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NONINVASIVE STIMULATION OPPORTUNITIES IN A MARGINAL GAS FIELD

1. INTRODUCTION

Laslau Mare field is 40 year old dry gas field (99.5% CH_4) located in the central part of the Transylvanian Basin. The field is managed by Schlumberger SPM/Romgaz project Team as part of a 15 years, gain-share association with Romgaz, the national gas company of Romania.

The main objectives of the association was to increase production through a new Field Development Plan (FDP), maximize the recovery factor and bring new technologies in the area. Within the FDP, until this moment, 29 workovers and more than 1000 rigless jobs were performed.

The field produces through 4 sandstone packages. Top ones being more permeable than the deeper ones. Wells are completed either in one or two packages in single selective completion mode. The current average reservoir pressure is around one third of their initial values.

Laslau Mare wells are vertical completed with a single 2 7/8" tubing string, in a 5.5" production casing. Wells' depths vary from 1,800 and 3,000 m.

Pressure depletion, increasing water production and the previous acid jobs created problems such as production of fines, salt, scale and created skin with different degrees depending on which package the well is completed in and on the well operations history. Less and less perforation intervals are performing at potential as proved by different Production Logging surveys. Skin, pressure decline, well water loading affect drastically the daily gas production rates and ultimately the final gas recovery factor. Several stimulations and wellbore clean-up techniques were tried and implemented in the field. Acid

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wash and near-wellbore stimulation using pulsing tools were implemented with both good results and unsuccessful outcomes. Hydraulic fracturing stimulation is currently piloted in the field, although it is not seen as a viable technology for medium to lower producers due to the challenging economical payout and is not recommended in wells with ageing tubulars. Matrix acidizing was studied and is not expected to have results as proper acid formulation for the current rock is very challenging to put in place. Long perforated intervals with different productivity make the operation's success chances to be quite low. Re-perforation looks a great alternative, but a perfect balance between proper gun sizing and perforation media is never achieved. We are constrained to either perforate with high performance, larger size guns in overbalanced media or with lower performance, smaller size guns in underbalanced media.

2. PROBLEM DEFINITION

Being a depleted dry gas reservoirs, any sort of water based fluids in contact with these reservoirs severely impairs productivity. Also, presence of skin is associated with migrated silt, fines, sand grains and carbonate/halite scales.

Wellbore and near wellbore wash treatments were executed with both acid and water. Although not directly targeting skin reduction, this sort of treatments have shown formation damage mitigation to a certain extent as the acid/water dissolves precipitates in the near wellbore area. The wells in Laslau Mare field have long perforated intervals (50–200 m of open perforations). The lithology is of stratified thin layers of sandstone interbedded with shale. The rock cementation material is carbonate based. The success was seen to depend a lot on the reaction time of the acid/water in hole and on the permeability degree of the producing reservoir. These two aspects need to be addressed individually for every well and most of the time a compromise between the two has to be made in order to preserve the reservoir rocks cementing material or to prevent liquid losses in high permeable zones (best producing zones). Also, planning a fully successful treatment would require high quality reservoir data which we lack.

Apart from the operational challenges, the effect of this cleaning is not addressing a satisfying skin reduction, as the treatment mostly targets vertical obstructions and perforation wash. It was observed that subsequent near wellbore acid treatments are not so effective as the first ones. The treatment is losing efficiency with repeating operations (Fig. 1).

Another stimulation option is to re-perforate the wells. Considering many of the reservoir layers are low permeability (up to 1 mD), re-perforation not only works as a skin by-pass operation, but also works in the advantage of increasing area open to flow. Perforations with deep penetration seem to be the enhancement fit-for-purpose solution for our reservoir.

Re-perforation can be done during workover operations or rigless well intervention. It is obvious that during workover, the perforations are done in over-balanced mode whereas during well intervention, perforations can be performed under-balanced with liquid in hole or during production, underbalanced, if the tubing tail depth allow. Through tubing perforations are limited by the completion size.

