

# HydroPull™ Coil Test

Tempress Technologies, Inc.

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## Executive Summary

A test of a Tempress 1.11/16" HydroPull™ tool was completed on a 3000-m length of 1-1/2" coil at the Trican Red Deer Test facility. The tool generated cyclic water hammer pulses at a rate of up to 10 Hz and induced traction loads on the end of the coil of 700 daN at 140 lpm flow rate. The vibration induced by this tool is comparable to or greater than a competitive 2-7/8" downhole vibrator tool. The induced traction load is unique to the HydroPull™ tool. The tool was operated for 10 hours including 2 hours operation on commingled nitrogen and water without significant wear or damage to the tool or the coil connection. The pulse in the commingled flow was half the amplitude of the straight water hammer pulse but should still provide a significant benefit for extended reach coil deployment. The HydroPull™ operating pressure differential is comparable to competitive tools and can be reduced for specific applications. The tool has no practical temperature limitations.

The logo for Tempress Technologies, Inc. features the word "TEMPRESS" in a bold, italicized, green sans-serif font, followed by a registered trademark symbol (®).

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## Introduction

The oil and gas industry has been extending the lateral range of horizontal wells to improve production. Rotary drilling techniques allow wells to be drilled to over 6000 m horizontally. Coiled tubing is typically much smaller in diameter than the open wellbore and does not rotate. These factors severely limit the lateral range of coiled tubing well interventions. Existing technologies for extending coil reach include well tractors and vibrating tools. Well tractors are complex tools that are relatively expensive to operate. Downhole vibration tools are becoming an accepted method of increasing coil range<sup>1,2</sup>

The HydroPull tool, shown in Figure 1, incorporates a valve that periodically interrupts the flow to create internal water hammer pressure pulses. These pulses exert traction forces that pull the coil into the well. The cyclic pulses also vibrate the coil, reducing the contact friction between the coil and the wellbore friction.



**Figure 1. HydroPull™ tool.**

The HydroPull™ tool is designed to operate at the end of a long string of coiled tubing. Closing the valve generates a water hammer pressure pulse with a magnitude of 1.5 MPa

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<sup>1</sup> Roche, P (2008) “The Uncoiler: Downhole tool extends reach of coiled tubing in horizontal wells” *New Technology Magazine* November 35-36, [www.ntm.nickles.com](http://www.ntm.nickles.com).

<sup>2</sup> [www.andergauge.com](http://www.andergauge.com)



per m/s of the flow velocity in the coil. The pulse propagates up inside the coil at the speed of sound of water. The HydroPull™ tool generates pulses with a duration of 10 to 100 ms at a cycle rate of 5 to 10 Hz. The longer pulses have more inertia and will generate a greater impulse on the end of the coil. These pulses are tailored to overcome the inertia and friction of the coil in a long horizontal well.

## Tests on Coil

Testing was carried out using a coiled tubing unit with 3000-m of 1.50” coil. A dimple style connector was used to attach the BHA to the coil as shown in Figure 2. The HydroPull tool was suspended over a tank to capture water used in testing. Clean water was used and recycled during the test.



