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АКАДЕМИЯСЫ» РҚБ

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ХАБАРЛАРЫ

ИЗВЕСТИЯ

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CONTROL OF THE FACTORS AFFECTING WELL PRODUCTIVITY

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Abstract. It is known that various complications arise during the operation of gas and gas condensate wells. These negative phenomena lead to a decrease in well production. It should be noted that complications occur both during the drilling process and operation. Basically, they lead to a decrease in the natural permeability of the formation. Methods. Various geological and technical measures are being taken to increase or maintain well productivity. These measures include the following: - treatment of the wellbore zone using acids and surfactants; - hydraulic fracturing, etc. There are a number of methods for increasing the filtration and capacitance characteristics of the bottomhole zone. The choice of one method or another depends on the reservoir conditions. Results. Treatment of horizontal wells to control water inflows is most effective when the treatment zone is isolated from the rest of the wellbore. In cased wells, this task is solved mechanically by installing packers. A special annular chemical packer has been developed for such situations. Scientific novelty. Preventive control of water inflows involves covering high permeability zones to ensure more uniform sweep coverage. The production (or injection) profile can be improved by selectively treating low permeability zones. Flexible tubing is used for accurate placement of small hydraulic fractures.

Keywords: complications, well, treatment, efficiency, water inflow, hydraulic fracturing, limitation

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ҰҢҒЫМАНЫҢ ӨНІМДІЛІГІНЕ ӘСЕР ЕТЕТІН ФАКТОРЛАРДЫ БАҚЫЛАУ

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Аннотация. Газ және газ конденсаты ұңғымаларын пайдалану кезінде әртүрлі асқынулар туындайтыны белгілі. Бұл жағымсыз құбылыстар ұңғымалар өндірісінің төмендеуіне әкеледі. Айта кетерлігі, асқынулар бұрғылау процесінде де, жұмыс кезінде де пайда болады. Негізінен олар түзілудің табиғи өткізгіштігінің төмендеуіне әкеледі. Әдістері. Ұңғымалардың өнімділігін арттыру немесе қолдау үшін әртүрлі геологиялық және техникалық шаралар қабылдануда. Бұл шараларға мыналар жатады: — ұңғыманың ұңғыма аймағын қышқылдар мен беттік-белсенді заттардың көмегімен өңдеу; — гидравликалық сыну және т.б. Төменгі ұңғыма аймағының сүзу және сыйымдылық сипаттамаларын арттырудың бірқатар әдістері бар. Бір немесе басқа әдісті таңдау резервуардың жағдайына байланысты. Мысалы, гидравликалық сыну өткізгіштігі төмен, бірақ күшті тау жыныстарында, ал қышқылдандыру әдістері өткізгіштігі төмен карбонатты түзілімдерде қолданылады. Нәтижелер. Су ағынын бақылау үшін көлденең ұңғымаларды тазарту тазарту аймағы ұңғыманың қалған бөлігінен оқшауланған кезде тиімді болады. Қапталған ұңғымаларда бұл тапсырма орауыштарды орнату арқылы механикалық түрде шешіледі. Дегенмен, цементтеусіз сүзгіні немесе лайнерді орнату кезінде мұндай механикалық құрылғылар ашық сақинаны оқшаулауда тиімсіз. Мұндай жағдайлар үшін арнайы сақиналы химиялық орауыш әзірленді. Ғылыми жаңалығы. Су ағынын профилактикалық бақылау біркелкі сыпыруды қамтамасыз ету үшін өткізгіштігі жоғары аймақтарды жабуды қамтиды. Өндірістік (немесе инъекциялық) профильді өткізгіштігі төмен аймақтарды іріктеп өңдеу арқылы жақсартуға болады. Шағын гидравликалық сынықтарды дәл орналастыру үшін икемді құбырлар қолданылады.

Түйін сөздер: асқынулар, ұңғыма, тазарту, тиімділік, су ағыны, гидравликалық сыну, шектеу.

