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# Optimizing Reservoir Permeability to Hydrocarbons with Micro-solution Technologies

Gary Gwartney P. Eng. and Mark Stephen P. Eng., Birchcliff Energy Ltd., C. Monty Leeds, HiTech Fluid Systems Ltd. and Tony Rea, ARC Fluid Technologies, LLC.



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## Abstract

The focus of this paper is to discuss the importance of controlling multiple phase interfacial tension between all solids, liquids and gas phases associated with the drilling, completion and maintenance of wells. Particular emphasis will be placed on mature reservoirs, low pressure reservoirs, under saturated reservoirs, low perm reservoirs and their relative hydrocarbon production potential sensitivities associated with the interactions between the fluids and chemicals introduced during the various phases of the life of the well. Supporting laboratory studies and field case histories will be included.

Optimizing reservoir potential in mature, low pressure, under saturated and low perm reservoir environments requires a pro-active engineering design for the well construction and maintenance processes. The intermediate bridge technology between the reservoir and the mechanical equipment throughout the wells existence are the fluids employed to drill, cement, complete, workover and stimulate the well. These fluids and components therein are the primary bridge technologies for enhancing mechanical performance during the well construction process. More importantly these fluids are the primary foreign contact medium with the reservoir and therefore are secondary only to the reservoir quality in defining production potential.

Fluid and chemical selections are therefore dependent upon the rock and insitu fluid characteristics of not only the reservoir but all exposed formations during the drilling process. In all cases, fluid selection should focus on limiting the transference of free fluid from the bulk fluid phase to the reservoir, controlling highly mobile fluid invasion and optimizing surface forces between the rock, fluids and gases associated with the imbibition and invasion processes. Controlling the negative aspects of these interactions with micro-solution technologies minimizes filtercake lift off pressures, optimizes flow back of imbibed and invaded fluids during the drilling and completion processes and minimizes phase trapping. Employing micro-solution technologies in the workover processes improves remediating fluid efficiencies, idealizes the reservoirs permeability to hydrocarbons and the reservoirs production potential.

## Introduction

Spontaneous imbibition occurs within low permeability under saturated reservoirs whenever they come in contact with another fluid that has a high invasion potential. Invasion in higher perm rock or fractures and the depth of invasion therein is a function of annular versus reservoir pressure differentials and spontaneous imbibition associated with the secondary porosity and permeability within the rock. Highly invasive fluids typically contain a large percentage of highly mobile free liquids (HMFL). Typical HMFL fluids are drilling fluids which are intentionally designed to de-water or de-oil in an effort to deposit a solid phase semi-permeable filtercake across an exposed permeable rock in an effort to control invasion. Completion fluids such as brines also fall into the HMFL phase category as do foam based fluids. On a stand alone basis these HMFL fluids are well suited for well construction issues associated with normal reservoir pressures of moderate to high permeability. The water based systems typically offer little if any assistance for managing high capillary pressure driven instantaneous imbibition in low permeability, water wet, under saturated formations and in fact feed the beast.

The depth of imbibition into the rock is not only determined by the permeability and saturation of the reservoir but also the chemical affinities between the gases, fluids, rock and the invading liquids, semi-solids and solid chemical additives. Each of these interfaces has an associated surface energy. The chemical interactions taking place during the imbibition process involve more than just capillary pressures. The chemical affinities between the well construction fluids, the reservoir fluids and the rock itself clearly explains why under balanced drilling or managed pressure falls short on optimizing well production potential in low permeability under saturated reservoir environments. Simply being under balance to the reservoir pressure does not place the drilling process under balance to the capillary pressure threshold or provide any significant control on imbibition. Nor does maintaining the annular pressure under balance to the reservoir pressure overcome the chemically driven imbibition aspects associated with foreign fluids when they come in contact with the exposed low perm under saturated reservoir.

