AADE-18-FTCE-124

# While-Drilling 'Shield' Stabilizes Eagle Ford Wells, Eliminates Casing String

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## Abstract

Many Eagle Ford wells, particularly assets in the deeper northeast portion of the play, require mud densities higher than the fracture gradient of the overlying Wilcox sandstone. Accordingly, three-string casing designs have been required to isolate the fragile Wilcox. However, as illustrated in one two-string well design, significant gas influx encountered while drilling the lateral production section required higher-than-programmed (13.2-13.5 lb/gal) mud weight. Consequently, the operator encountered total lost circulation in the Wilcox while attempting to place a high density mud cap to assist in the over-pressured Eagle Ford. The subsequent wellbore instability caused by the lost circulation event resulted in significant non-productive time (NPT) and uncontrolled mud losses.

This paper discusses the application of a proactive wellbore shielding technology that enabled the operator to eliminate lost circulation and the NPT associated with whole mud losses and influxes, and allowed for the elimination of an intermediate casing string on subsequent wells (over 45 wells to date). The core of the technology is an ultra-low invasive additive that forms a low-permeability barrier over the pores and microfractures in mechanically weak, highly depleted formations.

The authors will explain how the technology has allowed Eagle Ford wells to be drilled total depth (TD) with mud weights greater than the maximum density predicted without the need of intermediate casing. Direct offset data analysis, including comparative NPT events, mud weights, lost volumes and tripping times, will be discussed to rationalize the average estimated savings of $500,000/well.

## Introduction

Drilling in the Eagle Ford shale presents challenges both in drilling and economics.

From an operational standpoint, controlling the Eagle Ford frequently requires mud density greater than the fracture gradient of the Wilcox formations. This typically results in the need for a three-string casing design in order to isolate the fragile zones from the higher mud densities required to control the excessive formation pressure. The need for intermediate casing significantly impacts the economics and return on investment for the operator.

## Geology of the Eagle Ford Shale and the Wilcox Sands

A number of wells drilled in the South Texas Eagle Ford play, particularly in its deeper northeastern quadrant (Karnes, Fayette, Gonzales and DeWitt counties) are often designed with three casing strings. The intermediate casing string is designed to isolate the overlying and fragile Wilcox sands. The focus of this paper covers one operator's experience on two different pads in DeWitt County.

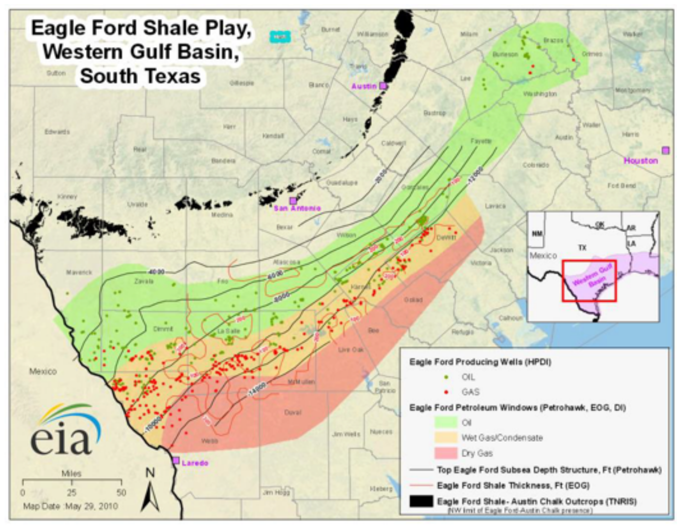



*Figure 1: Eagle Ford Shale Play*

According to the U.S. Geologic Survey, DeWitt County is divided by the Lower Cretaceous Shelf margin (an expanded fault zone) and a stable shelf.[1] The acreage owned by the operator included drilling through the Upper and Middle Wilcox formation, which primarily consists of sandstone, as well as the Lower Wilcox which is primarily composed of marine shale and fluvial/deltaic sands.[2] In planning upcoming wells, the operator utilizes data gathered from nearby offset wells to determine if there are opportunities to eliminate the intermediate casing string from their well design.