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УПРАВЛЕНИЕ ФАКТОРАМИ, ОКАЗЫВАЮЩИМИ ВЛИЯНИЕ НА ПРОИЗВОДИТЕЛЬНОСТЬ СКВАЖИН

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Аннотация. Известно, что при эксплуатации газовых и газоконденсатных скважин возникают различные осложнения. Эти негативные явления приводят к снижению дебита скважин. Следует отметить, что осложнения возникают как в процессе бурения, так и в процессе эксплуатации и приводят к снижению естественной проницаемости пласта. Методы. Принимаются различные геолого-технические меры для увеличения или поддержания дебита скважин. Эти меры включают следующее: - воздействие на призабойную зону скважины кислотами и ПАВ; -гидроразрыв пластов и др. Существует ряд методов повышения фильтрационно-емкостных характеристик призабойной зоны. Выбор того или иного метода зависит от пластовых условий. Например, в низкопроницаемых, но прочных породах применяется гидроразрыв пласта, а в низкопроницаемых карбонатных пластах – методы кислотной обработки. Результаты. Обработка горизонтальных скважин для борьбы с водопритоками наиболее эффективна, когда зона обработки изолирована от остальной части ствола. В обсаженных скважинах эта задача решается механически - установкой пакеров. Однако при установке фильтра или хвостовика без цементирования такие механические устройства неэффективны для изоляции открытого заколонного пространства. Для подобных ситуаций разработан специальный кольцевой химический пакер. Научная новизна. Профилактическая борьба с водопритоками включает в себя перекрытие зон с высокой проницаемостью, чтобы обеспечить более равномерный охват пласта вытеснением. Профиль добычи (или закачки) может быть улучшен за счет избирательной обработки низкопроницаемых зон. Для точного размещения небольших трещин гидравлического разрыва применяют гибкие НКТ.

Ключевые слова: осложнения, скважина, обработка, эффективность, водоприток, гидравлический разрыв, приток.

Introduction. Any unintentional resistance to the flow of fluids into or out of the wellbore is called reservoir damage. This definition of reservoir damage means flow restriction caused by a decrease in permeability in the near-wellbore zone of the formation, a change in the relative permeability to the hydrocarbon phase. This definition does not include tubing flow restrictions or those caused by incomplete completion of the reservoir by the well, although these restrictions may impede flow, they are either included in the well design or do not show themselves as typical formation damage, such as skin effect (reduction of permeability in the bottomhole zone).

In this way, it is possible to minimize the degree of damage inside the formation and around the wellbore and improve the production of hydrocarbons. As can be seen, preventing formation damage is more effective than remedial procedures such as acidizing and hydraulic fracturing.

To assess well productivity, the productivity coefficient (m^3/day/bar) is usually used:

$$J = \frac{q_0}{\overline{P}_R - P_{\omega f}} \tag{1}$$

But more often, the skin factor S, a dimensionless parameter of pressure drawdown caused by flow restriction in the bottomhole zone due to the damage the formation, is used. The skin factor is determined by the following expression:

$$S = \left(\frac{\mathrm{kh}}{18{,}66 q \mu B}\right) \Delta P_{\mathrm{skin}} \tag{2}$$

Restriction of flow in the near-wellbore zone of the formation can increase the pressure gradient, resulting in additional pressure losses caused by formation damage (ΔP_{skin}).

Standing introduced the concept of well inflow efficiency F, which he defined as

$$F = \frac{\overline{P}_H - P_{\omega f} - \Delta P_{skin}}{\overline{P}_H - P_{\omega f}} \frac{ideal \;\; drawdown}{actual \;\; drawdown} \tag{3}$$

The inflow efficiency $F = 1$ of a well corresponds to an undamaged well with $\Delta P_{skin} = 0$.

$F > 1$ corresponds to the stimulation of inflow to the well (maybe by hydraulic fracturing), and the inflow efficiency $F > 1$ corresponds to the damaged well. Obviously, to determine the inflow, it is necessary to know the average reservoir pressure P_R and skin factor S.

The effect of the skin effect on well productivity can be assessed using the relationship between the average pressure of the productive reservoir and the fluid inflow rate of the production well or using indicator curves (IC) of wells proposed by Vogel, Fetkovich and Standing. These indicator curves can be expressed by the following relationship:

$$\frac{q}{q_{\max}} = FY\left(x+1-FYx\right) \quad (4)$$

where

$$Y = 1 - \frac{P_{\omega f}}{\bar{P}_R} \quad (5)$$

When $x = 0$ a linear model of the indicator curve is implemented, when $x = 0,8$ we obtain Vogel's IC, when $x = 1$ we have Fetkovich's IC.

