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Acid Soluble Diverter Used to Free Differentially Stuck Coil Tubing

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Abstract

While drilling out frac plugs with a coil tubing unit in the Williston Basin, an operator became differentially stuck and was unable to pull the coil tubing free. This occurred because the lower zone that was exposed after drilling the previous frac plug had a significantly higher pressure than the last zone exposed, leading to cross zone flow.

The stuck pipe incident occurred around 16,000’ MD / 11,000’ TVD. Initially, conventional pipe freeing methods were attempted, including allowing pressures to equalize, but with an overpull of 25,000 pounds, the conventional attempts to free the coil tubing were unsuccessful.

At this point the decision was made to use a diverter to seal the upper, under pressured, zone. Since traditional options can impart a significant amount of formation damage that restricts production, it was important to the operator that the diverter selected was comprised of highly acid soluble materials. The acid soluble diverter contained an engineered blend of fiber, flakes, and granules with a broad particle size distribution. A 20-barrel pill was mixed containing 40 ppb of the diverter and pumped down the backside, while pressure was maintained on the coil tubing to prevent collapse. The first pill showed positive well head pressure results immediately, so three additional pills with the same concentration were pumped down the backside.

As the 4th pill arrived at the under pressured zone, a significant increase in well head pressure was identified. With 10 minutes of the increased wellhead pressure, the weight indicator indicated the pipe was free and the operator was able to pull out of the hole with no issues.

Introduction

Differentially stuck pipe while drilling out frac plugs is a potential risk that can lead to excessive downtime, pipe and equipment being left in the wellbore, and even loss of the wellbore.

Differential sticking occurs when the wellbore hydrostatic pressure is excessively higher than the formation pressure. This causes the work string to become fixed to the exposed formation. Differential sticking can be identified by the inability to reciprocate the pipe, while typically maintaining the ability to maintain fluid circulation.

Differential sticking often occurs while drilling in open wellbores and this type can have other contributing factors, such as low lubricity filter cake and excessive filter cake. Traditional pipe freeing agents typically work by removing or degrading this filter cake.

In completions operations, such as frac plug drill outs, the mechanism for pipe sticking is typically not filter cake related, due to clear fluids being utilized, making traditional pipe freeing methods non applicable. The most common approach is to lower the hydrostatic pressure of the fluid column to reduce the differential versus the lower pressured formation. Unfortunately, with extended reach drilling, other previously drilled out perforations exhibit higher wellbore pressures, which necessitate a higher fluid weight for well control than the newly exposed perforated zone will allow. Another scenario is drilling out a higher pressured zone, creating cross zone flow to a previously exposed zone.

Operational Problem

While drilling out frac plugs with a coil tubing unit in the Mountrail County, North Dakota, the 2-3/8” coil tubing became differentially stuck after drilling out a frac plug. This was due to the lower zone exposed after drilling the previous frac plug had a significantly higher pressure than the previous zone exposed, leading to cross zone flow.

The fluid being used at the time of the differential sticking of the 2-3/8” coil tubing was a 8.8 ppg clear brine. This was the minimum fluid weight required to maintain well control for previously exposed zones.

The stuck pipe incident occurred at approximately 16,000’ MD / 11,000’ TVD. Initially, conventional pipe freeing methods, such as spotting fluids and lubricant pills were applied, with no success. Lowering the fluid weight was not an option, as the hydrostatic was required to prevent influx form other exposed perforations. An attempt to allow pressures to equalize between the differentially pressured zones followed, but the zones would not equalize. Even with an overpull of up to 25,000 pounds, the conventional attempts to free the differentially stuck coil tubing were unsuccessful.

At this point the decision was made to attempt to seal the upper, under-pressured, zone with a diverter pill. The diverter selected was an acid soluble blend of fiber, flakes, and granules with a broad particle size distribution (PSD) designed to create a resilient near wellbore seal within the perforation.

Design Considerations

One of the first criteria in selecting the diverter was its ability to effectively create a near wellbore seal within the perforation. The seal had to be resilient enough to withstand the high hydrostatic and circulating pressures for the remainder of the drill out; in order to avoid potentially opening this zone up causing the work string to become differentially stuck again.

The chosen diverter had been extensively evaluated in the lab in which an apparatus was constructed to effectively simulate a proppant pack while allowing for both forward and reverse flow through it. A diagram of the apparatus can be seen in Figure 1 and the pressure responses during testing can be seen in Figure 2:

Figure 1 – Testing Apparatus Designed for Acid Soluble Diverter Development

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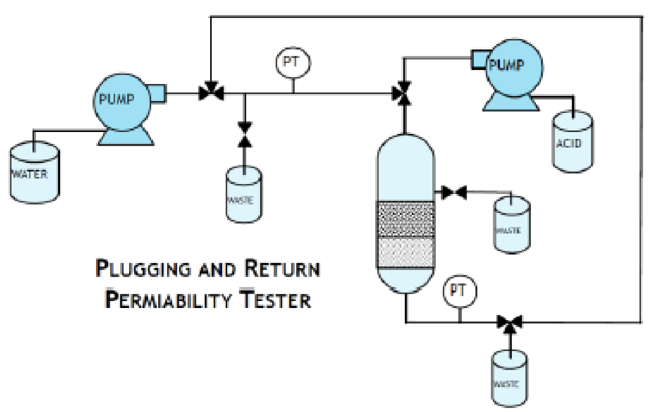