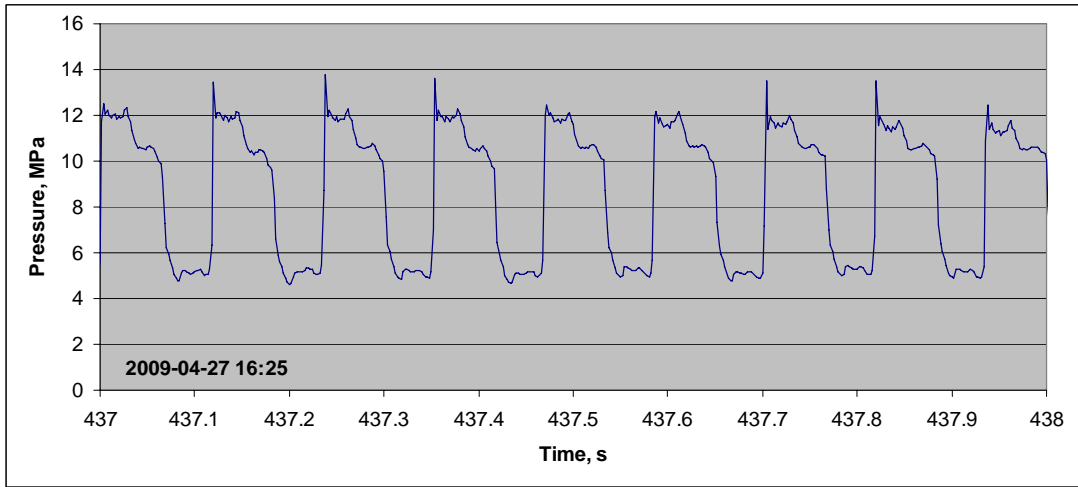
**Figure 2. Coiled tubing connection.**

## Pulse Profile

A typical pressure pulse profile is shown in Figure 3. The pulse width is .070 s and the amplitude is 7 MPa. The valve is closed approximately 60% of the time. When the valve opens, the differential pressure through the tool was 5 MPa, considerably higher than the 1.3 MPa for steady flow at 120 lpm expected from open flow testing. The high open flow differential occurs because the flow is limited to the time when the tool is open, only 43% in this case. The theoretical open pressure differential is 6.5 MPa. The flow rate when the tool is open is 280 lpm and the velocity in the coil ( $A_{ct} = 8.3 \times 10^{-4} \text{ m}^2$ ) is 5.6 m/s. The theoretical pulse height is 8 MPa compared with 7 MPa observed. The

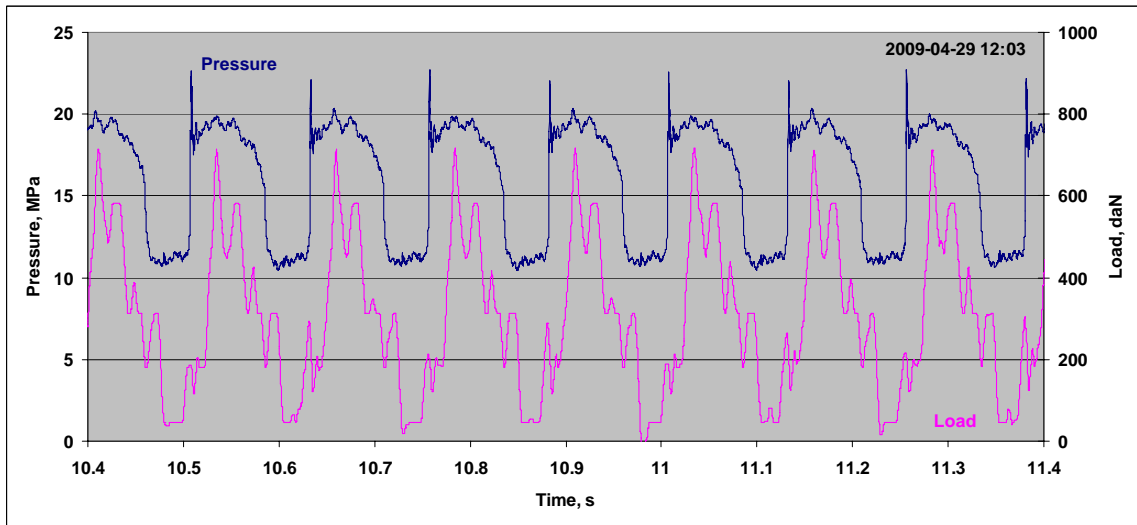


pulse width is 70 ms, which corresponds to a pulse length in water ( $c = 1460$  m/s) of 100 m or 85 kg of water hammer. The impulse energy is 2.7 kJ per blow, which is equivalent to dropping the same mass 1.6 m.



**Figure 3. HydroPull inlet pressure at 120 lpm water.**

A similar plot is shown in Figure 4 for operation at 140 lpm. This plot includes an observation of load from the injector load pin (Figure 5). The theoretical water hammer pressure differential is 10 MPa and the theoretical load is 870 daN. The observed pulse amplitude and load are about 80% of the predicted values.



