e-ISSN: 2582-5208
International Research Journal of Modernization in Engineering Technology and Science
Volume:02/Issue:10/October -2020 Impact Factor- 5.354 www.irjmets.com

A WAY TO INCREASE THE EFFICIENCY OF WATER ISOLATING WORKS USING WATER REPELLENT

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ABSTRACT

A method for isolating water inflow in gas wells is proposed, which consists in pumping a water-insulating composition into the water saturated interval using gas as a blowing fluid. The results of studies on physical models of the reservoir are presented, which prove an increase in the penetrating ability of the water repellent, blockage density of water-permeable channels and a decrease in phase permeability of water. These results were obtained in both water and gas saturated porous mediums. It is observed also that the gas blowing of a water isolating composition contributes in reduction of the reverse removal of the composition from the porous medium, as a result of a more uniform distribution of the water isolating composition in the porous medium.

Keywords: Water repellent, Penetrating ability, Gas blowing, Isolation, Resistance factor, Gas permeability.

I. INTRODUCTION

In oil industry different technologies has been investigated in the purposes of water isolating in the bottom hole formation, among which the use of the water repellent compositions [1, 2].

The most common way to carry out water isolating work in gas wells is to inject a water repellent into a water saturated interval with its subsequent isolation, for example, by installing a cement bridge. The water-repellent composition, penetrating into the formation, must prevent the drainage of fluid from the water saturated zone of the collector through cracks in the cement stone in the annulus [3]. These cracks are induced during the secondary opening (perforation process) at the bottom-hole formation zone.

A large number of reagents and compositions have been proposed for water insulation works. The hydrocarbons residues are recommended as a water repellent for the water isolation in the bottom-hole formation [4,5]. Organosilicon compounds are also recommended as a water repellent [6-8].

A common disadvantage, to varying degrees inherent of water repellent, depending on the composition, is low penetration and partial removal of the reagent by the flow of the water-gas mixture into the wellbore during operation.

In the course of previous studies [9-11] the effectiveness of thermal methods to increase the recovery rate for high viscosity deposits, it was found that the influx of water-gas mixture by changing the ratio of phase permeability provides a higher coefficient of oil recovery with less repression on the formation.

II. METHODOLOGY

Obviously, a similar effect should be observed when injecting into the water saturated interval, during the water isolating work, water repellent composition using gas as a blowing fluid. During the experiment the effect of gas pushing of the water isolating composition on its water-insulating characteristics was investigated in order to justify the method of increasing the effectiveness of the action of the water repellent solution. The study used water-saturated porous medium from river sand and rocks of the Cenomanian horizon.

In this work, we used a flow technique similar to that used earlier in [12-14]. As a water isolating composition, a solution of ABR water repellent (50 g / l) in a mixture of stable condensate (80% vol.) and fuel oil (20% vol.). The composition was prepared by mixing the components. The composition is resistant to stratification (with prolonged standing, stratification and sedimentation were not observed).

III. MODELING AND ANALYSIS

The methodology for preparing reservoir models was as follows. Cases of stainless steel models (length 34.5 cm, diameter 3 cm) with screw thread on the inside (to prevent breakthrough of fluids along the walls) were filled with river sand or extracted rock of the Cenomanian horizon. The permeability was determined by the dependence of gas flow on pressure drop (at least 5 points). After measuring the gas permeability of the reservoir model, the porous medium were saturated with a reservoir water model (density of 1009 kg / m^3, a solution of sodium chloride at a concentration of 18 g / l) and the water permeability of the models was determined. In the course of determining water permeability, at least two pore volumes (P.V.) of mineralized water — a model of formation water — was flowed through a reservoir model. The pore volume of the reservoir models was determined by the gravimetric method.

In the models of formation No. 24/10 and 25/10, gas-saturated porous medium with residual water saturation were simulated. To do this, compressed air was supplied through the top of vertically located reservoir models at a pressure of 0.0125 and 0.050 MPa, and displaced water was collected from below. Periodically (3-4 times) the flow direction was changed; the reservoir models were inverted for a more uniform distribution of residual water in the porous medium. In the first series of experiments, the main idea of the work was checked: increasing the water-insulating ability of the water isolating composition due to gas delivery.