## The Beginning

While drilling the first well of a four well pad, an Operator's initial plan was to set protective surface casing and drill the vertical section, kick-off point, build section and horizontal section to TD without utlizing intermediate casing. This aggressive well design required the potentially fragile Upper, Middle and Lower Wilcox to remain open while drilling the horizontal production zone.

While drilling the horizontal section with a programmed mud weight of 13.0 lb/gal, significant gas influx was encountered, requiring higher than programmed mud weights. The Operator increased the mud weight to 13.2+ lb/gal when initial mud losses began in the Wilcox, followed by wellbore ballooning/breathing. Conventional lost circulation material proved ineffective in controlling losses while attempting to drill ahead. As drilling continued, larger amounts of gas were encountered indicating a need for higher mud weights. Attemps at further increasing the mud weight led to even greater wellbore instability which eventually resulted in partial wellbore collapse as well as several stuck pipe incidents.

A decision was made to attempt setting a mud cap below the Wilcox and above the Eagle Ford formations with the intention of safely tripping out of the hole. While circulating and removing the mud cap, total lost circulation was encountered leading to significant mud losses, several days of non-production time (NPT) and ultimately failing to run production casing to total depth (TD).

## Field Trials of the Wellbore 'Shield'

The Operator decided to utilize a proprietary wellbore shielding additive (WSA) on a second well of the four-well pad. As in the first well, a large amount of gas was encountered in the horizontal section. The Operator succesffully increased the mud weight to 13.8 lb/gal without seepage losses or wellbore ballooning/breathing. Though large amounts of gas were encountered, the Operator was able to cautiously and safely pull the drilling assembly out of hole (POOH) and run production casing to TD and cement with full returns.

On the third well of the four-well pad, (second well using WSA), the operator once again encountered large amounts of gas in the horizontal section, where the decision to further increase the mud weight to 14.0 lb/gal. With the increase in mud weight, the Operator successfully ran production casing to bottom with full returns.

Prior to the fourth and final well of this pad, the operator indicated they wished to push the technical limit of the WSA for their future drilling locations. The next scheduled drilling location was designed with intermediate casing due to offset wells, indicating mud weight requirments exceeded 14.0 lb/gal. The operators' intent was to test the limit of the WSA in hopes of eliminating intermediate casing on future wells. The plan was to increase the density on the fourth well to 14.5 lb/gal prior to KOP and drilling into the horizontal section. The plan would expose the Wilcox to densities greater than 14.5+ lb/gal. If lost circulation was encountered in the Wilcox, the plan was to run intermediate casing prior to drilling to TD. Additionally, the operator decided to run a Pressure While Drilling (PWD) tool to monitor the downhole pressures and actual ECD.

The vertical section was drilled as planned and the mud weight increased to 14.5 lb/gal without incident and with full returns. The horizontal section was drilled and the mud weight was measured to have increased to 14.7+ lb/gal. The gas was killed, the pipe pulled out of hole, and production casing was run, set, and cemented with full returns.

The PWD data revealed that the formation experienced ECDs of 15.3 lb/gal with occasional "spikes" recorded at 15.8 lb/gal. In previous wells, wellbore ballooning and total lost circulation occurred when the mud weight reached 13.2 to 13.5 lb/gal. This indicates that during drilling, the downhole pressure reached 2.5 to 2.6 lb/gal above fracture gradient with full returns.

The operator credits the application of the ultra-low invasion, wellbore shielding additive, with stabilizing the overlying, mechanically weak Wilcox formation, thereby, enabling the operator to run mud weights of 14.7+ lb/gal. The ability to run the higher mud weight without losses in the fragile Wilcox allowed for the elimination of an intermediate casing string (fig. 2). Historically, the mud weight required to drill the overpressured Eagle Ford exceeded the fracture gradient of the highly depleted Wilcox, requiring the extra string of casing to avoid severe losses and wellbore stability issues. [3]