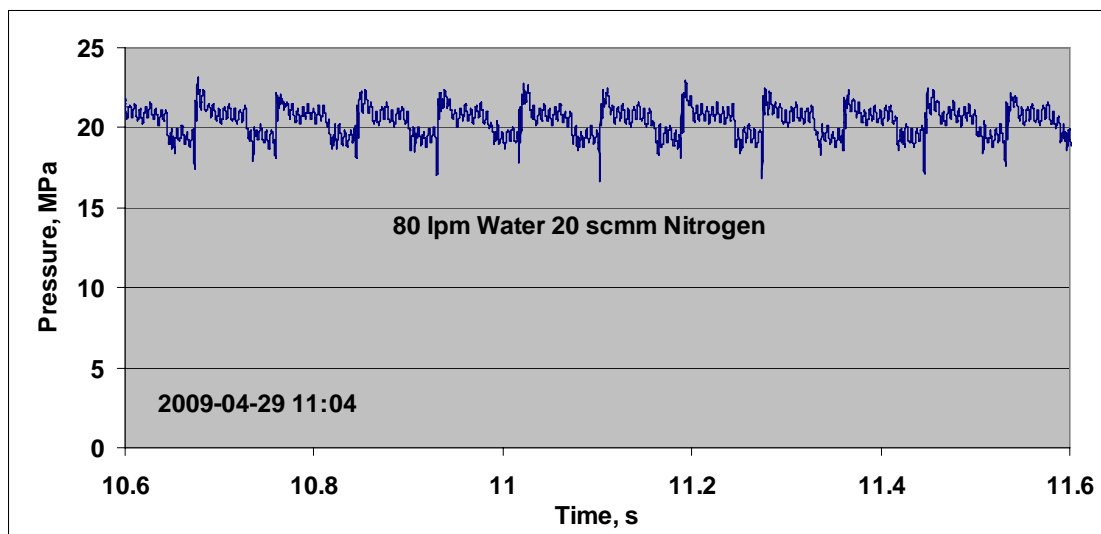
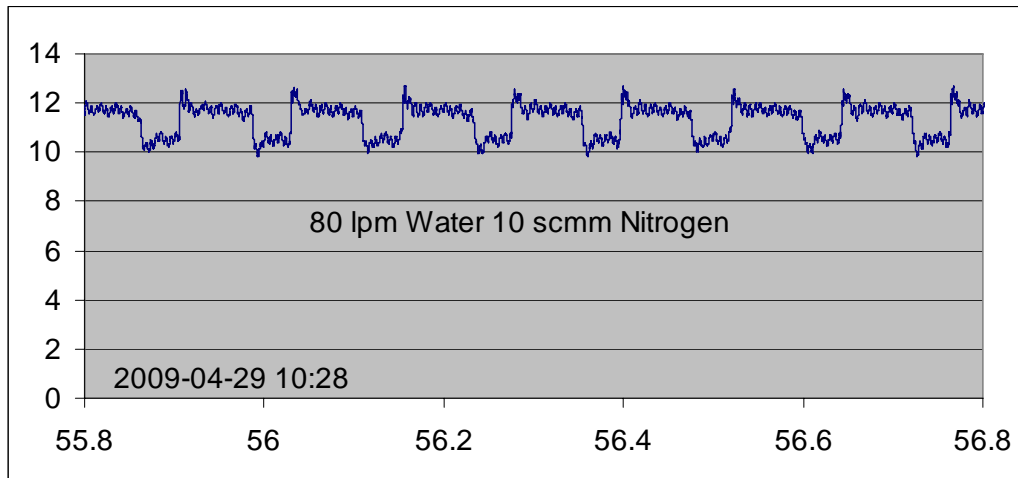
**Figure 4. Pressure and injector load at 140 lpm.**



**Figure 5. Injector load pin.**

## Nitrogen Effects

Nitrogen was added to the flow to observe the effect on pulse amplitude and tool operation. Water was pumped at 80 lpm and N2 added at 10 and 20 scmm. As the nitrogen moved through the coil, the pulse signal changed dramatically. The pulse amplitude started changing in cycles that increased in frequency until nitrogen exited the tool. At that point the pulse signal became significantly smaller. The water hammer pulse amplitude dropped to 2 MPa but the cycle rate and pressures remained the same as for the equivalent fluid flow rate. Increasing the nitrogen rate increased the cycle rate pulse pressure and average pressure. The pulse signals obtained with nitrogen at the tool are shown in Figure 6.



**Figure 6. Effect of nitrogen on pulse signal.**

The reduced pulse amplitude is consistent with increased compressibility of the commingled fluid. Operation in a well will result in higher coil pressure, reduced nitrogen compressibility and increased pulse amplitude. The tool can also be operated on slugs of straight fluid with periods of gas flow to provide high pulse amplitude to maximize deployment depth.



## Operating Characteristics Summary

The HydroPull™ operating pressures are summarized in Figure 7. The pump pressure and HydroPull™ differential pressures are fitted with a quadratic curve. The pulse amplitude is fitted to a line. The cycle rate and percentage time that the valve is closed are plotted in Figure 8. The high differential pressure and low cycle rate observed at 140 lpm may be related to residual nitrogen in the coil.