In order to exclude the influence of clay components of the formation rock, ground river sand was chosen as a porous medium. Two reservoir models, similar in permeability, were prepared (Table 1). A solution of sodium chloride in water with a concentration of 18 g / l (density 1009 kg / m^3) was used as mineralized water.

Table 1. The effect of pushing gas into water isolation parameters of the composition

Experiment	Gas Blowing	The initial permeability, μm2		Resistance Factor ,%		Water isolation, %	
		absolute	for water	maximum	residual	maximum	residual
10/10	No	1,59	0,0807	4,5 (100)	3,3 (100)	82	76,7
9/10	Yes	1,44	0,733	9,8 (218)	6,3(191)	91	86
20/10	No	1,83	0,780	2,60 (100)	2,15(100)	72,2	68,3
19/10	Yes	1,63	0,723	11,5 (442)	4,85(226)	92	82,9

The technique of the flow experiment was as follows. Through the outlet, a solution of the composition in an amount of 0.25 PV was injected into a horizontally located water-saturated reservoir model. In experiment No. 9/10, the composition was blown with gas, for which gas (air) was pumped through the top of a vertically located formation model at a pressure of 0.0105 MPa. At the same time, the output was monitored for the amount of water displaced from the reservoir model (the composition did not break).Water was then injected through the reservoir models (through the inlet at the horizontal location of the reservoir model) to determine the degree of decrease in its water permeability. The results of the experiments are given in Table1 and in Fig. 1 and 2.

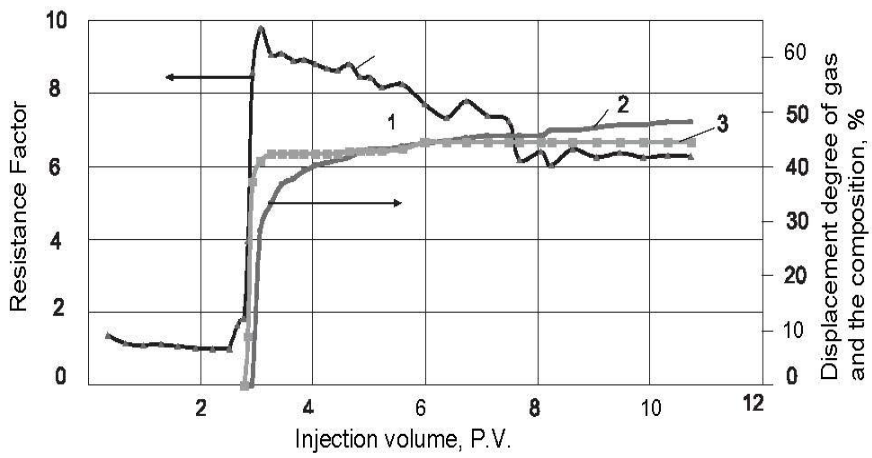

Figure 1: Flow dynamics in experiment No. 9/10: 1-Resistance factor; 2 - The degree of displacement of the composition; 3-The degree of displacement of the gas

