MULTI FRACTURED HORIZONTAL WELLS CHANGE THE ECONOMIC EQUATION IN ARGENTINA THROUGH IMPROVED RESERVOIR CONTACT, WELL PRODUCTIVITY AND OPERATIONAL EFFICIENCY

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1. Abstract

Operating companies are continuously trying to improve hydrocarbon recovery, and horizontal drilling has been a tool to get to this target. Horizontal well technology has evolved to a point at which, in most instances, horizontal wells are advantageous and favored over vertical and deviated wells. Horizontal wells can be drilled and completed at comparable costs to vertical wells while offering the advantage of higher production rates and better access to reserves. Often fewer horizontal wells are required to develop a field given the larger drainage area of horizontal drilling. However, when results do not match expectations, or a "surprise" is found, horizontal drilling leaves little alternative for stimulation, water shutoff treatments or workover intervention in general. Many horizontal wells in the world are completed open hole or, worse, with slotted or pre-perforated liners with no choices for production or treatment.

Argentina hasn't escaped to the general industry trend of finding reserves in ever challenging environments. Complex geology and low permeability are the common denominator in today's environment. Developing reserves under these conditions with conventional vertical wells is in most cases uneconomical. In this setting, horizontal wells have come to mitigate the problem, however in most unfavorable conditions where oil and gas are found in tight formations fracture stimulation needs to be added to the equation.

Conventional multistage fracturing techniques including perforating, fracture stimulating and isolating stages with a composite bridge plug have been applied in some cases with limited success. The time consumed in the completion operations extends over weeks making wells uneconomical. In addition, the prolonged time over which the frac fluid remains in the formation before being flowed back often affects well productivity.

This paper describes the experience of the implementation of more than 10 new completion systems to overcome the time consuming and productivity limitations of conventional completions described above.

The new completion system is run as part of the production liner, does not require cementing and provides positive mechanical diversion at specified intervals, so fracturing and stimulations can be pumped effectively to their targeted zone. The system has also been designed, so all of the fracturing or stimulation treatments along the horizontal wellbore can be pumped in one continuous operation, thus minimizing the associated risks and optimizing the efficiencies of both the personnel and equipment needed to perform the work.

The conclusions will show the operational efficiencies and reliability of this novel completion system, as well as analyze the cost benefits and production increases that have been observed.

2. Introduction

Operating companies are continuously pushing to improve hydrocarbon recovery, a task that is becoming more and more difficult as they are pushed to develop fields in more complex settings and with poorer reservoirs properties. Horizontal wells have been a tool widely used to improve both production rates and recovered reserves per wellbore in order to improve the economics of particular projects or make them commercially viable in extreme cases.

Over the last two decades many developments have enabled accelerated growth in horizontal well applications. Drilling has led the way, with current technology capable of drilling thousands of feet laterally through a hydrocarbon reservoir. Drilling technology has evolved to a point where horizontal wells can be constructed at comparable costs to vertical wells while offering the advantage of higher production rates and better access to reserves. Oftenly fewer horizontals are required to develop a field given its larger drainage area. However a horizontal well completion has lagged behind, in particular when a stimulation treatment is part of the completion or has to be applied as a remedial treatment in wells performing below expectations[1].

Until recently there have been essentially two completion and stimulation options. The horizontal can be completed open hole, barefoot or with slotted or perforated liner. This has essentially negated any

effective stimulation along the entire length of the horizontal wellbore. The second completion system requires cementing the production liner and multiple trips to effectively treat different sections of the wellbore. Each section is individually perforated, stimulated, flowed back and isolated in multiple trips. This process is then repeated for the desired number of stimulations in the horizontal wellbore. After all the stages have been completed, CT is used to clean out sand plugs or recover/drill out the bridge plugs used for isolation and establish access along the horizontal. Although effective, the inherent cost of multiple interventions with CT, perforating guns and deployment of fracturing equipment needed for each stage are extremely high, not to mention very inefficient and time consuming. This cost, coupled with the associated mechanical risks often does not allow for the optimum number of fractures to be placed along a given horizontal interval[2].