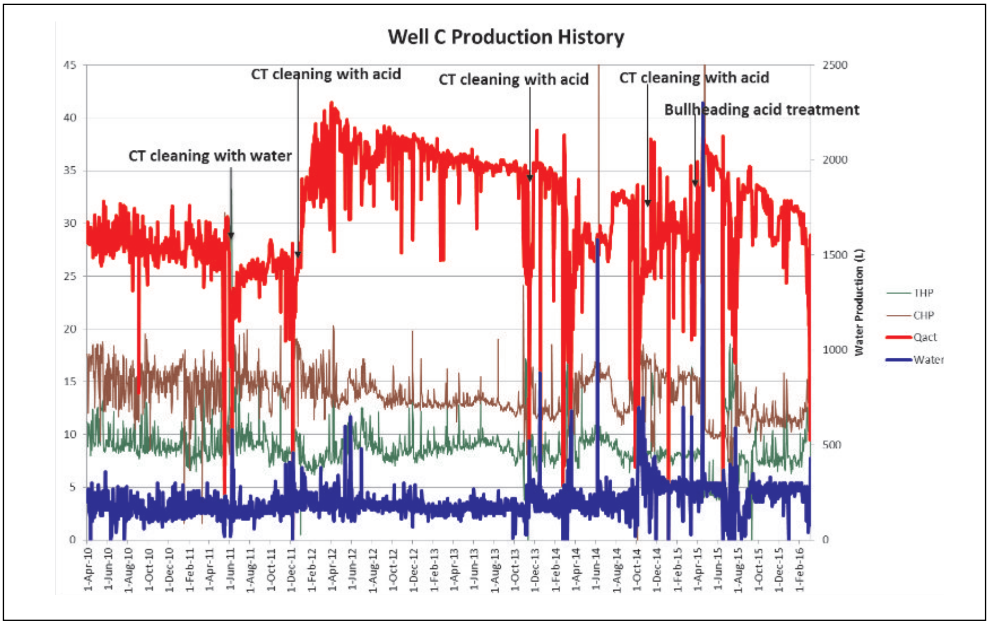

Fig. 1. Batch treatment examples in one of the wells. Observe recovery times up to 3 months after liquid treatments. Acid effect is not seen with time (lately mostly used to dissolve wellbore restrictions)

As one would expect, through tubing perforation performance is theoretically and practically proven to have less performance than casing guns. A simulation in SPAN, Schlumberger's perforation analysis software shows the penetration to be minimized to half from tubing guns to casing guns and the overall guns' performance more than 4 times as shown by the Area Open to Flow (AOF)(see Tab. 1).

Table 1

Perforation performance between through tubing gun (2") and casing guns (3.67")

Gun system	API penetration (inch)	Total penetration (inch)	ACF (cm^2/m)
2"HSD Powerjet Omega 2006, HMX, 60 deg phasing	21.8	8.03	4.62
3.67"HSD Power Jet Omega 3506, HMX, 60 deg phasing	44.2	13.69	20.35

Neither of the two modes of perforation options is bringing us the full well potential. During workovers the water based fluids used offset the stimulation effect. The performance of the through tubing guns are poor in comparison with the casing guns. A brief introduction of workover fluid effect on Laslau Mare wells will be explained below.

First workovers were done with brine. Severe losses were observed during the operations and long periods of time were needed for the production to recover (from 6 months to 2.5 years recovery). The recovery times directly translate into production deferral and loss of revenue for the association in addition to frequent nitrogen lifting operations to speed up the process. One example can be seen in Figure 2.

