Multifold Productivity Improvement through Innovative Rigless Post Perforation Dynamic Underbalance Technique: Case Studies from Western Offshore

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Keywords

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Summary

Development of skin is one of the major challenges which leads to production decline in wells along with increased pressure drawdown. Regular treatment and stimulation of wells to remove skin is a good practice in such wells to boost and optimize well produciton. However a thorough analysis is always recommended to study the suitability and operational feasibility of various stimulation techniques and apply the best possible method.

The stimulation techniques can vary significantly depending on the well condition, type of skin, produced fluids etc.

This paper presents case studies from one of the marginal fields of Western offshore, where a proper root cause analysis and application of a relatively new stimulation technique helped in significant enhancement in oil production and production optimization.

Introduction

A marginal carbonate field in Western Offshore India was undertaken for development recently. During its exploration phase, more than two decades ago, thick oil layer was discovered with high sour gas content (around 14000 ppm). The reservoir was delineated in small oil pool, where six wells were completed for production, including one water injector for pressure maintenance to support oil recovery. Production behavior of most of the wells had a unique response of rapid decline from around 2000 bbls to 300 bbls in short period of time with loss in THP from 42 kg/cm2 to the level of 10-12 kg/cm2 without any change in water cut. Production response of all these wells led the suspicion of near well bore skin development as a root cause behind sharp decline in production.

Acid treatment as a quick fix solution in carbonates was ruled out because of possible communication with bottom aquifer; coil tubing had multiple operational challenges in such a high H2S environment. To overcome the challenges and perform root cause analysis, it was planned to acquire the best possible set of data acquisition with rigless wireline operations and plan ahead for the short term productivity.

Production Logging, being an ideal diagnostic tool, was chosen to study the production profile and understand the reservoir and well behavior.

However, any operation in high sour gas environment is challenging in each and every aspect and requires perfect planning and preparation to ensure safety of personnel and tools.

Special H2S resistant cable was deployed for these operations and tools tested for H2S ratings. Safety aspects on the field were properly analyzed and availability of oxygen cylinders and SCBA (Self-contained breathing apparatus) were ensured for all personnel. Proper provision for refilling of oxygen cylinders were also reviewed and confirmed.

The tools were downhole for a total of about 300 hours to carry out all the operations with about 50-60 hours in a single run, making it one of the longest rigless operations in such hostile environment.

Post analysis, a relatively new concept of selective stimulation with post perforation controlled dynamic underbalance was considered to be the best fit solution to address the production decline problem in the field.

Post Perforation Controlled Dynamic Underbalance:

Perforations are always associated with crushed zone, which creates an unwanted skin. Permeability of crushed zone is typically < 10% of the undamaged formation permeability i.e. $K_c/K < 0.1$ (Fig-1). Crushed zone of the perforation tunnel can be removed by creating a controlled Dynamic Underbalance (DUB) in front of existing perforations.

Controlled DUB is created when a gun chamber is instantaneously opened at the existing perforations to create a sharp pressure drop lasting for few milliseconds to clean the crushed zone (Fig-2). Perforation cleanup is driven by an effectively induced large and rapid pressure drop creating strong transient flow leading to tensile failure of the crushed zone from formation through tunnels into the wellbore. It removes the crushed zone of the perforation tunnel, cleans surrounding area from solids, fines, scales that are plugging perforations. Furthermore these materials are collected inside the gun chamber, providing an excellent way to analyze the actual cause of perforation plugging. The debris collected in the gun are brought to the surface and can be analyzed (fines, type of radioactive minerals, scales etc.)