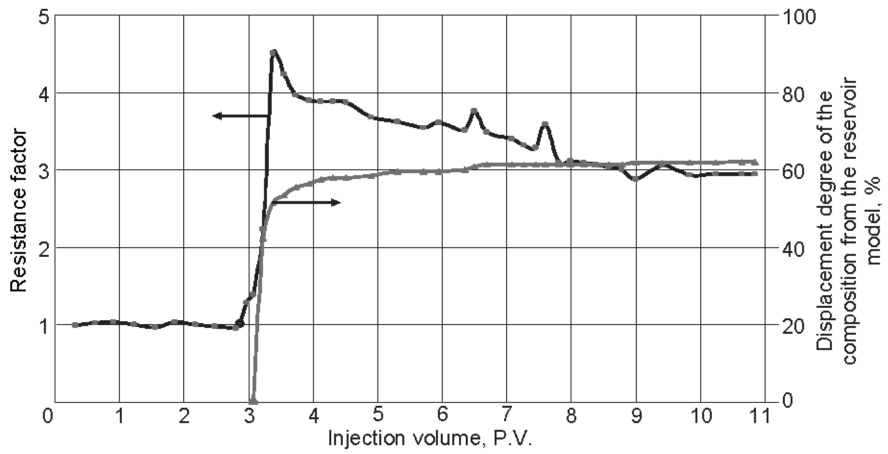

Figure 2: Flow dynamics in experiment No. 10/10

The first series of experiments

In experiments No. 9/10 and 10/10, the injection of the composition into water-saturated porous medium took place at relatively small resistance factors (the maximum resistance factors were 1.81 and 1.39, respectively), that is, the previously obtained results were reproduced [1]. The composition flow into a porous medium in experiment No. 9/10 was quite easy. A gas breakthrough through the porous medium occurred 12 minutes after the start of delivery. From the volume of liquid (water) displaced from the reservoir model, it can be estimated that the gas saturation of the porous medium at the moment of gas breakthrough left about 11%. After two hours of gas blowing (pushing), the gas saturation of the reservoir model reached 32%. During the blowing, only water was displaced from the reservoir model - the composition did not break through the reservoir model. After the blowing and holding to complete the physicochemical processes in a porous medium, a large amount of water was flowed through the model (about 8 PV total).

In experiments No. 9/10 and No. 10/10, the transition to water injection was accompanied by a rapid increase in the pressure drop. However, in experiment No. 9/10 (after gas blowing), the increase in pressure drop and resistance factor was more than 2 times higher than in experiment No. 10/10, that is, gas blowing increases the water-insulating effect of the composition. After reaching the maximum value, the resistance factor begins to decrease, which is explained by the removal of part of the injected composition from the reservoir models. It should be noted that in experiment No. 9/10 the removal of the composition from the reservoir model is significantly less, and the residual resistance factor is much higher than in experiment No. 10/10.

Thus, the results of experiments Nos. 9/10 and 10/10 showed the following. The use of gas as a blowing fluid significantly increased the degree of water insulation as a result of injection of the composition. The inverse resistance factors were 1.9–2.2 times higher if the composition was blown by gas. The degree of water insulation was also higher (by 9%). Gas blowing also had a positive effect on the efficiency of injecting the composition: a noticeably smaller volume of the composition was displaced by water from the reservoir model. Thus, in experiment No. 10/10 (without gas blowing), water displaced 62% of the injected composition from the reservoir model, and 48.2% of the injected solution was displaced from model No. 9/10. Analysis of the reservoir model showed that the depth of penetration of the composition into the reservoir model as a result of blowing increased approximately 2 times (from 13-16 cm to 29-32 cm).

The second series of experiments

In the second series of experiments, experiments were carried out using a porous medium from rocks of the Cenomanian horizon. The experiment was carried out according to the method described above. The results of the experiment are given in Table1 and Figs. 3 and 4. The injection of the water isolating composition into water-saturated porous medium in experiments No. 19/10 and 20/10 was accompanied by a moderate increase in pressure drop (maximum resistance factors after injection 0.25 PV of the composition were 2.6 and 3.17, respectively). Blowing the composition with gas into the porous medium in the experiment 19/10 was carried out quite easily, the gas breakthrough occurred in about 15-20 minutes. After the gas breakthrough, the displacement of water from the porous medium continued, and by the end of the blowing, the gas saturation reached 19.4%.The breakthrough of the composition through the model was not observed.

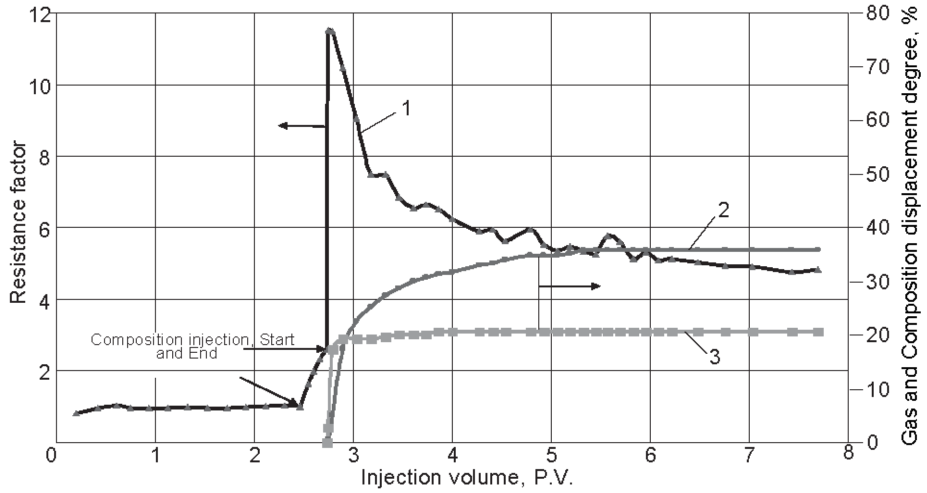

Figure 3: Flow dynamics, experiment No. 19/10: 1- Resistance factor; 2 – The displacement degree of the composition; 3-The displacement degree of the gas

