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Hydraulic Toe Valve Specifically Designed for a Cemented Environment

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Abstract

A large majority of North American long lateral wells are cemented and thus require initial toe injection before these multi-stage wells can be completed. To increase efficiency, minimize cost and reduce risk of the toe injection, research and field trials have proven that toe injection sleeves can eliminate the need for the costly and time-consuming use of coiled tubing (CT) or tubing conveyed perforating (TCP) to initiate toe injection.

The toe initiation sleeves are run as an integral part of the shoe track and further allow the operator to pressure test casing to frac pressures prior to opening the valve. Once the casing has been surface-tested to frac pressures, additional pressure is applied to open the valve and inject into the formation.

Once activated, the valve is always open and information about the reservoir can be gathered that will influence the frac design before assembling the required pumping equipment, such as a diagnostic fracture injection test (DFIT) analysis.

Frac sleeve technologies are used for both open hole and cased hole applications. The efficiencies found in open hole applications are desirable in completions that utilize cement for annular isolation. However, unreliable toe sleeves in a cemented environment will ultimately inhibit the use of ball-activated frac sleeves in the remaining lateral.

This paper presents the field trial, testing and results of a new toe initiation sleeve designed specifically for a cemented environment. There are no moving parts on either the inside or outside of the valve. With three layers, including the patented inner piston, only the middle layer moves, differentiating it from previous tools. This particular feature allows the tool to function regardless of any residual or tail cement left in the casing. Additionally, the tool allows for higher operating pressures and temperatures than other tools.

This paper will discuss field trials in the Eagle Ford, Utica and Barnett shale plays. The tool has been tested more than 300 times and by more than a dozen operators and has shown to save anywhere from $80,000 to $120,000 per well.

Background

In the continental United States, horizontal unconventional wells typically range from 4,000-to-10,000 feet. The majority of these wells are cemented and require an initial toe injection prior to completing the well. And, in almost all cases, the wells are completed with either the “plug-and-perf” method or the “ball-activated frac sleeve” method. To better understand toe initiation, one first must understand the current completion techniques utilized today – “plug-and-perf” and “ball sleeve.”

The plug-and-perf method uses a combination of frac plugs and perforation clusters to complete the well. Once the lower most zone is hydraulically fractured, a frac plug (bridge plug) is pumped to depth and set. The zone above the frac plug is then perforated with wireline and subsequently hydraulically fractured. Completing wellbores using this technique requires an initial toe injection to pump down the first frac plug and gun set.

Historically, the initial toe injection is established with the use of tubing conveyed perforating (TCP). With TCP, perforating guns are deployed on threaded pipe or coil tubing, often times below a snubbing unit. This technique is time consuming, costly and adds a safety issue with perforating guns on surface.

The ball sleeve method utilizes ball-activated stimulation valves cemented in place along the lateral. In this case, which is similar to the open-hole scenario, individual balls are dropped to open each valve and subsequently hydraulically fracture each zone. Similar to the plug-and-perf method, an initial toe injection must be established in order to pump down the first frac ball. Failing to establish an initial toe injection typically results in all the ball-activated frac sleeves being drilled out in order for TCP to be run.

The next generation of toe sleeve technology is a sleeve that is designed specifically for a cemented environment and one in which the inherent risk of tool failure is mitigated with specific design characteristics.

The sleeve, once activated, fully opens regardless of whether or not excess cement has been left in the lateral. The sleeve remains fully open as hydrostatic pressure is constantly applying an opening force which is further secured with internal body-lock ring. The sleeve offers an alternative to costly TCP operations and allows for a DFIT prior to the mobilization of the frac fleet.

The Tool

The patented T1026 ORIO™ toe valve is a hydraulically actuated, hydrostatic-operated sliding sleeve which is run at the bottom of a cemented casing completion. And, once activated it is always open. Injection is established and subsequent treatment operations, such as plug-and-perf are facilitated. The tool is specifically designed for a cement environment and functions properly regardless of the amount of excess cement left in the casing.

Unlike previous generations of toe sleeve, this tool is designed with three layers and not two. The only part of the tool that moves is the middle layer, thus mitigating the risk of premature opening while both running in the hole or during the cementing operation.

The patented middle layer piston is protected with dual rupture disks phased 180^0 apart. Applied pressure is only required to rupture one of the disks. When one or both of the disks burst, pressure enters into the middle layer and acts to push the middle piston down into the atmospheric chamber, thus exposing the flow ports to the formation.

On previous generations of toe sleeves, the inner most piston moves within the inner diameter (ID) of the tool. This design is susceptible to both premature opening during the cementing operation and also failure if tail or residual cement is left in the low side of the casing. The new design mitigates that problem by having the three layers. With the three layers, the middle layer moves into the protected atmospheric chamber. Excess cement does not affect the tool at all.