A completion system to that is set in open hole, provides mechanical diversion and allows multiple fractures to be performed along the entire horizontal wellbore has solved all the problems associated with conventional horizontal completions. An Effective Multistage Fracturing System (EMFS) was developed, consisting of mechanical open hole packers, capable of withstanding high differential pressures at high operating temperatures, with specially designed fracturing ports (Frac-Ports) that would be located in between the packers. A series of these components are run simultaneously in the well as part of a completion liner allowing the fractures or stimulations to be pumped continuosly (Figure 1). This system eliminates the problems often encountered when cementing horizontal liners in place with the added benefit of having a liner in the horizontal, which is beneficial for CT access and remedial operations later in the life of the well. The necessity for repeated interventions and the repeated rigging up and down of the fracturing or stimulation equipment is also eliminated with this system. A great efficiency is realized by performing multiple fractures or stimulation in a single pumping operation, which equates to significant savings of time and money, while reducing the health, safety and environment (HSE) hazards associated with those activities. By addressing all the current limitations of open hole horizontal wells, this system significantly increased the reservoir contact for applications where horizontal drilling are viable by lowering the completion and operation costs and in many cases increasing production.

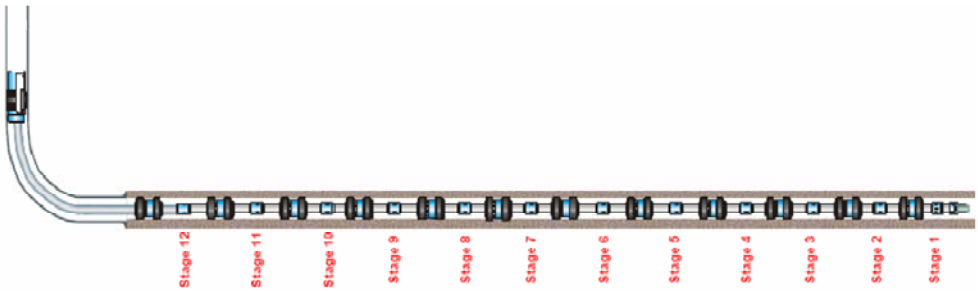


Figure 1. EMFS completion and fracturing system designed for horizontal open hole

The EMFS system is run as part of an uncemented liner and spaced out based on the required number of treatment sections. Once the system is run in place the packers are hydraulically set, a hanger is also hydraulically set to tie back the completion to the previous casing, or can also be run with the same liner size to surface. Then the treatment is pumped in separate stages but as a single continuous operation by dropping a ball in the flush of each treatment stage to isolate the previous treated section and activate the Frac-Port for the next section(Figure 2). After the stimulation treatment the system stays in the well as a part of the completion, and also serves to solve potential wellbore stability issues. The Frac- Ports are designed to have 20% more flow area than the actual openhole cross section area, therefore the flow restriction will be so small that it can be ignored. Also the Frac-Ports can be closed later as needed which would allow better reservoir management (water control). The system not only greatly increases the effectiveness of the stimulation treatment but also enables us to isolate suspected water bearing sections or selectively produce from different zones either at the time of the completion or further down the life of the well[3]. (Figure 3)

