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Study of the well near-bottomhole zone permeability during treatment by process fluids

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In the process of drilling-in productive horizons, several irreversible physical and chemical processes take place in the near-wellbore zone of the formation: stress state of the rocks changes, penetration of the filtrate and solid phase, as well as drilling mud into the reservoir, and swelling of clay particles of intergranular cementing material are observed. As a result, permeability of productive horizon is significantly reduced and, consequently, potential inflow of oil or gas from formation is excluded. An equally serious problem exists during well servicing and workover, when the use of irrational fluids of well killing causes negative consequences associated with deterioration of reservoir properties of formations in the wells being repaired. Article presents the results of the experiments on permeability of clayed porous samples after exposure to various compositions of liquids. In order to increase permeability of near-borehole zone of the formation and increase productivity of wells completed by drilling, and after well servicing and workover, a composition of the process fluid containing a 15 % aqueous solution of oxyethylene diphosphonic acid (OEDA) with addition of a surfactant is proposed.

***Kew words*:** well; drilling mud; permeability; near-bottomhole zone; process fluid

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Introduction. Oil and gas producing enterprises can provide high daily rates of oil or gas production only by putting into operation wells with potentially maximum productivity, thereby ensuring their high flow rate over a long period of operation. In the process of the formation drilling-in, a number of factors act that reduce reservoir properties of its bottomhole zone. Analysis of scientific literature [1, 7, 13, 18] shows the main reasons for decline in productivity of production wells:

• colmatation of borehole walls and pore space by drilling mud particles;

• reservoir swelling as a result of changes in properties of saturating fluid due to ingress of technological solutions' filtrate into the formation;

• adsorption of drilling mud filtrate's components and perforation fluid on surface of the pores and their retention by various forces, including of electrical nature;

• mechanical deformation of the formation in near-wellbore area during drilling and perforation;

• precipitation of salts as a result of interaction of the mud filtrate and perforation fluid with formation water.

Currently, many technical and technological solutions have been developed that contribute to preservation of natural reservoir properties at various stages of well completion [2, 15-17], which include: perfection of construction for near-bottomhole part of the well – open bottomhole with or without filter application, drilling-in of formations at equilibrium and depression using conventional and special drilling muds and gaseous agents, various compositions and technologies for regulating physical and mechanical properties and technological indicators of drilling muds for drilling-in productive formations in different geological and technical conditions, etc. However, despite the implementation of new technologies and tools, a significant number of production wells are being operated with production rates much lower than potential.

During well servicing and workover (WO) at fields, and especially at underground gas storages (UGS), at well killing with clay solution, a sharp deterioration of the formation's reservoir properties also occurs.

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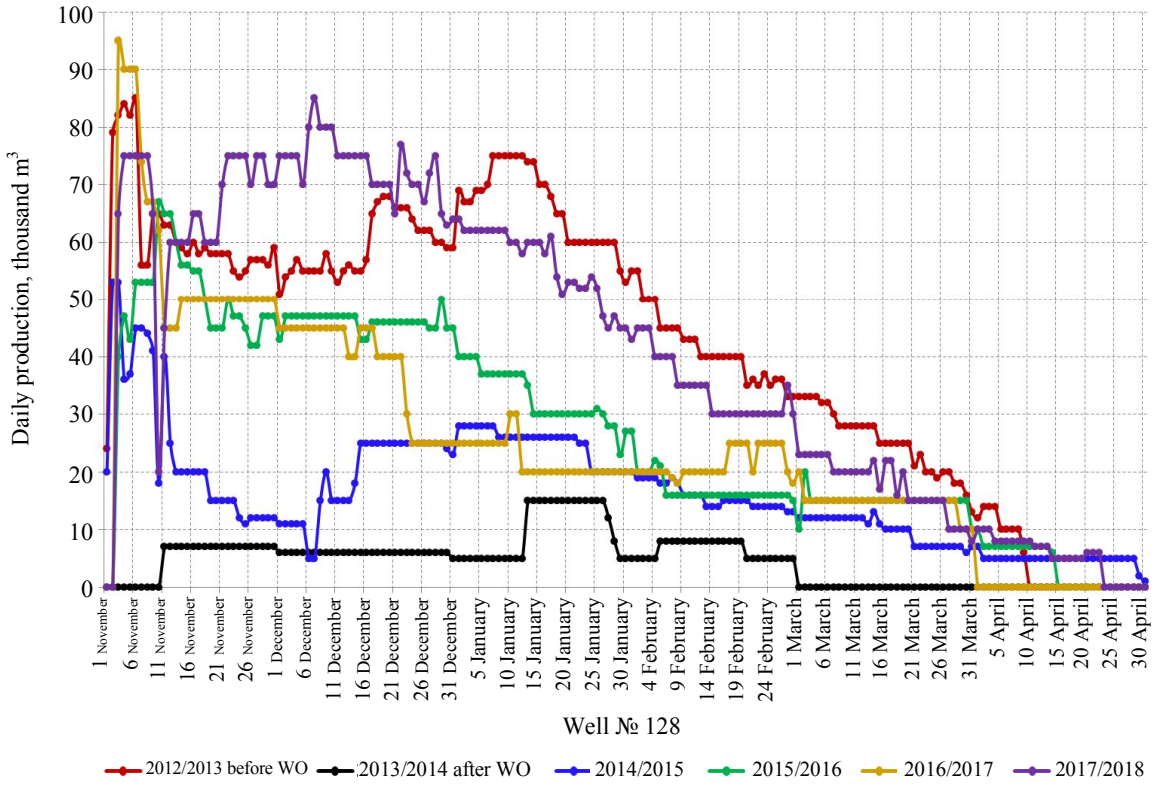