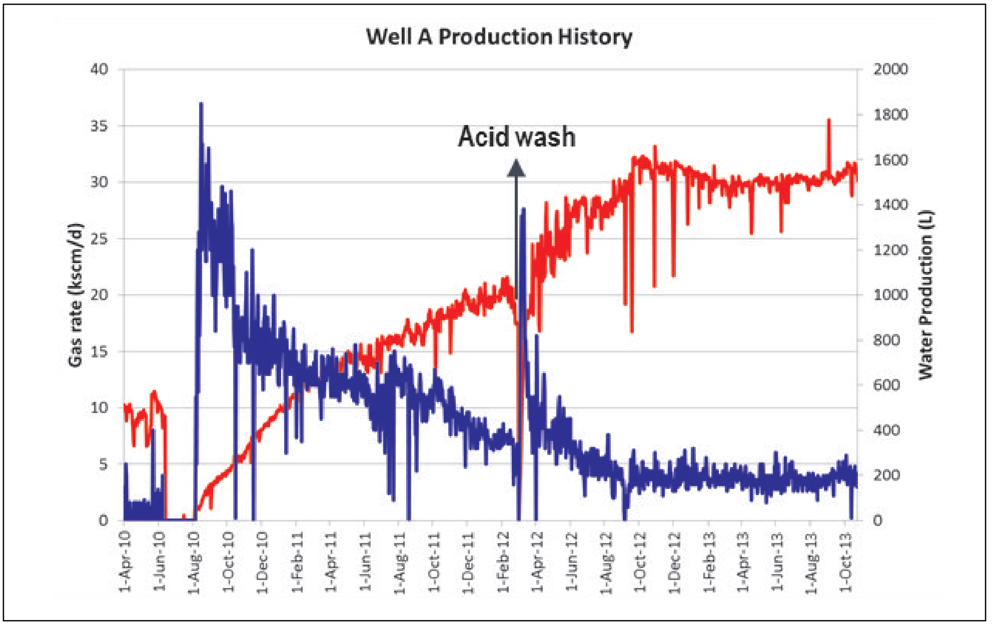

Fig. 2. Workover done with brine in the summer of 2010. Approximatively 87 m^3 of brine were lost in the formation leading to a recovery time of more than 2 years

Recent workover campaigns, FloThru® mud was used in order to prevent liquid losses in the reservoir. The solution was proved to be very effective from this point of view, by creating a stable filter cake which withstands the hydrostatic of the mud column. However, usage of the mud resulted in inducing a skin and recovery time although shortened, was still longer than expected. FloThru® should naturally get removed when the well is put back in production, although due to the low reservoir pressures additional acid wash jobs were needed. The acid wash jobs incur extra costs and risks. Some of the risks were outlined above. An efficient removal of the filter cake is done in at least two cleaning jobs or by using pulsing tools deployed by coiled tubing (CT) during time consuming operation. One example can be seen in Figure 3.

