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Advanced Additive Shields Formation

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HOUSTON–Operators in Oklahoma are reporting increased production of both crude oil and natural gas from the SCOOP and STACK plays, which can be attributed to improved drilling efficiencies and completion designs in the Anadarko Basin. Enhanced Oklahoma production also includes wells in the play area called the Merge, which overlies and ties together the STACK and SCOOP trends in Canadian, Grady and McClain counties.

Drilling programs vary, but one constant is the challenging geology and the need to maintain wellbore stability while drilling through several fragile formations before reaching the producing interval. Two operators in the Anadarko Basin are reducing wellbore instability issues using an innovative drilling fluid technology to "shield" the formation from drilling fluid invasion. This solution generates a fast, effective temporary barrier against fluid and pressure invasion at the fluid/rock interface to prevent depleted or weak formations from leaking off or fracturing.

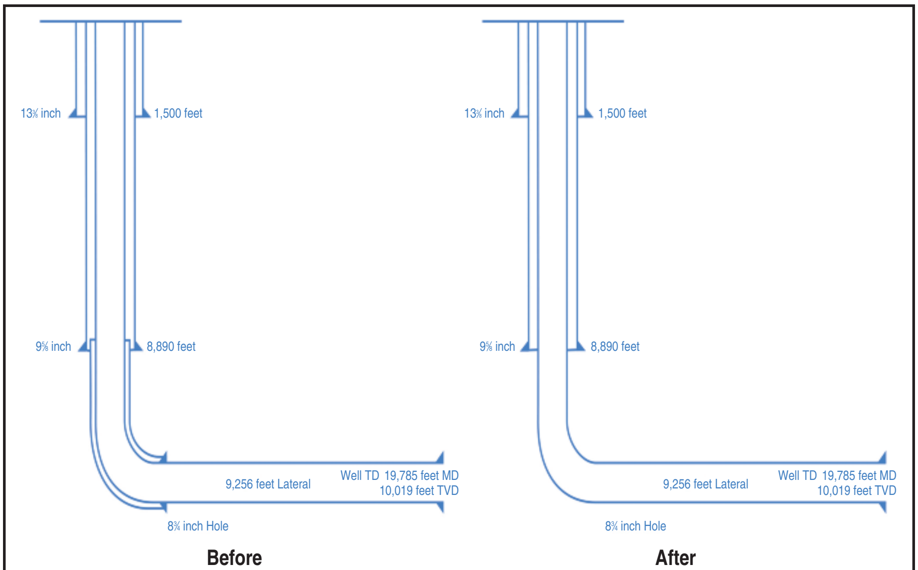
TABLE 1

STACK Well Lithology

MD	TVD	Casing/Hole Size Directional/Form Tops		Mud Type
			17½" Hole	Spud Mud
				Spud Mud
	1,500	**13⅜", 54.5#, J-55, ST&C**		
			12¼" Hole	
		Anhydrite Base		LSLD
	6,702	Tonkawa		
	7,312	Avant		
	7,399	Cottage Grove		
	7,639	Hogshooter		
	7,937	Checkerboard		
	8,007	Cleveland		
	8,279	Big Lime		
	8,375	Oswego		
	8,455	Cherokee		
	8,517	Verdigris		
	8,655	Pink Lime		
	8,842	Inola		
	8,890	**9⅝", 40#, P-1101C, BT&C**		
	9,027	Morrow	**8¾" Hole**	80/20 Diesel
	9,083	Springer		
	9,205	Chester		
	9,768	**KOP**		
10,335	9,654	Manning		
	10,047	Meramac		
10,529	**10,245**	**Target - Target**		
19,785	**10,019**	**5½", 23#. P-110 BTC-TXP**		

FIGURE 1

STACK Wellbore Diagrams Before and After Adopting Drilling Fluid Shield Technology



One of the production targets in the STACK play is the Meramac Formation below the Morrow, Springer and Chester formations. Drilling through the Morrow involves a risk for gas influx, but the Morrow is located directly above the mechanically weak Springer and Chester formations. The mud weight needed to control gas influx in the Morrow exceeds the fracture gradient of the Springer and Chester formations just below. Running the higher mud weight in the Morrow and continuing into the Springer and Chester formations at the same mud weight can lead to catastrophic drilling fluid losses. Therefore, the usual drilling plan requires running a liner prior to drilling the lateral section to mitigate the risk of fracturing the fragile formations and controlling the potential for mud losses.