The choice of indicator curve used depends on the fluid properties and formation displacement mode. The Standing indicator curve is most suitable for oil reservoirs with a dissolved gas drive, while the linear indicator curve is more suitable for oil reservoirs with a water drive, producing at pressures above saturation pressure, and for hydrocarbon fluids without significant dissolved gas.

Obviously, to quantify formation damage and study its impact on hydrocarbon production, it is necessary to have reasonable estimates of the inflow efficiency and well skin factor. A number of methods to estimate these quantities in oil wells have been proposed. The most common methods of wells and hydrodynamic studies in wells under unsteady flow conditions (well studies using the pressure build-up method) (Aliyev et al, 2001a; Aliyev et al, 2001b; Aliyev and Sheremet, 1995).

Methods and materials. In many gas and some oil wells, flow rates are quite high and cause significant turbulent or inertial pressure drops near the wellbore. In such cases, the additional measured pressure difference due to the skin effect can be confused with the pressure difference caused by deviation from Darcy's law or inertial flow. It is important to separate the pressure drawdown caused by turbulent flow from the pressure drawdown associated with the physical skin effect, since the latter significantly influences well stimulation recommendations.

Darcy's law for high-yield gas wells has the form:

$$m(\bar{p}_R) = m\left(p_{\omega f}\right) = \mathrm{A}q_{sc} + \mathrm{B}q_{sc}^2 \quad (6)$$

Here

$$m(P) = \int_{p_B}^{P} \frac{2P}{\mu_g z}$$

The inflow equation can be written as follows:

$$m(\bar{p}_R) = m\left(p_{\omega f}\right) = \mathrm{A}q_{sc} + \mathrm{B}q_{sc}^2$$

Here Aq_{sc} represents the pressure drop during laminar flow, and Bq^2_{qs} is the inertial or deviation-induced pressure drop (sometimes called turbulent pressure drop). Note that the A parameter contains a physical skin effect S, and the B parameter is directly proportional to the coefficient D that does not obey Darcy's law. Based on the results of tests in steady-state conditions, we plot a graph of the dependence $\frac{m(\bar{p}_R)-m(p_{\omega f})}{q_{sc}}$ on q_{sc} and obtain the values of the parameters A and B as the intercept point and the slope of the line, respectively. Next, it is able to compare the magnitude of the pressure drop caused by the value of S, with the pressure difference caused by inertial effects Dq_{sc}.

If $S > Dq_{sc}$, then treatment is recommended to intensify the inflow into the well. However, if $Dq_{sc} > S$, then it may be necessary to re-perforate or hydraulically fracture the well to increase the inflow area and reduce inertial effects.

Factors contributing to a decrease in well productivity can be divided into geological ones - this is the damage of the well bottom zone. If the productive layer consists of weakly consolidated rocks, then the operation of wells with an overestimated flow rate can lead to the damage of the zone around it. Particles of damaged formation contained in the product flow lead to corrosion of both wellhead and downhole equipment, the formation of plugs, and etc.

The appearance of water fingering effect in places where the Oil-Water Contact is located near the lower point of the perforation slot. To prevent the formation of "Water fingers", the production flow rate is reduced, which greatly depends on the pressure drawdown and the position of the bottomhole zone.

Technological factors include the accumulation of hydrates at the bottom and in the wellbore, corrosion of tubing, formation of hydrates in the bottomhole zone, the inevitability of cleaning the bottomhole from mechanical impurities, the need to clean the bottomhole from liquid and solid particles; reduction to the lowest loss of formation pressure and the highest condensate recovery coefficient of the formation (Aliyev, et al, 2001a; Aliyev, et al, 2001b).

Any resistance to the flow of fluids into or out of the wellbore is called formation damage. This, in turn, is associated with a decrease in the permeability of the near-wellbore formation zone, a change in the relative permeability for hydrocarbon phases, etc.

In recent years, much attention has been paid to formation damage issues due to two main reasons:

1. the great effect of filtration of the hydrocarbon phase in the bottomhole zone on the probability of fluid extraction from the reservoir;

2. control of drilling and completion of wells and production operations.

