MICRO-SOLUTION TECHNOLOGIES ENHANCE LOW PERM RESERVOIR PERFORMANCE

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ABSTRACT

During the drilling, completion and workover processes large quantities of fluid are trapped in the reservoir surrounding the wellbore. Less than half of these invading fluids are ever recovered through conventional means. These trapped fluids have a detrimental effect on the relative permeability of the rock and effective flow area of the bore seriously impairing well productivity. The Micro-solution technologies are custom designed to restrict imbibed fluid volume, improve the clean up of invaded fluids and optimize the reservoirs relative permeability to hydrocarbons.

The Micro-solution technologies restrict total imbibed fluid volumes by controlling leak off through filtercakes and into the capillaries of low permeability rock. They produce ultra-low interfacial tensions between the micro-solution phase and the excess oil and/or water phases, increasing the contact angle with the rock and overcoming the capillary forces that "trap" oil or water in a porous medium enhancing clean-up of these fluids.

KEY WORDS

Capillary end effect
Capillary pressure
Capillary pressure threshold
Contact angle
Highly mobile free liquid (HMFL)
Imbibition
Imbibition potential
Low permeability
Micro-solution (MicroFlow)
Permeability to hydrocarbons
Phase trapping
Ultra low interfacial tension
Under saturated

INTRODUCTION

The content of this paper and poster session are based upon proven field results and conclusive lab data detailing the benefits derived from this advantageous technology step change within the surfactant and solvent chemistries area of the Oil and Gas industry. The Micro-solution technologies are a low cost enhancer to existing waterbase and oilbase drilling, completion, workover and stimulation fluids. Improved IP's when applied pro-actively within low permeability reservoir have been dramatic. Though the primary function is to optimize low perm reservoir potential other benefits are continually being reported from drilling to remedial clean-up well treating processes.

DISCUSSION

Capillary pressure threshold or capillary end effect is primarily a function of permeability, water saturation and interfacial tension between the rock and the invading fluids. (Fig. 1) The lower the permeability the greater the capillary pressure threshold is within the rock. It is important to note that capillary pressure and reservoir pressure are different. The more under saturated the reservoir is the higher the capillary pressure within any given permeability is. The combined effect of permeability and saturation define the imbibition potential and the resultant degree of risk for inducing phase trapping during the drilling, completion, workover and stimulation processes as imbibed fluids alter the interfacial tensions between the various gas, liquid and solids phases within a reservoir rock.

Imbibition occurs within low permeability under saturated reservoirs whenever they come in contact with another fluid that has a high invasion potential. Highly invasive fluids include highly mobile free liquid (HMFL) phase fluids. 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. These HMFL fluids are ideal for well construction issues associated with normal reservoir pressures of high permeability. They offer little if any assistance for managing high capillary pressure driven imbibition in low perm formations and in fact feed the beast.

Fluid loss during the initial deposition of the filtercake with conventional HMFL fluids is high (Fig. 2). Dynamic and static fluid loss throughout the well construction phase is continual due to mechanical and chemically induced erosion of the deposited filtercake. Invasion of associated fluids within the reservoir will continue until such time as a new dynamic balance has been achieved. The altered reservoir saturation is the result of chemically enhanced interfacial tensions between the associated gases, liquid and solid phases within the rock. The net result is reservoir impairment typically defined as phase blocking or trapping.

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 and chemicals. 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.

Optimizing reservoir potential in low perm rock requires a pro-active engineering design for the well construction process throughout the life of the well. 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 are the primary foreign contact medium with the reservoir and therefore are secondary only to the reservoir quality in defining production potential. In addition, fluids are the primary bridge technology for enhancing mechanical performance during the entire well construction process.

Fluid selection is therefore dependent upon the rock characteristics of the reservoir. In low perm under saturated rock fluid selection should focus on limiting the volume of available free fluid, controlling whole fluid invasion potential and optimizing surfaces forces between the rock, fluids and gasses associated with the imbibition process.

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 surfaces 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 wells production potential.