STACK Case Study

One operator in Blaine County has successfully incorporated the wellbore shield drilling fluid additive in a number of STACK wells to prevent drilling fluid invasion and wellbore instability in the mechanically weak Springer and Chester formations. This technology has successfully drilled the Springer and Chester formations without requiring separate casing and liners to isolate the Morrow directly above. Table 1 shows the lithology of a STACK well in Blaine County, Ok., where these challenging formations were intersected directly below the intermediate casing shoe.

Before using the wellbore shield technology to control drilling fluid invasion, the operator had to run liners and still experienced wellbore instability before reaching the target Meramac formation. Figure 1 illustrates a typical "before" well schematic on the left. It shows the required liner when encountering a gas influx, mud losses or wellbore instability issues while drilling the vertical and curve sections below the intermediate casing point.

The "after" wellbore diagram on the right in Figure 1 depicts the elimination of the liner across the problematic formations using the wellbore shield drilling fluid technology. In this case, the operator had drilled multiple wells in the area in 2016 and encountered wellbore instability and the need to run a liner on about 10 wells. In 2017, while using the wellbore shield additive, the company was able to drill more challenging wells and ran liners on only two wells.

Cost savings while using the wellbore shield system for this operator included the cost to run the liner as well as the subsequent cement job. In addition, time in coordinating that work was saved as well as NPT directly related to wellbore instability issues such as stuck pipe and lost circulation to the depleted formations.

Merge Case Study

An operator drilling in the Merge play in southern Canadian and northern Grady counties consistently was encountering severe lost circulation (more than 3,000 barrels per well) while drilling the Tonkawa, Hogshooter and Checkerboard formations in the intermediate interval, as well drilling through the Red Fork sands and other depleted formations before setting casing in the Inola formation. Table 2 shows the lithology for a Merge well.

The "before" wellbore diagram at the left in Figure 2 shows the operator's well plan prior to adopting the wellbore shield additive. The program included a 7.0-inch casing string to cover mechanically weak formations. When previously encountering severe lost circulation, a contingency plan was in place which included running a 7.0-inch liner to cover these formations and resume drilling the lateral section with a 6⅛-inch bit.

After incorporating the wellbore shield technology, the operator reported zero mud losses, and was able to eliminate the intermediate casing string and liner planned as a contingency in case of a total lost circulation event. This allowed the company to complete wells using a monobore design without incurring any instability issues ("after" diagram in Figure 2).

The preferred drilling fluid system for both operators was an oil-based mud that displaced water-based mud from 1,500 feet to total depth. The operator in the Blaine County STACK play drilled with mud weights ranging from 13.5 to 15.2 pounds/gallon. Other properties of the OBM included plastic viscosities of 18-30 centipoise, yield points of 10-18 pounds/100 square feet, and high-temperature/high-pressure fluid losses of two-six milliliters/30 minutes. The wellbore shielding additive treatment level was three-six pounds/barrel of drilling fluid.

The operator in the Merge well referenced in Table 2 drilled with 9.0-9.2 pounds/gallon mud weights. With the lower mud weight, the required concen-

TABLE 2

Merge Well Lithology

Formation	TVD RK8	Hazards
Heenner Shale	5,287	Shale
Douglas	5,437	Washouts
Tonkawa	6,145	Sandy Shale-Gas-Loss Zone
Cottage Grove	6,955	Sandy Shale
Hogshooter	7,169	Sandy Shale-Gas Show
Checkerboard	7,285	Sandy Lime-Possible Loss
Cleveland	7,462	Sandy-Possible Loss
Oswego	7,952	Lime
Verdigris	8,131	Lime w/Sand-Sh Intervals
Skinner	8,213	Sand/Shale-Washouts
Redfork	8,291	Sand/Shale-Washouts
Inola	8,354	Lime-Washouts
Atoka	8,402	Shaly Lime
Meramec	8,444	Shaly Lime
MRMC E	8,468	Shaly Lime
MRMC D	8,503	Shaly Lime
MRMC B	8,519	Shaly Lime
MRMC B10	8,551	Shaly Lime
MRMC A	8,573	Lime
WDFD	8,641	Shaly Ohert
WDFD OHERT Base	8,680	Shale
Target	8,700	Shale
WDFD Mid	8,723	Shale
HNTN	8,758	Lime

FIGURE 2

Merge Wellbore Diagrams Before and After Adopting Drilling Fluid Shield Technology