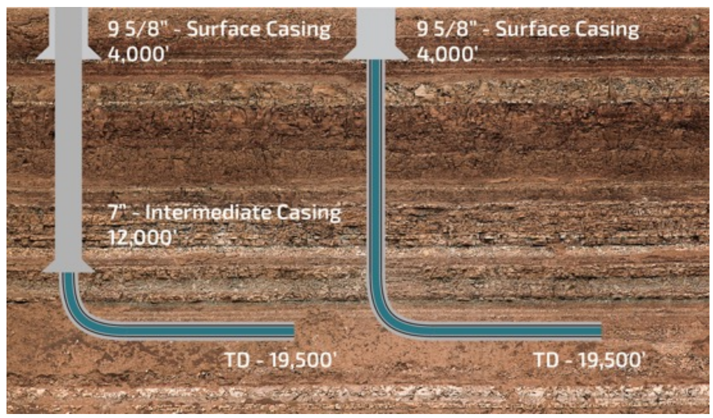



*Figure 2 This image illustrates the three-string and two-string casing package this operator uses in the Eagle Ford. The Shielding Additive is used in place of the intermediate casing on the two-string casing package (right).*

## The Push to Optimize

On a six-well pad, the Operator attempted to optimize the concentration of the WSA such that excess product consumption and cost was minimized.

On the first well of the pad, the initial mud system was treated with 4 lb/bbl WSA while drilling the vertical and build sections. A mud weight of 13.4 lb/gal was required to drill to a TD of 18,900 ft. No losses, influxes or tight hole were encountered and the Operator was able to drill the well with two casing strings, running production casing to TD and cementing with full returns in 10 days.

The second well on the pad was drilled to 12,000 ft. without adding any additional WSA, believing that the background concentration of the WSA was adequate. Losses occurred while drilling the Lower Wilcox using 13.4 lb/gal mud and the WSA was added at that time to attempt to cure the losses. The WSA is a preventative additive and is not a lost circulation material. The addition of WSA was not effective to cure losses once they were induced. The Operator then attempted to run a 7" intermediate casing string, but was not able to run the casing to the section TD and had to sidetrack the well from 4500 ft. Losses continued while drilling the sidetrack and 7" intermediate casing was run and cemented at 10,500 ft. The horizontal section was drilled to TD of 16,000 ft. with no issues. A total of 12 additional days, and 4 casing strings was required to drill the same hole interval on the second well.

The third well on the pad reverted to building the WSA concentration to 6 lb/bbl above the Wilcox formation and maintaining the concentration while drilling the curve and the horizontal section. Again, the hole was drilled with two casing strings, without losses, influxes or tight hole, and the production casing was run and cemented to TD of 18,800 ft. with 13.6 lb/gal mud.

The Operator again attempted to optimize the WSA concentration on the fourth well on the pad and did not add the shielding additive prior to drilling the Wilcox formation. The well was drilled to a TD of 19,300 ft. with minimal additions of WSA that did not maintain the critical concentration required to shield the wellbore formations. When attempting to trip out of hole at TD the hole was packing off and the mud was becoming gas cut. The mud weight was increased 0.6 lb/gal and the well became static. The production casing was run in the hole and experienced complete lost circulation. The mud weight was reduced, and the well commenced to flow. The production casing was tripped out of the well and lost circulation materials were pumped to attempt to stabilize the well. Intermediate casing was then run but became stuck at 7,800 ft. Following 25 days of attempting to cure the losses and free the stuck casing, the well was plugged and abandoned.

The fifth and sixth wells on the pad were drilled with a three-string casing design. These wells took on average 16 days to drill and case (compared to 12.5 days with the WSA) and incurred the additional cost of running intermediate casing (estimated $500,000 USD per well – per the Operator, fig. 3).

