



Vortex Tools: Production Enhancement in Horizontal Wells

Vortex tools are added to existing oil and gas wells to enhance production and extend the flowing life of these wells. In a 2014 case study in the Four Corners area, Vortex downhole DX-I tools, in conjunction with gas lift, saw beneficial increases in oil and gas production along with enhanced water removal.

A publicly-held oil and gas operator deployed the patented Vortex DX-I tools at the end of tubing, inside the liner, and in the horizontal lateral (typically set at 80° of deviation). In each case where Vortex tools were installed, the oil production increased significantly and, in one reported case, the oil production increased from 80 barrels of oil per day to over 400 barrels of oil per day. The utilization of the Vortex tools also permitted the tubing to be set deeper in the lateral over 200 feet on average (measured depth), thereby increasing efficiency and, in some cases, gained over 400 feet of measured depth.

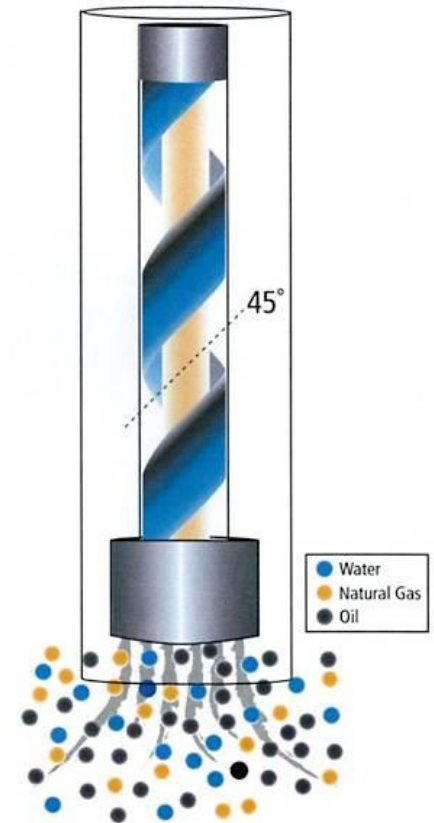
The production from this one reported well in a 10-day period exceeded 3,200 barrels of oil (or \$345,000 in production values). The Vortex tools for all five wells were paid for in less than one day.

Technology Overview

In simple terms, the Vortex tool develops a “tornado in a pipe.” This proven, patented process forces heavier liquid-bearing components to the outside of the tubing string to travel in a helical pattern. At the same time, lighter gas is pulled to the center of the spinning vortex to travel at substantially higher velocities.

By eliminating the “slip” between liquid droplets and gas, the efficiency of this vortex flow produces a reduction in the flowing tubing pressures (lower pressure drop due to friction) and a reduction in the critical rate required to lift liquids to the surface. The reduction in flowing pressures and critical rate translates to more efficient production (reduced slugging) and improved oil production, particularly in deviated wells. Vortex tools also require a lower critical velocity to continuously unload liquids from the wellbore, thereby extending the free-flowing life of a well.

This technology was the subject of an extensive study at Texas A&M University which is reported in SPE paper #84136.



Vortex in Deviated Wells

With the benefits of directional drilling, horizontal wells have become the norm in many formations. However, perfectly horizontal laterals are rare and liquids typically accumulate in the heel-toe dip and in deviations in the undulating portions of the tubing:



Toe-up lateral

Has a single liquid accumulation spot close to the deepest penetration as liquids run back down.



A 90-degree “perfect” lateral

Ideal, with no expected place for liquids to accumulate. Probably doesn’t exist.



Toe-down lateral

Has a single liquid accumulation spot farthest from kickoff.