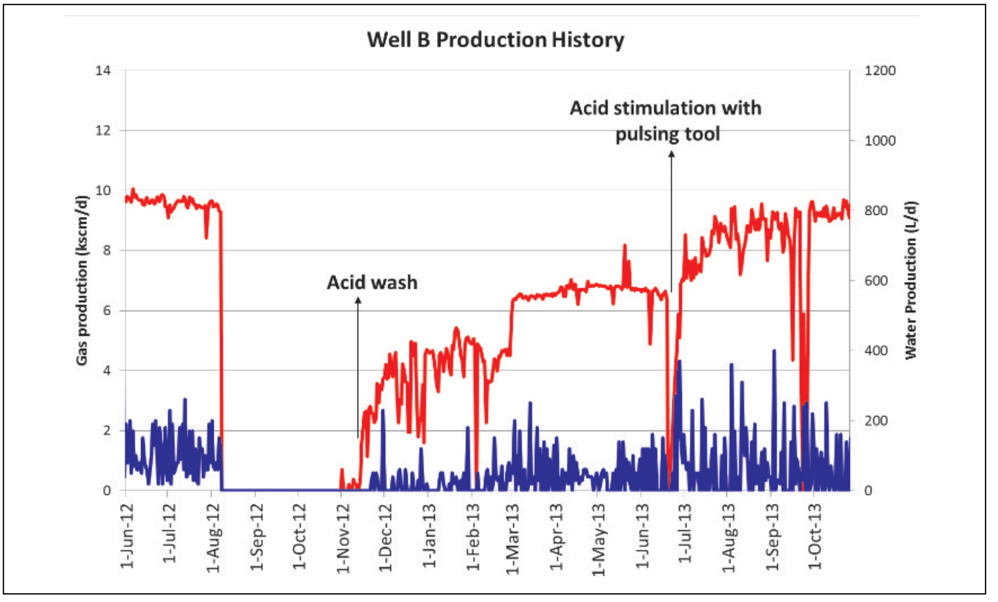

Fig. 3. Workover done with mud in the summer of 2012. Minimum losses were observed, although two acid wash jobs were performed in order to recover the well's production. Approximately one year was the recovery time in this well

In order to perform a very efficient stimulation operation, a liquid/mud non-intrusive technique must be implemented. The method must not induce any additional damage to our water sensitive formation.

3. PROPOSED METHODOLOGY

End of 2014 a new technology has been introduced to the field, the snubbing workovers. The work done for the pilot two wells were simple live well recompletions (lowering of tubing shoe and replacing a tubing string). The way forward was to involve snubbing units in more complex workover operations involving challenging workflows (CO_2 foam fracturing operation, operations requiring fishing, difficult recompletions etc). The use of snubbing unit to retrieve completion tubulars and perform under-balanced re-perforate (with casing guns) was proposed as a non-invasive approach, expected to have immediate incremental and to bring production closer to wells' potential.

A Snubbing System is basically a well servicing system capable of running and retrieving tubular under live wells conditions (even with the well on production). The use of a Snubbing Unit is providing cost effective technology for a wide range of drilling and well servicing applications. The unit comprises of two sets of BOPs (one used for well control, and one used primarily for tripping pipe in and out of hole). The tripping procedures involve stripping the pipe through the annular BOP or through stripping rams.

The hoisting system in a rig is replaced by an elevator system, with two sets of hydraulic tongs that work sequentially to maneuver pipe. The primary barrier envelope for a live well trip using snubbing unit is the tubing string itself secured with a plug in its tail.

4. IMPLEMENTATION OF THE METHODOLOGY

In 2015 two pilot operations were executed. For one of the wells, the re-perforation was part of a more detailed stimulation operation which included a foam fracturing intervention as well, as for the second one, the sole scope of the job was to re-perforate underbalanced with casing guns, in underbalanced conditions.

The general operational steps for the snubbing re-perforation stimulation are described below. The sequence was used in the second pilot well and was, as it is presented here, part of the operational sequence of the first pilot.

A tubing plug was run in the last joint of tubing in order to secure a primary internal barrier, prior to snubbing unit mobilization. The plug was inflow tested and the snubbing unit was mobilized once the test was positive.

A back pressure valve was installed in the tubing hanger to act as a secondary barrier. The X-mass tree was nippled down and the snubbing BOP was nippled up. Snubbing unit rig up continued after removing the back pressure valve.

A landing joint was run to retrieve the completion string. Only straight pull was needed in order to unset the production packer. The tubing was at the same time released from the tubing hanger. The string was pulled out of hole.

Wireline equipment was rigged up on the BOPs of the snubbing unit. A drift and correlation run was run. Perforation in dry conditions, partially underbalanced, was then performed. The guns systems used were 4" guns, 5 spf, 60 degree phasing and 3–3/8" guns, 4 spf, 60 degree phasing. Two gun systems were used due to availability of the guns in the country. The intervals to be perforated with the 4" more performant guns were the ones showing more potential as per the gas saturation logs available in the two wells.

The wireline equipment was afterwards rigged down and the completion string rerun in hole. Snubbing unit was afterwards demobilized.

5. RESULTS OF THE INTERVENTION

Based on the objectives set, the operation was considered successful.

Incremental was seen from all the re-perforated intervals showing significant skin reduction.

