Emerging Technology
The Refrac Road Map™
Focused Production Measurement

Jay Miller
Tech-Flo Consulting, LLC

ABSTRACT
There is a renewed focus on lowering the cost to drill and complete wells. To lower the costs further, the industry is going to have to revisit current completion strategies and take advantage of recent innovations in technology. This paper will revisit an evaluation method that was first used and proven to be successful in the late 90s. (1) It will go through the adaptation of that system to work in today's modern wells to obtain reliable production data. It will also discuss hurdles faced in designing and selling a new service offering into a depressed market, the strategy of teaming with other service companies to offer a complete service and finally, to introduce further advancements that are being worked on to enhance this service offering.

INTRODUCTION
Production logging without stage isolation is not a reliable way to evaluate the production of a well. Production logs are great at determining the phases of flow in horizontal or vertical wells. Determining which stage or cluster that the production is originating from is more of a challenge, if not impossible.

Fiber optic cable run in the initial completion of the well or in new services like fiber coil are great for determining where the flow is entering the wellbore, but they won't tell you how much fluid is entering the wellbore. They also won't tell you whether it is oil, gas or water. This leaves operators guessing as to what is actually happening downhole in their wells.

There is a need for a service that can accurately determine fluid entry and measure the phases of the flow in today's modern wells. The industry is actively searching for a service to provide this information.

1999
While sitting in the Chevron office in Midland, Texas, in a meeting with Andy Padilla, Engineer at Chevron, the discussion focused around methods to evaluate sections of an open hole lateral to determine where the produced fluids were entering the wellbore. In their early efforts to do so, they used straddle packers and well swabbing to produce the well. Feeling that they were not achieving sufficient drawdown in the lateral, the system was modified and they tried an ESP along with the straddle packers to produce the well.

This worked great and they were able to produce the well. They achieved consistent drawdown and very reliable results. There was an issue with this method though. To test multiple zones in the well, the ESP and packers had to be pulled, reconfigured and rerun. This proved to be too time consuming and expensive.

The focus then shifted to a new method of testing that was reliable and movable without pulling the well. One that could also produce the well to full drawdown. That tool string was configured with three inflatable packers and a hydraulic jet pump. (Figure 1) This system was mechanically successful and obtained desirable results.

A paper was written chronicling this testing and was presented at the SWPSC in 2000. (1) Despite the success of the system described above, the players involved in the initial work changed jobs and without the focus that had been applied by them, the system was only run a few times since then.

2015

In June 2015 while onboarding at a new job, the subject of the jet pump straddle testing was raised. The topic changed from being a good idea and a great way to feature a jet pump's flexibility, to how the original configuration could be modified and simplified to do focused production measurement in today's unconventional completions. Wells with multiple stages or zones provide challenges when trying to use methods like this to evaluate them. The system used in 1999 was too complicated to deploy.

Jet pumps produce the fluid into the casing annulus. To get the desired drawdown in a formation, the jet pump needs to be deployed at the deepest point possible in a well. Doing so, mixes produced the fluid from the isolated stage with produced fluid from other zones in the well making an accurate measurement impossible. For that reason, the 1999 (BHA) bottom hole assembly used 3 inflatable packers (Figure 1). This ensured that the produced fluid that entered the well bore was pumped into the vertical part of the well above the open zones. It could then be produced to the surface for measurement. To do so, contributed to the complexity in the BHA. To ensure that all of the packers inflated at the same time, ¼" tubing was connected to all three packers. Depending on the length of the lateral, the 1/4" tubing could be very long. If the lateral length is 5000', then you need 5000' of ¼" tubing to connect the upper packer to the straddle packers.

THE NEW SIMPLIFIED BHA

Advancements in downhole measuring devices have dramatically improved since 1999. Two packers could now be used rather than three to isolate the produced fluid. A miniaturized memory PLT then allowed a measurement of the produced fluid to be made downhole. (Figure 2)

The new BHA consists of a Tech-Flo Hydraulic jet pump, two Openfield PLTs, 2 TAM International External Inflate Packers and a ported sub. (Figure 2)

The jet pump is the most flexible form of artificial lift and is tailor-made for this application. They can be run in high gas rate wells as well as wells that make solids. They can also be configured to produce multiple rates without pulling the BHA to change its configuration.