Knowing of the causes and consequences of formation damage during various production operations can significantly reduce formation damage and increase well productivity.

Generally, preventing formation damage is more effective than remedial procedures such as acidizing and hydraulic fracturing.

Fine particle migration is a recognized source of formation damage in some production wells, especially in low consolidated sandstones (Aliyev and Sheremet, 1995; Grachev, 2016). Direct evidence of formation damage caused by fine particle migration in production wells is often difficult to find. While most other forms of formation damage have obvious indicators of a problem, the field causes of fine particle migration are much more diffuse.

The most common issue is indirect indicators such as decreased productivity over several weeks or months. This reduction in productivity can usually be corrected by acid treatment. This pattern is typical for a large number of wells around the world, when a decrease in productivity is compensated by a subsequent significant increase after acid treatment. Such behavior of the well is most often associated with the accumulation of fine particles in the near-wellbore zone over a certain period of time. Field studies and laboratory experiments have shown that fine particles of clay, feldspar, plagioclase cause reduced permeability. Because mobile fines are composed of a wide variety of minerals, the clay content of a reservoir may not always be a good indicator of the formation's sensitivity to water (Gracheva, 2011).

Laboratory tests of core permeability clearly show that when low salinity solutions (<2%) are injected into wettable rocks, permeability drops dramatically (up to 500 times). It is now established that this sharp drop in permeability is almost entirely the result of migration of fine particles.

Reversing the flow direction leads to a temporary increase in permeability, since when the flow is reversed, small particles clogging the pores (Hussein, 2005; Bachman et al, 2011).

Fine-grained minerals are present in most sandstones and some carbonates. They are not held in place by rock pressure and can move freely with the liquid phase that wets them (usually water). They remain attached to the pore surface by electrostatic attraction and Van der Waals forces. At "high" (>2%) salt concentrations, Van der Waals forces are strong enough to hold small particles on the surface of the pores. As salinity decreases, electrostatic repulsions increase because the negative charges on the surface of pores and fine particles are no longer shielded by ions. When the electrostatic repulsive forces exceed the Van der Waals attractive forces, small particles are detached from the surface of the pores.

There is a critical salt concentration below which small particles become free. Typical critical salt concentrations range from 5,000 to 15,000 mg/L (1.5%) sodium chloride. For divalent ions this concentration is much lower. If waterwet sandstone is exposed to a brine with salinity below the critical salt concentration, fine particles become loose and a significant reduction in permeability is observed.

It has been obtained experimentally that critical flow rates for migration of fine particles are lower when saline solution is the mobile phase. With residual saturation of the saline solution, the critical velocities are an order of magnitude higher. This means that the migration of fine particles becomes more important when well water begins to be produced, which is what actually happens. It is often observed that after the start of water production, the productivity of wells decreases much intensive. In such cases, more frequent acid treatments are necessary to maintain oil production after water breakthrough.

The observed degree of permeability reduction also depends on the wettability of the rock. Most oil-wet rocks have reduced water wettability, possibly because the fine particles are partially coated with oil and are not as easily accessible to the brine. Significantly smaller decreases in permeability are observed as the rock becomes less water-wetted.

The above observations indicate that fine particle migration can be caused by any operation that introduces solutions of low (<2%) salinity or high (>9%) pH into a water-wet formation. Migration of fine particles can also be caused by high flow rates in the near-wellbore zone of the formation, especially in watered wells. Examples of such operations include absorption of freshwater drilling fluids or completion fluids, injection of steam during steam cycling to recover heavy oil, injection of water from a water source, high well flow rates (with flow rates above the critical velocity) and water breakthrough into production wells.

Clearly distinguishing the effects of liquid phase precipitation and deviations from Darcy's law based on well productivity and well flow tests in transient wells can be difficult and require the use of compositional numerical models. Such models are available and have been used to estimate the productivity of gas wells (taking into account condensate accumulations).

The most direct way to reduce condensate accumulation is to reduce the drawdown on the formation so that the bottomhole pressure remains above the dew point. Where this is not desirable, the impact of condensate accumulation can be reduced by increasing the inflow area and achieving linear rather than radial inflow into the wellbore. This minimizes the effect of reducing gas permeability in the near-wellbore zone of the formation. Both of these benefits can be realized through hydraulic fracturing (Bachman, et al, 2011, Joshi, 2001).