Fig.1. Well production before and after WO

As an example, fig.1 shows daily production of exploitation well № 128 of Gatchinskoe UGS before WO, after WO and in subsequent seasons of gas withdrawal. Before WO, maximum daily well production in 2012/13 gas withdrawal season amounted to 84 thousand m^3/day (November 4, 2012). Well was operated for 160 days, 7.755 million m^3 of gas was withdrawn from it. During scheduled workover to replace the borehole equipment, well was killed with mud solution. After WO in 2013/14 gas withdrawal season maximum daily production was 15 thousand m^3/day, well was operated for 109 days, with volume of gas withdrawn 0.815 million m^3. Under-withdrawal of gas negatively affected daily storage capacity, especially during period of maximum peak load in December. In subsequent seasons of withdrawal, volume of gas taken from the well gradually increased and in 2017/18 withdrawal season almost reached the pre-repair volume, 7.51 million m^3 of gas were withdrawn from the well.

Search for scientific and technical solutions aimed at increasing the productivity of wells by cleaning NBHZ from clay colmatizing particles is one of the urgent tasks.

Methodology. Currently, the most popular method for increasing the productivity of production wells is NBHZ treatment with physical and chemical active compounds of process fluids [5, 6, 8-10]. In literature, rock permeability is studied in laboratory facilities both by simple methods [3], which do not take into account some factors, and by complex methods [4, 11, 14], allowing experiments to be carried out under conditions of real pressures and temperatures. Given the "scarcity" of rock sample material, a preliminary selection of effective fluid compositions was carried out on porous samples on a device for studying filtration processes in the formation rock during well killing [12].

Fig.2 shows a scheme of the device, on which: 1, 11, 17 – needle valves; 2 – metal case; 3 – retaining nut; 4 – clamping ring; 5 – sealing element; 6, 7 – metal and rubber rings; 8 – investigated composition of the process fluid; 9 – clay cake; 10 – drainage; 12, 16 – upper and lower perforated discs; 13 – mesh cylinder; 14, 15 – quartz sand particles of different diameters.

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To assess the permeability of an artificial porous sample, Darcy's law was used, according to which the permeability coefficient was determined by formula

$$k = \frac{4\mu l Q}{\pi d^2 (P_1 - P_2)},$$

where μ – fluid dynamic viscosity, Pa·s; d, l – diameter and length of the sample, m; P_1, P_2 – pressure at the inlet and outlet of the sample, respectively, Pa; Q – volumetric flow rate, m^3/s.

Laboratory study on change in the permeability of a porous sample was carried out in three stages [12], as a result of which following parameters were determined:

- initial coefficient of porous sample permeability when filtering water through it k_1;
- permeability coefficient of a porous sample when filtering drilling mud through it k_2;
- permeability coefficient of a porous sample after physical and chemical exposure to studied composition of the process fluid k_3.

Aqueous solutions of OEDA (oxyethylene diphosphonic acid) with a concentration of 5 to 20 % and containing a surfactant in an amount of 0.1 to 1.5 % were studied as compositions of process fluids to increase the permeability of clayed porous samples. Parameters of the clay solution pumped through porous sample are as follows: ρ = 1075 kg/m^3, F = 5 cm^3/30 min, T = 33 s, $SSS_{1/10}$ = 9/17dPa, k = 1 mm.