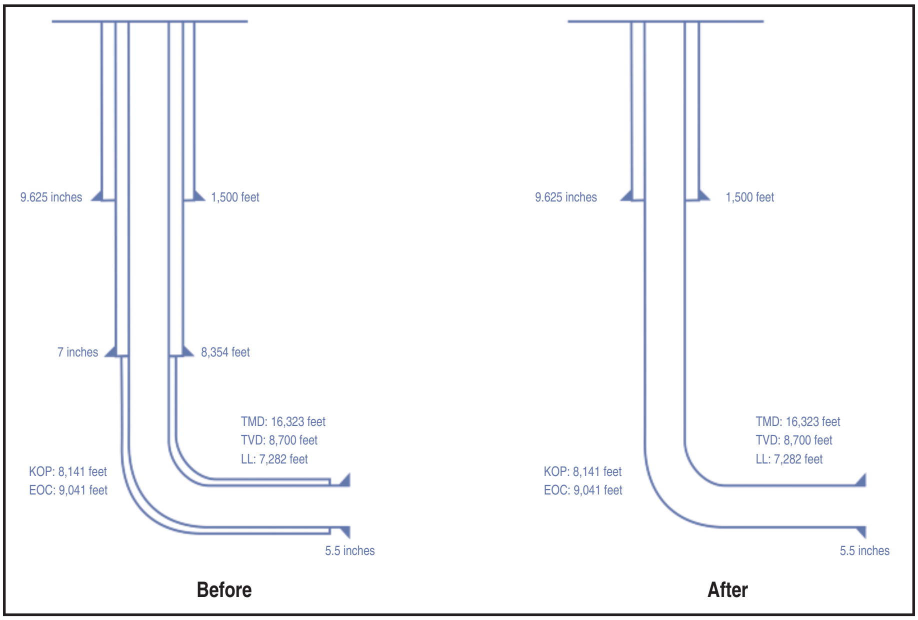
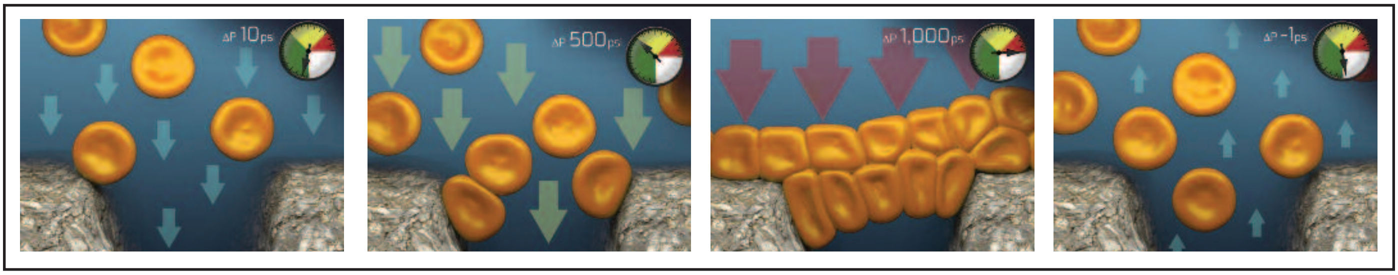


FIGURE 3

Formation of Protective Isolation Barrier (A-C) and Release of Shielding Particles (D)



tration of the wellbore shield additive was 8-10 pounds/bbl of fluid. This concentration was maintained in the drilling fluid while drilling the intermediate interval. The properties of the OBM included plastic viscosities of 10-16 cP, yield points of 9-12 pounds/100 square feet, and HTHP fluid losses of two-six mL/30 minutes.

Mechanical Shield

The technology used by both operators was a preventative "mechanical shield" that creates a temporary low-invasion barrier between the formation and the drilling fluid. The barrier protects the formation and mitigates losses, enabling unstable, mechanically weak shales to be drilled successfully. In both scenarios, the technology has mitigated wellbore instability, prevented lost circulation, and eliminated the need for intermediate casing and remedial liner jobs.

Figure 3 illustrates the formation of the wellbore shield barrier to isolate the formation from drilling fluid invasion. Note the shape of the shielding technology is not entirely spherical. Initially, the additive is mixed directly and free-floats in the drilling fluid system. As differential pressure increases, the shielding additives migrate to the areas where pore pressure is lower, allowing drilling fluid to potentially invade the formation. The shield additive particles are attracted to one another and the formation to form a protective mechanical barrier at the wellbore face, isolating the formation from the drilling fluid (first three panels in Figure 3).