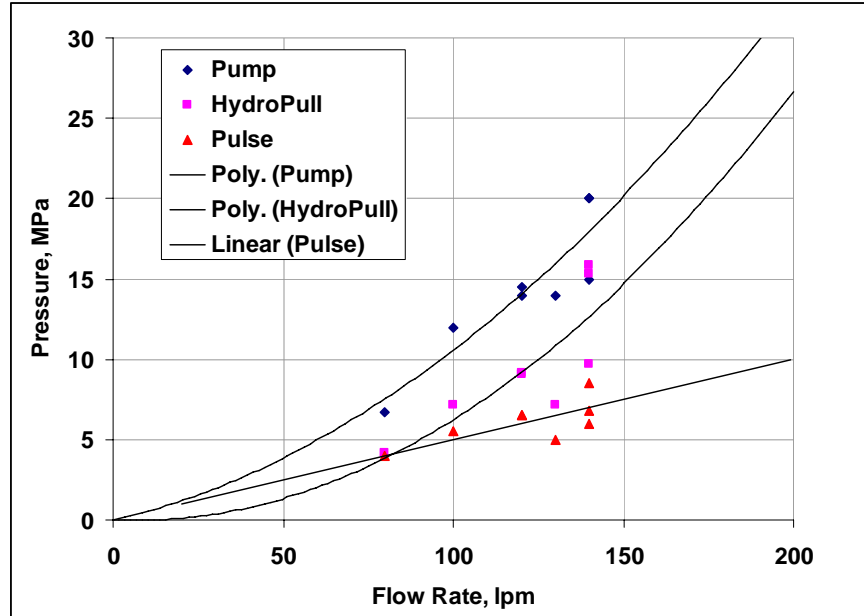


Figure 7. Operating pressures (3000 m 1-1/2" coil).

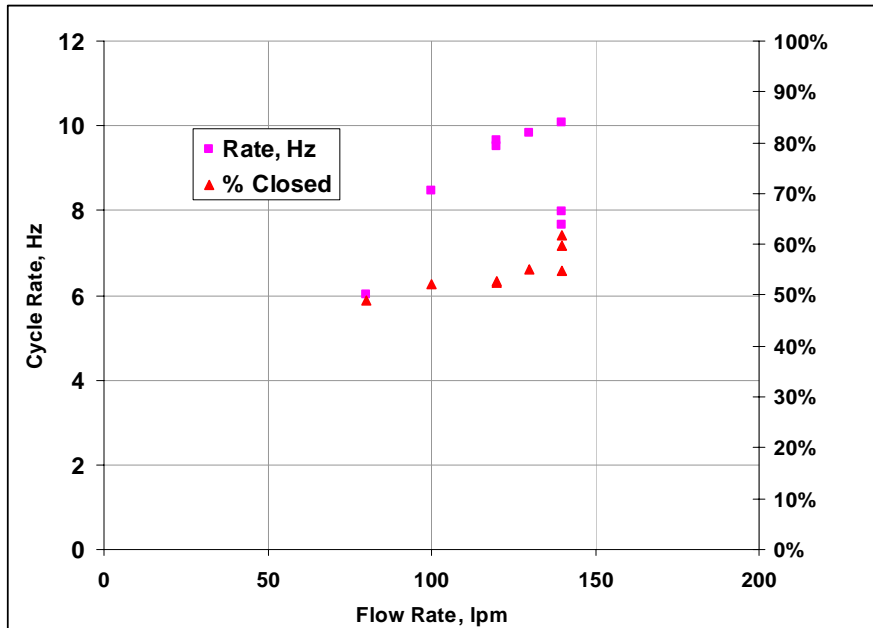


Figure 8. Cycle rate and % time the valve is closed.



The pulse width varied from .055 to .090 s as shown in Figure 9.