Fifteen years gave us much-needed improvements in the technology for this service offering. The jet pump, in the assembly was redesigned in 2012 and has the Largest flow areas of any other pump on the market.

The Openfield PLT, hit the market commercially in 2015 and allows measurements of the produced fluids downhole. It was field tested in Argentina and does several things to simplify the BHA: (Figure 3)

1. Measures the produced fluids downhole.
2. Uses Doppler flow measurements rather than spinners.
3. Eliminates the need for the third packer since we no longer need to get the produced fluid to the surface.
4. Eliminates the need for a long ¼" tubing to connect the third packer to the straddle.

FOCUSED PRODUCTION MEASUREMENT, WHAT IS IT AND WHAT DOES IT DO?

- Utilizes the flexibility of a hydraulic jet pump to produce and stabilize the well while each zone/stage is isolated between straddle packers.
- Increases and measures a flowing well's production.
- Produces and measures a dead well's production.
- Produces a zone/stage's absolute open hole potential (Pwf =+/- 0).
- Measures 3 phase flow from isolated zones in a multistage vertical or well.
- Measures static and flowing bottom hole pressure from isolated zones to determine inflow performance.
- Measures temperature in isolated zones in a multistage well.
- Can be run in memory mode or real-time mode.

CONVEYANCE METHODS.

The system was initially designed to be run on coiled tubing or jointed pipe in 1999. In 2015 with advancement in technology, Fiber coil can be added into the mix. Fiber coil allows the tool to be run to depth and be utilized in real-time mode.

How Focused Production Measurement (FPM) works in memory mode conveyed on coiled tubing or jointed pipe.

The BHA is made up onto the coiled tubing or jointed pipe and run to the desired depth. Then the power fluid is pumped down the tubing to the jet nozzle in the jet pump. The nozzle creates back pressure that inflates the connected packers once the pressure reaches 1000 psi. The well bore fluid is produced through a perforated sub. It passes through the top packer past the PLT that is installed in a pup jt. The produced fluid is measured as it passes the PLT. The produced fluid is mixed with the power fluid and pumped into the casing where it may or may not reach the surface. The surface pump is shut down and the BHA is moved to the next zone/stage to be tested. Once all zones have been tested, the BHA is pulled to the surface to download the data that is stored on the PLT.

TECHNOLOGY ADVANCES

Mini Production Logging Tool.

In 1999, tools like the Openfield Mini PLT did not exist. In fact, they did not exist commercially until 2015. A typical PLT suite capable of measuring 3 phase flow in a well is a modular tool suite. The typical length of that suite is 12’ to 26’ and 1 11/16” OD. The MINI PLT is also a modular tool, is 34” long and 1 11/16” OD. It features 3 phase flow measurement. Doppler sensors for the flow measurement. MEMs sensors for pressure. It can store 1 million data sets and has 150 hours of continuous recording. The pressure rating is 15 KPSI. Temp rating is 302 F. The interface is plug and play USB. It does not need a separate platform, like Warrior, to download and manage the data.

Fiber Coil

Halliburton’s Fiber Coil is just gaining traction in the US market. It is a replacement for permanent fiber run in a well. Fiber coil is mainly run post frac or pre-refrac to determine where fluid is entering the lateral.

HOW FOCUSED PRODUCTION MEASUREMENT WORKS IN REAL-TIME MODE CONVEYED ON FIBER COIL.

Fiber from the FPM BHA is spliced onto the fiber at the bottom of the fiber coil. The BHA is then made up onto the fiber coil connector and run to the desired depth. Distributive Temperature Analysis (DTS) and Distributive Acoustic Analysis (DAS) are run on the fiber coil. An analysis of the DAS and DTS is performed to determine fluid entry into the well. In order to determine what the fluid is, the BHA is moved to the first zone that needs further investigation. Then power fluid is pumped down the tubing to the jet nozzle in the jet pump. The nozzle creates back pressure that inflates the connected packers once the pressure reaches 1000 PSI. The well bore fluid is produced through a perforated sub. It passes through the top packer and past the PLT that is installed in a pup jt. The produced fluid is measured as it passes the PLT. The produced fluid is mixed with the power fluid and pumped into the casing where it may or may not reach the surface. The surface pump is shut down and the BHA is moved to the next zone/stage to be tested. Once all zones have been tested, the BHA is pulled to the surface to download the data stored on the memory of the PLT.

