation. In addition, the required TOC was obtained.

Conclusions

The use of this customized spacer technology helped to reduce downhole losses, allowing the cement to be successfully placed in the well. The WBS spacer and CwD technologies are still in use as of the publication of this paper. The wellbore spacer was instrumental in controlling losses and achieving top of cement placement.

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Nomenclature

NPT = *Non-Productive Time*
CwD = *Casing While Drilling*
WBS = *Wellbore Stabilization Spacer*
TOC = *Top of Cement*
LCM = *Lost Circulation Materials*
YP = *Yield Point*
TD = *Total Depth*
SBT = *Sand Bed Tests*

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