Stripper Well Consortium
Vortex Flow, LLC Technical Progress Report
Final Report

Prepared by: Jeff Boothman
Vortex Flow
1963 Jasper Street, Unit #1
Aurora, CO 80011

Report Date: July 2004
Reporting Period: July 1, 2003 - December 31, 2004
DOE Award #: 2547-VF-DOE-1025

Report Title: **"Downhole Field Testing Grant"**

"Downhole Field Testing Grant"

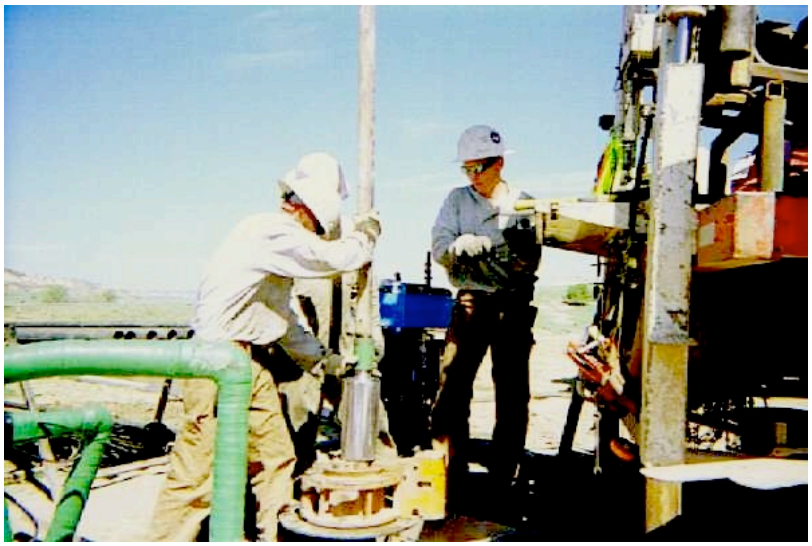
This project was a follow-up project to work completed in 2002 where several Vortex DX downhole tool designs were tested and developed. In the course of the 2002 work, a most optimum tool design was determined to be most effective in reducing pressure loss in a tubing string and in assisting in unloading wells of liquids (mostly water). The work completed in this grant period was designed to determine the effectiveness of the technology and related tool design in a field situation and as a means of replacing ESP's and PCP's as artificial lift methods and as a means of increasing production in flowing wells,. Especially those with produced water

The scope of our project was divided into two main sections:

1) To field test Vortex DX downhole tools in live field situations to determine if the technology is effective as a replacement for PCP's or ESP's in increasing produced gas and/or produced water. In other words, can wells using these production methods be converted to 24/7 "flowing" wells.
2) To determine if the tools can be used to increase production in flowing wells.
3) To review and analyze field data to prove or disprove efficacy of the technology. Also, to take collected data to determine if any prescriptive well parameters could be set in place in order to improve the success rate of installed tools.

Seven gas wells, owned and operated by Marathon Oil Company were selected for the testing. All of the wells were in located in Wyoming in the Powder River and Oregon Basins. Wells were typically low pressure (most were below 40psi at the wellhead) and all had a variety of liquid produced, either oil and water or solely water along with produced gas. Detail of the wells is included in Table 1 in the Experimental Apparatus Section.

As a result of the work from this grant, we were able to confirm that the Vortex DX tool is effective in a field setting; however, the technology cannot be used universally as a substitute for all other artificial lift methods. See the Data Reduction section for key learnings from this project.



Experimental Apparatus: All tests were completed in operating wells in Wyoming with 7" casing and 2 3/8 tubing. Test well details at the time of installation are as follows:

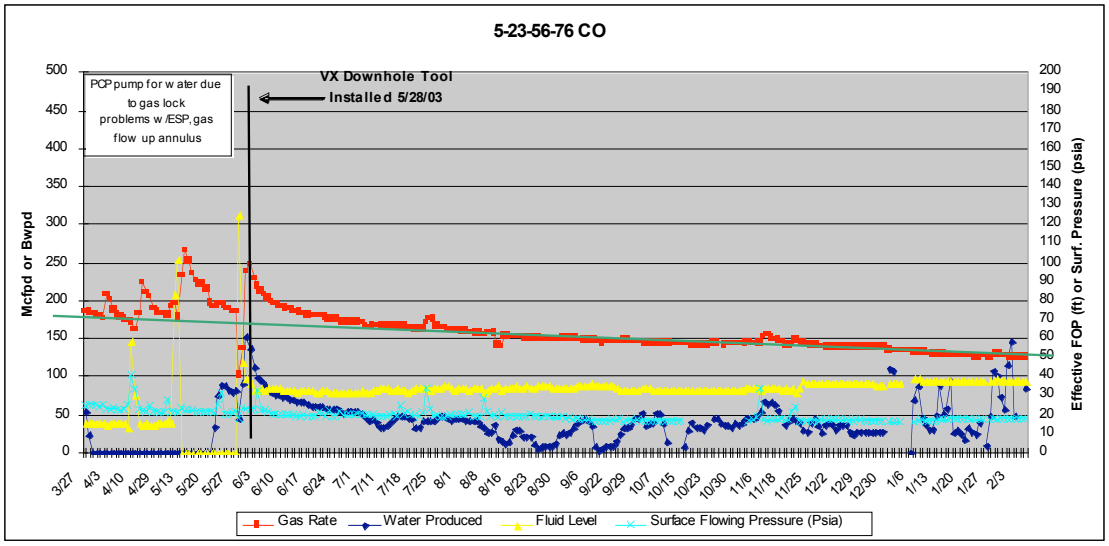
Well	Install Date	Well Depth	Casing Pressure (PSI)	Wellhead Pressure (PSI)	Gas Rate (MCFD)	Water Rate (BWD)	Basin
Oriva Hills 1-7-73 A	7/17/03	805'	30	22	60	0	Powder River
North Barker 11-3-51 A	7/11/03	860'	85	20	120	50	Powder River
West 5-23	5/29/03	623'	85	20	190	60	Powder River
Spell 12-32-A	7/24/03	562'	100	23	100	80	Powder River
Spell 8-31 -A	7/15/03	840'	115	22	0	0	Powder River
Custer 12-C	11/13/03	3,911'		75	200		Oregon
Spell 12-34	7/24/03	'550	90	See Chart Below	See Chart Below	See Chart Below	Powder River

Tests on all wells were made with standard Vortex VX tools. Tool specifications are as follows:

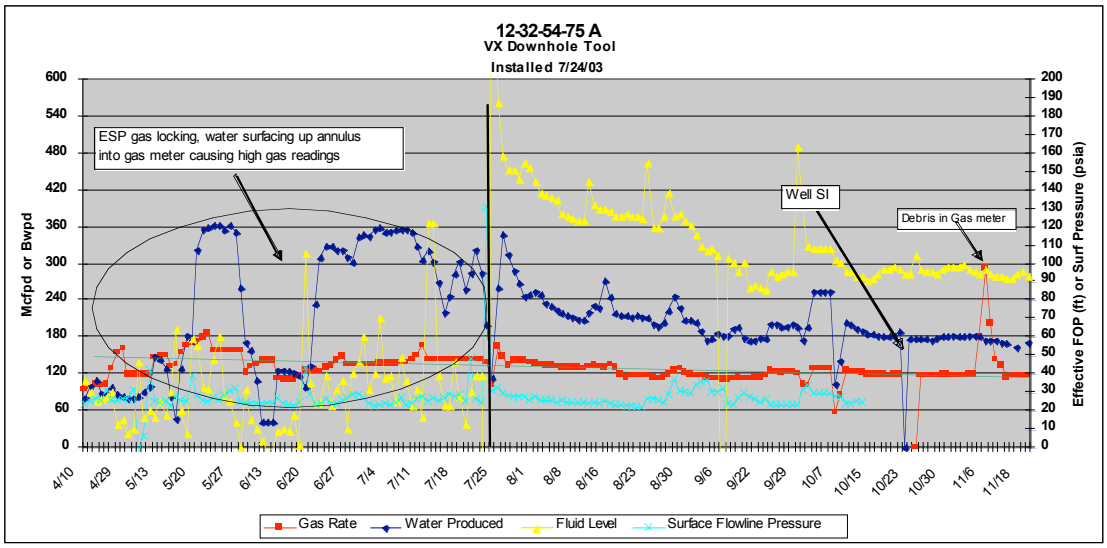
Tool size (outside diameter):	4" or 5"
Inlet Ports:	2
Inlet Chamfer:	Yes
Steel Specification:	304L Stainless
Weld Specification:	316L specification
Tubing Thread:	2 3/8"

Data Reduction:
Narrative results are given for each installation due to the extreme variability of data collected. Included is a narrative of each installation:

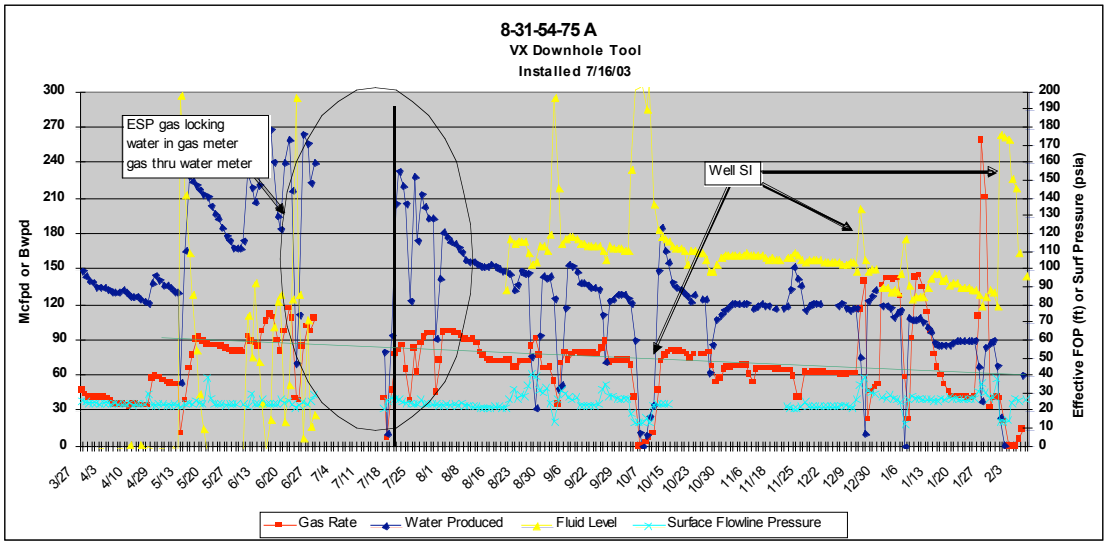
West 5-23: Prior to installation, the West 5-23 was producing 190 MCFD of gas and ~60 bd of water using a PCP pump. Production was on a rapid decline since the well was completed. The PCP pump was replaced and the Vortex VX tool was able to stabilize and maintain production at a rate similar to the pre-installation rate but on a much flatter decline curve.



Spell 12-32-A: Prior to installation, the Spell 12-32 was producing 120 MCFD of gas and ~133 b/d of water. Production for the 12 months prior to installation was erratic and ranged between 60 and 150 MCFD for gas and between 30 and 200 b/d for water using an ESP pump. The Vortex VX tool was installed on 7/24/2003 and the ESP pump removed. After installation, both gas and water rates stabilized. The water rate stabilized at ~133 b/d, the high end of the water rate range before installation. Gas rates stabilized at 120 MCFD, about 20mcfd above the previous run rate. After consistent water production for several months, the gas rate for the well then rose to ~190 MCFD**. This well was a success in that the well was converted to a flowing well, without the use of an ESP**.



Spell 8-31A: Prior to installation, the Spell 8-31 was producing water up the annulus on occasion that would reek havoc on the gas measurement as well as putting water into the gas flowline. Additionally, the water would sometimes not make it completely to surface, then fall back down the annulus and force gas into the ESP pump. This would cause the pump to gas lock and fail. After the DX tool was installed the well was able to flow consistently for a number of months. The well's non-insulated separator froze on a couple of occasions during the winter causing well downtime.



North Barker: Prior to installation the gas rate was 120 MCFD and the water rate was 20 b/d using an ESP pump. Initially, a 5" tool was installed. After installation, the gas rate fell to 80 MCFD and produced water fell to ~20 b/d. A 4" tool was installed in place of the 5" tool after about 2 month. The change did not effectively change produced gas