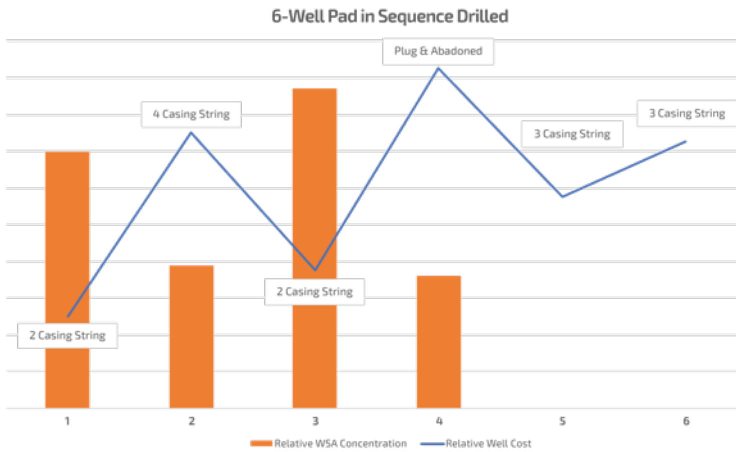



*Figure 3 This chart demonstrates the WSA concentration versus relative well cost in a six-well pad. Note when the WSA relative concentration was applied correctly, the total relative well cost significantly decreased.*

## How the Shield Stabilizes Fragile Formations

The wellbore shielding additive is a proprietary cellulosic material engineered to form a thin, deformable but strong layer, or shield when added to the drilling fluid system.[4] Once introduced into an active drilling fluid system, these particles produce an extremely low permeability barrier at the fluid-rock interface, thus delivering an equally low invasion area across a broad range of permeability and microfractures, up to 250 µm.

Specifically, when a fracture begins to develop, a low permeability seal instantly forms over the core of the fracture itself, preventing the continued invasion of fluid into the fracture and shutting down ongoing fracture propagation. (fig. 4)

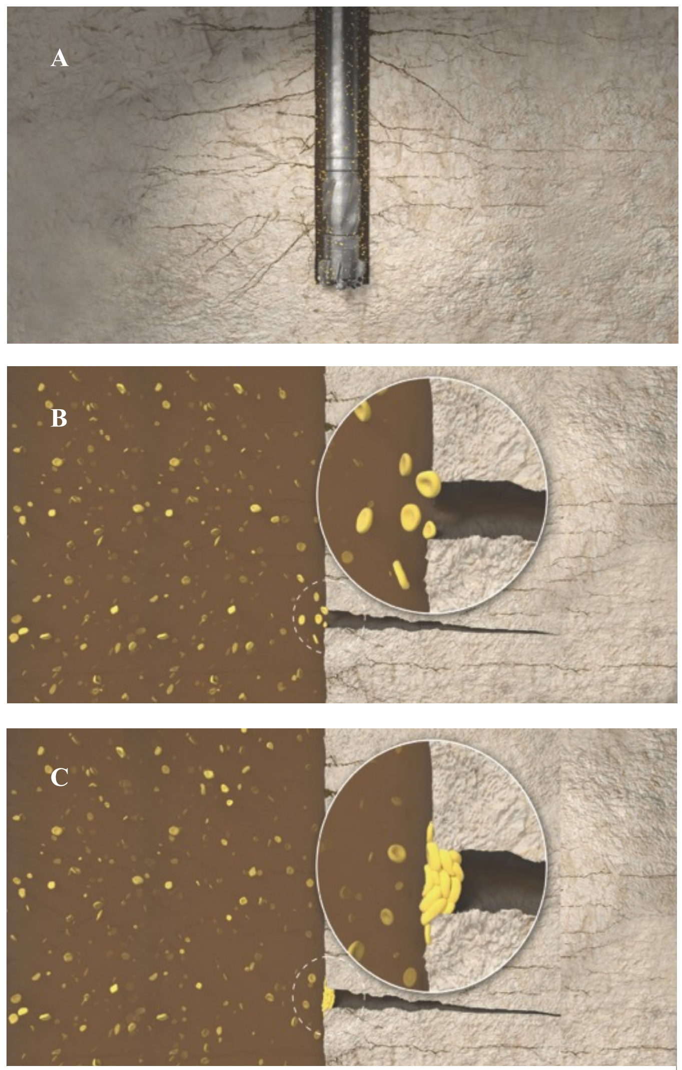



*Figure 4 (A-C) The WSA is free-flowing in the drilling fluid. When differential pressure increases, the shielding additive forms a nearly impenetrable barrier against fluid and pressure invasion.*