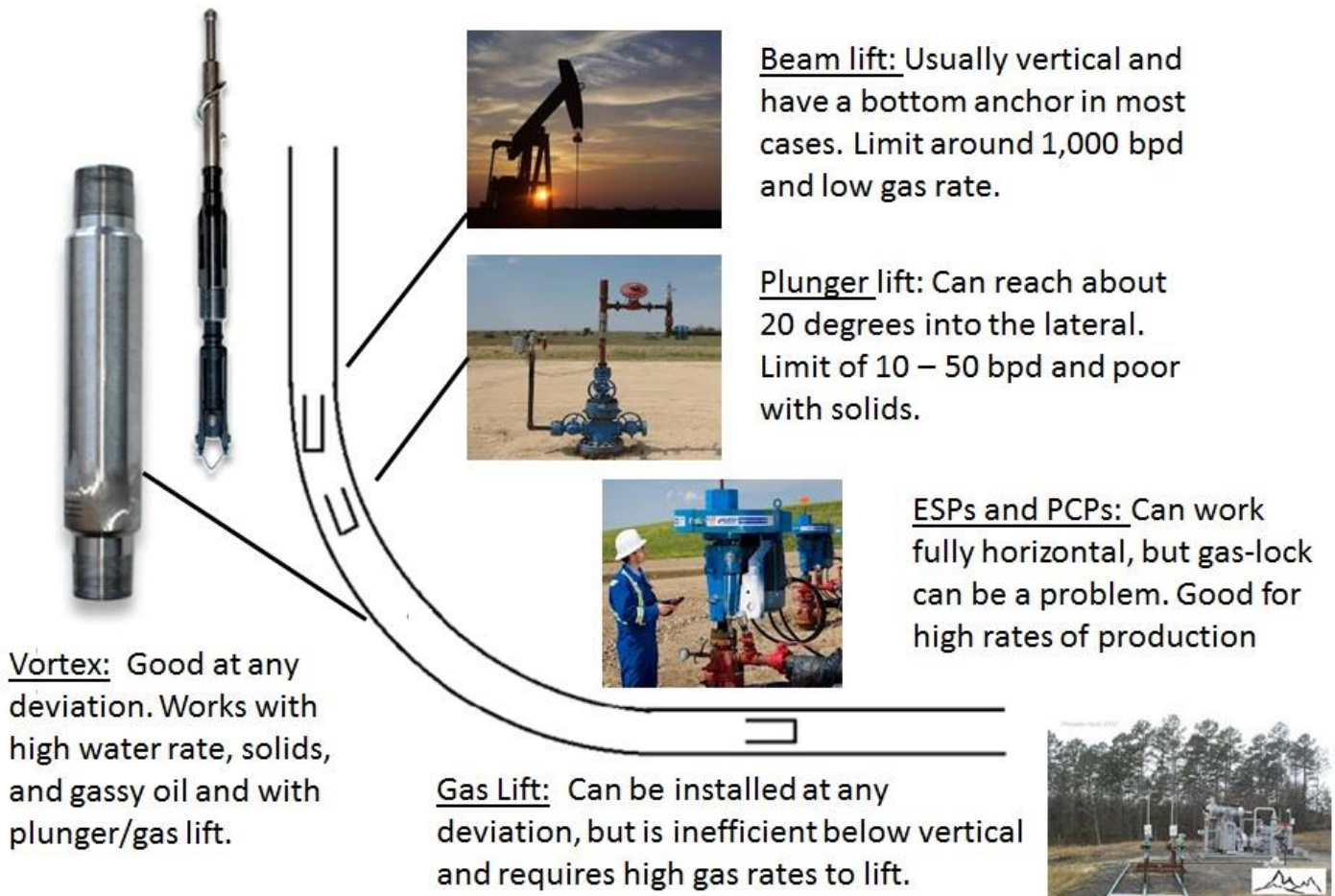
Undulating (or “porpoising”) lateral

A nightmare for operators. Has several hard-to-predict accumulation spots for liquids.

While there is a substantial bounty of increased production from directional drilling, this method of recovery also creates new load up issues as these wells decline. This is because many deliquification technologies (increasing recovery by utilizing the energy of the well) and artificial lift technologies (increasing recovery by adding an energy source) are unable to function efficiently in deviated portions of horizontal wells.