CHALLENGES FACED GETTING EMERGING TECHNOLOGY INTO A MATURE MARKET.

- Low tolerance for mistakes and failures.
- Why change? We are making more oil & gas than the world needs.
- I can’t add more cost to my current completions.
- I am fighting to keep my job and I am not changing to anything new.

SERVICE COMPANY TEAMING

Not all services are designed by one company. Teaming with other service companies can provide a more robust and complete service offering. In order to provide the best solution to the customer, 4 service companies have teamed together for the FPM Service offering:

- Tech-Flo, LLC provided the Jet Pump
- Openfield Technology provided the MINI PLT
- TAM International provided the Inflatable Packers
- Halliburton provided the Fiber Coil

Further advances may require teaming with more service companies. One major hurdle when teaming with other companies is the not invented here issue. Companies are proud of their technology and new services that point out shortfalls tend to challenge and upset them.

FUTURE ADVANCEMENTS PLANNED

The FPM will work in 80% of the unconventional reservoirs in the world. To increase that number to 98% a few changes/advances are being worked on at the present time. They include, but are not limited to the following. The FPM will currently work at a max TEMP of 250F due to the temperature rating of the inflatable packers. Efforts are being made to increase this temp rating to 300F with inflatable packers and 350F with mechanical packers. A CCL will be available in early 2017 along with a Gamma Ray Detector. Adding a 4th phase of measurement is also a goal and should be available in mid to late 2017. The intent is to measure both the grain size and volume of the sand passing the tool.

WHERE ARE WE TODAY?

As of today, the FPM Service has not been run in a well in its current configuration. Discussions have been had with many operators and several have expressed interest in running it soon. An updated paper will be submitted once test results are available.

CONCLUSIONS

- An accurate and cost-effective method to measure fluid entry in horizontal and vertical wells is necessary to verify and optimize successful well projects.
- Jet Pumps provide an artificial lift method that is flexible, stable and effective in varying inflow rates at full drawdown conditions for selective testing.
- Inflatable packers used for selective testing applications have proven reliable and effective.
- Improvements in the design of inflatable elements have greatly increased their reliability in multiple set-testing operations.
- Advancements in technology have allowed test systems to be modified for work in today's modern wells.
- Multiple set inflatable straddle packers with jet pumps and production logging tool combinations will drastically reduce testing costs and provide more thorough testing information in both horizontal and vertical wells.
- This is emerging technology and field trials are essential to its acceptance in the industry.
- We are currently looking for field trials.

References: 1. Miller, J. and Padilla, A. 2000. SWPSC Locating and Controlling Water Production in Horizontal Wells (Permian Basin)