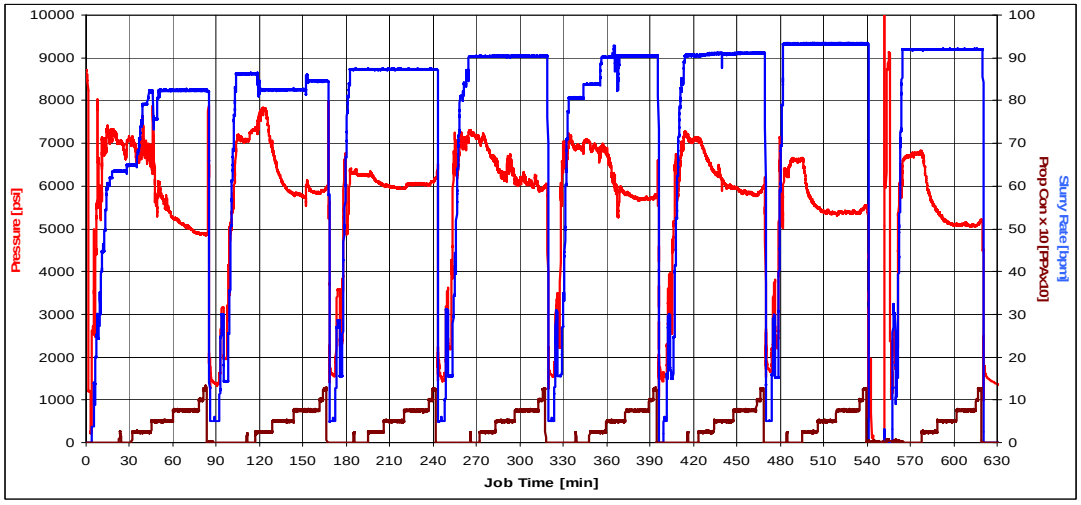


Figure 2. EMFS and operational efficiency: 8 frac stages pumped in 8 hours

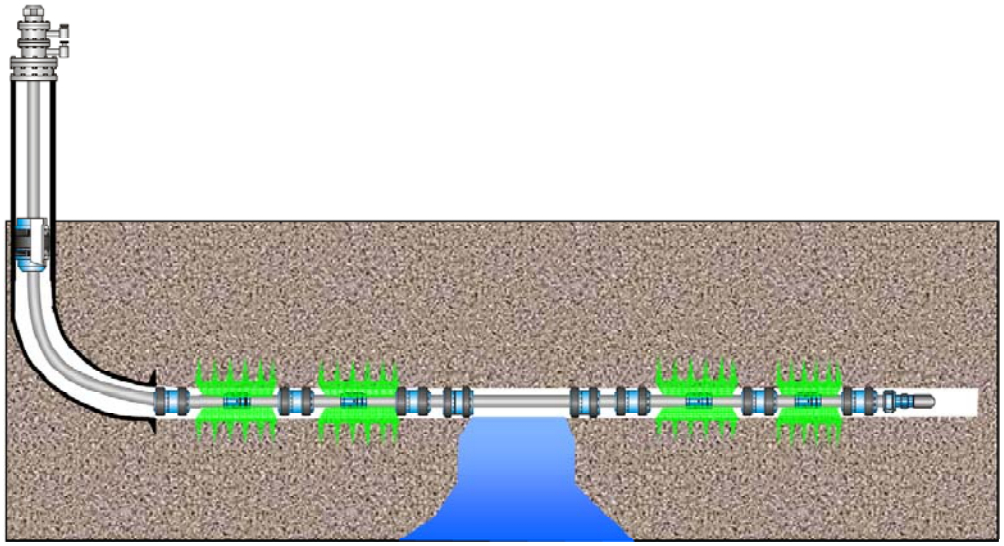


Figure 3 – Wellbore diagram showing one application isolating a watered out area.

The following sections describe the experiences with EMFS with various operators in Argentina and the improvements made on reservoir and reserves contact, production gains and completion operations time savings and efficiency.

3. Development: EMFS applications in Argentina

Declining oil & gas production in Argentina has provided an incentive to explore new ways to enhance the recovery of existing reserves. This situation opened the door for 2 operators in Argentina to explore new ways of enhancing existing reserves through maximizing reservoir contact in developing their fields in Neuquen Basin, Argentina.

The Schlumberger and Packers Plus EMFS completions technology offered an innovative alternative to complete and stimulate the oil / gas wells.

3.1. A step-change technology

EMFS is one of the breakthrough technologies from the Contact Fracturing Services Family[4]. It permits very precise placement of fractures to maximize reservoir contact and increase resource recovery. Since its introduction in 2002, EMFS has been used successfully in more than 2,900 stages in more than 1.75

million ft of open hole. EMFS permits multiple fractures of an uncemented borehole in a single pumping treatment (Figure 1). Openhole packers run on conventional casing are used to segment the reservoir. Hydraulically activated Frac-Ports are located between each set of packers. Balls dropped from the surface during pumping act to open each port, isolating previously fractured zones.

