Enhancement of Oil and Gas-Condensate Wells Productivity by Artificial Alteration of Wettability in Reservoirs Bottom - Hole Zones

L. Berman, K. Mirotchnik
NMR Plus Inc., Canada

K. Zhao
Enecal Canada Corp.

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ABSTRACT

The actual productivity of many oil and gas-condensate wells is lower than calculated figures despite the fact that the calculation was based on correct values of hydroconductivity, formation pressure ($P_f$), and producing bottom hole pressure ($P_p$). These discrepancies are especially significant in two cases:

- Producing bottom hole pressure in oil well is lower than bubble-point pressure ($P_{bp}$);

- High initial condensate gas ratio ($CGR_0 > 1$ gal./Mcf) in the gas-condensate reservoirs and, especially, when residual oil is present in gas-saturated part of the reservoir.

The decline of a wells’ productivity in course of time has been noticed during development of several oil and gas-condensate fields. This is especially characteristic of the deep oil and gas-condensate reservoirs ($H>3000m$) as well as of reservoirs saturated by oils containing asphaltenes. These effects are more prominent in heavy oil reservoirs.

Also the decrease of a wells’ productivity usually occurs after fracturing of reservoirs saturated by oil with high asphaltenes content. These effects were reported after frac-packs operations performed with pure frac sands as well as with Resin Coated Propants (RCP).

The experimental program was carried out for the study of physical-chemical phenomenon inducing these
effects during the exploitation stage. The new method for bottom hole zones treatment was developed based on the results of this research. The artificial alteration of wettability conditions (hydrophylization) of pore surfaces in near wellbore zones is the basic procedure utilized in this technology.

The Low Field NMR method was used for this phenomenon investigation and for simulation of the wettability conditions monitoring during reservoir treatment.

INTRODUCTION

The decline of a wells' productivity over the course of time has been noticed in the process of development of some oil and gas-condensate fields[2,3,9]. This is especially characteristic of the deep-seated oil and gas-condensate reservoirs \( h \geq 3000\text{m} \) as well as of oil reservoirs saturated by oils containing the polar hydrocarbons, especially asphaltens.

A sharp decline of a wells’ gas-condensate productivity (to a third of the initial value and even less) took place in some gas-condensate fields soon after these wells were put on stream. The initial condensate content in the reservoirs of these fields exceeds 3 gal/Mcf. The gas-condensate wells are often characterized by unstable productivity. The productivity decline is usually accompanied by a change of the physical-chemical properties of condensate (density decrease, etc.). The determination of the optimum operational drawdown pressure at the late stage of development of the gas-condensate fields is quite difficult since in some cases high drawdown is accompanied by a reduction of the specific condensate content in the extracted product.

Occurrence of the free gas in the bottom hole zone of the oil wells brings the decline of productivity. Therefore determination of the optimum operational drawdown pressure in the oil wells often depends on the probability of free gas occurrence in the bottom hole zone. This is especially important in case of the oil-gas fields and the oil reservoirs having great variations of permeability and considerable recoverable reserves in the low-permeable rocks.

The presented above conditions cause reduction of the rate of oil, gas and condensate recovery as well as lessening of the recoverable reserves.

One of the main reasons of the productivity decline in the oil and gas-condensate wells is a partially hydrophobic surface of the largest pores \([1,4,7,10,11]\) that causes a high probability of the critical pressure gradient \( (G_g) \) occurrence in the reservoirs when the mixture of liquid and gaseous hydrocarbons is flowing. The flow of gassy oil and, in some cases, gas flow through the hydrophobic pores occurs only under some pressure gradient higher than the critical value. The value of \( G_g \) (in the lithologically similar oil and gas-condensate reservoirs) depends on distribution of the hydrophobic and hydrophilic pores according to their diameter and total rock volume. Experimentally measured \( G_g \) for gas has reached about 100 Psi/m. The measurement has been carried out for the core samples having the irreducible water-saturation \( (\text{Swirr}) \) equal to the formation \( \text{Swirr} \) value. The \( G_g \) values for condensate in these rocks under the same temperature-pressure \( (P-T) \) conditions exceed the \( G_g \) value for gas by about 30 times\([1-3, 5]\). Increase of the static pressure was recorded in gassy oil producing wells up to 3000 psi after wettability alteration (hydrophylization) of the near well-bore. But, \( G_g \) prevented (affected) the free hydrodynamic conductivity (under any differential pressure) of a near wellbore zone (with precipitated condensate) and rest of the reservoir.