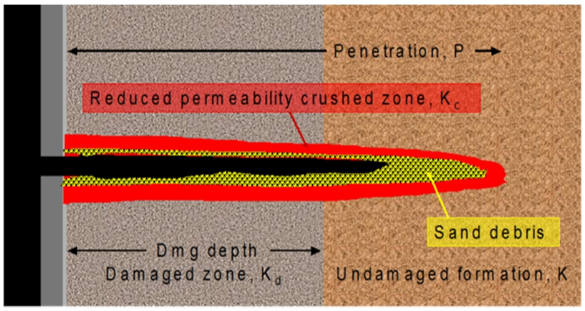

Fig-1: Perforation characterstics

The efficiency of the operation depends on:

- Rate of pressure drop.
- Magnitude of pressure drop.
- Duration of pressure drop.
- Tailored Analysis and design

It uses hardware and simulator with their design oriented to get the maximum DUB. Shaped charges are not used for P3 operation. P3 charge density is increased in order to optimize flow area in the guns and maximize DUB transient.

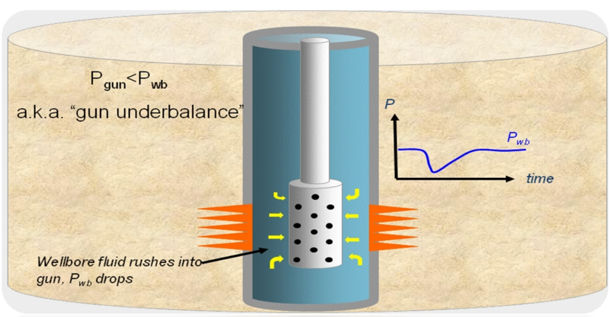

Fig-2: Dynamic Underbalance by the technique

PL Analysis & Production Optimization in Well A:

Out of the five wells, three wells were drilled intially and put on prodcution in 2014. Out of these three wells, well "A" showed tremendous decline in production rates and pressures within a month, hence it was chosen as a suitable candidate for analysis in the field.

To ascertain zonal production rates and to diagnose the problem, multi-choke production logging with electrical and optical probes was planned in the well, followed by short pressure build up data acquisition to determine the reservoir pressure and near wellbore skin.

Identification of inactive zones apart from the water producing zone was done based on data analysis. It was also observed that the well was producing below bubble point pressure and gas was being produced from all oil contributing zones (Fig-3). Based on the results, inactive zones were re-perforated.

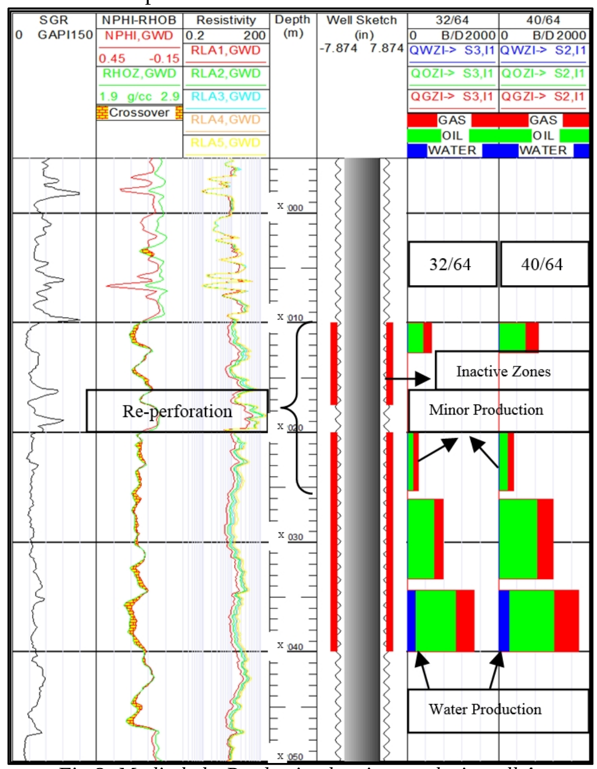

Fig-3: Mutli-choke Production logging results in well A

After reperforation, through tubing post perforation DUB operation was planned for the low pressured reservoir (~2600 psi) with 2" OD 6m gun system using the pressure build up study results (Fig-4) and cleaning with P3 was carried out. A DUB of around 400 psi was achieved and recorded with downhole fast gauge (Fig -5) and perforation debris were collected in the gun body which indicated proper cleaning of the tunnels (Fig -6). The operation resulted in THP gains at surface without any significant production increase. Nodal analysis showed the production to increase about 20 percent (500bbls) at similar THP as before operations. Increasing the choke size later proved the results to be near accurate.