3.2 First Operation in Argentina

The main objective of this treatment was to increase the production of oil / gas of a Horizontal well in Neuquen Basin. Five stages were programmed to cover the 518 meter-long open hole wellbore. The job was divided into two parts, the first one included stages 1 and 2, and the second part consisted of the three last stages due to limitations on proppant and fluid volumes available o location to perform all 5 states in a single treatment. Stage two on the first day was screened out , what required an extra coiled tubing trip to clean out excess proppant and continue with stages 3 to 5 on day 2. Due to anomalies in the well trajectory while drilling, frac stage number 2 was planned on a poorer section of the reservoir where chances of screening out were high. All stages were completed as planned delivering the 5 frac stages in 2 days wich represented a record for the area. Figure 4 shows the completion schematic. A similar completion in the area performed conventionally (cemented and perforated) demanded 21 days; the 19 days saved with the EMFS represented the main achievement of the project. Following the frac treatment an excessive water cut was observed due to the likely propagation of the frac into a nearby water bearing formation. Due to this fact production results were not achieved, however the concept of efficiently performing multiple fracs along a horizontal wellbore with the EMFS was fully proved as was intended for the trial.

3.3 Deployment EMFS in gas field Argentina

The EMFS was then introduced in one of the main gas field in Neuquen Basin, Argentina. This field has been in production since 1977, showing a strong decline in recent years with a 30% drop from 2003 to 2007. Due to the high gas demand in the local market gas production increase is currently one key focus area. In an effort to improve production from this mature field, Operator has been drilling horizontal wells with increased reservoir contact. Previous fracturing attempts in a typical well in the area required a total of 15 to 20 days to stimulate just three zones of interest. This Operator needed a technique that could treat more stages in a shorter period of time, and that could place a larger amount of proppant in the formation.

The innovative EMFS service was selected by this Operator to meet their objectives for this field. In the first well, more than 500,000 lb of 20/40 proppant were placed in 5 fracs distributed along an open hole section of about 800 m. This job was the one with largest amount of proppant ever placed in a horizontal well in this field, approximately three times the maximum amount achieved by the previous methods (Figure 5).

Eleven horizontal wells were fractured in the initial campaign. The EMFS completion required just two days in average and could have been done in one if certain equipment limitations were not a factor in field operations. While the objective was to try and complete these wells in one day, this was nonetheless a significant improvement in time required for the well completion and the team was pleased with the results.

Production also improved significantly compared to offset wells. Results have been impressive in the eleven stimulated wells in this field exceeding an average four-fold increase in production, with one of them becoming the largest gas producer in the field.

Based on these excellent results, this Operator used the EMFS service in most of horizontal wells in the area as the preferred completion option.

4.1. Payback considerations

The economical analysis has shown that the payback period of the wells that used EMFS has reduced at least by 50% in comparison to an OH wells without stimulation. It is worth to mention that some of the wells were not producing any gas before being treated with EMFS, following the stimulation treatment they became better-than-average producers. Another thing to take into consideration is the time and associated rig rate savings gained with EMFS. These savings can reach as much as U$500,000 per completion considering that a conventional multi-stage fracturing completion takes 15 to 20 days and the typical workover and drilling rigs cost of U$10,000/day and U$ 25,000/day respectively. Additionally, in conventional completions, the cementing, perforation and completion costs have to be included while they are saved with EMFS.