CRITICAL PRESSURE GRADIENT AT GAS FLOW THROUGH POROUS MEDIA

The basic ideas of the mechanism of gas and water flow through the porous medium were established experimentally more than 100 years ago by H. Darcy who studied the process of a single-phase flow. By now, there are several approximations describing relation between the rate of gas flow and the pressure gradient. It was accepted until recently, that in the real gas-water-saturated porous medium, containing only irreducible water \( (\text{Swirr}) \), the gas flow begins under any pressure gradient, no matter how small it is. The theoretical description of the process of gas flow through the gas-water-saturated porous medium assumes that the mechanism of flow does not depend on the pressure...
gradient and that the mobility of gas can be determined by the curves of relative permeability.

The design of the gas and gas-condensate fields’ development program usually deals with two models of the reservoir:

- **Model 1:** A gas-dynamically single reservoir.
- **Model 2:** A reservoir is a combination of the gas-dynamically separated units or lenses. In this case each single unit or lens actually represents the Model 1. Model 2 is usually applied in the tectonically faulted reservoirs.

Under the gas regime of exploitation corresponding to the Model 1 (gas-saturation of productive deposits is constant) distribution of the current formation pressure \( P_f \) in the reservoir is determined by the rate of gas production, hydraulic conductivity of the different parts of the reservoir, location of the producing wells, geometry of the pool, etc. It was found out by numerous model calculations, that under this regime the recovery efficiency of gas practically does not depend on the wells’ grid and rate of production. Therefore location of the producing wells is conditioned only by their probable productivity in the different parts of the reservoir and by the cost of the gathering system and gas-condensate treatment before further transportation.

The analysis of results of the fields’ exploitation indicates\(^3,9\) that in the majority of cases the adopted reservoir models do not fit the real reservoir and do not meet the accuracy required by modeling:

- Actual recovery efficiency of gas from already depleted reservoirs depends on the grid of producing wells. The more wells the higher recovery efficiency of the gas;
- Reliable and stable in time evaluation of the drained volumes of the reservoir \( V_t \) may be obtained only when all the producing wells are in operation and recovery reaches not less than 10-20% of the total in-place gas reserves;
- The theoretical evaluation of the volumes and rates of the formation water encroachment into the gas-saturated reservoirs in the process of long-term production of gas and condensate provides solutions with low accuracy;
- In depleted gas fields that are turned into underground gas storage, essentially different formation pressures appear when the reservoir was exploited as a field and when it became a gas storage. It should be noted that in both cases the volume of gas in the reservoir was the same.

These results of field observation can be explained by presence in the reservoirs of the gas-saturated rocks in which the gas flow occurs only when the pressure gradient exceeds some critical value \( G_g \).

### RESULTS OF EXPERIMENTAL STUDIES OF CRITICAL PRESSURE GRADIENT

The extensive experimental studies of \( G_g \) phenomenon were carried out on Cenomanian core samples from the Urengoy gas reservoir (W. Siberia), results were obtained and published elsewhere\(^3,5\). The study of the gas-water-saturated porous medium was carried out by using the equipment that enable to determine of the permeability of samples under various stresses. The natural and artificial samples have been used for this study.

The existence of \( G_g \) becomes apparent from the fact that there is no gas flow through the samples under small pressure gradients. Gas begins to flow when the difference \( \Delta P \) between the inlet pressure \( P_1 \) and the outlet pressure \( P_2 \) exceeds some threshold of pressure gradient \( \Delta P_g \). Under this condition, when \( P_1 - P_2 = \Delta P > \Delta P_g \), the rate of gas flow is determined by the difference \( P_1^2 - P_2^2 \). Then the pressure gradient is given by the equation:

\[
G_g = \Delta P_g \times L_o^{-1}, \quad \text{.................................................................(1)}
\]

where \( L_o \) is the length of the sample.

The results of this study show that hysteresis for irreducible water distribution in the process of gas flow did not appear. Repeated measuring of the electric resistivity also indicated the absence of irreversible changes in irreducible water distribution. The value of critical pressure gradient in the studied gas samples was
approximately 100 psi/m, for condensate - approximately 3000 psi/m.

The influence of the initial pressure gradient on development of gas-bearing reservoirs was also investigated on Gazli gas field, Uzbekistan. The field-trial data from these studies were presented and discussed in open literature\[3,5,9\].