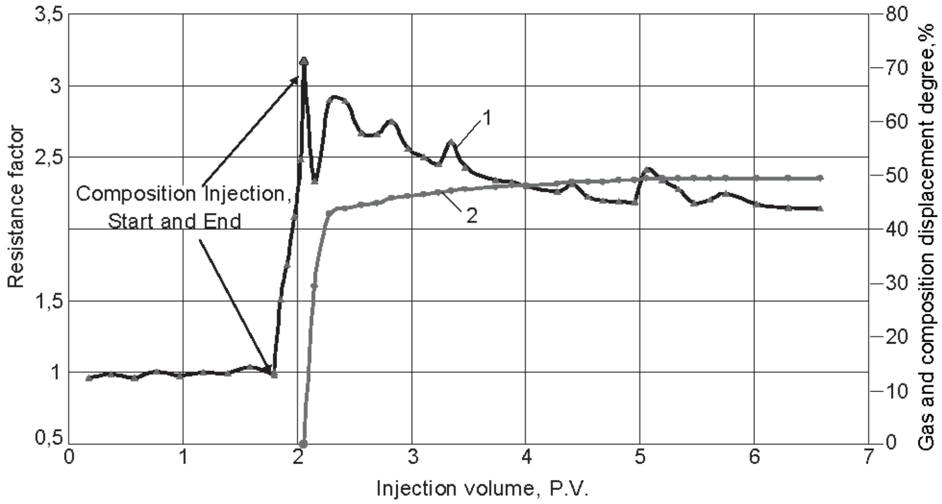

Figure 4: Flow dynamics, experiment No. 20/10: 1-Resistance factor; 2 – The displacement degree of the composition

The transition to water injection in experiment No. 19/10 was accompanied by a significant increase in the pressure drop; the resistance factor reached a value equal to 11.5. In experiment No. 20/10, water flow did not lead to a noticeable decrease in permeability: the resistance factors during water flow were not higher than the resistance factors during injection of the composition. In general, the results of experiments No. 19/10 and 20/10 fully confirmed the results of experiments No. 9/10 and 10/10.

The study using porous medium from the rock of the Cenomanian horizon showed that as a result of gas (air) blowing, the water-insulating efficiency of the composition significantly increased. The maximum and residual resistance factors increased 4.4 and 2.3 times, respectively. The degree of water isolation (maximum and residual) increased by 14–20%. The depth of penetration of the composition into the porous medium also increased (approximately 1.5 times, from 11–12 cm to 16–18 cm). The degree of displacement of the composition from the porous medium is also reduced as a result of the use of air blowing.

So, in experiment No. 20/10, water displaced 49.3% of the injected composition and in experiment 19/10 - 35.8%.

A comparison of the results of experiments on river sand and on the core of the Cenomanian horizon shows that in the case of a reservoir model from a clay rock, the penetration depth of the composition into a porous medium is noticeably lower, which indicates a more complete displacement of water from the reservoir models of the Cenomanian horizon. Such an increase in the degree of displacement indicates that the developed surface of clay minerals absorbs a greater amount of reagent than quartz sand.

The third series of experiments

The goal of the third series of experiments was to study the effect of gas blowing of compositions on the dynamics of restoration of the permeability of gas-saturated porous medium after treatment. It is assumed that the gas blowing of the water isolating composition allows creating gas-saturated channels in the treated intervals of the formation, which should facilitate the start-up of wells after treatment [15, 16]. To assess the effect of gas blowing on the rate of restoration of the gas permeability of porous medium after injection of the composition, experiments No. 24/10 and No. 25/10 were carried out. The experimental results are given in Tables 2 and 3, and in Fig. 5.