The utilization of rupture disks allow the tool to actuate at very precise opening pressures. The pressure can be pre-set to within 2% of required actuation pressure. The surface actuation pressure is simply the disk rating minus the hydrostatic pressure in the casing at the tool. This configuration allows casing tests up to 20,000 psi prior to actuation.

Fields Trials

The ORIO toe valve has been successfully employed in almost every North American shale play, and internationally in China, Russia and Australia. The tool has been tested more than 300 times and by more than a dozen operators and has shown to save anywhere from $80,000 to $120,000 per well.

Prior to full commercialization of the tool, field trials were conducted by three separate operators in the Eagle Ford, Utica and Woodbine plays. A total of 62 wells were reviewed. The wells were horizontal, with lateral lengths ranging from 4,500-to-9,000 feet in length. The tools were run on either 4.500-in or 5.500- in casing.

In some cases, mixed strings of 5.500-in and 4.500-in casing were run. Hole sizes ranged from 6.125-to-8.750-in with the most common being 7.875-to- 8.750-in in diameter. Bottomhole temperatures ranged from 135^0-to-275^0 Fahrenheit. The cement displacement fluid was either fresh water or light brine.

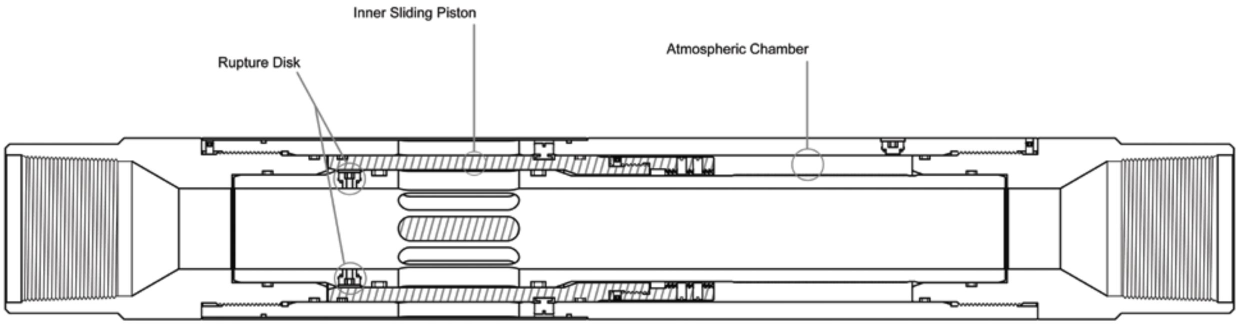
Each tool was assembled with well-specific rupture disks to allow the operator to first test the casing to anticipated frac pressures and further open the toe valve. Injection rates were then established allowing wellbore cleanup and subsequent plug-and-perf operations.

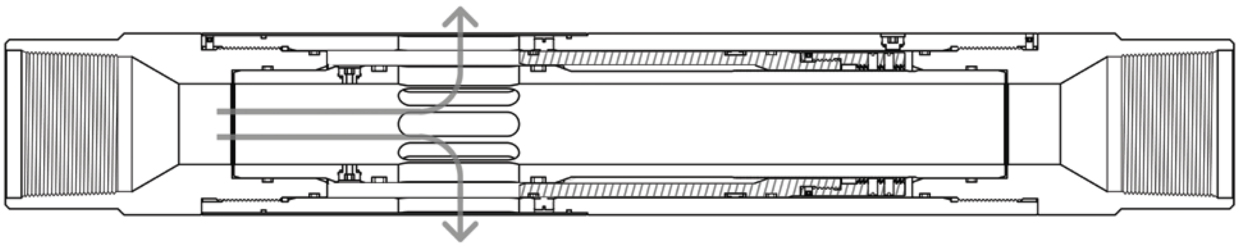
Of the 62 wells reviewed, five wells were removed from the sample because of operational issues that prohibited the toe valve from being tested. The chart below lists the data obtained. The data captured illustrates designed opening pressure, actual opening pressure and opening pressure variance. Forty-seven out of 52 tools opened, with the average opening variance for all the tools at -2 percent.

Of the five wells that did not open, three had failed cement jobs with 50-to-150 feet of cement left above the tool. It is unknown if attempts were made to open the toe valve after cement was drilled out. Removing the three wells with failed cement jobs resulted in a success rate of 50 of 52, or 96 percent.

The Utica wells were 100 percent successful with a 1.02 variance, but with one well significantly above the designed opening pressure. The Woodbine wells, which represent the smallest sample, had one tool that did not open but the others opened with an average variance of 1.01. The Eagle Ford represents the largest sample at 40. Of the 40, four tools failed to open. Of the four, three had failed cement jobs. The 36 tools that did open had an average variance of 0.97 percent.