The presence of $G_g$ during the gas flow in the reservoir causes an incomplete build-up of $P_f$ in the wells after testing. The gas flow to the bottom hole zone from gas-saturated rocks with $G_g \neq 0$ (semi-permeable membranes) ceases (during this investigation) when the pressure distribution in the vicinity of the borehole meets the following condition:

$$\Delta P_i \times L^{-1} \leq G_g ;$$

where ($P_i$ is the pressure differential between the bottom hole zone and the rest of the reservoir and $L$ is the distance between the bottom hole and the part of reservoir, where the pressure is equal to $P_f$.)

This extensive experiment also proved the critical pressure gradient phenomenon.

POSSIBLE MECHANISM OF GAS FLOW UNDER CRITICAL PRESSURE GRADIENT

There is no reason for the appearance of $G_g$ in the process of gas flow if gas in the porous medium represents a single coherent phase. The $G_g$ may occur if gas does not form this sort of coherent phase since, in particular, the narrow parts of the pore space (throats) are filled up with water or other liquid. In order to provide the coherence of gas phase and gas flow under these conditions a partial transfer of the blocking liquid is necessary. The extent of this liquid involvement in the flow depends on the completeness of water-saturation, water distribution in the porous medium, wettability of the pore surface and the pressure gradient in the process of gas flow.

In case of Swirr and small pressure gradients, water may be displaced into the gas-saturated pores and retained there by capillary forces - this is a local two-phase flow. After a reduction of the pressure gradient owing to capillary forces and because of elasticity of gas bubbles jammed within the pores’ space, water may again return to a most “stable” state. At water-saturation higher than Swirr or at higher-pressure gradients, water may be redistributed. The critical pressure gradient in the process of gas flow may be also caused by water displacement within the pore space of variable diameter because of the various capillary forces in its different parts. In order to provide the gas flow, the capillary attracted water should be squeezed out.

If the blocking oil or condensate has contact with partially hydrophobic pore surfaces then the hysteresis of wetting angle occurs in case of the liquid displacement \[6\].

Thus, the non-coherent gas phase becomes movable when liquid is displaced and the coherent gas phase is formed. Accordingly, the Jamin effect may be one of the causes of the existence of the critical pressure gradient in the process of gas flow.

The presence in the gas reservoirs of the gas-water saturated rocks containing the non-coherent gas phase may be caused either by the variety of the conditions under which the reservoirs have been formed or by changes of the reservoirs thermodynamic situations.

The mechanism of gas flow under the critical pressure gradient is not completely understood yet. Taking into consideration the different wettability of surface of variable diameters’ pores\[4,7,10,11\], the hypothesis of wetting angle and effect of this phenomenon deserves a social attention. This hypothesis has been proved by the study of oils with gas bubbles in the hydrophilic and hydrophobic quartz capillary of the same diameter\[6\]. Figures 1 and 2 show the relationship between rate of flow ($V$) and pressure gradient ($\Delta P$) for two oils as well as the length of gas bubble and diameter of capillaries. In the hydrophilic capillaries the relationship between $V$ and $\Delta P$ is linear and the line crosses the zero point, i.e., the flow is governed by the Darcy law. In the hydrophobic capillaries this relationship is nonlinear. The system behaves as a liquid with Bingham yield point ($P_0$) in case of high enough flow rate:

$$P_0 = \frac{2\sigma \times (\cos \theta_x - \cos \theta_y)}{r}; \text{...................................................(2)}$$
where \( r \) is the pore radius;

\[\sigma\] - liquid surface tension;

\( \theta_a \) and \( \theta_r \) - values of the advancing and retreating wetting angles, accordingly.

The effect that the hysteresis of wetting angle influenced on the relation between \( V \) and \( \Delta P \) may be evaluated by measuring this angle for studied oils on plane surface. Results of measurements are presented in Table 1.

The relationship between \( V \) and \( \Delta P \) in case of low flow rate is nonlinear and at certain point the line breaks. The \( P_0 \) value increases with the increase of the number of gas bubbles (Figures 1 and 2). The calculated and experimentally obtained \( P_0 \) values are in satisfactory concurrence.

**PROPOSED METHOD**

The shortcomings related to the presence of the critical pressure gradient effect may be overcome by the application of a method of Increasing of Oil and Gas-Condensate Wells’ Productivity by Hydrophilization of Reservoir in Bottom Hole Zones.