Imbibition cannot be stopped. However, the depth of invasion during the imbibition process can be controlled and the negative aspects of altered surface forces can be mitigated. In fact, the insitu surface forces within the low perm under saturated rock can actually be beneficially altered thus optimizing the relative perm to hydrocarbons as a result of the controlled imbibition process. So, we can either allow the negative results of uncontrolled imbibition to dictate the wells production potential or we can employ the forces associated with imbibition process to our benefit pro-actively improving the reservoirs production potential.

**Laboratory Data**

The following is a recent return perm study performed with reservoir core and field mud. Please note that the permeability is “permeability to air” so the actual reservoir permeability is very low. This is a carbonetic sandstone reservoir. The ability to achieve 100 % regained permeability with a simple gel-chem system and drop the cake lift off pressure from 10,000 kPa to 37 kPa truly defines the importance of controlling multiple phase interfacial tension to optimize well construction fluids and reservoir performances. Tables 1 and 2 define the mud properties as used in the core test and were developed from actual field properties of the muds used in the drilling of the analogous wells.

Table 1 Gel-Chem Mud Product Concentrations

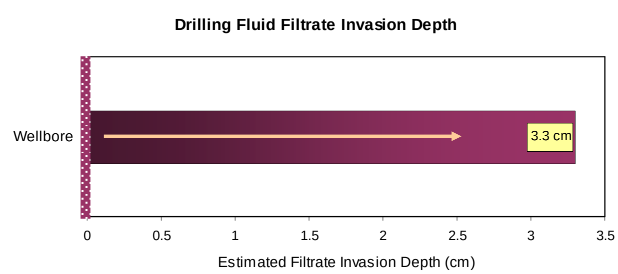
| | Kg/m$^3$ |
|---|---|
| Caustic Soda | 0.62 |
| Bentonite | 62.11 |
| PHPA | 0.62 |
| Regular PAC | 1.41 |
| Soda Ash | 0.56 |
| Lignite | 0.56 |

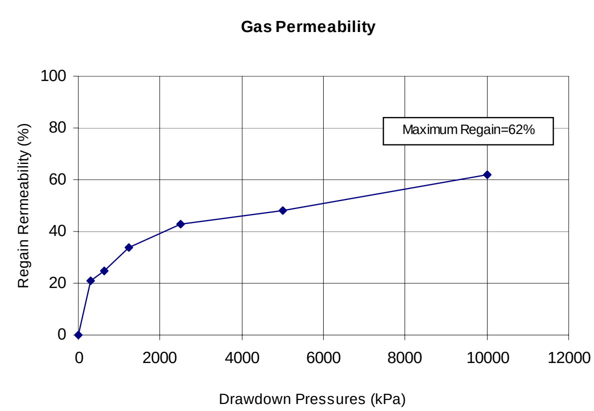
Table 2 Gel-Chem Field Mud Properties

| | | |
|---|---|---|
| Density | 1120 | kg/m$^3$ |
| Funnel Viscosity | 75 | sec./L |
| Fann 600 | 59 | |
| Fann 300 | 40 | |
| Fann 6 | 5 | |
| Fann 3 | 3 | |
| 10 sec. gel strength | 2 | Pa |
| 10 min. gel strength | 6 | Pa |
| 30 min. gel strength | 11 | Pa |
| Apparent Viscosity | 29.5 | mPa/sec. |
| Plastic Viscosity | 19 | mPa/sec. |
| Yield Point | 10.5 | Pa |
| API Fluid Loss | 6.8 | ml/30 min. |
| Filtercake | 1 | mm |
| pH Meter | 8 | scale |
| Alkalinity pf | 0.05 | ml |
| Alkalinity mf | 0.2 | ml |
| Chloride | 80 | mg/L |
| Calcium | 40 | mg/L |
| Carbonates | 136 | mg/L |
| Bicarbonates | 122 | mg/L |
| Methylene Blue | 35.6 | kg/m$^3$ |
| Sand Content | 0.01 | % |
| Oil Content | 0 | vol. frac. |
| Water Content | 0.925 | vol. frac. |
| Solids Content | 0.075 | vol. frac. |
| Lo-Grav. Solids | 195 | kg/m$^3$ |
| Drill Solids | 159.4 | kg/m$^3$ |