One of the obvious restrictions to using conventional lift methods to transport the oil and gas in horizontal wells is the tight turns and long laterals. There are a variety of artificial lift systems that can be used in liquids production. However, each system brings its own set of challenges when applied to horizontal wells, in part, because of the deviation angle of the well:

- While beam pumping may be the most efficient, it is also susceptible to gas locking in highly deviated wells. These pumps were developed for vertical wells and the deviated section of a horizontal well can cause problems with rod wear, gas locking, and the effects of back pressure.
- Conventional gas lift also faces challenges with horizontal wells. Gas tends to “roof” when flowing in the horizontal and bend sections of the well, thereby reducing lift efficiency. By installing a Vortex tool in the horizontal or near-horizontal section, the helix created makes gas lifting more efficient.
- This customer has also tried using plunger lift in conjunction with gas lift, but reported that plungers typically failing when they reach deviations above 20°.
- ESPs and PCPs can work fully horizontal, but have similar gas-lock problems, especially with high gas-to-liquid ratios. Both of these solutions handle dry operation or gas production poorly and must be set in a straight section of the wellbore to prevent bearing failure.
- When used in conjunction with gas lift, Vortex tools unlock the true potential of horizontal completions with shallow or deep laterals. Here is a visual comparison of where lateral solutions are placed and have the best success in the life of a well:



Deploying a Vortex DX-I tool (on the left in the previous image) at end of tubing in the lateral of a producing oil well helps organize the three-phase flow (of oil, gas, and water) while reducing bottom hole flowing pressure. Originally used to help clean out frac sand in deviated gas wells, these tools have been in continuous operation in northern Colorado gas wells (typically 4,800 feet deep) since 2006. The Vortex DX-I tool was also added to the end of tubing in several deviated gas wells in central Texas (at 7,000-9,000 feet deep, with the tool landed at 80-95° of inclination). These Texas wells saw 2-3 times greater removal in water with reduced slugging and lower flowing pressures.

Gas production also increased consistently 20-30% (with increased water removal) when Vortex was added. However, this “benefit” of increased water removal and gas production was seen against a backdrop of falling gas prices. At this time, gas prices were low enough that operators had little motivation to increase gas lift efficiency. After this, higher oil prices renewed interest in rich natural gas technology solutions. Finally, reported challenges with production deep in laterals in producing oil wells created a new opportunity to revisit the Vortex end-of-tubing tools.

Vortex Tools with Gas Lift

A major independent decided to use the Vortex DX-I tool in several of its oil and gas wells in northern New Mexico. Five wells in two different producing formations were selected for this 2014 trial.

The objective of the trial was to see if:

- Production would be enhanced by adding tubing extending into the curve section; and
- To see if adding Vortex would help move slugs of liquids accumulating in the bottom of the lowest part of the wellbore.

These were horizontal wells flowing with a combination of gas lift and a two-part plunger used to manage paraffin accumulation. The customer reported problems with the plungers’ descent, noting that they would not fall past 20-30° of deviation. There were also reports of significant liquid loading in the horizontal portion of the well, causing higher than expected tubing and casing pressures.

During a planned work-over of each well, the Vortex tool was landed at the end of tubing at various degrees of inclination in the lateral portion of the five wells. Four of the five wells had gas-lift valves installed and tubing was run deeper into the lateral, increasing the measured depth by an average of 500 feet. Vortex tools were landed at the end of tubing and set at 80° of inclination. Previously, the end of tubing was set at only 40-50° in the lateral. Finally, gas-lift valves were removed on the fifth well and this well was operated as a “poor-boy” gas lift for comparison.

Test Results

One of the five wells was discounted by the customer early in the trial due to reported problems with a hot-oil treatment some months earlier. However, the data was still gathered for comparison and is reported below.

- In the first two wells, oil production increased by an average of 58%, whereas the remaining three wells all saw a beneficial flattening of the long-term decline curve, albeit with no increase in daily production.
- The increased oil recovered from these first two wells produced an additional 8,658 barrels in the analyzed two-and-a-half-month period following the Vortex installation.

- Water removal increased by as much as 700% while flowing tubing and casing pressures reduced substantially (52% and 42% lower respectively).
- In gas-lift operations, these wells typically “recover” less gas than the gas that is “injected” to lift and produce the oil. With the addition of the Vortex tools, injection rates were reduced by up to 50%, and four out of five wells (including the well on poor-boy gas lift) moved to net recovery of gas from net injection.
- The two wells which saw the greatest increase in oil production (57.4% and 58.3%), also saw the highest increase in gas rates (76% and 95%).
- Water removal in these two wells also increased substantially (600% and 700% respectively).

Even in the well where operational problems were previously reported (following a hot-oil treatment), the well is producing more evenly and has a flattened/improved decline curve. Other longer term benefits included stable (and lower) flowing tubing/casing pressures.