Stimulation through hydraulic fracturing is the most common method used to solve the problem of condensate accumulation. The creation of fractures leads to a significant reduction in the drawdown on the formation, necessary for the operation of the well. In addition, the accumulation of liquid hydrocarbon phase on the surface of fractures does not affect productivity as much as radial flow around the wellbore.

Recently, the use of solvents and surfactants such as methanol has been proposed as a method of stimulation for gas condensate wells where hydraulic fracturing is not a preferred option.

In oil reservoirs with a dissolved gas regime, when the formation fluid pressure drops below the saturation pressure, a gas phase is formed. If this phenomenon occurs in the wellbore, the gas bubbles that form, help bring liquid hydrocarbons to the surface. However, if the saturation pressure is achieved in the near-wellbore zone of the formation, then a significant gas-saturated area is formed around the wellbore, which leads to a decrease in the relative permeability of oil. As would be expected, this form of reservoir degradation most likely occurs late in the field's life when the average reservoir pressure falls below the saturation pressure (Hurst, 1953).

This type of drop can be diagnosed if phase behavior is well understood and operational data is available. However, in many cases, lack of access to this data can lead to misdiagnosis of declining well productivity. This diagnosis becomes the basis for erroneous recommendations for the use of stimulation operations.

If a well consumes large volumes of water-based drilling or completion fluids, zones of high water saturation will develop around the wellbore, where the relative permeability of the hydrocarbon phases is reduced, resulting in a net loss of well productivity.

Areas of high water saturation, or water barriers, around the wellbore are expected to dissipate over time as hydrocarbons are produced. When viscous forces are significantly greater than capillary forces, the water barrier disappears quite quickly. However, capillary forces hold water in place greater than viscous forces (for example, in tight gas reservoirs), water barriers can persist for very long periods of time. To quantify this effect, the capillary number, defined as the ratio of viscous forces to capillary forces, can be used. When capillary forces are greater or comparable to viscous forces, water barriers are difficult to remove. On the other hand, when viscous forces dominate, water barriers disappear within hours or days. Typically, water barriers are a problem in low-permeability, depleted gas reservoirs where the capillary number is below unity.

To remove water barriers, three main methods are used, (1) pressure pulsation or swabbing of wells in order to temporarily increase the capillary number, (2) reducing surface tension by adding surfactants or solvents, which also increase the capillary number by reducing the tension at the boundary separation of hydrocarbon and aqueous phases, allowing the removal of the water barrier by reverse flow, and (3) the use of mutual solvents such as alcohols to dilute the water and remove it by changing the behavior of the phases. All three methods have been successfully applied in field conditions. The advantages of one method over another depend on the specific ratios of formation permeability, temperatures and pressures.

Water inflow control. Mechanical or expandable packer plugs are the best option for solving problems in the near-wellbore zone: non-hermetic casing strings, behind-the-casing cross-flows, rise of bottom water in the last layer and watered formations without cross-flows. These plug packers can be run on coiled tubing or wireline to seal intervals in cased and open hole wells. If the wellbore must be opened to horizons located deeper than the water influx intervals, then a repair lining can be installed inside the casing through the tubing. One technology involves placing a flexible, expandable composite bladder (made from carbon fiber, thermoset plastic, and a rubber bladder, for example) against the area to be treated. The pump then expands the chamber along with the composite shell, pumping in well fluid that heats the resins, initiating the polymerization process. After the plastic has cured, the pressure is released and the chamber is removed from the well (Joshi and Ding, 2006, Joshi, 1988, Gasumov et al, 2004).

Increasing the productivity of gas and gas condensate wells. During the operation of gas and gas condensate wells, a number of problems are possible that negatively affect the technological characteristics of the production process, and, as a result, a decrease in flow rates is observed.

Improving the quality of filtration and capacitance characteristics of the bottomhole zone is carried out through various technological measures aimed at improving permeability.

Acidizing is performed either to stimulate inflow greater than that from the reservoir or to repair formation damage. In principle, there are two types of acidizing, which are determined by injection rates and pressures. Injection rates that create pressures below hydraulic fracturing pressure are called acidizing, and above hydraulic fracturing pressure are called acid fracturing.

