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Improving Zonal Isolation in Horizontal North Texas Wells

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Abstract

In development drilling projects, primary cementing operations often become a "go to" source for cost savings. The drawback is while drilling and completion costs may become more economical in the short term the consequences of compromised zonal isolation can be costly. A poor cement job can destroy the economic viability of a well. The failure to isolate the pay may not be immediately evident but may manifest later in the form of gas flow up the annulus, communication between pay zones, loss in recoverable reserves or regulatory fines and increased regulatory agency scrutiny of all operations. Once the cement is in place, remediation efforts to repair the primary cement job are often difficult, unsuccessful and more costly than the primary cementing job. The inability to fix the problem reinforces the importance of designing and executing the primary cementing operations correctly from the onset. This paper details a case study to determine the cause of poor zonal isolation in horizontal north Texas wells and the steps taken to improve the process in an effort to improve the results.

Introduction

The field discussed in this paper is one of the largest producing gas fields in North America. The process of horizontal drilling and completion operations the process has become very efficient since the onset almost 20 years ago. Wells are being drilled in record times and completion operations are often referred to as "frac factories". Operators look for ways to economize as operating efficiencies improve in development projects like north Texas.

One of the common sources for cost savings in this field is cementing operations. It is a widely held belief that anyone can cement a north Texas well. This is apparently supported by the number of cementing service companies in the area. The belief is not based on post job evaluation but rather the lack of operational problems during the job i.e. the plug bumped and the floats held. Relatively few operators evaluate the zonal isolation in the well after the primary cement job. The first indication problems exist unfortunately may show up when gas flows up the backside or communication occurs between pay zones during the frac. At that point it becomes a remedial issue and remedial cementing successes are rare.

A few operators began to suspect lack of operational problems did not insure good zonal isolation. They began running CBLs and mapping tools to evaluate the cementing results upon seeing communication between zones during completions. What they discovered was inadequate zonal isolation. In reality, cement cost savings were not really saving money at all due to the remediation expenses and lost revenue due to incomplete stimulation operations. A study was initiated to review the drilling and cementing practices. The goal was to determine how to achieve better zonal isolation as cost effectively as possible.

North Texas Cementing Case Study

The case study was initiated by the operator in the spring of 2010. The operator requested the cementing service companies to conduct a thorough review of current cementing practices in their north Texas operations to determine the root cause of poor cement bond due to inadequate zonal isolation in several wells in the field. These wells showed poor cement bonding across the zones of interest on conventional CBLs and cement mapping presentations. Remedial cementing attempts had been unsuccessful in most cases. Poorly cemented pay intervals remained unstimulated behind pipe resulting in a loss of production and revenue. Concurrently, an industry recognized cementing consultant was hired to conduct an independent evaluation and make recommendations.

The Review Process

For the case study referenced in this paper, the service company region engineer spent time in-house at the operator's office reviewing the subject well files identified by the drilling engineers.

- 13 wells with "good" bonds
- 5 wells with "poor" bonds
- 1 well scheduled for cement evaluation

The review data included:

- Well spreadsheet (prepared by the drilling engineers)
- Drilling reports
- Mud logger reports
- Field maps
- Cementing reports
- Cement lab reports
- Conventional CBLS
- Ultrasonic cement displays ("maps")

The second part of the review involved studying all of the service company lab testing, cement treatment reports and job charts. Additionally the jobs were modeled using the actual job data to determine displacement efficiencies, ECDs and fluid placement.

The Findings

Two weeks after completion of the study, the service company engineer presented the findings of the study. The operators' drilling engineers, management and the independent consultant were in attendance. The following findings were presented.