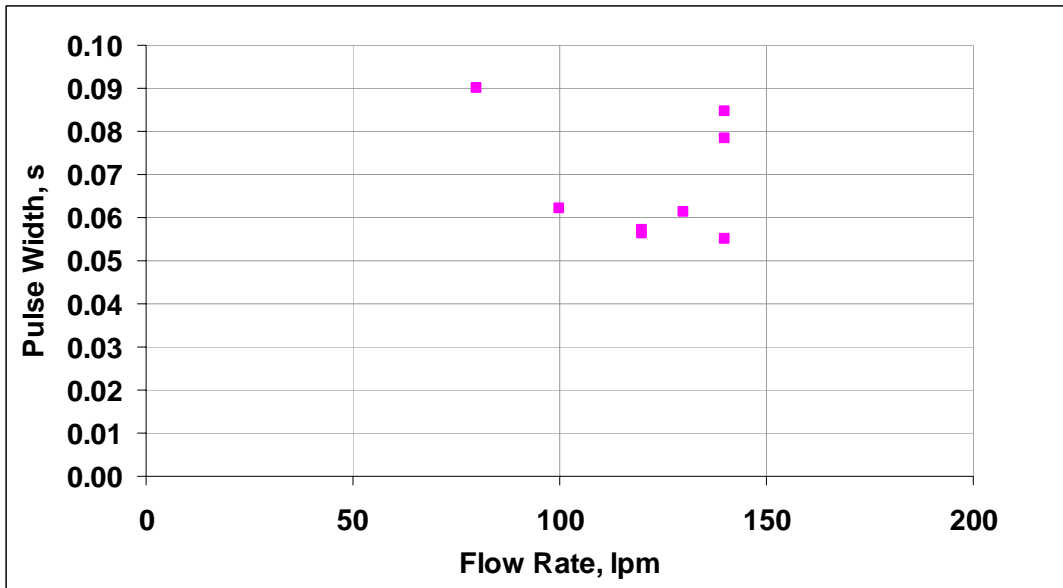


Figure 9. Pulse width

### Endurance Test

The tool was operated for 10 hours at a flow rate of 140 lpm over the course of three days. Two hours of testing on the final day included nitrogen. No leakage or damage to the coiled tubing connectors occurred. The pump pressure and flow rate profiles during three days of testing are shown in Figure 10. Testing on the first day was interrupted by sand in the coil and periodic stops to check the tool.

No change in operating characteristics was observed during the course of testing. Following the tests the tool was disassembled and inspected. No damage other than minor wear was observed on the tool.

### Conclusions

The Tempress 1-11/16” HydroPull™ tool was tested successfully on coiled tubing for sufficient time to simulate a downhole deployment. The tool generated high amplitude pressure pulses and axial pull loads on the coil at levels anticipated. No issues with mechanical performance of the coil connector or HydroPull™ were observed.

The addition of 10 to 20 scmm of nitrogen to the flow reduced the pulse amplitude by 50% and increased the cycle rate slightly. This pulse amplitude will still provide a benefit for extended reach applications.

The HydroPull™ water-hammer pulse exerts a forward pull on the coil that is unique to this tool and results from the abrupt closure of the valve. The pull force of up to 700 daN will add significantly to the reach of coil. The load amplitude generated by the 1-11/6” tool is higher than the total effect of a 2-7/8” AG-iterator tool.