As differential pressure increases, the shielding particles form a nearly impenetrable surface layer and seal microfractures (the additive is not designed for use in vugular formations where the fracture size exceeds 3,000 microns). As differential pressure is released, the shielding particles are lifted off and return to the flowing fluid, leaving the formation with essentially no permeability damage (fourth panel in Figure 3). Because the technology does not affect the chemical properties of the drilling fluid, the additives easily flow back during the production phase. Independent formation testing has been performed to validate the nondamaging nature of this type of drilling fluid technology.

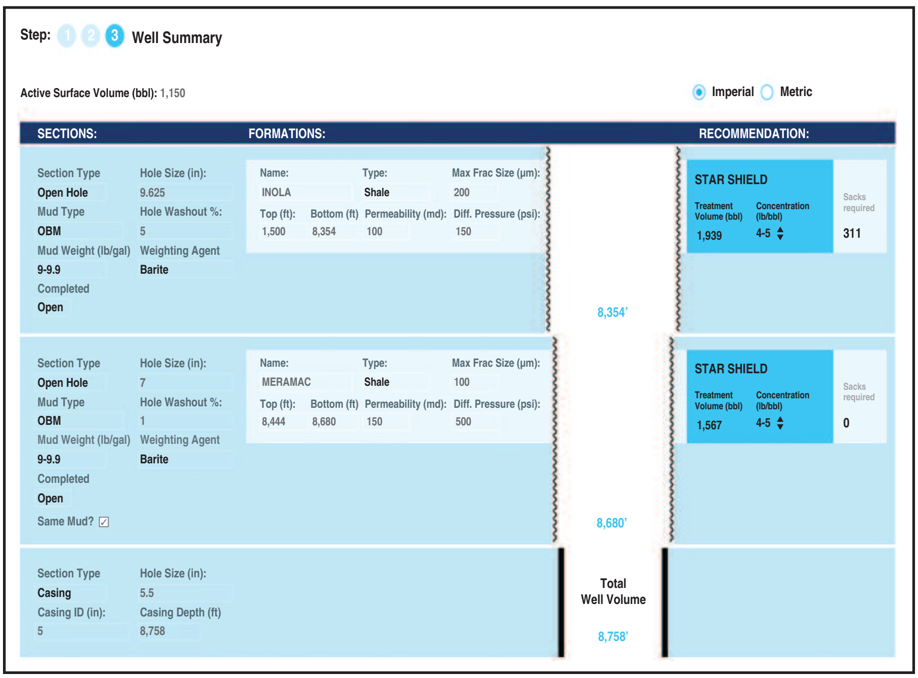
The wellbore shield drilling fluid technology uses a unique surface attraction principle, producing a thin and impermeable membrane at the face of the formation. Contrary to the conventional approach of bridging the drilling fluid, the shielding technology seals the formation by the attraction force of the particles inside the fluid, concentrating them at the surface of the rock. The benefits include effective sealing of heterogeneous permeable formations, increased leak-off pressures, wider mud weight windows, and sealing of permeable formations and microfractures in shales.

By sealing against permeable formations while drilling, the technology forms a temporary, but strong filter cake that acts as a "casing-like" shield. This results in a reduction of differential stuck pipe risks and mitigates wellbore instability caused by drilling fluid invasion.

The technology is compatible with all types of drilling fluids, including both oil- and water-based systems, to isolate the formation and mitigate wellbore instability caused by drilling fluid invasion. Ease of use during field implementation was key in the design process associated with the additive's development. The technology

FIGURE 4

Software for Calculating Concentration of Shielding Additive to Drilling Fluid



can be added directly to the circulating system at comparatively low concentrations, which translates to minimal impact on basic mud properties and less complex solids control–keeping dilution costs low and minimizing transportation and storage fees.

A software program has been developed from the additive's applications in wells in Oklahoma and other locations over the past few years. The software is designed to calculate the needed concentration of additive based on a number of data inputs, from mud weight and mud volume to section-specific measurements (Figure 4). Another relatively new development is a proprietary tool that is used in the field to monitor the technology's critical concentration in the drilling fluid throughout the operation. The field apparatus tests to ensure a seal can be formed between proppant and the drilling fluid treated with the wellbore shield additive.

The wellbore shield drilling fluid technology has proven instrumental in preventing wellbore instability when encountering mechanically weak and depleted formations in the STACK and Merge plays. Controlling fluid invasion and increasing the fracture gradient has been key to successfully eliminating the need for casing strings and liners in fragile formations, leading to more economical wells. ❒

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