- "Poor" jobs could not be tied to a common contractor, rig, engineer or job design.
- Several design and operational changes had been implemented to improve cement bonds including changes to the cement slurries, spacers and scavengers, but there was no post job evaluation to determine the effectiveness of one change before making another.
- Pre-cementing hole conditioning operations were inconsistent with regards to mud conditioning, circulation rates, circulation duration and casing movement.
- Spacer volumes, densities, pressure hierarchies, annular contact times and chemistry were not consistent.
- Actual tail cement tops were low compared to the designed tops in 26 of the 30 data based wells.
- Caliper logs indicated the OBM drilling fluids produced near gauge open hole diameters.
- Scavenger slurries aided mud displacement and provided economic solution for OBM recovery.
- All the logged wells showed casing arrivals on VDLs. In other words, some of the wells were rated "good" but none could be rated as "excellent".
- Extended open hole logging times affected hole conditioning and mud properties due to gel strength development while static.
- Cement testing temperatures were based on measurements taken from MWD tools. The temperatures were inflated due the heat generated while the tool was drilling. This was confirmed by the temperatures recorded on the post job logs.
- Cement thickening times were erratic and several hours longer than the pump time plus a one hour safety factor.
- High cement displacement rates generated ECDs that caused intervals with .54 - .60 psi/ft frac gradients to fail. As a result the wells incurred losses and diminished returns during cementing.
- The cased hole post job analyses were inconsistent. The waiting time between the cement job and the logging operations ranged from a few hours to several days. A variety of tools and logging equipment was used making correlations difficult. The evaluations were graded by several different engineers using different evaluation methods making the process more subjective.

The Recommendations

Following the presentation of the findings the service company engineer made recommendations to improve zonal isolation.

- Request the cement service companies test their cement using the BHCTs calculated from the temperatures measured on offset CBLs.
- Standardize the lab testing and reporting procedures.
- Develop a spacer and scavenger program to create a density and friction pressure hierarchy, increase the annular contact time, test spacer and mud compatibility before each cement job (adjusting the spacer as needed) and leave the casing water wet ahead of the cement placement.
- Replace the lead and tail slurry design with a single slurry designed to reduce density, thickening time, free water, fluid loss, rheologies and settling. Add particulate LCM to control losses and a bonding agent to improve the bond to the casing.
- Incorporate the use of a weighted scavenger to recover behind pipe losses
- Lower the ECDs by reducing fluid densities and pump rates.
- Replace casing reciprocation with rotation if possible to eliminate surge and swab effects.
- Consistently condition mud prior to cementing to obtain the lowest density and viscosity possible while maintaining well control. Continue circulating for 1.5 – 2 hours after the mud becomes stable (no visible cuttings and "mud properties in = mud properties out")
- Do not use scratchers, wipers or turbulators due to the low frac gradients. Use may increase losses and create instability across the zones.
- Increase casing stand-off to 85-90% by installing more centralizers through the build and lateral sections
- Develop cementing and lab testing standards based on industry recognized Cementing Best Practices.
- Standardize the cased hole logging procedure.
- Avoid "cookie cutter" cement designs. Engineer the cement design for each specific wellbore and drilling fluid.

New Design and Operations

Following the presentation the operator personnel and the outside consultant agreed to implement all the changes except the reduction in pumping rate. They met with their drilling foremen and completions engineers to discuss the steps they would need to take to increase stand-off, improve mud and hole conditioning, implement consistent pipe movement programs and standardize the post job evaluation procedures. The next step for the cementing company was to design and test the new slurries and spacer/scavenger slurry systems to improve mud displacement efficiency and cement bond to the pipe and formation. Once the slurries were designed modeling was performed with actual well data to determine rates, volumes, pressures and ECDs for the new fluids. When the design and testing work was completed another presentation was made to the operator outlining the testing, modeling and proposed changes. Again, everything was accepted as presented except for the reduction in pump rates.