The proposed method is based on the study of wettability of the pore surfaces of the productive deposits and on the specifics of gassy oil flow through the hydrophobic and hydrophilic porous media.\(^{3, 4, 6, 7}\) The results of the comprehensive study are as follows:

1. In the majority of cases the physical-chemical properties of recovered oil and residual oil in the depleted reservoirs are essentially different\(^{4, 12}\);

2. Residual oil in the reservoirs developed under the displacement process of oil by water may be divided by its viscosity, as a first approximation, into two types:
   a) oil adsorbed on a surface of large pores;
   b) oil jammed in mainly small pores.

The jammed oil exists in all oil-saturated rocks. The physical-chemical properties of this oil are close to the properties of recovered oil.

The NMR spectra characterization of oils at different conditions that illustrates the above statement are presented in Figure 3.

The adsorbed oil contains more heavy fractions and it is essentially more viscous than the recovered oil\(^{7,12}\). The better petrophysical properties of the productive deposits and the lower Swirr values as well as the higher viscosity and asphaltene’s content of the recovered oil - the larger share of the adsorbed oil in the total volume of residual oil in the reservoir. The adsorbed oil is mostly associated with the largest pores and it makes their surface hydrophobic. At the same time the surface of the small pores may remain hydrophilic.

An additional considerable sorption of the heavy fractions of oil and condensate may occur on the pore surface when the temperature - pressure conditions are changed, particularly, in the bottom hole zone. This phenomenon may be observed in reservoirs with either heavy oil or light oil having low content of the heavy fractions in the produced oil and condensate. Similar effect was also found during experiments carried out with samples presented by resin coated proppants (RCP). The NMR spectra delivered from measurements on RCP packs saturated by oil and measured at 25°C after treatment at 40°C and 80°C are shown in Figure 5. The sorption effect is clearly indicated. The sorption activity for different RCP products during filtration of the identical oil is different (see Figures 4 and 5).

Occurrence of \( G_g \) in the process of gas flow through the porous medium containing gas, oil (condensate) and irreducible water is caused by breaking down the gas phase coherence. This is characteristic of the large hydrophobic pores as well as of the small hydrophilic pores with high water-saturation. The \( G_g \) value in the process of gas and condensate flow could be especially high in the case of condensate precipitation in the bottom hole zone and formation pressure reduction. In this case the critical pressure gradient \( G_g \) may also appear in the rocks where it did not exist before the start of production. This is characteristic of the reservoirs with high initial condensate content.

The proposed method requires the following main operations for its application:
• Optimization of the solvent/surfactant recipe based on the laboratory study (routine or with application of the low field NMR technique).
• Injection of a solvent that washes the pore surface free of the adsorbed heavy fractions of oil (condensate) and asphaltenes;
• Replacement of the solvent by the solution, which may make the hydrophilic pore surface;
• Putting the well on the stream again.

The optimum chemical composition of the operational solution (solvent/surfactant) as well as the regime and volume of its injection depends in each case on the petrophysical properties of the given reservoir (filtration heterogeneity, lithology, etc.) and on the formation fluids’ properties. The NMR method is a very sensitive tool that can be efficiently used for monitoring all of the stages of the simulation process in laboratory for the purpose of recipe optimization. Results from the NMR method for determination of the optimum solvent for investigated oil and final effect from hydrophylization of core plug’s pore surface is presented in Figure 6.

The hydrophilization of pore surfaces brings the essential improvement of filtration properties of productive deposits in the vicinity of the borehole owing to the following effects:
• Reduction \( G_g \) in the oil- and gas-condensate-saturated beds and in some cases (if the hydrophilic agent is selected properly) - reducing its value to nil;
• Excluding \( G_g \) occurrence in the oil-saturated beds when a free gas appears;
• Washing out condensate that precipitates in the bottom hole zones of the gas-condensate wells;
• Lessening of the probability of \( G_g \) occurrence in the gas-condensate-saturated rocks in case of the formation pressure reduction.

RESULTS FROM LABORATORY STUDIES

Figure 7 shows the results of the experimental study that illustrates the efficiency of the pores’ surface hydrophilization in the process of gassy oil flow through the hydrophobic quartz capillary\[6\]. The artificial hydrophilization of the capillary under conditions at pressure difference \( \Delta P = \text{constant} \) brings an essential increase of the flow rate.