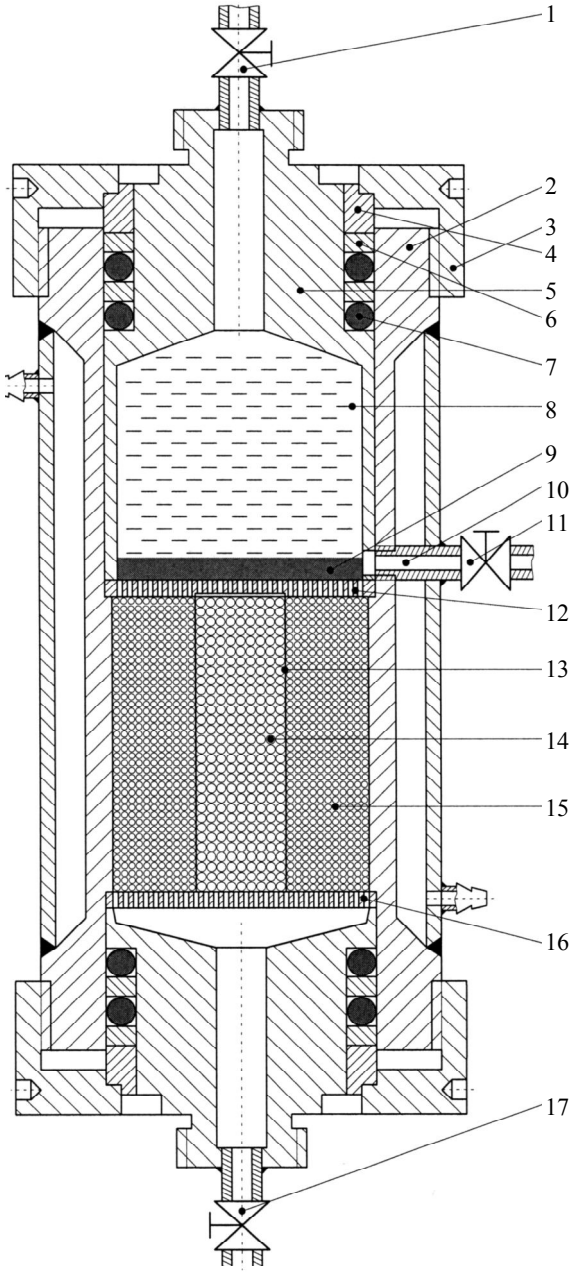


Fig. 2. Scheme of the device

Discussion of the results. Due to shortage of rock sample material, preliminary experiment on selection of optimal fluid composition were carried out on artificial porous samples. In the course of the experiment, it was found that during NBHZ treatment in order to increase the productivity of wells, the developed formulation of the process fluid should be used, in which optimal OEDA content is 13-15 and 0.4-0.5 % is cationic surfactant. Table 1 presents the compositions of process fluids and values of the coefficient of permeability for samples during the experiments.

Table 1

Compositions of process fluids and coefficients of permeability for samples

Composition of process fluid	Permeability coefficient of samples, μm^2			k_3/k_1, %
	k_1	k_2	k_3	
13 % OEDA + 0.4 % Surfactant	0.58	0.08	0.42	72.4
15 % OEDA + 0.5 % Surfactant	0.58	0.08	0.44	77.7

It should be noted that when using rock samples as formation models, the structures of a real formation (its size, composition) and conditions of the process are schematized. As a result, scheme

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is more or less different from reality. Therefore, when setting up experiment, it is necessary to choose such conditions for their implementation that would reproduce as accurately as possible not only the model itself and natural conditions, but also the processes taking place in them. One of these installations is UIPK-1M, which allows performing laboratory study to determine the permeability of rock samples with simulation of formation conditions. Table 2 shows values of the rock permeability coefficients before and after physical and chemical exposure to 15 % aqueous OEDA solution with a 0.5 % surfactant additive.

Table 2

Values of the rock sample permeability coefficients before and after exposure to the process fluid composition

Rock sample	Rock sample permeability coefficient, μm²			k_3 / k_1, %
	k_1	k_2	k_3	
Rock sample № 1	0.63	0.04	0.26	41.2
Rock sample № 2	0.92	0.04	0.51	55.4

Conclusion. Based on laboratory study aimed to increase the productivity of UGS wells after completion of workover to replace borehole equipment (wells were killed with clay solution), NBHZ was treated with a 15 % aqueous OEDA solution with a 0.5 % surfactant additive. After operation, flow rate of wells increased:

- in well № 83 from 90 to 149 thousand m³/day;
- in well № 117 from 131 to 212 thousand m³/day;
- in well № 125 from 168 to 289 thousand m³/day;
- in well № 128 from 103 to 174 thousand m³/day.