Table 2. Conditions and results of the flow experiment No. 25/10

Stage	Injected fluid Type	Injection volume, P.V.	Experiment time, hr	Pressure drop, MPa	Flow rate, ml / h	*T*, °C	Flow direction
1	Mineralized water (injection via the inlet)	2,31	–	0,0106	47,7	25	→
2	Residual water saturation modelling (Gas blowing)	–	20,0	0,0125–0,050	–	23–26	↓↑*
3	Composition (injection via output)	0,32	–	0,0132	30,3	25	→
4	Gas blowing (via output)	–	2,0	0,00125	–	25–26	↓
Stop flowing for 42.5 hours							
5	Gas flow (modelling the process of putting a well into operation), flow via inlet	–	31	0,0120–0,0135	–	21–24	↓

* The direction of flow was changed several times to more evenly distribute of water along the length of the reservoir model. Composition: a solution of the ABR water repellent (50 g / l) in a mixture of stable condensate (80% vol.) and fuel oil (20% vol.). Description of the reservoir model: core extracted rock of the Tazovskoye field; gas permeability —1.56 μm^2, mineralized water Permeability — 0.553 μm^2; pore volume - 112.1 cm^3; initial water saturation - 40.5%; length - 34.5 cm, diameter - 3 cm.

In experiments No. 24/10 and 25/10, reservoir models with very close gas and water permeability, the same geometry of the porous medium and close pore volumes were prepared (Tables 2 and 3). Subsequent operations in preparing the reservoir models for operation and conducting experiments were carried out in parallel to exclude the influence of external factors.

The experimental procedure in experiments No. 24/10 and 25/10 was as follows. The bodies of the reservoir models were filled with extracted alcohol-benzene mixture from Sandstone of the Cenomanian horizon of the Tazovski field. After determining gas permeability, formation models were saturated with mineralized water (formation water model with a density of 1009 kg / m^3). The permeability of the reservoir models with mineralized water was determined. Then residual water saturation was simulated in porous medium by blowing the water from reservoir models with gas (air). In the reservoir model No. 24/10 and 25/10 with residual water saturation, 0.32 P.V. were pumped through the outlet. The solution of the water isolating composition consists of 50 g / l ABR water repellent in a mixture (by volume) of 80% stable condensate and 20% heating oil. The amount of injected solution was determined by the gravimetric (weight) method (the composition did not appear at the exit from the reservoir models).

Table 3. Conditions and results of flow experiment No. 24/10

Stage	Fluid injection	Injection Volume, P.V.	Experiment time, hrs	Pressure drop, MPa	Flow velocity, ml/hr	*T*, °C	Flow direction
1	Mineralized water (injection via the inlet)	1,66	–	0,0104	47,2	28	→
2	Residual water saturation modelling (Gas blowing)	–	23	0,0125–0,050	–	23–26	↓*
3	Composition (injection via output)	0,32	–	0,0192	32,5	27	→
Stop flowing for 42.5 hours							
4	Gas flow (modelling the process of putting a well into operation), flow via inlet.	–	31	0,0120–0,0135	–	21–24	↓

* The direction of flow was changed several times to more evenly distribute of water along the length of the reservoir model. Composition: a solution of the ABR water repellent (50 g / l) in a mixture of stable condensate (80% vol.) And fuel oil (20% vol.). Description of the reservoir model: core - extracted rock of the Tazovskoye field; gas permeability - 1.67 μm2, mineralized water - 0.522 μm2; pore volume - 112.9 cm3; initial water saturation - 43.0%; length - 34.5 cm, diameter - 3 cm.

e-ISSN: 2582-5208
International Research Journal of Modernization in Engineering Technology and Science
Volume:02/Issue:10/October -2020 Impact Factor- 5.354 www.irjmets.com

In experiment No. 25/10, the water isolating composition was forced into the formation by air (through the outlet). For this purpose, gas with a pressure of 0.0125 MPa was supplied from above, through the inlet of a vertically located reservoir model. A gas breakthrough occurred after 15–20 minutes. In this case, the liquid was not displaced from the reservoir model, and it became possible to start measuring the gas velocity at the outlet of the reservoir model with a foam rotameter. Gas blowing lasted 2 hours, but no water or composition was recorded at the outlet of the reservoir model. After injecting and blowing the composition, the reservoir models were left alone for 42-42. 5 hours. After settling, the start-up of wells was simulated.