Figure 8 shows the relationship between condensate recovery and pore’s surface wettability in the process of the gas-condensate reservoir depletion (mixture of condensate and natural gas; \( \text{CGR}_0 \) value is about 15 gal/Mcf; saturation pressure 2690 Psi). A vertical model of “reservoir” made of grained quartz sand has been used for the study. The length of the model was 1100 mm, diameter - 35mm, permeability - about 120 MD, porosity - about 32%. Prior to the beginning of depletion, wettability has been regulated by two different solutions. In the process of study a relative wettability of the maximum hydrophobic pore surface was taken as nil and wettability of the completely hydrophilic pore surface as 1. A maximum hydrophobization of pore surface has been achieved by squeezing of the gas-condensate mixture through the dry sand. The maximum value of condensate recovery in the process of study was taken as 1, the recovery values under various conditions of the pore surfaces are shown as a portion of the maximum value. The effect of pore surface wettability on the extent of condensate recovery is significant (see Figure 8).

Figure 9 illustrates the process of depletion of the mentioned above reservoir model with similar initial wettability achieved by application of different solutions (relative wettability is 0.59; see Figure 8). It is worthy of notice that treatment of the pore surface by solution 2 brought much higher condensate recovery than by solution 1. The observed differences of the condensate recovery have been caused by the different dynamics of the recovery process at the final stage of depletion (see Figure 8). Probably, the solution 1 tears the hydrophilic film on the pore surface and, as a result, condensate sticks to it earlier than in case of the solution 2. This emphasizes a special importance of the proper selection of the solvent and the hydrophilic solution for the each given reservoir.

At the end of the depletion process the gas permeability reduction in the maximum hydrophobic model was about 40% higher than in the hydrophilic
model. In addition to the measurement of the recovered volume of gas and condensate in the process of model depletion, the chromatographic analysis of condensate under the pressure 1545 Psi has been carried out. It was established that the model of the reservoir with hydrophilic pore surface provides higher content of heavy fractions in the recovered condensate than the model at hydrophobic pore surface.

FIELD TRIALS

Several modifications of the above method have been successfully applied in some onshore and offshore gas-condensate fields of the former USSR (Central Asia, Azerbaijan, W. Siberia, Ukraine, etc.). The wells’ depth was in the range 1200 - 5000 m, condensate content in the range 0.2 - 4 gal/Mcf. The trials have resulted in an average increase of well’s productivity by about 50% for condensate, about 30% for oil and about 20% for gas. The treatment of a gas-condensate well lasts not more than three days. After this the well has stable productivity for an average period of 6 months. Then a new treatment is advisable.

Some results of the method application in the offshore gas-condensate fields of Azerbaijan are displayed in Table 2 (fields: Bakhar; Sangachaly-sea - Duvanny-sea - Bulla-island). Table 2 indicates that the treatment resulted in an increase in condensate and gas productivity as well as in the density increase of stable condensate. The density situation according to the chromatographic analysis is illustrated by Figure 10.

PLANNING FOR METHOD APPLICATION

The working plan for method application can be proposed in the following general terms:

- Examination of heavy hydrocarbons’ properties which possibly dictate hydrophilization of the pore surface of more permeable rocks in a specific reservoir.
- Selection of solvents and hydrophilizing substances (mainly surfactants) for the rocks with various petrophysical properties.
- Simulation of washing off and hydrophilization processes on core samples at the reservoir conditions.
- Simulation of extraction processes using the initial and hydrophilized models of the productive deposits.
- Selection of the top priority wells for re-completion.
- Preparation of programs for the treatment of specific wells.
- Treatment of the pilot well (wells).
- Pilot production operations.
- Analysis of the production data.
- Correction of the work plans for typical wells.

The proposed method is workable under any development regime and its application can be adjusted to any type of field. Our experience shows, and results of the continuing research enforce that the method can be further developed and improved, especially regards to oil wells.

CONCLUSIONS

This developed method for the Increase of Oil and Gas-Condensate Wells’ Productivity by Hydrophilization of Reservoir in Bottom Hole Zones provides the following advantages:

- Stable exploitation of oil and gas-condensate wells;
- Elimination of the discrepancy between the actual and projected productivity;
- Restoration of well’s productivity when either condensate precipitation or sorption of heavy
fractions of oil or asphaltenes in the bottom hole zone occur;

- Increase of the optimum operational drawdown and, accordingly, the production rates of the producing oil and gas-condensate wells;

- Increase of the ultimate oil, condensate and gas recovery from the reservoirs.