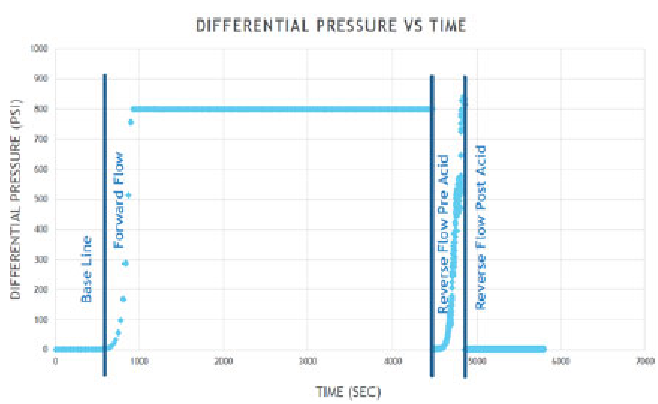

Figure 2 – Differential Pressure vs Time

In this laboratory evaluation, the diverter was used to effectively seal the simulated proppant pack and held for 1 hour with minimal fluid loss as evidenced by the steady pressure profile in Figure 2. Prior to an acid treatment, back flow through the proppant bed was not achieved showing the sealant held when exposed to both forward and reverse flow confirming that it was able to create a strong resilient seal capable of withstanding complex pressures over the course of the drill out.

Acid solubility was the second critical design point for the pill, to assure production of the perforated zone would not be affected. The wide particle size distribution and variety of materials was critical, because of uncertainty of the porosity and permeability of the formation in question. Previous testing had shown that the selected product was 91% acid soluble in both hydrochloric acid and Safe T acid.

Figure 3 – Acid Solubility

Product	15% HCl Acid Solubility	Safe T Acid Solubility
Acid Soluble Diverter	91%	91%

This acid solubility was confirmed in the testing as well. After the acid treatment, in which an acid flush was pumped across the face of the proppant bed for 30 minutes, reverse flow was achieved. Not only was reverse flow achieved, but it was in line with the base line pressure prior to any treatment; thus demonstrating a full return of permeability to the proppant bed. With these criteria met, the decision was made to proceed with the application.

Application

To begin, a 20 barrel pill was mixed with the 8.8 ppg clear brine and 40 ppb of acid soluble, broad PSD diverter. The pill was thoroughly mixed to assure homogenous blending. This pill was then pumped down the backside, while pressure was maintained on the coil tubing to prevent collapse. Upon being spotted, the diverter pill penetrated the under-pressured zone, assisted by the differential pressure from the cross flow mentioned previously. The broad PSD, shown in Figure 1, allowed the pill to seal a variety of fracture and pore sizes effectively.

The first pill spotted showed positive well head pressure increases, so 3 additional pills with the same composition were pumped down the backside and spotted across the under-pressured zone. As the two following 20 barrel pill, with 40 ppb of acid soluble, broad PSD diverter reached the under pressured zone, a further increase is well head pressure was noted.

As the 4th pill reached the under-pressured zone, the well head pressure a significant increase in well head pressure was identified. The pill was left in place, with the hydrostatic pressure of the fluid column and cross flow pressure from the higher pressured exposed zone acting as a mechanism to squeeze the product into the exposed problematic formation.

After 10 minutes of the allowing the 4th pill to be in place across the face of the exposed zone, there was a significant increase in wellhead pressure as the zone sealed off. The weight indicator indicated the pipe was no longer differentially stuck and the operator was able to pull the work string out of the hole with no issues. Operations resumed and the remaining frac plugs were drilled out and the well completed.

Conclusions

Broad PSD, acid soluble diverters can be an effective tool for combating differentially stuck pipe. This method can also be applied to non-coil tubing operations. And by transitioning to the correct lost circulation materials, could also be very effective in drilling applications.

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Nomenclature

PSD =*Particle Size Distribution*
MD =*Measured Depth*
TVD =*Total Vertical Depth*
PPG =*Pounds per Gallon*
PPB =*Pounds per Barrel*
Pill =*a specified volume slurry, usually pumped downhole and left in place at a designated place in the wellbore.*
Frac plug =temporary barriers placed in the wellbore to isolate these individual fracturing stages
Coil tubing = a long, flexible, metal pipe used in the oil and gas industry for drilling, production, and maintenance. Coil tubing is supplied on a large reel and has no joints.

References

1. Turi, Z., Hayes, B.. 2020. “Unconventional Reservoir Depletion Generates the Need for a Dissolvable Cased Hole Sealant.” AADE-22-NTCE-015, AADE National Technical Conference, Houston, April 19-20, 2022. Available from www.aade.org