For this, gas (air) was supplied from above, through the inlet of vertically located formation models, at a pressure of 0.0120–0.0135 MPa. Both reservoir models were connected in parallel to a common gas source (compressed air line) and blowing was carried out simultaneously. Simultaneous blowing allowed avoiding the influence of pressure fluctuations, at the inlet of the reservoir model, and the temperature in the room on the results of the experiment.

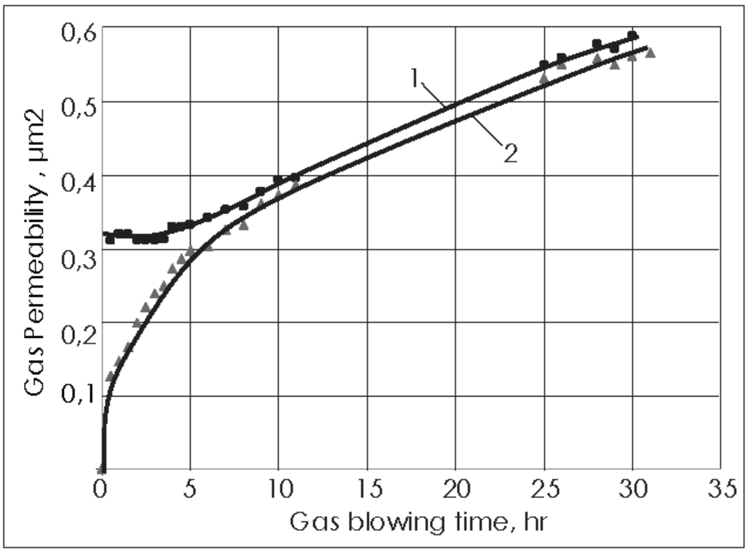

Figure 5: The effect of gas delivery of the water isolating composition on the dynamics of restoration of permeability when blowing the porous medium with gas: 1 - experiment No. 25/10 (with gas blowing of the composition); 2 - experiment No. 24/10 (without gas blowing of the composition).

The data presented in Fig. 5, show that as a result of blowing composition with gas in a porous medium significantly changed the dynamics of permeability recovery during gas flow. The reservoir model in experiment No. 25/10 initially had a permeability of 0.315 mm^2, which increased to 0.586 mm^2 as a result of a 31-hour gas blowing. In experiment No. 24/10, the gas breakthrough was preceded by liquid flow: about 4 ml of the composition (11% of the total injection volume) was displaced from the reservoir model, only after which gas flow began. Comparison of the dynamics of gas permeability recovery in experiments No. 24/10 and 25/10 shows that the effect of gas blowing of the composition is especially noticeable at the initial stage of blowing (in the first 8-10 hours of the experiment).

The second important result of the experiment is a decrease in the removal of the composition (liquid) from the porous medium as a result of a more uniform distribution of the water isolating composition in the porous medium. In the experiment with gas blowing (No. 25/10), the removal of the composition was 4.4% of the injection volume, and in the experiment without gas blowing (No. 24/10) it was 24%.

The analysis of reservoir models showed that gas injection increases the depth of distribution of the composition in a porous medium: in experiment No. 24/10, the penetration depth of the composition was visually estimated at 14–17 cm from the entrance in the reservoir model, and in experiment No. 25/10, it was 20–25 cm.

IV. CONCLUSIONS

Thus, the results of the experiments showed that the gas blowing of a water isolating composition for water-saturated porous medium: increases the depth of penetration of the composition into water-saturated porous medium by 1.5–2 times; increases the water-insulating ability of the composition in 1.9–4.4 times; reduces the degree of reverse removal of the composition from the porous medium by 1.29–1.38 times.

For gas-saturated porous medium with residual water saturation, the blowing of the water isolating composition into the formation by gas: reduces the negative effect of liquid injection on the gas permeability of the reservoir; accelerates the process of restoring the gas permeability of a porous medium after injection of the composition; reduces the removal of the composition from the porous medium during gas flow; increases the penetration depth of the composition into gas saturated layers.

The proposed method is universal, technically easy to implement and does not require additional costs.

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