Graphics/Tables/Figures





UTICA FIELD				
Well #	**Plug Bump**	**Designed Opening Pressure**	**Actual Opening Pressure**	**Variance**
1	Unknown	7,751	7,573	0.98
2	Unknown	7,728	7,860	1.02
3	Unknown	7,949	9,621	1.21
4	Unknown	9,503	9,244	0.97
5	Unknown	9,511	9,140	0.96
6	Unknown	9,418	9,286	0.99
7	Unknown	9,430	9,695	1.03
8	Unknown	9,527	9,850	1.03
9	Unknown	9,608	9,610	1.00
10	Unknown	9,442	9,260	0.98
			Average	**1.02**

WOODBINE FIELD				
Well #	**Plug Bump**	**Designed Opening Pressure**	**Actual Opening Pressure**	**Variance**
1	Unknown	0	Tool Did Not Open	
2	Unknown	8,643	8,460	0.98
4	Unknown	8,643	8,400	0.97
5	Unknown	8,870	9,430	1.06
6	Unknown	8,856	8,670	0.98
7	Unknown	9,001	9,400	1.04
			Average	**1.01**

EAGLE FORD				
Well #	**Plug Bump**	**Designed Opening Pressure**	**Actual Opening Pressure**	**Variance**
1	Yes	10,661	10,500	0.98
2	**No**	10,661	10,800	1.01
3	**No**	10,661	10,225	0.96
4	Yes	10,657	11,500	1.08
5	Yes	10,668	10,000	0.94
6	Yes	10,689	10,200	0.95
7	Yes	10,221	10,450	1.02
8	**No**	10,208	Did Not Open, tagged cement 103 ft above tool	
9	Yes	10,696	10,405	0.97
10	Yes	10,528	10,458	0.99
11	Yes	10,450	10,450	1.00
12	Yes	10,087	9,850	0.98
13	Yes	10,567	10,397	0.98
14	Yes	10,545	10,349	0.98
16	Yes	10,502	10,500	1.00
17	**No**	10,575	11,500	1.09
18	Yes	10,061	9,400	0.93
20	**No**	11,015	Tool Did Not Open	
21	Yes	10,474	10,050	0.96
22	Yes	10,143	9,150	0.90
24	Yes	10,219	Did Not Open, tagged cement 57 ft above tool	
25	Yes	10,443	10,000	0.96
26	Yes	10,490	Did Not Open, tagged cement 72 ft above tool	
27	**No**	10,357	9,700	0.94
28	Yes	10,550	10,000	0.95
29	Yes	10,086	9,600	0.95
30	Yes	10,179	9,450	0.93
31	Yes	10,612	10,000	0.94
33	Yes	10,676	11,300	1.06
34	Yes	10,829	9,500	0.88
35	Yes	10,633	9,985	0.94
36	Yes	10,352	9,850	0.95
37	Yes	10,176	9,450	0.93
38	Yes	10,534	10,500	1.00
39	Yes	10,466	9,200	0.88
40	Yes	10,264	10,425	1.02
			Average	**0.97**

Conclusion/Summary

Intervention-less toe initiation toe valves are utilized to increase efficiency, minimize cost and reduce risk of the initial toe injection. Research and field trials have proven that toe injection sleeves can eliminate the need for the costly and time-consuming use of coiled tubing (CT) or tubing conveyed perforating (TCP) to initiate toe injection while also allowing casing tests prior to opening the sleeves.

The new toe sleeve design incorporates patented features to mitigate the risk of failure because of excess cement or failed cement jobs. The patented middle layer piston is able to fully stroke even with excess cement left in the casing. The utilization of dual opposing rupture disks allow the tool to open at various precise opening pressures.

The data collected from three operators in the Utica, Woodbine and Eagle Ford shale plays illustrate that the average opening variance is within 2 percent. This small variance allows the operators to precisely test the casing prior to opening the sleeve.

The overall success rate of the tool provides a viable option to costly TCP, saving an estimated $80,000 to $120,000 per well.

Acknowledgments

Stephen Chauffe is an industry-recognized expert in cased and open hole completions. Chauffe holds B.S .degree in Petroleum Engineering from Texas A&M University and a MBA from The University of Houston Victoria. He has more than 19 years of domestic and international experience with Baker Hughes and TEAM Oil Tools in varying capacities, such as field engineering, operational management and product line management. He currently serves as The Director of New Technology for TEAM Oil Tools based in The Woodlands, Texas.

References

1. Johnson, C.C., Kellner, J., and Mailand, J.: "New Pressure-Actuated Valve Allows for Interventionless Access to Formation in Cemented Applications." SPE 159589, SPE Annual Technical Conference and Exhibition, San Antonio, October 8-10, 2012.