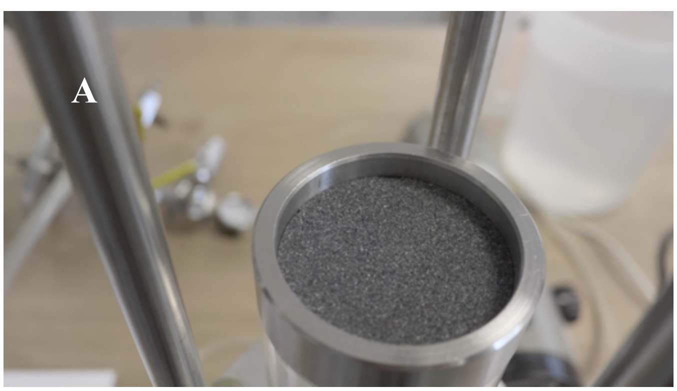
By laying down the impenetrable shield over pores and microfractures, the technology effectively restricts the transmission of destabilizing wellbore pressure to the pore fluid and reduces filtrate invasion into the matrix permeability and microfractures. This mechanism, in essence, increases the fracture initiation pressure by shielding or isolating the mud pressure in the wellbore from the surrounding geology, thus inhibiting the fracture propagation process.

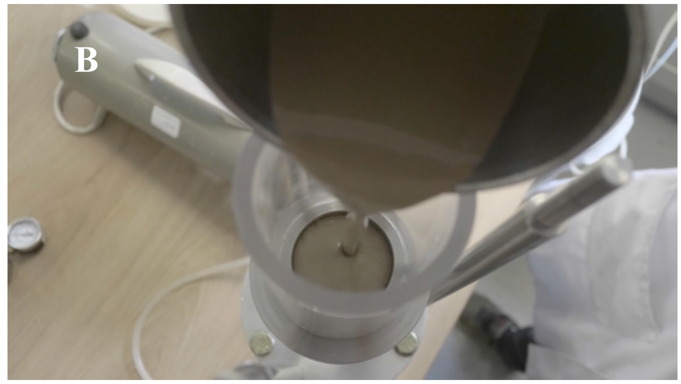
Since the resulting barrier is designed with low flow initiation pressure characteristics, in most circumstances, it is removed easily by simply flowing the well. Specifically, as the product particles deposit themselves along the wellbore, much like plates or 'shields,' and once production is initiated, the inflow of the well lifts off the plates, requiring minimal differential pressure to achieve exceptional return permeability. (fig. 5)

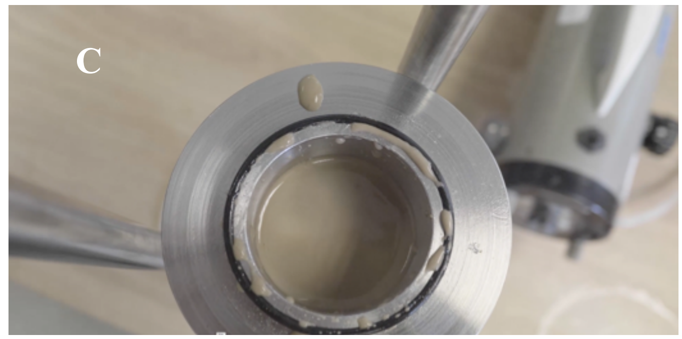
Since the unique sealing mechanism limits the transmission of wellbore pressure into the geology, the dramatic reduction of fluid influx in the microfractures minimizes the risks of formation breakdown and effectively stabilizes weak shales.

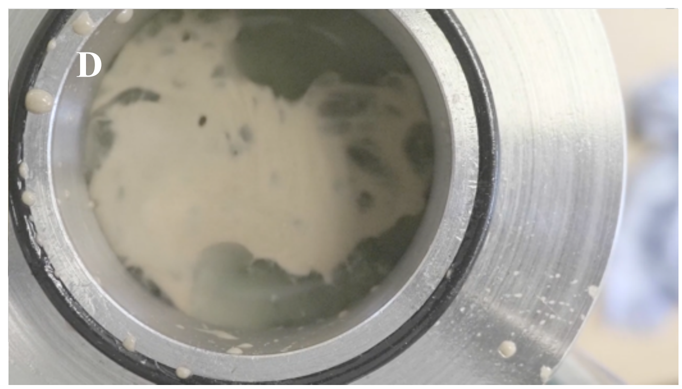
The shielding approach differs distinctly from conventional lost circulation materials (LCM) such as calcium carbonate, graphite and other wellbore sealing materials that are ineffective until the wellbore becomes destabilized, i.e., losses are occurring. The shield's proactive approach prevents the wellbore from destabilizing whereas conventional products are only reactive and must wait for the formation to adversely change and/or destabilize before the LCM can be utilized for its intended purpose.