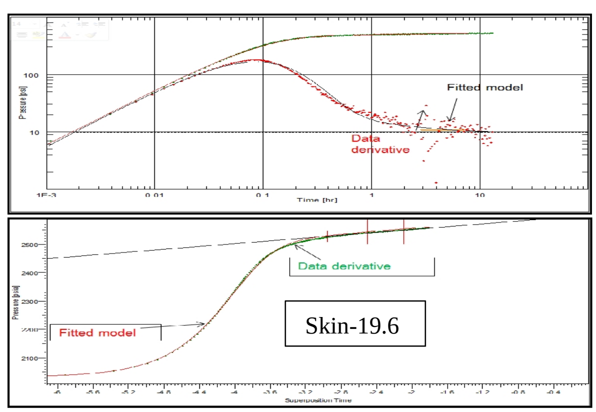

Fig-4: Pressure buildup study in well A indicating high skin

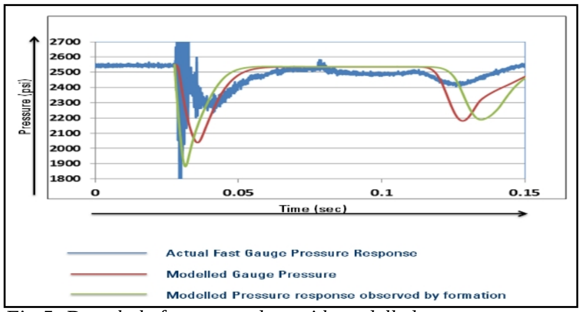

Fig-5: Downhole fast gauge data with modelled pressure response

Fig-6: Debris collected after operations in well A

PL Analysis & Production Enhancement in Well B:

In 2015, another two wells were drilled and completed in the same layer with similar completion system. The initial production trends in one of these wells, well 'B' (1100 BOPD, FTHP 15.4 Kg/cm2), were not encouraging and it further decreased gradually. The problem was suspected to be associated with wellbore skin development and hence similar operation in well 'B' was planned. But before the operation, the production profile and the reservoir section were evaluated with production logging.

PLT results (Fig-8) showed negligible contribution from the bottom part of the perforation, where mostly water recirculation was observed. The top part of the perforation was contributing most of the hydrocarbon at a very low bottom hole flowing pressure (~830 psi) subjecting the reservoir to a very high drawdown. The PLT operation was followed by pressure buildup analysis which complemented the PLT data by indicating a very high skin of around 26. (Fig-9)

Since the well was producing at a large drawdown of around 1700 psi, a small DUB similar to well 'A' might not have been effective in this well. Learning from the earlier experience and using the results of pressure build up study, post perforation DUB job was planned with 2" OD 6m gun with an additional 3m of blank pipe to provide more volume for dynamic drawdown, causing subsequent DUB.
By the time the well could be taken up for DUB operations, the production rates had fallen to less than 300 BOPD at an FTHP of 9 kg/cm2. Hence to revive the well and boost production, re-perforation and P3 operations were carried out against target zones identified with PL results.