Fig 1. Drilling Fluid Evaluation with Gel-Chem

Well Location: 15-36-72-5W6M
Core Number: SP25A
Depth (m): 1626.89
Porosity (fraction): 0.134
Air Permeability (mD): 13.72

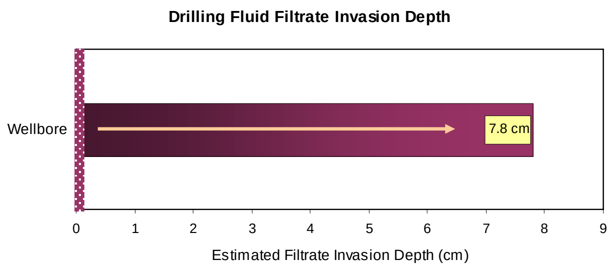


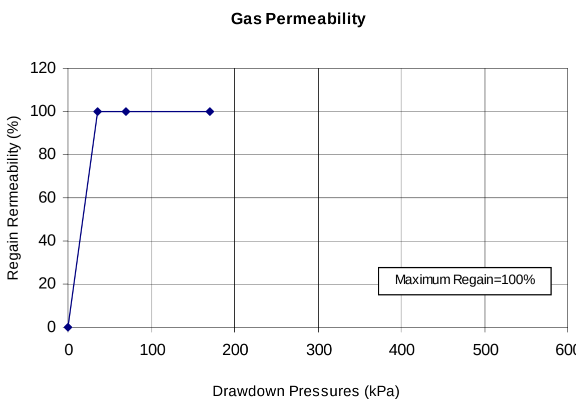



As illustrated by Figure #1, the drilling fluid invasion into the core plug of the untreated mud was 3.3 cm and a maximum permeability regain of 62% was achieved with a 10,000 KPa drawdown pressure.

Fig 2. Drilling Fluid Evaluation with Gel-Chem and ½ of 1.0 % by volume Micro-solution.

| | |
|---|---|
| Well Location: | 15-36-72-5W6M |
| Core Number: | SP25B |
| Depth (m): | 1625.84 |
| Porosity (fraction): | 0.133 |
| Air Permeability (mD): | 16.2 |




For the treated mud system, Figure #2 illustrates the filtrate invasion of 7.8 cm into the core plug and a 100% permeability regain with only a 35 kPa drawdown. Note the core that was tested with the micro-solution treated field mud exhibits greater volume and depth of filtrate penetration. This is to be expected if the micro-solution technology is doing its job of reducing the multiple phase interfacial tension by more than 50 %. Standard comparative results of API fluid loss analysis between similar base fluids that are treated and untreated with the micro-solution technology display a higher initial spurt loss and lower extended cumulative volume of filtrate with the treated fluids.

With more than double the depth and volume of filtrate penetration the micro-solution treated core produced a filtercake lift off pressure reduction to 37 kPa from 10,000 kPa on the untreated core. This opens the door for debate as to whether or not simply controlling API fluid loss is sufficient protection for mature, low pressure, under saturated and low perm reservoir environments.

**Field Trial Data**

The micro-solution technology has been used on three wells drilled in this field to date. All of these wells exhibited substantial inflow on perforation compared to five analog wells completed in the same zones in the same field with the same gel-chem drilling fluid and no micro-solution additive. Of the five analog wells, one produced without stimulation, one produced without stimulation despite substantial skin damage, two were stimulated without success and one could not be stimulated due to proximal water concerns.

Treated Wells

Well 1:

| | |
|---|---|
| Formation: | Gething |
| Perforations: | 1,263-1,267.5 meters |
| Pressure: | 11,695 kPa |
| Completion: | Perforation only |
| qi= ($e^3m^3$/d): | 46.9 $e^3m^3$/d |
| FTP (kpag)=: | 7,992 |
| AOF w/h (stab): | 23.1 |
| Skin: | 11.1 |