The ultra-low-invasion barrier has proved to be effective at controlling fluid invasion at relatively low solids concentrations (6-8 lb/bbl). The shield does not adversely affect drilling fluid flow properties and thus does not contribute to elevated ECDs.

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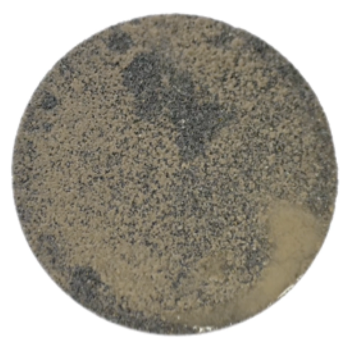

*Figure 5 (A-E) Impact Technology Center conducted a back-flow test. The initial filter cake formed on a PPA aloxite disc with the WSA in a polymer-based drilling fluid system. The fluid was pressurized for one hour at 100psi. The filter cake was produced (C). The fluid was then back-flowed for 45 minutes at 100 msl/minute (D). The last picture (E) shows the filter cake removed after the back-flow testing.*

## Conclusions

PWD tools have documented the successful drilling without losses using ECD that exceeded known fracture gradient using the low-invasion wellbore shield.

The ability to increase the ECD has enabled drilling operations to safely and successfully eliminate intermediate casing in the well design, thus improving the economics of the well.

There is a critical concentration of WSA required to shield the wellbore formations. This concentration must be in the mud system prior to drilling the fragile Wilcox formation. The shield has proven effective at supporting mud weights greater than the formation frac gradient, providing wellbore stabilization, adequate mud weights to prevent influxes and to avoid tight hole.

The WSA has been used in nearly 50 wells (to date) for this Operator with a 100% success rate in the Wilcox when applied correctly. Other operators have also used the shielding additive in the Eagle Ford with continued success. More specifically, the WSA is now used in all Eagle Ford wells as a standard operating procedure when excessive formation pressure is expected for two active operators.

Since introduction to this field in 2013, the WSA has been successfully used to prevent and stabilize the vertical fractures and mitigate lost circulation in the Upper, Middle and Lower Wilcox Sand on over 300 wells.

## Acknowledgments

Impact Fluid Solutions would like to thank the Operators that continue to use our technology in the Eagle Ford. Thank you AADE for the opportunity to present our technology.

## Nomenclature

*NPT* = *Non Productive Time*
*TD* = *Total Depth*
*PWD* = *Pressure While Drilling*
*ECD* =*Equivalent Circulating Density*
*KOP* =*Kick Off Point*
*WSA* =*Wellbore Shielding Additive*

## References

1. Warwick, P.D., 2017, Geologic assessment of undiscovered conventional oil and gas resources in the lower Paleogene Midway and Wilcox Groups, and the Carrizo Sand of the Claiborne Group, of the northern Gulf Coast region: U.S. Geological Survey Open-File Report 2017–1111, 67 p., https://doi.org/10.3133/ofr20171111
2. Patton, Kathryn, Halliburton, Walker, Luke BHP Billiton, 2015. "Eagle Ford Horizontal Drilling Optimization in Karnes and DeWitt Counties." URTeC, San Antonio, Texas. SPE-178535
3. Redden, Jim, 2016, Eagle Ford/Pearsall Shale Only The Core Survives Mounting Ror Pressure, *World Oil,* August 2016 p 58-63
4. Herdes, M, Aguilar, K, Fernandez D, Garcia, J, Moreno, J, and Maldonado, R, 2017. "Ultra-Low-Invasion Fluid Technology Increases Operational Window to Enhance Drilling, Reduce Damage in Unstable Venezuela Formations."
SPE APOGCE, Jakarta, 17-19 October 2017. SPE-18640