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ANALYSIS OF METHODS LIMITING GAS BREAKTHROUGHS INTO PRODUCTION WELLS AT THE FEDOROVSKOYE FIELD

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АНАЛИЗ МЕТОДОВ ОГРАНИЧЕНИЯ ПРОРЫВОВ ГАЗА В ДОБЫВАЮЩИЕ СКВАЖИНЫ ФЕДОРОВСКОГО МЕСТОРОЖДЕНИЯ

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Abstract. The article explores the reasons causing gas breakthrough from the gas cap into the producing wells and oil penetration into the gas–saturated part of the formation at the Fedorovskoe Field. It appears that gas breakthrough to the perforated intervals of producing wells are mainly caused by the geological structure of AS4-8 formations (absence of robust shale break/screen) and relatively small distances from the upper filter holes to the gas– and gas-and-oil–saturated portion of the formation. Two operation modes applicable for this field are described: for the wells intersecting the formation with horizontal shaft under impermeable shale break between gas-and-oil–saturated layers (cases of gas breakthrough are excluded) and for horizontal and vertical wells in the contact zones of gas-and-oil reservoirs or areas with thin split shale breaks (there is continuous gas breakthrough). The article describes engineering solutions ensuring insulation of gas breakthrough into wells. In particular, a method based on creation of an extended radial insulating screen in the formation is reviewed. A technology successfully used at the field is described, which is designed to insulate behind-the-casing gas leaks by installing VP-135 explosive packer inside the well, perforating the gas-saturated portion of the formation and injecting insulating material into special holes under pressure. Based on the analysis of geological and process conditions at the Fedorovskoe Field and success of the technology applied, new methods of gas breakthrough control have been suggested: application of asphaltic-resinous substances as the insulating agent; application of foaming agents; and injection of aqueous solution of alkali–metal and alkali–earth metal chlorides into the formation.

Аннотация. В статье исследуются причины прорывов газа из газовой шапки в добывающие скважины и внедрения нефти в газонасыщенную часть пласта на Федоровском месторождении. Выяснено, что прорывы газа к интервалам перфорации добывающих скважин обусловлены, в основном, геологическим строением пластов АС4-8 (отсутствием надежного глинистого раздела — экрана) и сравнительно небольшими расстояниями от верхних дыр фильтра до газо– и газонефтенасыщенной части разреза пласта. Описаны два режима эксплуатации, пригодных для данного месторождения: для скважин, вскрывающих пласт горизонтальным стволом под непроницаемым глинистым прослоем между газо– и нефтенасыщенными толщинами (прорывы газа исключаются), и для горизонтальных и вертикальных скважин в контактных зонах газонефтяных залежей или зонах с тонкими прерывистыми глинистыми прослоями (предусмотрен постоянный прорыв газа). Описаны технические решения, обеспечивающие изоляцию прорыва газа в скважины. В частности, рассмотрен метод, основанный на создании в пласте на уровне раздела протяженного радиального изолирующего экрана. Описана успешно примененная на месторождении технология изоляции заколонных перетоков газа путем установки в скважине взрывного пакера ВП-135, вскрытия перфорацией газонасыщенной части пласта и закачки изолирующего материала в спецотверстия под давлением. На основе анализа геологических и технологических условий Федоровского месторождения и успешности используемых технологий, были предложены новые методы борьбы с прорывами газа: использование в качестве изолирующего агента асфальтосмолистых веществ; применение пенообразующих агнентов; закачка в пласт водного раствора хлоридов щелочных и щелочноземельных металлов.

Ключевые слова: прорывы газа, изоляция перетоков газа, изолирующий экран, пенообразующие агенты, взрывной пакер.

Keywords: gas breakthrough, isolation of gas cross-flows, insulating screen, explosive packer.

The problem of gas breakthrough from the gas cap into production wells and oil penetration into the gas-saturated part of formation, leading to an undesirable increase in a gas factor and loss of oil as a bottom heel in the formation, is quite sharply manifested in the conditions of the Fedorovskoye Oil and Gas Field. The main stock of producing wells of the field is exploited by the AS4-8. The oil and gas reservoir of AS4-8 formations is represented by an oil rim located between the gas cap and the bottom water. At the AC4-8 facility it is possible to penetrate with wells as purely oil, gas and water saturated strata separated by impermeable natural interlayers, as well as contact gas, water and oil strata, and also all possible intermediate variants. In the oil zone of the formation, the amount of gas dissolved in the oil depends on the well position structure, and on the phase state of the formation fluid in the bottomhole zone. In the case of breakthroughs of the gas cap to the natural gas well, the value of the gas factor can vary upward in an uncontrolled manner. As follows from the results of field trials, when natural gas penetrates into a well (up to 6 000–7 000 m^3/t), the density of associated gas is sharply reduced compared to the oil wells due to the preferential gas offtake of the gas cap. The gas breakthrough from the gas cap to the perforation intervals of production wells is mainly due to the geological structure of the AS4-8 strata, when the lack of a reliable screen and relatively short distances from the upper holes of the filter to the gas- and gas-oil-saturated part of the formation, do not allow operating wells in gas-free regimes even at low pressure draw-down [1, 2].