An excellent dynamic drawdown of around 1200 and 1000 psi was achieved in two P3 runs in this low pressured reservoir (2600 psi) with the modification in the gun design, helping in cleaning the perforation to maximum extent. (Fig-7)

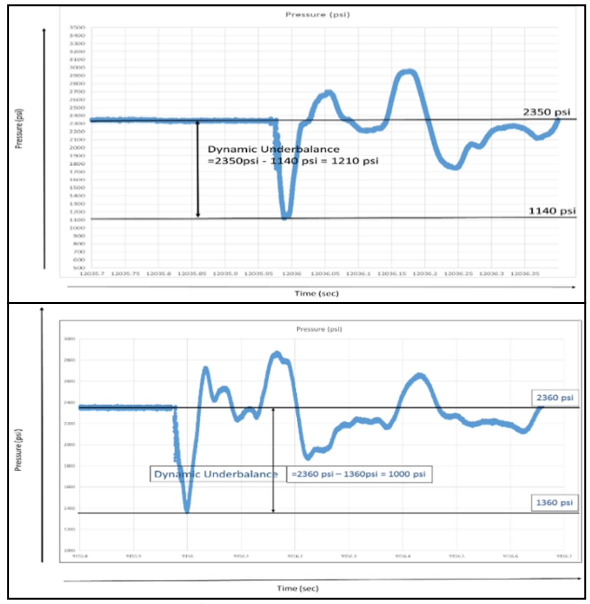

Fig-7: DUB of 1200 psi & 1000 psi obtained in well B

To observe the change in flowing bottom hole pressure post operations, it was decided to experiment by keeping the DUB gun downhole post operations to record the FBHP data with fast gauge, which worked out very well. The well was flowed back for 6 hours post operation and a tremendous improvement was observed in FBHP, which was around 1570 psi after DUB operation.

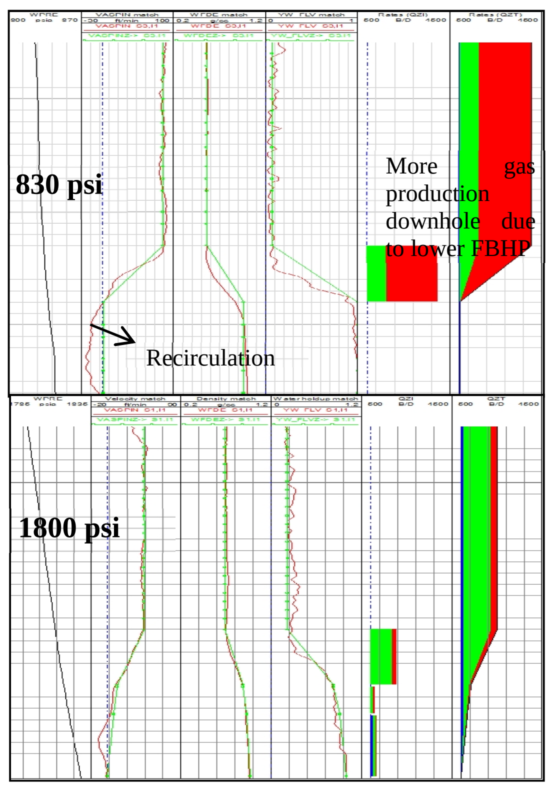

Fig-8: PL results, Pre and Post DUB operations in well B

The flow rate before DUB job in well B was 298 BOPD with negligible water and it increased to 1054 BOPD with negligible water cut after the DUB job resulting in an oil gain of 1054 BOPD.

To better understand the changed reservoir dynamics after DUB operations, another PL and pressure buildup study was planned and done in the well. PL results (Fig-8) showed that the complete perforation interval is now active and contributing hydrocarbon; the top part of the perforation interval still is major hydrocarbon contributing interval. The FBHP was observed to be near 1800 psi as compared to 830 psi in the first PL run.