Thus, economic effect of using developed composition of the process fluid for treating NBHZ is achieved by increasing well productivity (by an average of 67 %) and increasing maximum daily production of UGS during gas withdrawal in winter months.

REFERENCES

1. Makarova A.A., Mishchenko I.T., Mikhailov D.N., Shako V.V. Sensitivity analysis of the dynamics for well and near-wellbore zone cleaning to formation parameters, perforation and drilling mud properties. *Neftyanoe khozyaistvo*. 2015. N 3, p. 79-83 (in Russian).

2. Basarygin Yu.M., Bulatov A.I., Proselkov Yu.M. Well completion. Moscow: OOO «Nedra-Biznestsentr», 2002, p. 667 (in Russian).

3. Gudok N.S., Bogdanovich N.N., Martynov V.G. Determination of physical properties of oil and water containing rocks. Moscow: «Nedra-Biznestsentr», 2007, p. 592 (in Russian).

4. Zhukov V.S., Lyugai D.V. Determination of reservoir properties and elastic properties and electrical parameters of rock samples in modeling formation conditions. Moscow: Gazprom «VNIIGAZ» 2016, p. 56 (in Russian).

5. Ivanov S.I. Intensification of oil and gas inflow to wells. Moscow: OOO «Nedra-Biznestsentr», 2006, p. 565 (in Russian).

6. Ishbaev G.G., Dilmiev M.R., Gorpinchenko V.A. Process fluid for chemical cleaning of near-bottomhole zone of a well during completion with an open wellbore. *Burenie i neft*. 2013. N 12, p. 49-52 (in Russian).

7. Krylov V.I., Kretsul V.V., Gimazetdinov V.M. The main factors affecting the pollution of productive formations, and development of recommendations for improving well productivity. *Stroitelstvo neftyanykh i gazovykh skvazhin na sushe i more*. 2015. N 12, p. 31-36 (in Russian).

8. Krylov V.I., Kretsul V.V. Improvement of well completion by methods of chemical cleaning of near-bottomhole zone of the wellbore. *Stroitelstvo neftyanykh i gazovykh skvazhin na sushe i na more*. 2004. N 11, p. 40-45 (in Russian).

9. Litvinenko V.S., Dvoinikov M.V. Justification of the technological parameters choice for well drilling by rotary steerable systems. *Zapiski Gornogo instituta*. 2019. Vol. 235, p. 24-29. DOI: 10.31897/PMI.2019.1.24

10. Nikolaev N.I., Shipulin A.V., Kupavykh K.S. Research results and effectiveness of integrated technology for chemical treatment of near bottomhole formation zone. *Territoriya neftegaz*. 2015. N 4, p. 79-83 (in Russian).

11. Nikolashev V.V., Skorokhod R.A. New equipment for rock sample research. *Oborudovanie i tekhnologii dlya neftegazovogo kompleksa*. 2008. N 1, p. 7-11 (in Russian).

12. Rogov A., Soldatkin S.G., Barshchev M.Yu. Russian Federation patent for utility model N 132200. Device for conducting studies of filtration processes in the formation rock during well killing. Opubl. 10.09.2013. Byul. N 25 (in Russian).

13. Podgornov V.M. Well completion. Part 2. Formation of near-bottomhole zone of the well. Moscow: OOO «Nedra-Biznestsentr», 2008, p. 253 (in Russian).

DOI: *10.31897/PMI.2020.2.169*

14. Troitskii V.M., Grigorev B.A., Rassokhin S.G., Sokolov A.F. Physical modeling of gas injection and gas withdrawal cycles during development and operation of UGS. Hysteresis of phase permeabilities. *Vesti gazovoi nauki*. 2019. N 1, p. 18-27 (in Russian).

15. Fursin S.G., Griguletskii V.G. On completion of wells in a controlled depression. *Stroitelstvo neftyanykh i gazovykh skvazhin na sushe i na more*. 2014. N 1, p. 17-23 (in Russian).

16. Yangazitov M.N., Dotsenko B.A., Oganov A.S. Well drilling at equilibrium pressure with a system of "continuous" circulation of the drilling mud. *Vestnik Assotsiatsii burovykh podryadchikov*. 2011. N 2, p. 17-22 (in Russian).

17. Dennic Denney. Balanced-pressure drilling with continuous circulation using jointed drillpipe. *Journal of Petroleum Technology*. 2007. Vol. 59. Iss. 4, p. 62-65.

18. Skalle P. Drilling Fluid Engineering. Ventus, 2011, p. 125.

19. Tiab D., Donaldson E.C. Petrophysics: theory and practice of measuring reservoir rock and fluid transport properties. Oxford: Gulf Professional Publishing, 2011, p. 976.

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