The deposit was drilled by controlled directional and horizontal wells. According to the data available for the AS4-8 facility development, the operating stock comprised of 1,344 production wells. Of 1,317 production wells, 1279 (ESP unit — 1,155, SRP unit — 124) were operated by mechanical means, 38 — by free-flow production method.

Out of 38 flowing production wells (15 - horizontal, 23 - controlled directional), 21 were operated by a fountain through a pump, including 9 horizontal ones. The reason for the wells operation in a free-flow mode through the pump is a large amount of gas coming from the gas cap. This is due to the fact that in some areas of the development site there are no impervious natural screens between gas-, oil- and water-saturated strata, which does not allow exploiting wells in gas-free and anhydrous mode even at low pressure draw-down. The main complicating factor in the wells operation of the AS4-8 development facility is a breakthrough gas.

Parameters of the flowing wells operation at the Fedorovskoye Field are presented in Table 1.

Table 1

FLOWING WELLS OPERATING PARAMETERS AT THE FEDOROVSKOYE FIELD

Parameter		*AS4-8 Facility*	
		horizontal wells	*controlled directional wells*
Number of wells		*15*	*21*
Casing head pressure, MPa	average	2.6	2.4
	maximum	5.0	5.2
	minimal	1.5	1.5
Bottom-hole pressure, MPa	average	16.7	16.9
	maximum	17.4	17.8
	minimal	15.5	14.0
Pressure draw-down, MPa	average	2.2	2.0
	maximum	3.4	4.9
	minimal	1.5	2.1
Average production rate, t/day	oil	6.56	7.26
	fluid	112.40	48.15
Average water cut,%		*94.16*	*84.92*

Table 2 shows the average values of the pumping wells operation parameters. It follows from the Table that the lowest average pressure drawdown (3.5 MPa) is maintained in horizontal wells equipped with ESPs. High bottomhole pressures keeping in horizontal wells equipped with ESPs is also associated with the fact that the bulk of horizontal wells penetrate and operate areas where there is no shale break between gas-, oil- and water-saturated strata.

Depending on the geological conditions of the bottomhole zone of wells and the adopted development system of the Fedorovskoye Field, two conditional well operation modes are possible.

The first mode is applicable to wells entering a formation with a horizontal shaft under a shale seal between gas- and oil-saturated zones [3]. There is also an impermeable parting in the bottomhole zone of wells. It is assumed that cementation is performed with good quality. The technical requirement for well operation in this case:

–integrity and tightness of impermeable parting and cementing;

–parting drawdown is not more than 1.5 MPa per 1 m of fluid thickness and 0.7 MPa in gas;

–location of the bottomhole at a distance no closer than 350–450 m from the current oil and gas areal limits.

If these conditions are met, it is assumed that the gas cap does not enter the well shaft. Breakthrough of high-pressure gas at the wellhead in this case is considered an emergency situation.

The second mode of field operation provides for a permanent breakthrough of high-pressure gas from the gas cap in the well shaft. These are horizontal and vertical wells in contact zones of gas-oil deposits or zones with thin intermittent shale breaks between gas- and oil-saturated zones of the formation.

In any case, the well operation technology should provide their stable, manageable, trouble-free operation [4].

Table 2

PUMPING WELLS OPERATING PARAMETERS AT THE FEDOROVSKOYE FIELD
AS OF 01.01.2014

Parameter		*Value*			
		horizontal wells		*controlled directional wells*	
		ESP	*SRP*	*ESP*	*SRP*
Number of wells		*777*	*50*	*378*	*74*
Pump running depth, m	average maximum minimal	1211 1912 643	1131 1520 753	1311 1835 773	1138 1512 673
Drawdown level, m	average maximum minimal	387 910 0	537 1002 0	416 987 0	505 921 98
Bottom-hole pressure, MPa	average maximum minimal	15.4 18.2 14.0	14.3 18.3 13.8	14.9 18.0 13.7	14.6 17.4 14.0
Pressure drawdown, MPa	average maximum minimal	3.5 4.9 0.7	4.6 5.1 0.6	4.0 5.2 0.9	5.3 4.9 1.5
Average production rate, t/day	oil	4.68	1.53	4.21	2.03
Average production rate, t/day	fluid	262.62	15.44	155.74	15.75
Average water cut,%		*98.22*	*90.06*	*97.3*	*87.03*