The Outcomes

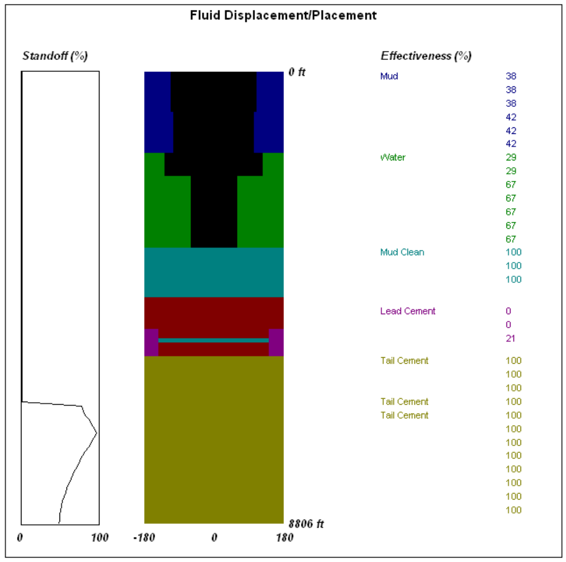
The new design was pumped in August of 2010. For the most part the job was an operational success. High displacement rates caused the well to frac and there were some losses which diminished returns and left the cement top short of design. Not fully convinced, a second job was pumped at higher displacement rates with the same results. On the third and all subsequent jobs the displacement rates were slowed and full returns were maintained throughout the job. Since implementing the changes, 17 wells have been cemented with the new design and post job results have been excellent ("best in the field"). Word of the project success has spread and other operators are adopting the approach with great results.

While the cost of cementing services doubled, the dollars spent on remediation went to zero. Likewise the operator did not have to sacrifice reserves from zones that could not be completed due to lack of zonal isolation. The increased cost of cementing has been offset by the elimination of these unplanned expenses and losses. The operator still challenges the cementing company to seek ways to economize without negatively impacting the cement performance. The cement company continues to look for new technologies that will meet the challenge.

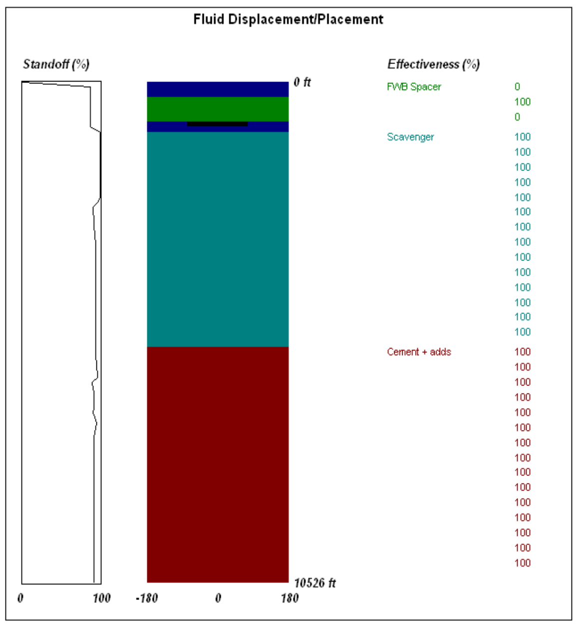
Graphics

The graphs included below are the modeling results comparing the old new and new designs. The old design models the actual jobs pumped prior to the design changes. The new design models the proposed changes including the lower rate. All of these modeling results were presented to the operator for review before instituting any new design.

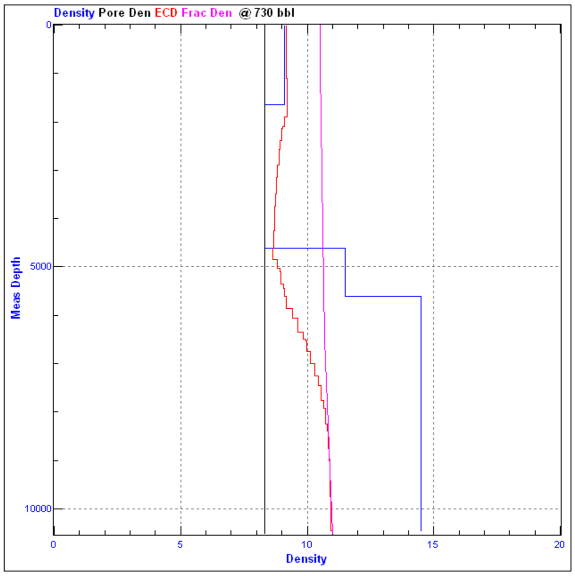
1. Mud Removal and Fluid Placement – Original Design