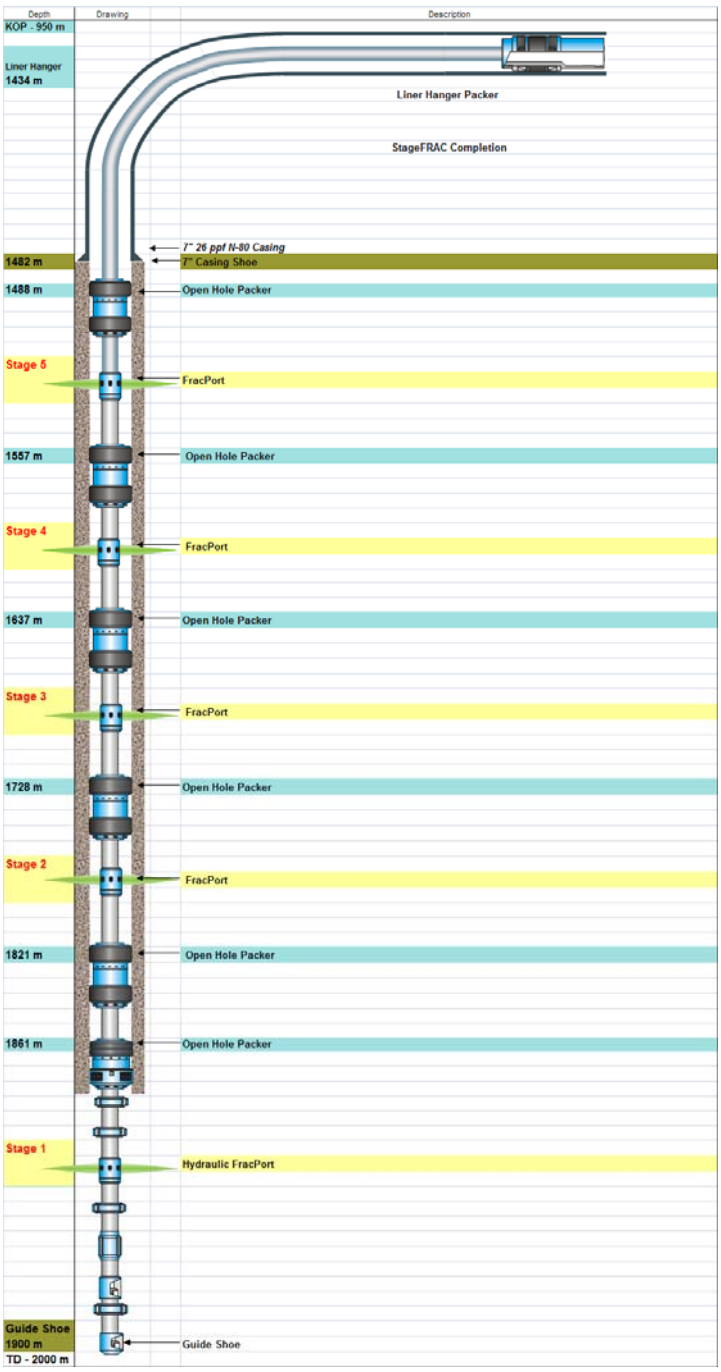
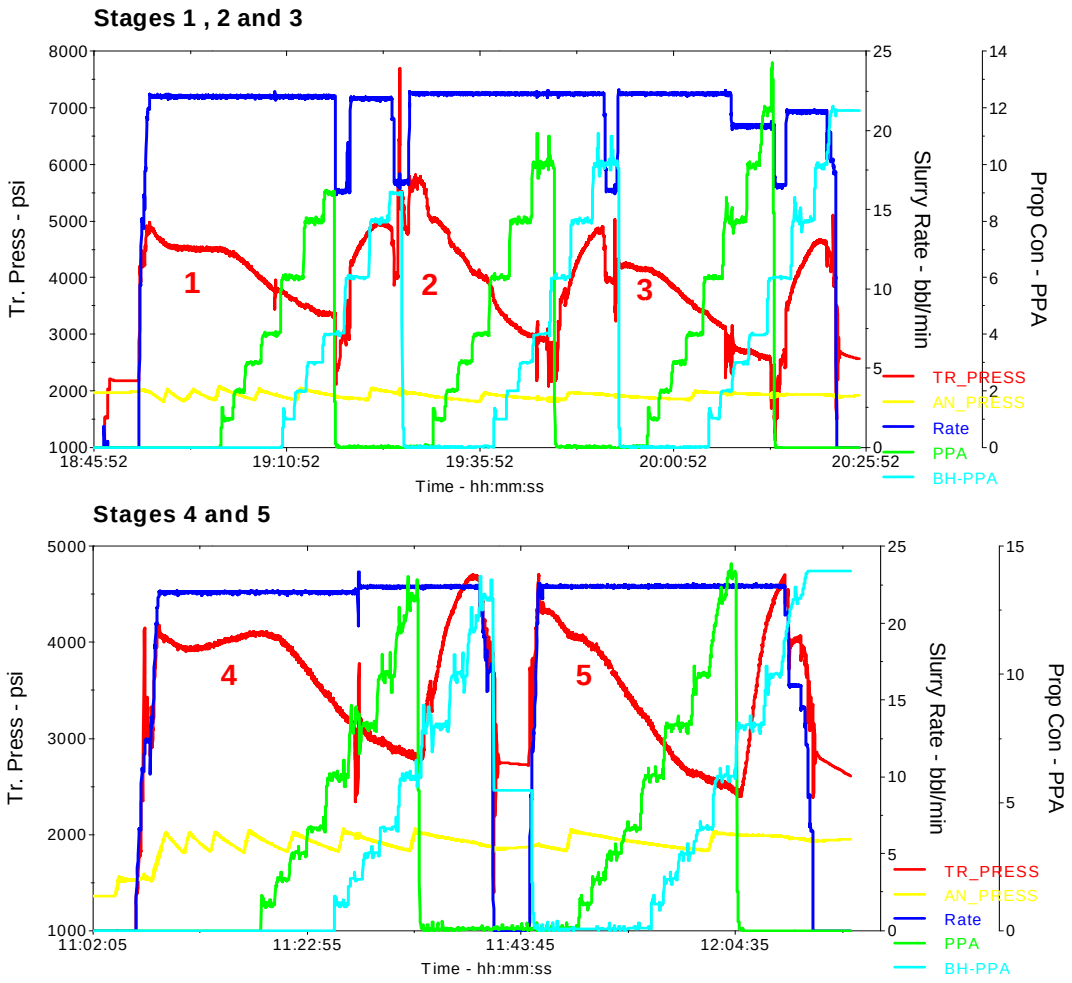