The base fluid selection for any given application in low perm under saturated reservoirs is critical. The aphron fluid technologies offer the lowest imbibing fluids available today. (Fig. 3 and Ref. 1) By design the aphron system restricts imbibition by severely limiting free water availability, free water mobility and aggressively controls whole mud invasion due to its unique design. Coupling the aphron fluids with the micro-solution technologies provide the most advanced pro-active fluids based production optimizing package available in our industry today.

The micro-solution systems associated with invading fluids provide a production optimizing building process by:

1. initially penetrating the contaminating oil or water layers through the solvent micro-solution mechanism,

2. their by driving micro-emulsification of the oil, water or gel components into the aqueous phase and

3. water-wetting of the underlying solid surfaces through the surfactant/detergent action.

The results of these actions are the micro-solution systems produce ultra-low interfacial tensions between the micro-solution phase and the excess oil and/or water phases increasing the contact angle with the rock, thereby overcoming the capillary forces that “trap” oil or water in a porous medium. The micro-solution surfactant and solvent components work in a combined fashion to increase the penetration and cleaning capacity of the product within the reservoir. (Fig. 4)

The combination of these modes and the fact that they are working in the 10 – 50 angstrom size range is why they significantly out perform conventional organic solvents and surfactant systems. (Fig 5)

CONCLUSIONS

- Capillary pressures and reservoir pressures are two different issues and must be approached independently when designing fluid programs.
- Capillary pressures cannot be controlled to any great degree with UBD.
- Limiting the volume of HMFL that comes in contact with high capillary pressure low perm reservoirs is a key fluids design objective.
- Optimizing the relative perm to hydrocarbons with the invading fluids during imbibition is fundamental to achieving production goals.

COMMENTS

1. The use of KCL for clay inhibition is an industry standard. The chloride ion concentration difference between the reservoir fluids and the drilling, completion, workover or stimulation fluids can have significant impact on the depth of invasion during the imbibition process. Obviously the potassium ion will aid in controlling clay swelling. Again, two different things entirely.

2. The MicroFlow additive in 2 % KCL will help in what you are seeking to achieve as can be observed in Figure 5. It is highly probable that by further restricting the available HMFL the permeability damage percentage can be further reduced.

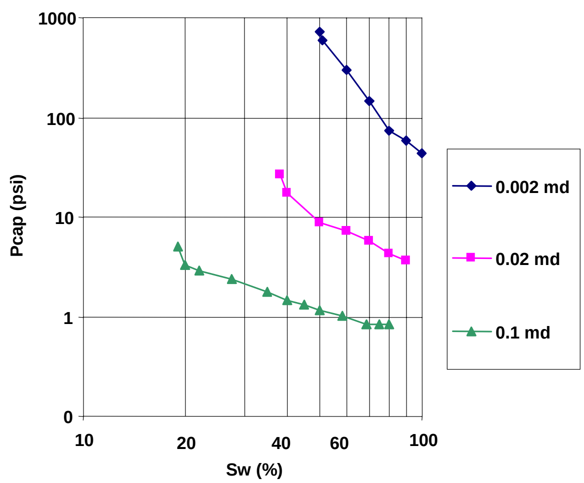
3. Frac fluids typically employ high LSRV to aid in propant delivery; this also contributes to limiting HMFL availability for feeding imbibition into the reservoir along the frac faces.

REFERENCES

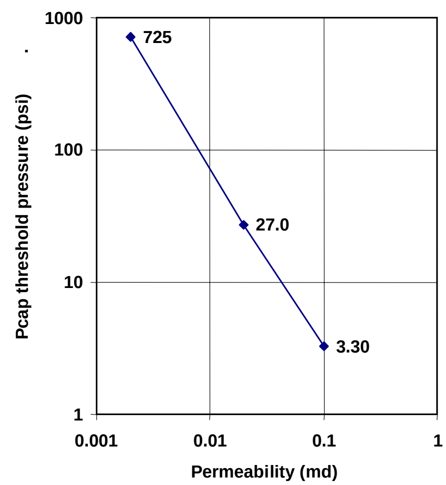
1. “Drilling Fluid Selection To Minimize Invasion – A New Test Method”; Tatiana Hoff, Robert O’Connor and Fred Growcock, MASI Technologies LLC and M-ISWACO; Paper: AADE-05-NTCE-73

FIGURES

Figure 1



Capillary Pressure vs. water saturation for low permeability reservoirs



Capillary Pressure threshold or end effect vs. permeability over three orders of magnitude of permeability.