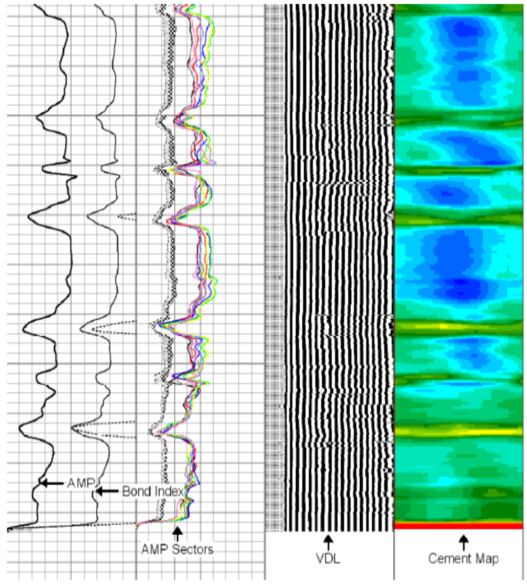
2. Mud Removal and Fluid Placement – New Design



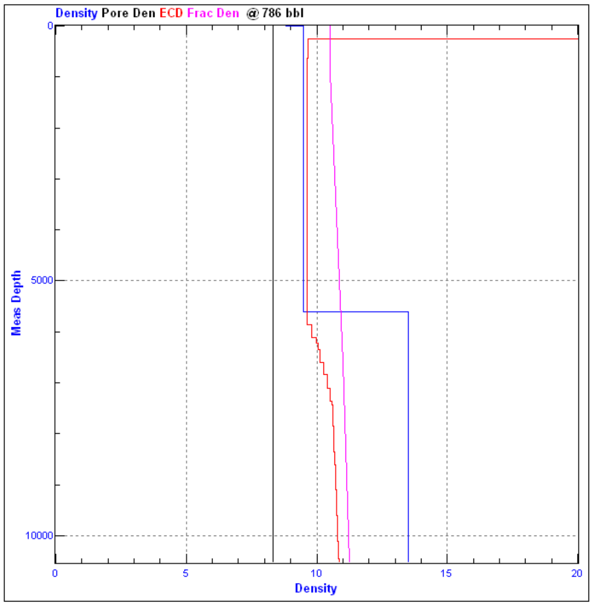
3. ECD's – Old Design



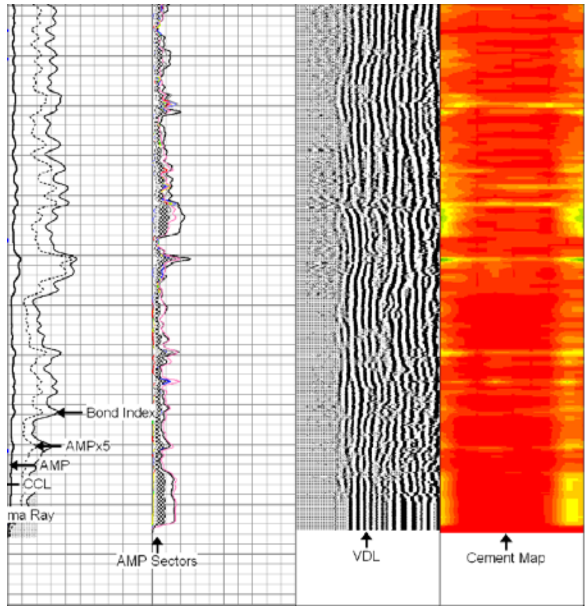
5. Post Job Evaluation – Old Design



4. ECD's – Old Design



6. Post Job Evaluation – New Design



Conclusions

It is important to control costs in development drilling projects. Failure to do so affects profitability and allocation of resources. However, the long-term effects of cost savings need to be considered. In the case of the north Texas horizontal drilling project, cuts to cementing operations appeared to be prudent based on short-term operational results. Yet when some wells developed problems due to lack of adequate zonal isolation these cost saving changes had to be reconsidered. At this point everyone stepped back and evaluated the cementing operations results and looked for practical ways to improve. The complete review and a return to following “Cementing Best Practices” resulted in success.

Acknowledgments

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Nomenclature

ECD = *Equivalent Circulating Density, ppg*
LCM = *Lost Circulation Material*
BHCT = *Bottom Hole Circulating Temperature, °F*
CBLs = *Cement Bond Logs*
OBM = *Oil Based Mud*
VDLs = *Variable Density Log*

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