- Ability to rehabilitate of the water encroached intervals in hydrocarbon’s producing wells.

The combination of routine laboratory techniques with SCAL methods, especially with low field NMR technology, provides the advantage of the method optimization.

**NOMENCLATURE**

- CGR condensate gas ratio
- CGR₀ original condensate gas ratio
- \( G_g \) critical pressure gradient at gas flow through porous medium.
- \( H \) reservoir depth
- \( L \) the distance between the bottom hole and part of reservoir where the pressure is equal to \( P_f \).
- \( L_o \) the sample length
- \( P_{bp} \) bubble-point pressure
- \( P_f \) formation pressure
- \( P_{f0} \) original (initial) formation pressure
- \( P_p \) producing bottom-hole pressure
- \( R \) pore radius
- \( S_w \) water saturation
- \( S_{wirr} \) irreducible water saturation
- \( V \) filtration (flow) velocity (rate)
- \( V_r \) drained volume of the reservoir
- \( \Delta P \) pressure difference
- \( \Delta P_g \) threshold of pressure gradient
- \( \sigma \) liquid surface tension

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**REFERENCES**


Table 1

<table>
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<th>Liquid</th>
<th>$\theta_a$ value on plane surface, degrees*</th>
<th>$\theta_a$ value on plane surface, degrees*</th>
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* Re-treating wetting angle $\theta_a$ for oil is close to nil in all cases.

Table 2.
Increase of Oil and Gas-Condensate Wells’ Productivity by Hydrophilization of Reservoir in Bottom Hole Zones in the Offshore Gas-Condensate Fields, Azerbaijan.

<table>
<thead>
<tr>
<th>Well number</th>
<th>Gas-Condensate Productivity before treatment</th>
<th>Increase after treatment, %</th>
<th>Condensate density, kg/m³</th>
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*/ - Results after repeated treatment.
***/ - Averaged value calculated without data from well 300
Figure 1. Relationship between $V$ and $\Delta P$ in case of gassy oil flow through the hydrophilic (diameter $=10 \, \mu m : A$) and hydrophobic (diameter $=11 \, \mu m : B$) capillaries. The Salym field oil, W.Siberia\textsuperscript{[6]}.

![Figure 1](image1.png)

Figure 2. Relationship between $V$ and $\Delta P$ in case of gassy oil flow through the hydrophilic (diameter $=10 \, \mu m : A$) and hydrophobic (diameter $=11 \, \mu m : B$) capillaries. The Samotlor field oil, W.Siberia\textsuperscript{[6]}.

![Figure 2](image2.png)

Figure 3. The Cumulative NMR spectra for initial oil (viscosity $\sim 250$ Cps), residual oil in sample with different petrophysical properties and oil displaced from these samples.

![Figure 3](image3.png)
Figure 4. The NMR spectra for bulk oil (viscosity ~250 Cps) and RCP packs (different products), saturated by oil after treatment at temperature $T=40^\circ C$ and $T=40^\circ C$. The NMR Measurements at ambient conditions ($T=25^\circ C$).

Figure 5. The part of cumulative NMR spectra for RCP packs (oil in samples after $80^\circ C$ treatment)
Figure 6. The Cumulative NMR spectra for following samples:
   a) bulk oil and mixture of oil with different solvents at identical concentrations;
   b) indication of the effectiveness of the hydrophylization process of the pore surface.

Figure 7. Relationship between V and $\Delta P/L$ in case of oil and gas mixture flow through the hydrophobic and hydrophilic Capillaries (diameter =11 $\mu$m)$^6$.

Figure 8. Relationship between relative recovery efficiency of condensate and relative water wettability at depletion system of the model of the gas-condensate reservoir.
1, 2 - the different solutions, used for hydrophilization of the pore surface.
Figure 9. The depletion curves of the model of gas-condensate reservoir at relative water wettability 0.59.
1, 2 - the different solutions used for hydrophilization of the pore surface.

Figure 10. The unification chromatograms of the condensate samples.
A - before and B - after the treatment of gas-condensate well using method of Increase of Oil and Gas-Condensate Wells' Productivity by Hydrophilization of Reservoir in Bottom Hole Zones.
Numbers on the graphs are carbon atoms in the normal alkanes.
The analyses were made in the capillary column 30 m length, with Apiezon L, at regime of programming of temperature from 100°C (3°C per minute).