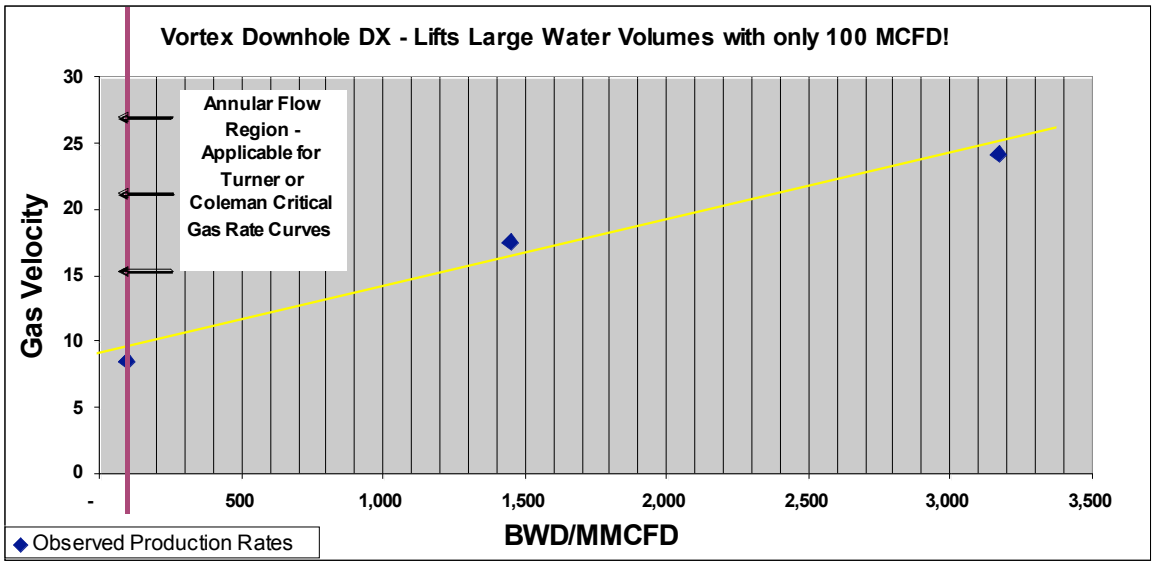
however, produced water fell to virtually 0. Although production was greatly stabilized, it appears that the post installation gas and water rates were below pre-installation levels. It did not appear as though the 85 PSI bottom-hole pressure was adequate to lift the approx 50 BWD up the 806' of tubing. This 50 BWD appeared to be the rate that the reservoir needed to produce in order for the well to stay 'unloaded'.

Oriva Hills 1: Prior to installation, the Oriva Hills 1 was flowing ~ 60 MCFD of gas and no water using an ESP. The tool was installed on 7/17/03. After installation, the gas rate stabilized at ~60 MCFD (same as pre install levels) however, over the next several months, the gas rate increased to 70 MCFD. The lack of water in this well limited the impact that a DX tool could provide. Also, the bottom hole pressure of only 30 PSI with 22 PSI of surface pressure was insufficient to lift liquid even with a DX tool in place.

Custer 12 C: This Oregon Basin well was flowing approximately 200 MCFD of gas and small amounts of both water and oil (less than 1b/d each). After the Vortex VX installation on 11/13/03, the well was able to stay remain flowing for longer intervals without logging off. The well was not able to flow 24/7. Monthly production increases of 15-20% were seen over the course of the following six months as a result of increased on-time and some field compression being put into place in 12/03.

Spell 12-34: In this well, we carried out additional experiments where we increased the flowing wellhead pressure to see how the well would be able to lift water under various pressure conditions. We were then able to plot a straight line curve correlation between gas velocity (calculated from surface pressure and gas rate) and MMCF/BW (gas to water ratio). It should also be stated that the production rates tested went far beyond the 'annular flow region' gas/water ratios that were used by Turner and Coleman when they developed the industry standard liquid lifting curves.

	Data Point 1	**Data Point 2**	**Data Point 3**
Casing Pressure	100	94	83
Surface Pressure PSIG	60	47	27
Gas Rate MCFD	53	90	100
Water Rate BWD	5	130	266
Gas Velocity ft/sec	8.5	17.5	24.2
BWD/MCFD	94	1,444	3,167



The main conclusions drawn from data reduction are as follows:

1) The Vortex DX tools can indeed be used as a replacement for PCP and ESP systems. The key variable here is the amount of bottom-hole pressure. The bottom-hole pressure needs to be at a minimum level to support the weight of the fluid column in the tubing. In the Powder River, it appears that at least 85 PSI (for a shallow well) of casing pressure is the break point to support the typical 20 – 100 BWD.
2) The Vortex DX tools will increase produced water, oil and gas in flowing wells. Lifting 266 BWD with only 100 MCFD is an impressive result!
3) The Vortex DX is cannot be used as a UNIVERSAL replacement for both PCP and ESP systems.

Hypothesis and Conclusions:

Initial Hypothesis: The Vortex Downhole tool will organize a single or multi phase flow in a tubing string. This organized flow allows for a reduction of pressure (via a reduction in the pressure lost to a disorganized flow) in the tubing string which, in turn, allows for greater reservoir optimization (higher production rates and overall recovery) and more efficient lifting of liquids.

Conclusion: The Vortex Downhole tool is effective as a means of improving production in flowing wells. The Vortex DX can be used to convert wells currently using PCP and ESP artificial lift to flowing wells.