Value-Added Benefits with Vortex

The following chart provides a detailed look behind the numbers for three of the wells that were the subject of this study. These wells are comparable since they are all in the same formation, with similar depths/completions (7” casing and 2 & 7/8” tubing), and were all operated with gas-lift valves:

| | Well A | Well B | Well C |
|--|------------------------------------|------------------------------------|------------------------------------|
| Operating method: | Gas Lift w/Vortex | Gas Lift w/Vortex | Gas Lift w/Vortex |
| Oil before Vortex: | 81 Bbls/day | 84 Bbls/day | 152 Bbls/day |
| Oil after Vortex: | 137 Bbls/day (+69%) | 124 Bbls/day (+48%) | 139 Bbls/day (-9%) |
| Oil Trend Line: | Actual/trended Up | Actual/trended Up | Trended Up |
| Water Removed Daily: | 36 Bbls/day (+620%) | 32 Bbls/day (+700%) | 44 Bbls/day (+57%) |
| Daily Gas Impact: | 170 Mcf/d increase | 190 Mcf/d increase | 153 Mcf/d decrease |
| Injected Gas rate: | 200 mcf/d decrease | 56 mcf/d decrease (average) | 200 mcf/d decrease |
| Net sales gas: | 675 Mcf/day average | 246 Mcf/day | 106 Mcf/day |
| % of injected gas (no Vortex) to sales: | 92% of injected gas without Vortex | 75% of injected gas without Vortex | 89% of injected gas without Vortex |
| % of injected gas (w/Vortex) to sales: | 344% of injected gas with Vortex | 155% of injected gas with Vortex | 138% of injected gas with Vortex |
| Tubing Pressures: | Reduced by 62% | Reduced by 53% | Reduced by 52% |
| Financial benefit (3 months of trial): | \$587,192 | \$461,138 | \$38,196 |

The customer noted: “All wells have been producing for over 10 days and have not lined out.”

This was well past the benefit of any flush production. They modified some of the gas-lift variables and continued to see increases across the board with Vortex.

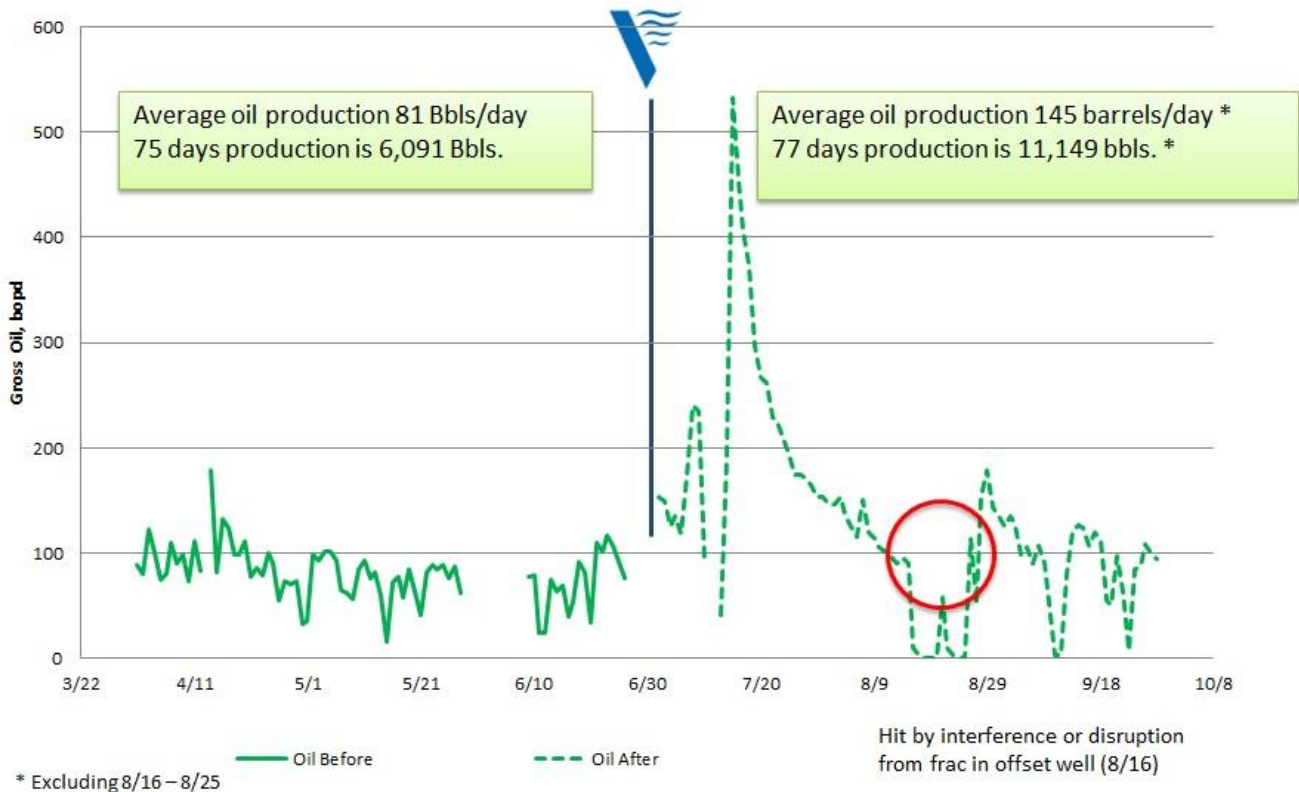
Looking specifically at Well A:

When used in conjunction with gas lift, the Vortex DX-I Tool:

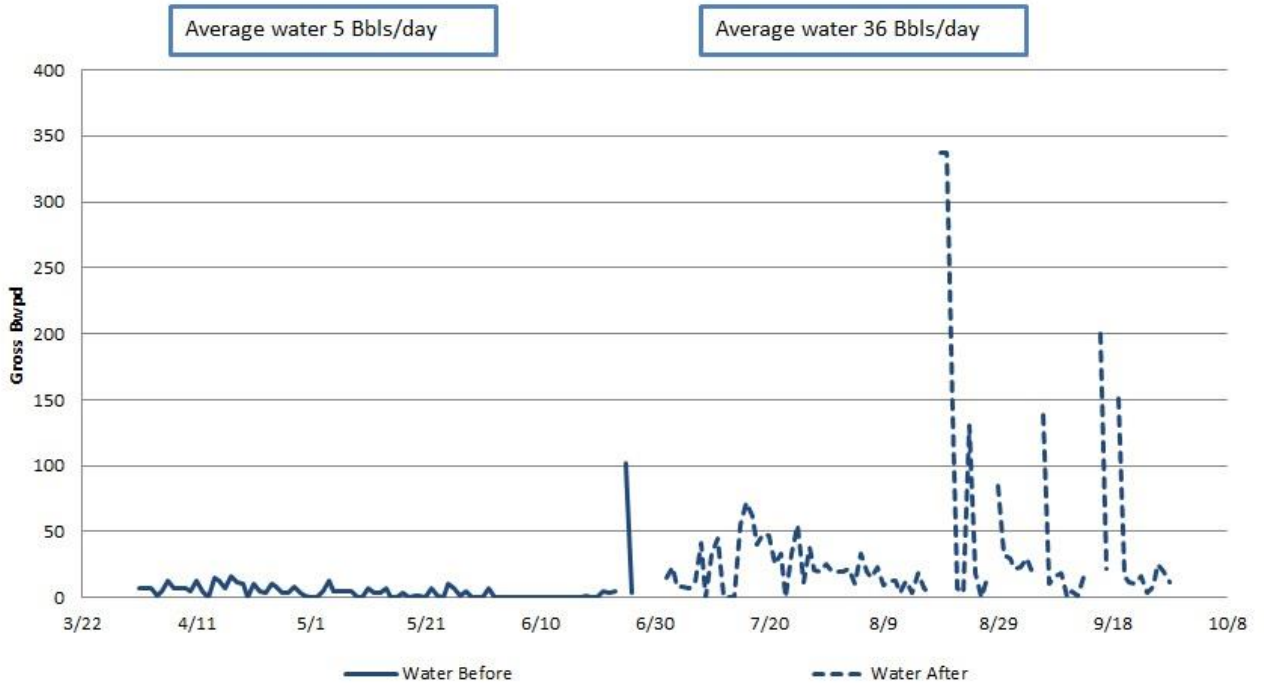
- Increased oil production (by 76%)
- Increased water removal (by 620%)
- Required less gas to be injected, yet recovered more gas to sales (by 90%)
- Reduced tubing pressures (by 52%)
- Reduced casing pressures (by 42%)
- Increased the total economic value of the well (by nearly \$600,000 in the analyzed data period)