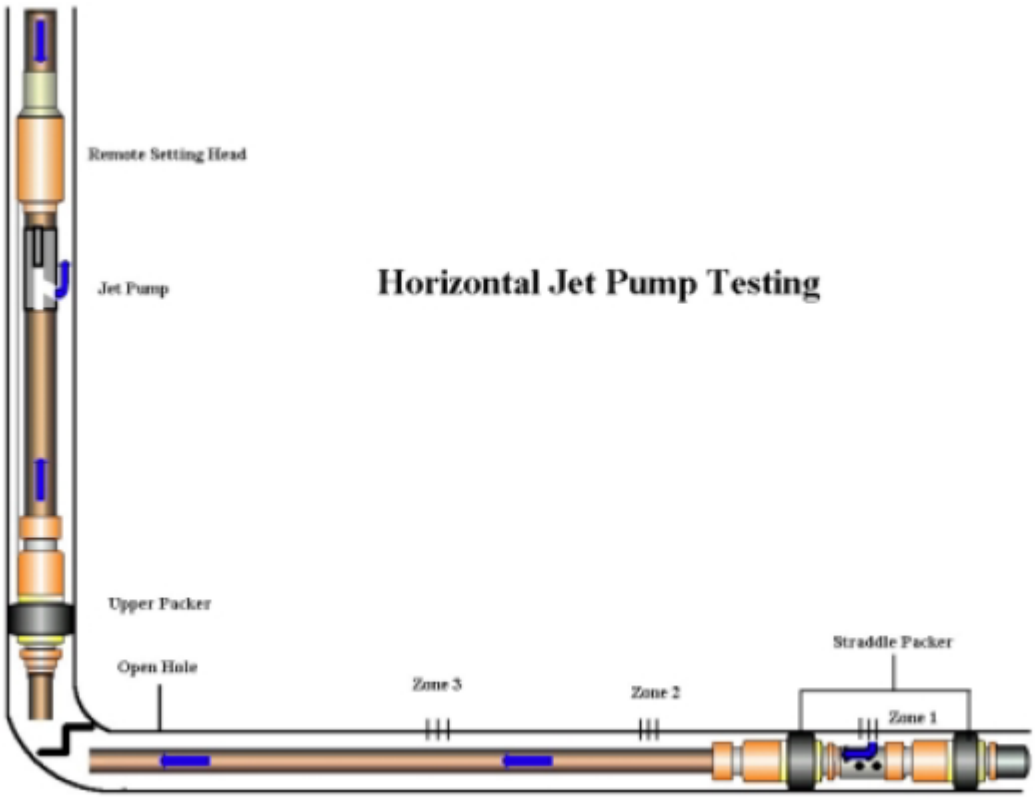

Figure 1 - 1999

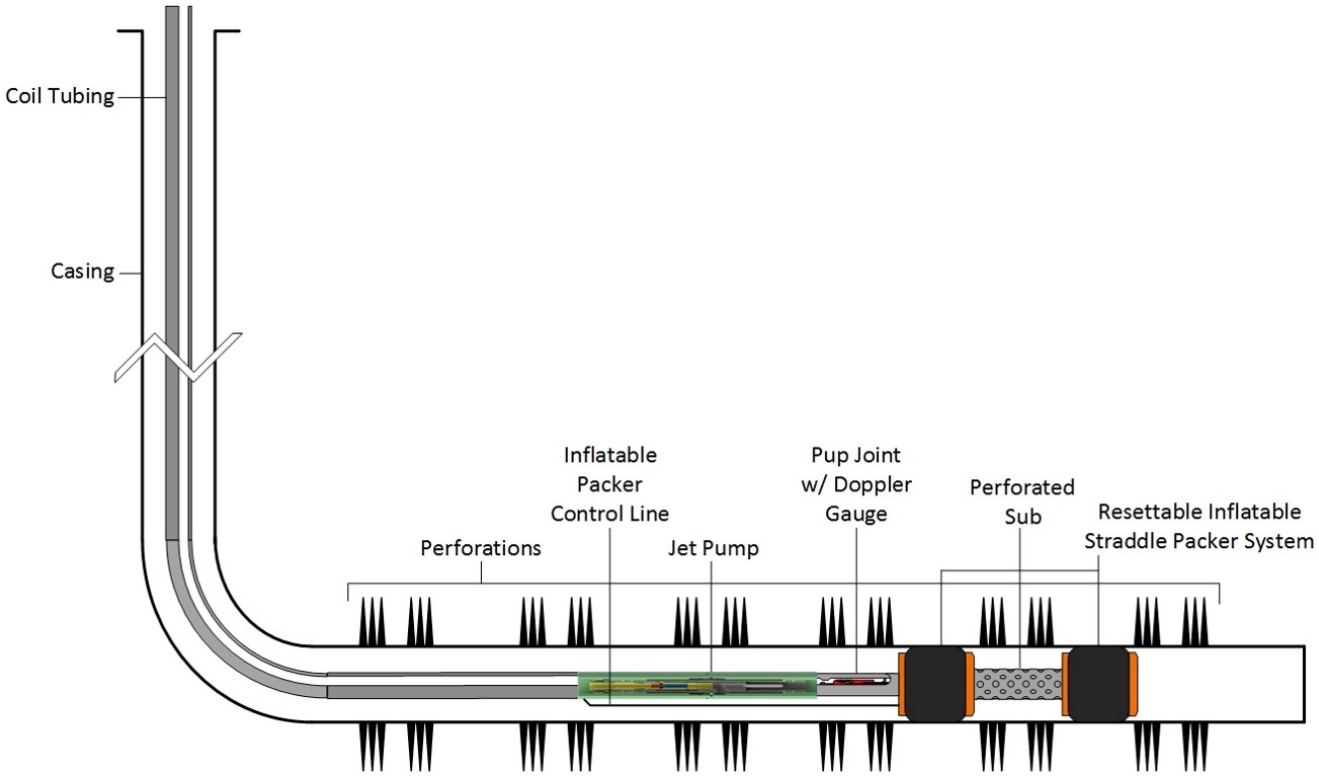