Figure 4. EMFS 1st application in Argentina - Installation schematic

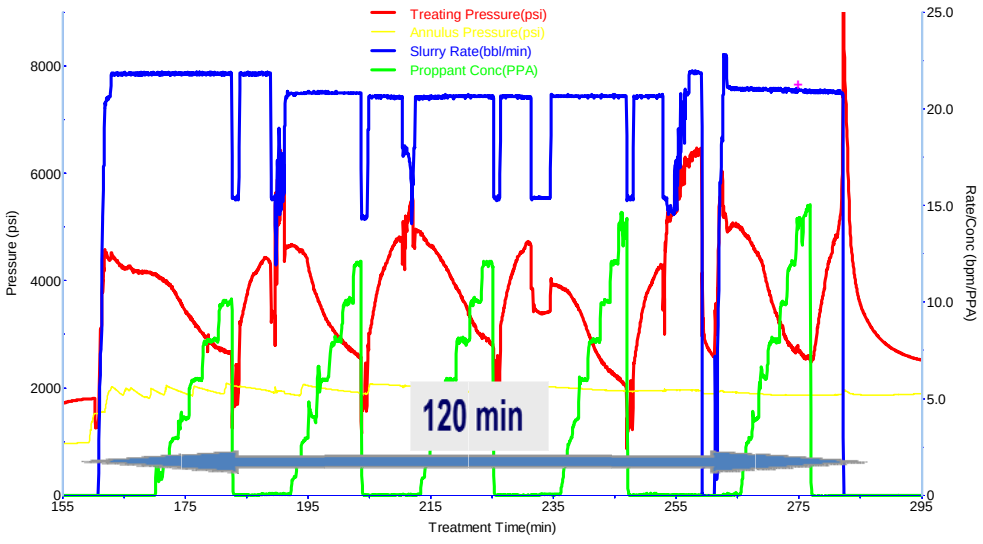
Figures 5: Rig-up showing the largest EMFS completion to date in Argentina, in terms of total amount of proppant pumped with a total of 500,000 lb placed in the formation.