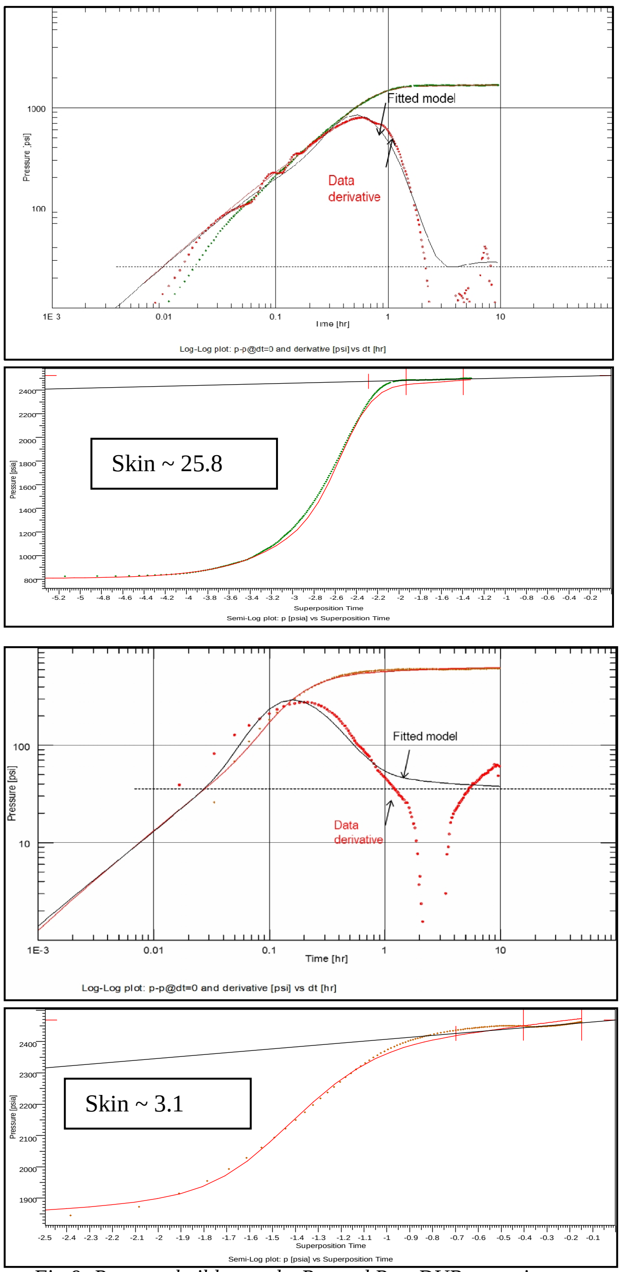

Fig-9: Pressure buildup study, Pre and Post DUB operations

The pressure transient analysis (Fig-9) showed a decreased skin of around 3.1 as compared to the initial obtained 25.8 skin, highlighting the massive cleaning done by post perforation DUB job.

Debris Analysis and Solvent Job:

The debris obtained in carrier gun from DUB operations were tested in lab to understand the nature of skin formation and identify the root cause of skin formation. The lab results showed presence of high asphaltene content in the debris, forming the major component of the skin.

This result was also supported by the downhole gauge pressure data in another well 'E' where a high FBHP in past 2 years did not probably allow formation of asphaltene, hence a minimal drop in production rates were obtained. Similar production trends were being observed in well 'D'where the surface pressure and production rates were consistent.

Based on the lab results, Wells A, B and C were treated with organic solvents to dissolve asphaltene content. Significant oil gain of was achieved in wells A, B and C which showed gains to the tune of 1800, 600 and 1000 BOPD respectively along with rise in THP

Conclusions and Way Forward:

These case studies clearly demonstrated that skin removal and improvement in productivity could be achieved through Dynamic Underbalane operations against existing perforated intervals. With proper design of the perforating gun system and process, good results can be achieved even in low pressured reservoirs.

This also marked an operational excellence in terms of rigless job execution in such high sour gas field.

The Post Perforation Dynamic Under Balance operation also facilitates collection of debris for analysis, which helped in identfying the root cause for skin development. The debris analysis was used in designing appropriate solvent. After solvent job, there was a further enhancement in production of the wells.

Furhter to optmize the production, PVT analysis of the fluid was recommended to determine the asphaltene onset pressure, so that the well system can be designed to maintain downhole pressure above it.

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