Figure 2

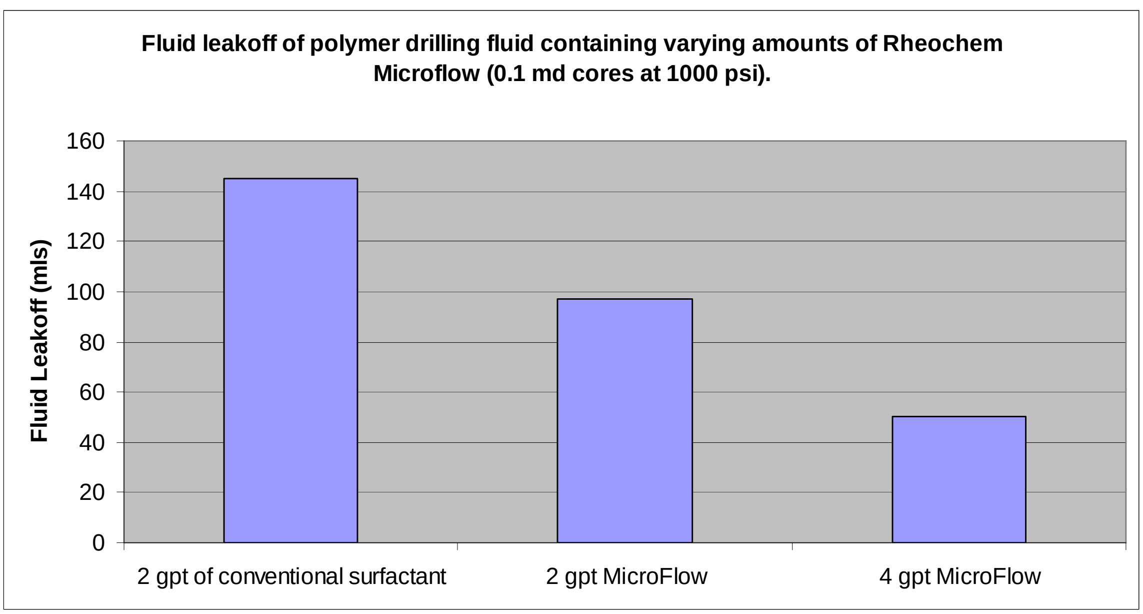


Figure 3

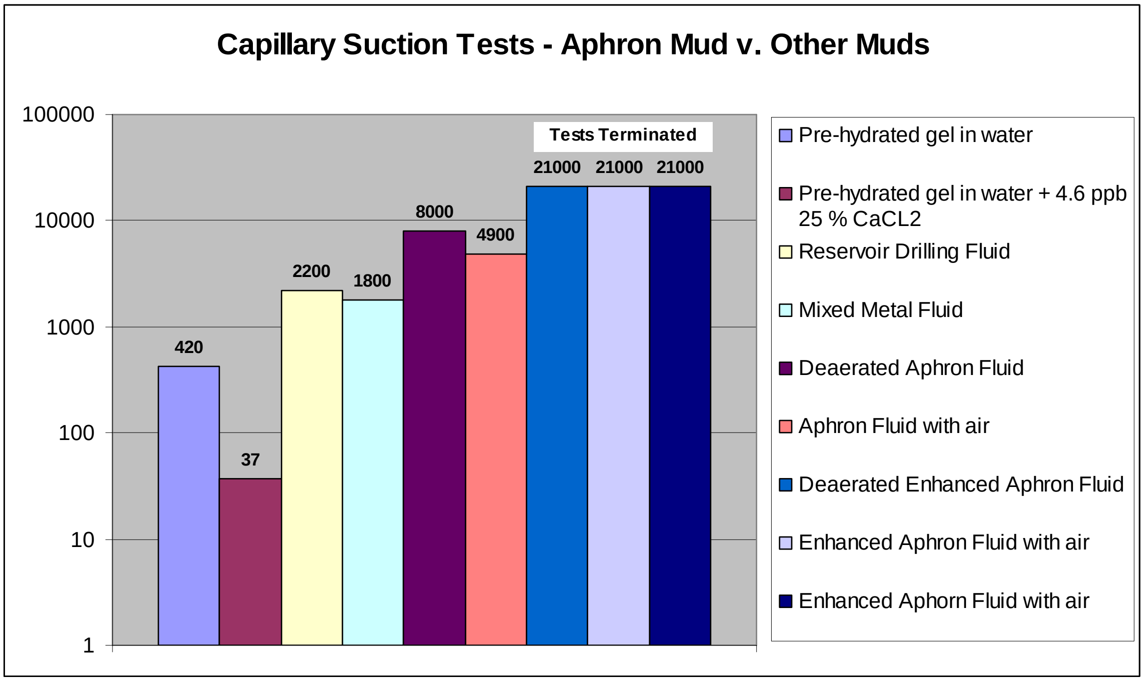
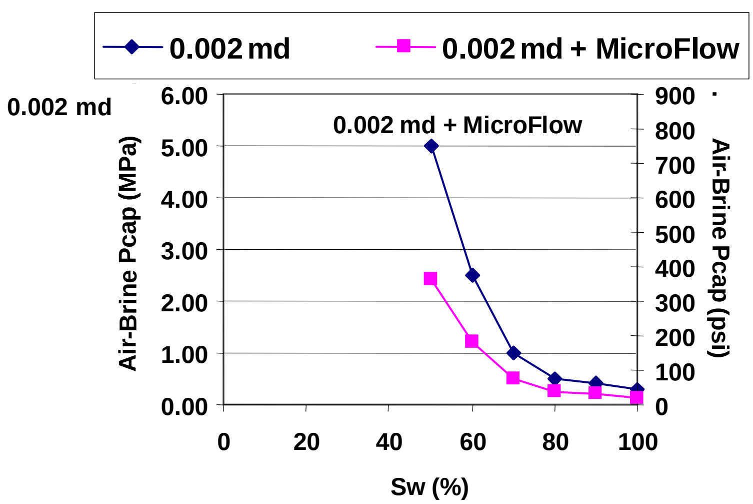
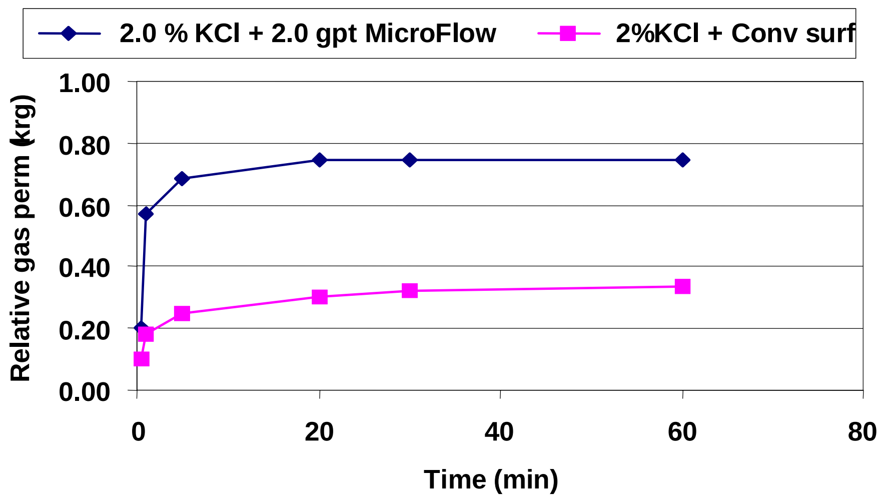


Figure 4



Capillary pressure with conventional surfactant vs. Micro-solution (MicroFlow) at 2.0 gal/1000 gal.

Figure 5



Relative permeability to gas of 0.1 md sandstone cores treated and regained at 1000 psi with and without Micro-solution (MicroFlow).

Figure 6