Well 2:

| | |
|---|---|
| Formation: | Gething |
| Perforations: | 1,326-1,333 meters |
| Pressure: | 11,336 kPa |
| Completion: | Perforation only |
| qi= ($e^3m^3$/d): | 9 mopd + 3.4 $e^3m^3$/d |
| FTP (kpag)=: | 2,000 |
| Comment: | API = 22 oil. |

Well 3:

| | |
|---|---|
| Formation: | Cadomin |
| Perforations: | 1,653-1,654 meters |
| Pressure: | 15,384 kPa |
| Completion: | Perforation only |
| qi= ($e^3m^3$/d): | 18 $e^3m^3$/d + 22.7 $m^3$/d 80% BSW |
| FTP (kpag)=: | 1,000 kpa |
| Comment: | Good inflow but substantial water. |

Non Treated Wells

Well 4:

| | |
|---|---|
| Formation: | Gething |
| Perforations: | 1704 - 1715 meters |
| Pressure: | 15,204 kPa |
| Completion: | Perforation only |
| qi= ($e^3m^3$/d): | 40.0 $e^3m^3$/d |
| FTP (kpag)=: | 6,000 |
| AOF w/h (stab): | 19.9 $e^3m^3$/d |
| Skin: | 92.0 |
| Kh (mDm) | 24.9 |
| Comment: | Good inflow but substantial Skin. |

Well 5:

| | |
|---|---|
| Formation: | Gething |
| Perforations: | 1,659-1,662 meters |
| Pressure: | N/A |
| Completion: | Perforation |
| qi= ($e^3m^3$/d): | TSTM |
| FTP (kpag)=: | Atm |
| Comment: | Proximal to water. No inflow or stimulation. |

Well 6:

| | |
|---|---|
| Formation: | Gething |
| Perforations: | 1646-1648 meters |
| Pressure: | N/A |
| Completion: | Perforation, N2 sqz, Mutual Solvent sqz |
| qi= ($e^3m^3$/d): | TSTM |
| FTP (kpag)=: | Atm |
| Comment: | Stimulations unsuccessful |

Well 7:

| | |
|---|---|
| Formation: | Gething |
| Perforations: | 1681-1684 meters |
| Pressure: | 6000 + kPa |
| Completion: | Perforation, CO2 sqz |
| qi= ($e^3m^3$/d): | 1.2 $e^3m^3$/d |
| FTP (kpag)=: | 100 kPa |
| Comment: | Stimulation unsuccessful |

Well 8:

| | |
|---|---|
| Formation: | Gething |
| Perforations: | 1615-1622 meters |
| Pressure: | 15,470 kPa |
| Completion: | Perforation only |
| qi= ($e^3m^3$/d): | 39.1 $e^3m^3$/d |
| FTP (kpag)=: | 8690 kPa |
| Skin=: | 11.5 |
| AOF= ($e^3m^3$/d): | 57.1 $e^3m^3$/d |

**Conclusions:**

By controlling the interfacial tensions between the liquids and solids within a drilling fluid and reservoirs better production performance is achievable. When additives that are designed to build a filtercake seal can flow through the liquid phase of a drilling fluid more efficiently they provide better utility. Relieving these additives of the interference of multiple phase interfacial tension significant benefits are received. One is the products move more easily through the liquid phase of the drilling mud and are deposited as a filtercake more efficiently. Secondly their resistance to lift off when the well is brought on line is significantly reduced. Couple these features to the added benefit of the micro-solution traveling with the filtrate that enters into the reservoir when the filtercake seal is created. In so doing, all interfacial tensions between fluids and solids encountered by the micro-solution are reduced by more than 50 % thus optimizing flow back. This reduction of multiple phase interfacial tension reduces the water saturation and optimizes the permeability to hydrocarbons within the reservoir.

Little if any negative affects on drilling fluid properties have been noted. In fact, field reports of reduced torque and drag, better quality DST's and fast clean up time are the norm. The technology is applied at ½ of 1% by volume during the drilling operation. It should be added a couple of hours prior to drilling into the 1st production zone and the concentration maintained thereafter to TD of the well by applying daily treatments in accordance with the additional volume being built while drilling.

Similar results to those discussed herein have also been observed with oilbase drilling fluids.

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