Figure 1 illustrates the linear increase in pressure with increasing injection rate until the fracture propagation pressure is reached, after which the injection rate can continue to increase, but the pressure above the fracture propagation pressure will change little. Acidizing is used primarily to remove damage, while acid fracturing is used to increase the effective radius of a well by creating acid-treated fractures that penetrate deep into the wellbore zone with relatively low permeability to increase well productivity by several times (Novruzova, et al, 2021).

Formation acidizing is used primarily to remove damage caused by drilling, completion and workover fluids and solids deposited from produced water or oil (i.e., scaling). Removing severe plugs from carbonates or sandstones can result in significant increases in well productivity (Mityuk, et al, 2008). On the other hand, if there is no damage, rock treatment rarely increases the natural productivity of a well by more than 50%, depending on the amount of treatment and the depth of penetration of the active acid.

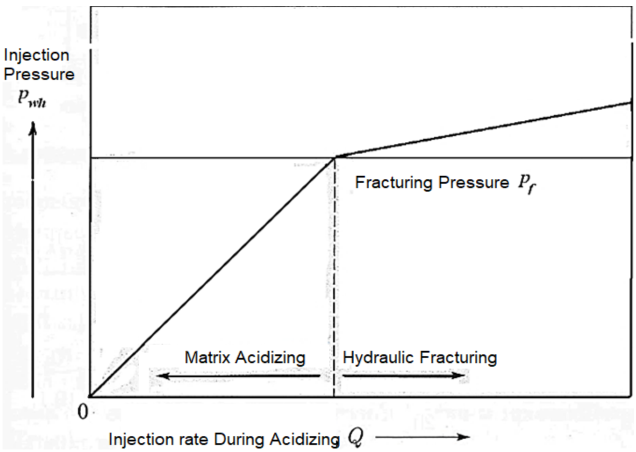


Figure 1 Injection rates during rock acidizing below hydraulic fracturing pressure

Wells can perform poorly or worse than expected due to three different factors:

1. The size of the tubing string in the flowing well is incorrectly selected or ineffective equipment is used for artificial lift using pumping units or gas lift;
2. Low permeability of the formation;
3. Restriction in the wellbore due to formation damage or incomplete perforation.

Any well producing from a formation with a permeability greater than 10 mD and whose permeability in the permeable zone of the formation or in the perforated interval has been reduced due to plugging by solid particles can be taken for acidizing the rock.

Mechanical plugging is caused by either suspended solids in completion or workover fluids, or migration of fine particles into the formation along with incompatible fluids. If the reason for the decline in well productivity is formation damage, then the well is a good candidate for acidizing.

Hydrochloric acid also opens many narrow channels in the drainage zone, which increases the drainage area of the well and leads to increased production. Therefore, the main goal when treating the bottomhole zone of a well with hydrochloric acid is to ensure that the acid solution acts at a minimum distance from the well. The depth of acid penetration into the formation depends on the rate of reaction between the acid and the rock. The reaction rate, in turn, depends on the chemical composition of the rock, the volume of acid, temperature and reservoir pressure (Mityuk, et al, 2008).

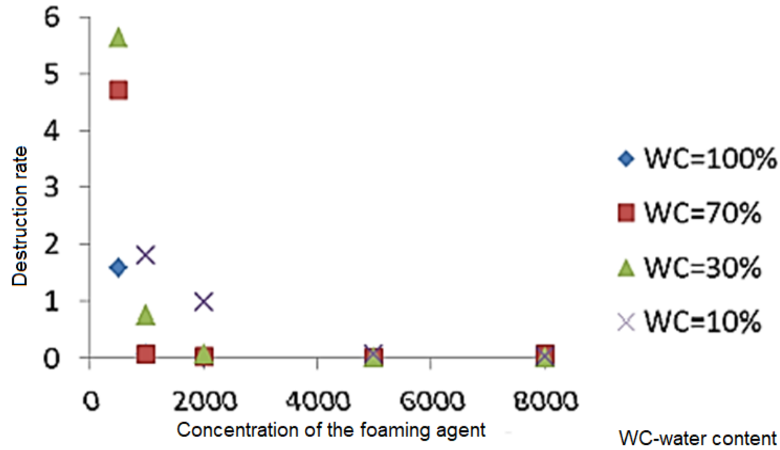
Selecting a foaming additive for removing water from the bottom of production gas wells. In wells where there is accumulation of water at the bottom, it is necessary to remove it in order to restore stable hydrocarbon production. The choice of foaming agent and its chemical stability are the most important indicators for ensuring the high efficiency of the measures taken to remove the problem that has arisen. The following is a study of three foaming additives under other equal conditions, and also shows the effect of high temperature on the effectiveness of foaming additives.