Figure 2 - 2015

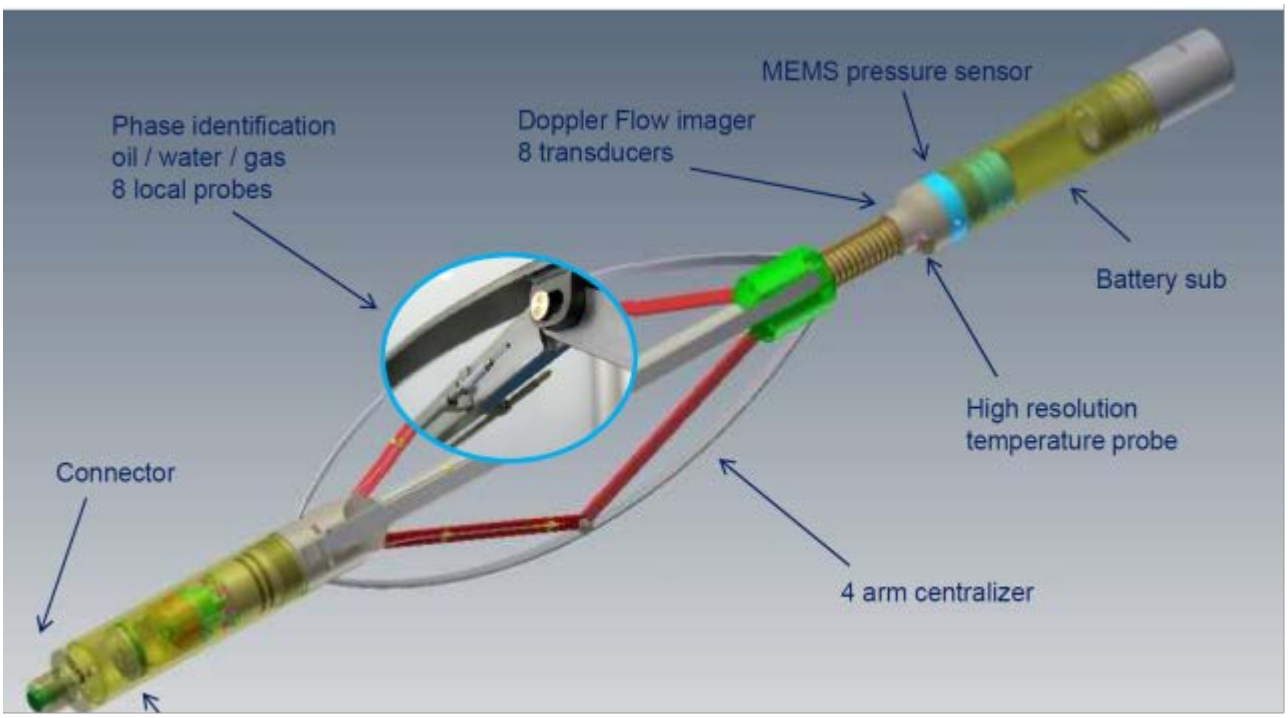

Figure 3 - Mini PLT