4.2. Benefits observed

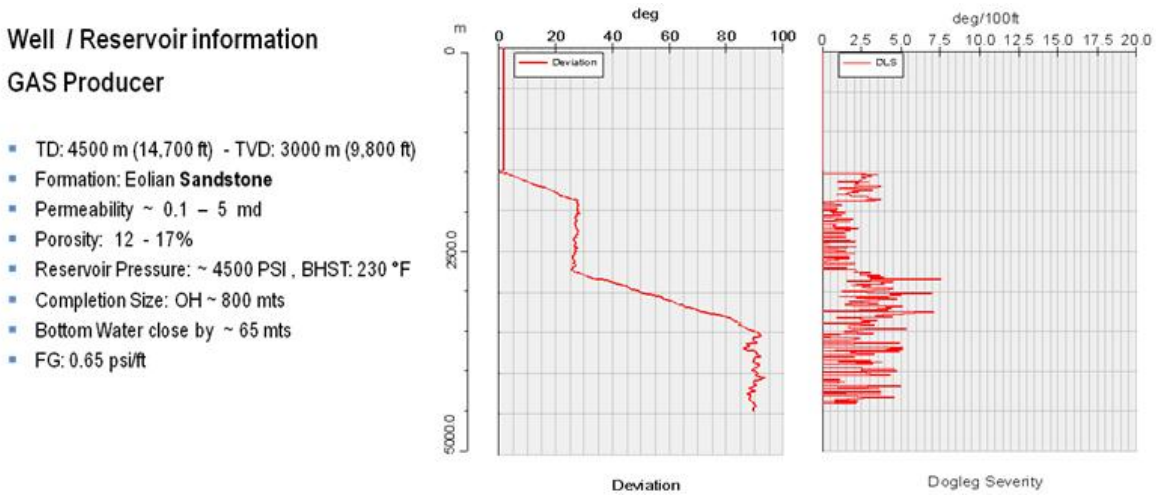
This Operator was looking for ways to improve production in horizontal wells given that conventional fracturing and completion technologies did not fulfill its expectations. EMFS maximized reservoir contact and productivity in treated wells, the eleven treated wells exceeded production expectations with one of them becoming the number one gas producer of the area with more than 500,000 m3/day of gas as initial production. Completion times reduced from average of 21 days in the area to just 2 days using one single system to effectively treat and produce the entire Horizontal section. In one of the jobs performed in the same field, 380,000 kg of the same proppant were pumped in just 120 min getting till 15 PPA as maximum proppant concentration, wich represent a record for the Argentinean Stimulation market. (See Fig. 6-a and 6- b below). The typical well configuration for the Gas wells is showed in figure 7. The final table in figure 8 sumarize all the MLEF jobs performed since 2007 in Argentina.



Figures 6 - a: EMFS Charts for the first job in a GAS well. This was the largest EMFS in Argentina. The operation has to be divided in two parts for logistical limitations.



Figures 6 - b: This EMFS job chart shows 5 fracs performed in 120 min in a continuous operation



Figures 7: Well and reservoir parameters of a typical GAS well treated with EMFS

Well #	Oil / GAS	# Stages	Proppant (lB)	Completion time (days)
1	Oil	5	120,000	2
2	GAS	5	500,000	2
3	GAS	5	400,000	2
4	GAS	5	350,000	2
5	GAS	5	350,000	1
6	GAS	5	350,000	1
7	GAS	5	350,000	1
8	GAS	5	350,000	2
9	GAS	5	350,000	1
10	GAS	5	400,000	1
11	GAS	5	400,000	1
12	Oil	3	90,000	1
13	Oil	3	90,000	1

Figures 8: Summarizing table for MLEF job performed in Argentina since 2007.

5. Conclusions

EMFS provides effective ways to complete horizontal wells in a time efficient manner lowering the well development total cost. Completion times reduced from average of 21 days in the area to just 2 days using one single system to effectively treat and produce the entire Horizontal section.

EMFS maximized reservoir contact and productivity in treated wells, most of them exceeded production expectations with one of them becoming the number one gas producer of the area with more than 500,000 m3/day of gas.

EMFS maximized stimulation coverage through effective mechanical diversion with reliable isolation in open hole and enable the placement of fractures precisely at optimal locations. Besides, EMFS allowed the isolation of undesirable zones, for example, zones that could produce water.

EMFS minimized workover activities and downhole tools (packers, bridge plugs) manipulation and decreased the risk of getting stuck in vertical and horizontal wells.

EMFS minimized completion skin.

6. Acknowledgements

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7. References

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4 . Trade Mark of Schlumberger