Result and Discussion. It should be noted that the accumulation of water at the bottom of gas wells is a common problem for wells exploiting fields that have been in development for quite a long time. This is explained by insufficient pressure and flow rates to ensure the removal of water to the surface. In addition, the most commonly used method for removing the aqueous phase from the bottom hole is the injection of foaming additives. By pumping surfactants into the tubing string, the surface tension is reduced, which, in turn, leads to the formation of a stable bubble structure, that is, foam. Foam has a density lower than liquid and therefore can be transported much more easily from the bottomhole of the well to the surface (Saduakassov, et al, 2024, Moldabayeva et al, 2023).

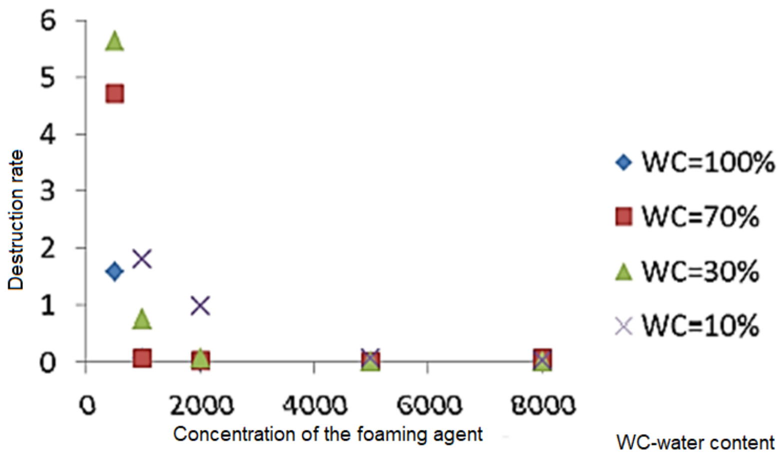
As a result of two consecutive tests, namely the influence of the hydrocarbon phase and the concentration of the foaming additive, as well as assessing the influence of temperature effects on foaming, stability and quality of liquid removal, the following was obtained.

Effect of the hydrocarbon phase. The amount of hydrocarbon phase (the ratio of hydrocarbon volume to total liquid volume) varies in a wide range from 0 to 90% in order to obtain the most reliable information about its effect on the process. The graphs below show the effect for different water content in the mixture (10, 30, 70 and 100%) and its influence on the formation of the foam system. It should be noted that the concentration of the foaming additive is directly dependent on the volume of water contained, and not on the total volume of liquid. All results are for the constant temperature of 25^{0}C and a constant injection rate of 0.5 m/s.

As can be seen from the dependencies, with an increase in the hydrocarbon phase, the rate of recovery and removal of liquid decreases. In addition, with a decrease in the aqueous phase, the stability of the foam system also decreases. It should also be noted that the efficiency of the process in terms of stability (monotonicity) decreases at low concentrations of the foaming additive and an aqueous phase content of about 10%. Such behavior is typical for the case when the amount of foaming agent and the degree of emulsification are quite low.



a)