In the first pilot, the best results were seen in the least permeable layer (Reservoir Y in Tab. 2), where constrained production was increased 163% and unconstrained production, observed during surface well tests was increased 306%. For the more permeable reservoir the incremental was of 15%.

Table 2

First pilot results from underbalanced re-perforation using snubbing unit. Rates and operations performance were evaluated using PLT surveys prior and post perforations jobs

PLT contribution and rates			
Reservoir	Before stimulation	After stimulation (constrained by flow regime)	After stimulation (unconstrained – surface well tests)
	Gas rate (kscm/d)	Gas rate (kscm/d)	Gas rate (kscm/d)
X	20.1	23	23
Y	4.9	8	15
Total	25	31	38

A Pipesim nodal analysis shows the skin was decreased from 7 to 3 in the first pilot.

The second pilot also shown good results, with an incremental of 5 kscm/d, accounting for 20% production increase (permeability is comparable to reservoir X in Pilot 1 well). These numbers refer to constrained production comparison before and after snubbing operation (Fig. 4).

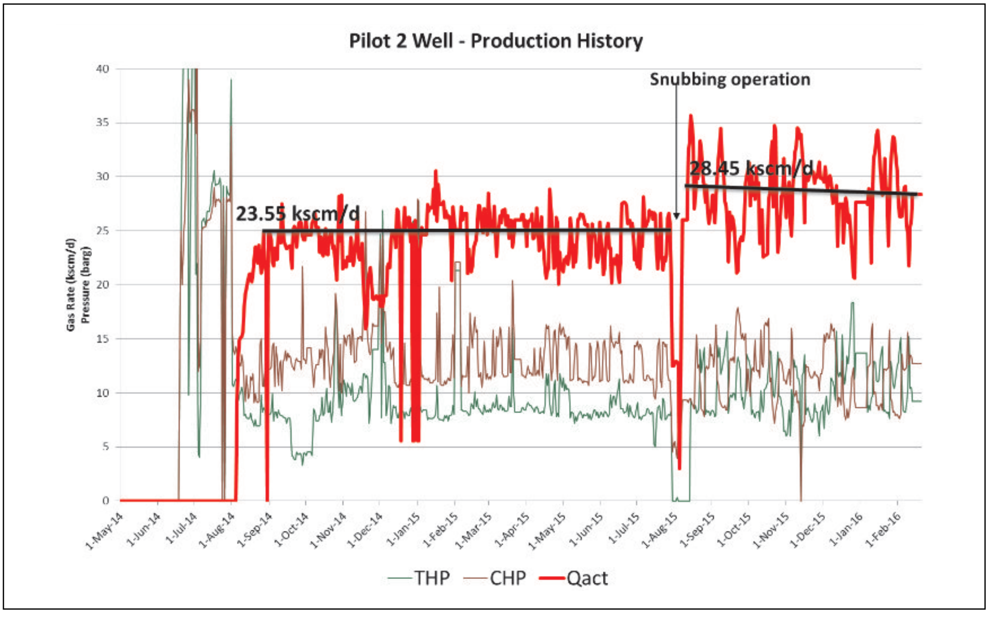

Fig. 4. Production performance of pilot 2 well before and after snubbing operation

6. CONCLUSIONS AND WAY FORWARD

Well stimulation initiatives have been previously implemented in Laslau Mare field. Due to reservoir rocks properties and depletion degree, any of the implemented techniques using water based fluids will limit the stimulation results. The only non-invasive opportunity implemented before was through tubing re-perforation in underbalanced conditions. This technique brings approximately half performance compared to casing guns re-perforation.

A new methodology for stimulating wells was introduced in Laslau Mare field. The methodology considers a noninvasive approach by re-perforating with casing guns using snubbing unit. The proposed and implemented solution is safe and has a great advantage as the incremental obtained is full and instantaneous.

Two stimulations were piloted. Lower permeability layers showed an increase of more than 160% in production while for higher permeable formations the incremental was around 20%.

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