Each of the following charts gives a visual to these improvements:

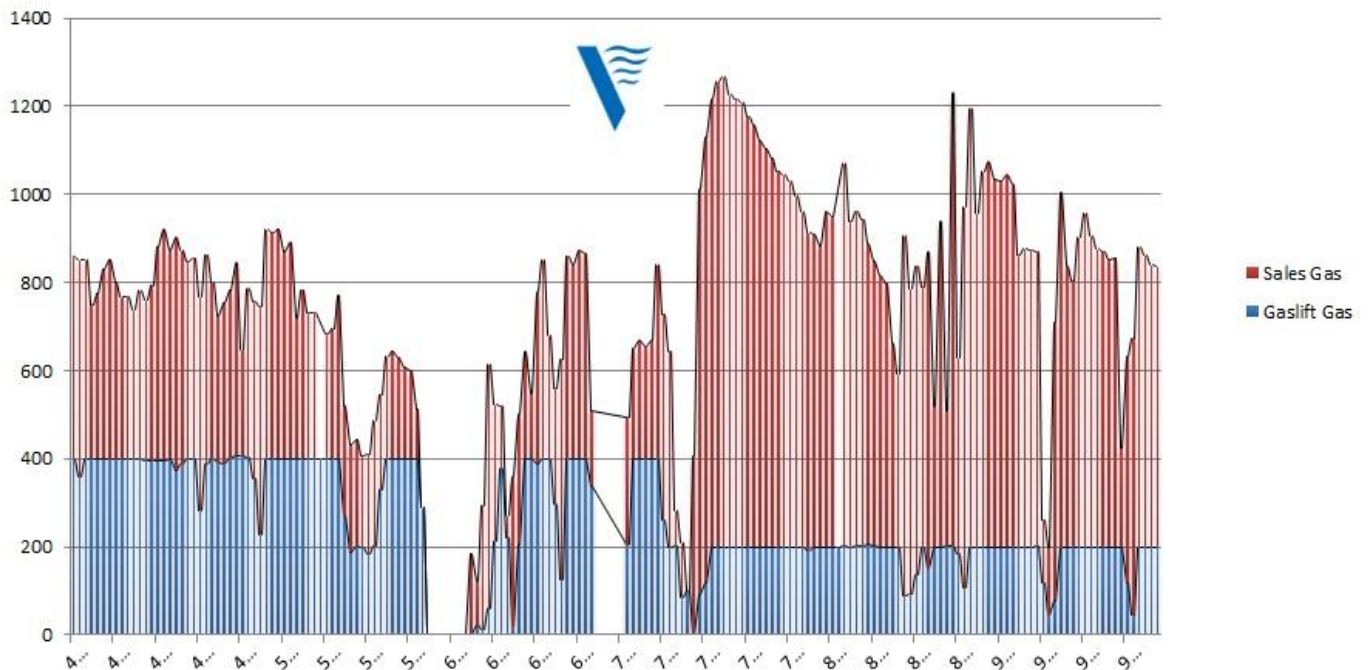
Well A: Increased Oil Production



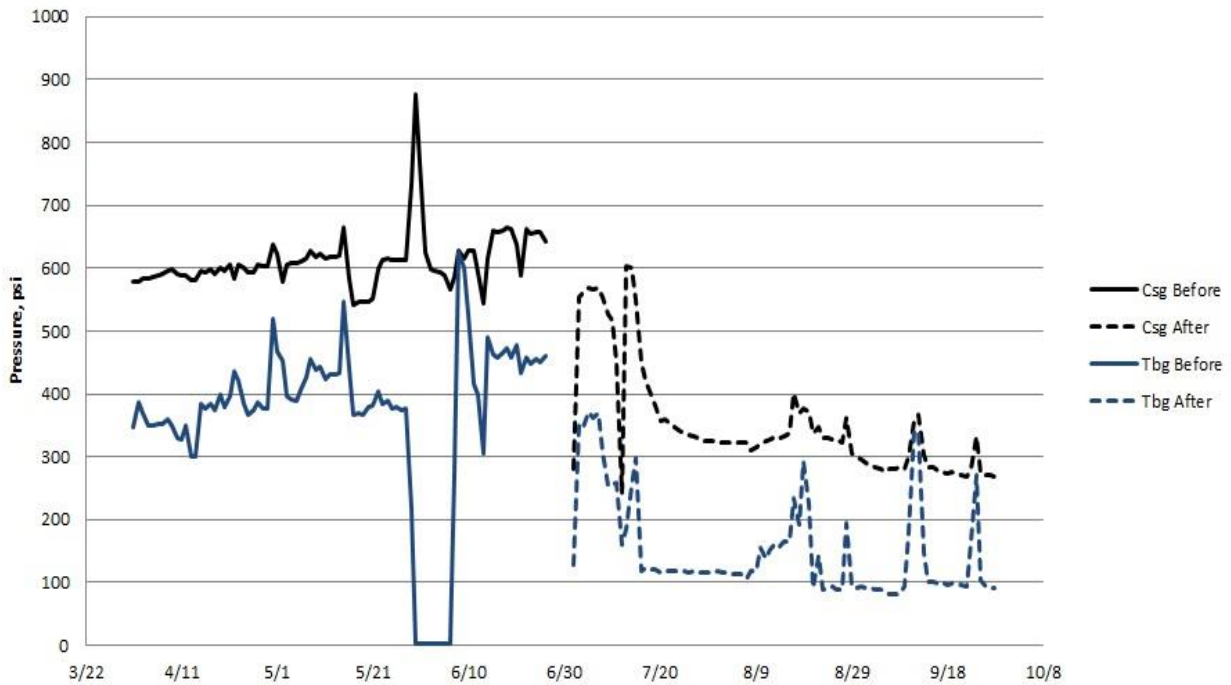
Well A: Increased Water Removal



Total Gas A: Before vs. After Vortex



Well A: Tubing/Casing Pressures



Well A: Summary Results

| | Before Vortex | After Vortex | Change |
|---|------------------------|--------------|---------------|
| Daily Oil Rate | 81 Bbls/day | 143 Bbls/day | 76% increase |
| Water Removal/day | 5 Bbls/day | 36 Bbls/day | 620% increase |
| Daily Gas to Sales | 355 Mcf/d | 674 Mcf/d | 90% increase |
| Additional Production (3 month period) | Oil | 5,144 Bbls. | \$462,960 |
| | Gas Sold | | \$83,912 |
| | Reduced Injection Rate | | \$40,320 |
| | Total Economic value | | \$587,192 |

As for the remaining two wells in the second formation, Well D:

- Produced with poor boy gas lift and Vortex.
- Oil production decreased (from 84 to 66 barrels/day), but showed an improved long-term decline curve.
- Water removal increased from 13 to 18 barrels/day (38% increase).
- Produced gas rates increased slightly from 361 mcf/d to 370 mcf/d.
- In percentage terms, gas recovery went from 90% of injected gas (before Vortex) to an average of 135% of injection gas rate recovered.
- Flowing tubing pressures remained very similar – 102 psi on average.

As mentioned previously, Well E was discounted from the trial by the customer. However, this well data was still analyzed for potential benefit with Vortex:

- Oil, gas, and water were all down marginally (although the long-term oil production curve showed improvement).
- This well continues to produce only 88% of the injected gas.
- Flowing tubing pressures reduced on average from 244 psi to 139 psi and there was a noticeable smoothing of the pressure spikes observed prior to the Vortex install.

Horizontal drilling and multistage hydraulic fracturing has unlocked vast quantities in shale plays. These same lessons learned are now being applied to unconventional tight oil plays throughout the U.S.

Summary

Vortex Tools offer a cost-efficient technology solution to the challenges of managing and optimizing liquids recovery from horizontal wells with long laterals, thereby increasing the economic value of these wells. When used in conjunction with gas lift, these Vortex tools increase oil production and water removal, reduce tubing and casing pressures, and require less gas-lift gas to be injected with more gas going to sales.

With no moving parts, requiring no maintenance, and using no chemicals, these patented and proven Vortex tools run in all tubing and casing sizes, offer well optimization benefits, and several monetizable opportunities.

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