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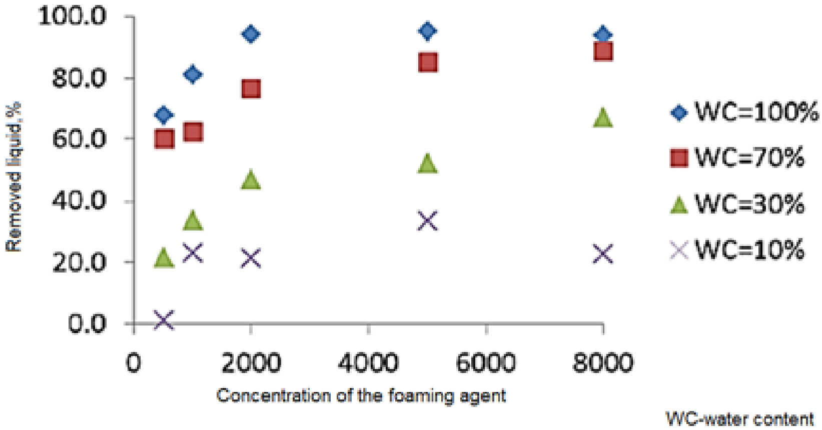

c)

Figure 2. Characteristics of recovery (a), destruction (b) and removed liquid (c) at various values of water content and foaming agent concentration

Therefore, the negative effect of the hydrocarbon phase on the stability of the bubble (foam) structure is explained by the fact that with its higher concentration in the liquid mixture, the coalescence process occurs faster, which leads to the formation of larger bubbles in the mixture.

Hydrocarbons tend to reduce the stability of the foam structure due to film rupture and stretching mechanisms according to the plasticizer principle. Thus, with an increase in the hydrocarbon phase, the efficiency of the liquid removal process will decrease. It should be noted that the volume of the hydrocarbon phase is the prevailing factor affecting the efficiency of the process compared to the concentration of the foaming agent. And this effect can be partially compensated only by increasing the concentration of the foaming additive) (Mityuk, et al, 2008, Shoeibi Omrani P. et al, 2016).

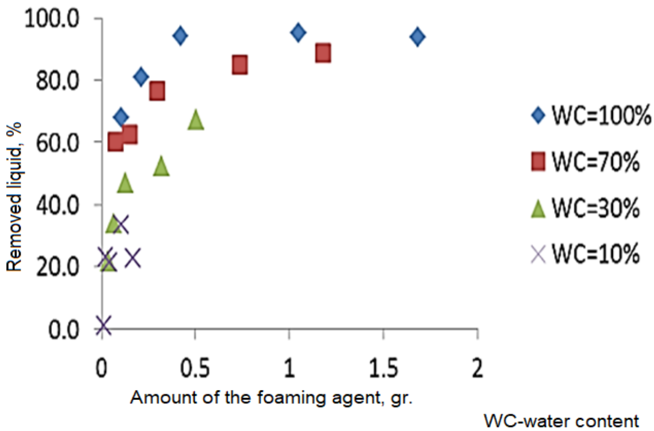

Figure 3. Dependence of the efficiency of the liquid removal process on the amount of foaming additive

Temperature effect. To identify the effect of temperature on the efficiency of the process of forming a foam structure and removing liquid from the bottom, several surfactants were tested under the same conditions. The temperature range ranges from 25 to 120^{0}C. The system disturbance rate has a constant level of 0.01 m/s in order to prevent evaporation of the liquid phase. In addition, this process can be controlled by increasing the pressure, reducing the gas flow rate, or pre-saturating the gas.

Certain difficulties arise only when monitoring gas quality and condensation. The maximum temperature decrease during the implementation of the process fluctuated within 5^{0}C.

It is important that the effectiveness of using foaming agents at high temperatures depends on the concentration of the surfactant, that is, the rate at which the efficiency of the foam system decreases for different additives is different, and a preliminary qualitative assessment of the process at temperatures in well conditions is significant (Shoeibi Omrani, et al, 2016; Aliyev. 2023; Iskandarov, et al, 2024).

Conclusion: The presence of the hydrocarbon phase and temperature are important parameters affecting the efficiency of the process of removing water from the bottom of gas wells. It has been shown that the qualitative characteristics of the process can vary significantly and be sensitive to the hydrocarbon fraction.

In addition, the negative effect cannot always be reduced by increasing the concentration of the foaming additive. Therefore, a preliminary assessment of the process must be carried out in accordance with the hydrocarbon phase in well conditions.

There was a decrease in quality characteristics in terms of foam recovery, stability and volumes of liquid removed from the bottom at high temperatures. Thus, a preliminary assessment of the effectiveness of the technological measure is necessary at temperatures that differ from well conditions by an insignificantly small amount.

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