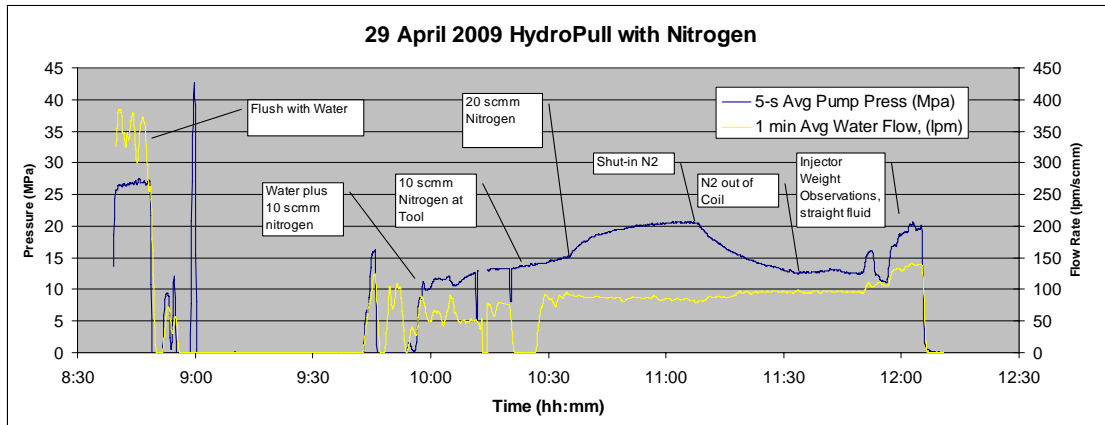
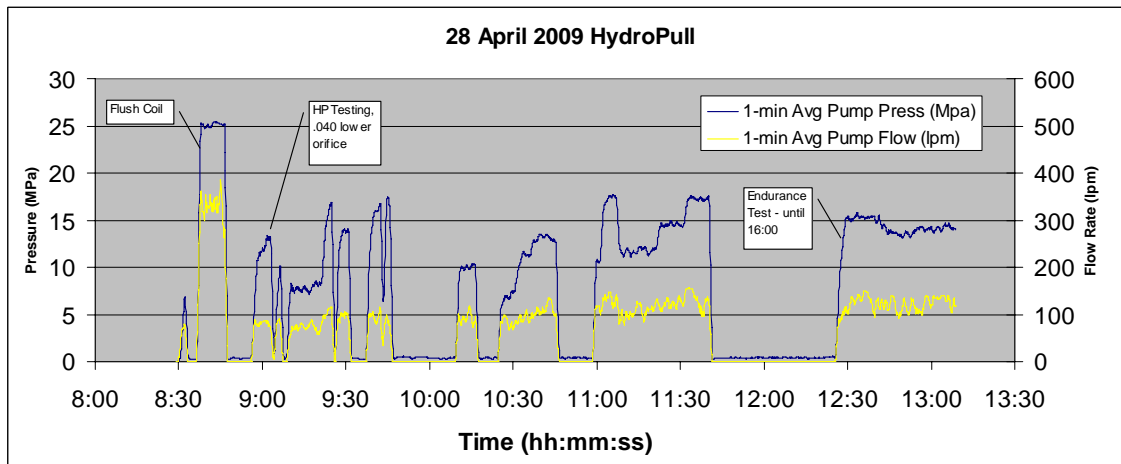
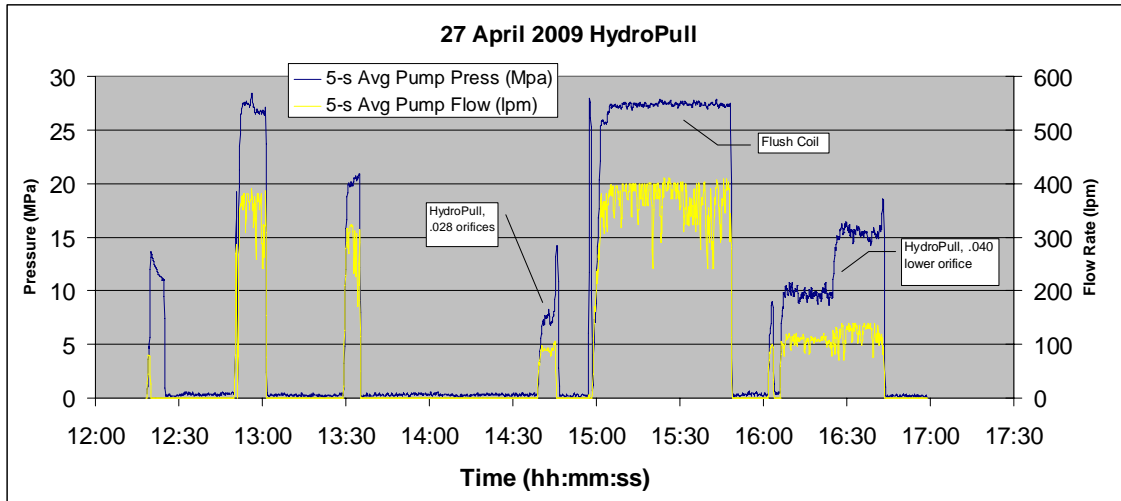


The tool generated a significant pressure differential (10 MPa) related to the fact the flow is stopped for about half the time. (This same effect is produced by the AG-imator tool at similar flow rates) When the valve opens, the flow is double the pump flow rate. The tool generates an intense high-pressure fluid jet pulse when the valve opens. This jet pulse should be effective for hole cleaning and stimulation with or without a rotary jetting tool. High-pressure coil may be required for deep deployments. The tool can also be modified to tailor the pulse width and pressure drop for specific applications.

When operating on a motor the average motor speed will not change but the motor will speed up and slow down in synch with the pulsations. For motor operation with the present HydroPull configuration, the pump flow should be set at half the maximum flow capacity of the motor.



### Pump logs



**Figure 10. Pump logs; flow rate and pressure.**