Horizontal and vertical wells that enter the formation *bottomhole zone* with thick (more than 1.5 MPa drawdown per 1 m) impermeable partings between the gas- and oil-saturated zones of the formation can be successfully exploited by traditional technical means using well-known technologies. The complexity of the other cases lies in the fact that, at high gas production rates, lifting along the entire length of the eductor is transferred to the plug and core-type gas-liquid structure. A steady flowing is disrupted (pressure pulsates at a bottom hole and a well head), which makes it difficult to manage the well. When moving to a core-type structure, high-pressure gas breaks through from the formation to the well head, and the well is transferred to the unserviceable stock. Decrease in the bottomhole pressure in wells operating with large breakthrough gas rates can lead to an increase in gas production, which will reduce the oil flow into the well shaft. In addition, due to the oil well stock aging, there was a significant increase in the leakage of casing strings in the gas-saturated formation interval and the presence of behind-the-casing gas flows. To prevent complications associated with the gas breakthrough into wells, in the context of a complex geological structure of oil and gas fields, the task of improving the isolating technology of gas inflows into wells exploiting the oil formation is extremely urgent. At present, field practice has effective technical solutions that ensure the isolation of gas breakthrough into wells operating oil and gas and oil and gas condensate deposits. Methods based on creation of an extended radial insulating screen in the formation at the interface level are of particular interest.

This technology is designed to isolate the gas inflows in operational gas-contaminated oil wells with a high gas factor and high casing head pressure, when a gas breakthrough occurred due to the gas coning, gas broke through into the well via permeable partings, or there is behind-the-casing gas circulation in the well.

The main volume of the insulating screen is formed from water due to the formation of a water-oil emulsion at the gas-oil contact and hydrate formation in the gas layer. A smaller volume is formed from a cheap gel-forming composition, and a small volume of more expensive but very effective silicone or other wall-sealing compound is required to fix the insulating screen in the formation.

With this sequence of radial arrangement of the insulating materials in the formation, as the drawdown increases when approaching the borehole wall from the depth of the formation, the insulating properties of the plugging materials are synchronously amplified. In the depth of the formation where the drawdown is minimal and at a certain distance from the well it tends toward zero, the insulating screen is represented by an oil-water emulsion with a high shear gradient sufficient to prevent gas breakthrough into the oil-saturated zone of the formation. As the drawdown increases, the strength requirements for the insulating screen should also increase, so a gel-forming compound is pumped into the formation following the water. Finally, in the zone of maximum drawdown located at the well wall, the insulating screen is formed from the organosilicon plugging compound, which, due to a combination of high mechanical and adhesive characteristics, is able to withstand a high pressure drop (up to 20.0 MPa) without gas breakthrough through the insulating screen. In addition, the large radial dimensions of the screen and fixation of the water-oil emulsion and gel-forming compound in the formation with organosilicon or other plugging material prevent their removal from the formation during development and operation of the well after remedial cementing and allow to predict the long duration of the process effect of remedial cementing.

The properties of the plugging material formed during the curing of the organosilicon compound make it possible to carry out complex isolation works to eliminate the gas inflows with subsequent clay-acid exposure of the well bore zone of the formation in order to involve low-productivity zones in the development. All this enables to consider this technology as one of the elements of the process flow diagram of complex impact on the well bore zone in order to regulate oil and gas deposits development and increase oil recovery.

NVTS-1 (VTS-1) (neonol-water plugging compound) and CROSS-1 or NVTS-2 (VTS-2) and CROSS-2 compounds are used for gas-insulating operations at the Fedorovskoye Field.

The technology of behind-the-casing gas flow insulation was successfully tested at the Fedorovskoye Field with impermeable partings between gas and oil formations. The technology included installation of VP-135 explosive packer in the well, penetrating the gas-saturated part of the formation and pumping the insulating material into special holes under pressure. SFZH-305 M phenol-formaldehyde liquid resin, hardened with Petrov contact, is pumped into the formation as an insulating material. The cement slurry was pumped into the formation to achieve the technological “screenout” and “reinforcement” of the insulating material.

The proposed options for the gas flows insulation the application of which is potentially effective for the conditions of the Fedorovskoye Field [5]*:*

–Application of asphalt-tarry substances as an insulating agent. In this case, asphalt-tarry substances are injected into the formation. Formation oil, aromatic hydrocarbons and carbon tetrachloride are used as solvents of asphalt and tarry substances. After treatment, the well comes into operation with simultaneous injection of viscous oil into the upper part of the formation to prevent a gas cone emergence.

–Application of foaming agents. In this case, it is recommended to repeat injection of the foaming agent solution in water or in a hydrocarbon liquid and gas several times. The depth of foam penetration into the formation should be 7.5–30 m from the bottom of the well.

–Aqueous solution of alkali-metal and alkaline earth metals chlorides. In this case, an aqueous solution of alkali-metal and alkaline earth metals chlorides is pumped into the formation. After that, the pressure in the gas-saturated zone is reduced to the water phase evaporation pressure at which the salts precipitate and form an insulating screen.

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