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Анализ эффективности технологий выравнивания профиля приёмистости на «Ω» месторождении.

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Введение

Быстрое обводнение скважин и пластов приводит к ощутимому снижению как текущей добычи нефти, так и конечного извлечения нефти (вода впустую перекачивается по промытым каналам, таким образом в пласте остаются зоны с нефтью нетронутые разработкой), к значительному снижению экономического эффекта, относящимся к подъему на поверхность, транспортировке, подготовке и обратной закачки в пласт значительных объемов жидкости (воды).

Одной из острых проблем нефтедобычи на месторождениях в Западной Сибири является уменьшение обводненности извлекаемой продукции и уменьшение попутно добываемой жидкости (воды). На этом фоне становится актуальным применение современных инструментов(методов) оптимизации разработки нефтяных месторождений, дозволяющих регулировать темп обводнения месторождения и нефтяных залежей, которыми являются физико-химические методы воздействия (ФХВ) на пласт.

На основании анализа трассирования фильтрационных потоков, проведенного на ряде месторождений, установлено, что от нагнетательных скважин преобладают фильтрационные потоки субширотного направления и значительными скоростями. Основные объемы воды нагнетательных скважин к добывающим скважинам поступают по пропластками с проницаемостью менее 0,1 мкм^2. Около 15–25% воды поступает по пропласкам с высокой проницаемостью более 0,12 мкм^2. Почти не установлены фильтрационные процессы по каналам с низкой проницаемостью менее 0,012 мкм^2.

Основная задача, которую решают (ФХВ) – это выравнивание профиля приемистости (ВПП), а также исправление путей движения потоков нагнетаемого агента при помощи сосредоточения системы каналов с высокой проницаемостью и трещин автогрп (техногенных) с целью привлечения к разработке запасов, находящихся в пластах и районах (зонах), не охваченных выработкой. Достичь данной цели можно при помощи направленного тампонирования физико-химическими составами с учетом поддержки давления нагнетания на уровне, без образования трещин автогрп. Обычно происходит перераспределение потоков, иначе говоря, снижение проницаемости высокопроницаемых пропластков, и даже их полная изоляция и дальнейшее подключение в работу ранее незатронутых разработкой зон.

Актуальность данной проблемы возникает для всех зрелых месторождений с высокой неоднородностью как в разрезе так и в латеральном направлении.

Целью исследования будет являться оценка эффективности проведенных работ по ВПП и выдача рекомендаций для дальнейшего применения данной методики.

Для достижения поставленной цели будут решены следующие задачи:

- Изучить особенности месторождения
- Изучить применяемые технологии ВПП на месторождении
- Изучить эффекты возникающие при применениях технологий ВПП
- Построение характеристик вытеснения для оценки эффекта от ВПП
- Заключительный анализ эффективности проведенных ВПП на основе экономических данных.

АННОТАЦИЯ

Залежи нефти пластов $АС_2$, $АС_8$, $АС_9$, $ЮС_{2–3}$ не разрабатываются. Основным нефтесодержащим объектом являются продуктивные пласты АС10–12, в которых сосредоточено около 98% запасов нефти категории $В+С_1$. Залежи нефти пластов АС10–12 охватывают большую часть площади месторождения. Залежи пластов группы ЮС содержат запасы нефти категории $С_1$ – 1,7% и $С_2$ – 38,5% от суммарных запасов по месторождению «Ω», имеют ограниченный размер.

Мощность осадочного чехла возрастает от районов границы впадины к центру до 8–9 км, залегающего несогласно на полигетерогенном фундаменте. В региональном тектоническом плане нефтяное месторождение «Ω», опираясь на данные тектонической карты центральной части Западно-Сибирской плиты (главный редактор В. И. Шпильман 1998 г.), расположено во Фроловской впадине между Сырьегайской террасой и Тундринской седловиной.

С начала разработки по месторождению Ω отобрано более 60 млн. т нефти и более 80 млн. т жидкости. Текущий КИН состовляет от 0,04 до 0,045, при проектном менее 0,3. Отбор от НИЗ составил около 15%, при обводненности менее 40%.

Фактическая добыча нефти не достигала проектной более чем на 14% по двум основным причинам. Первая – наблюдалось интенсивное падение дебитов жидкости по переходящему фонду добывающих скважин из-за отстающей динамики формирования фонда нагнетательных скважин и освоения их в ППД. На отдельных участках из-за недостаточной компенсации отбора закачкой наблюдалось падение дебитов жидкости за год на 25–30%, а дебитов нефти – на 35–40%. Вторая причина – двукратное отставание фактических дебитов нефти по новым скважинам, которое объясняется разбуриванием новых участков, характеризовавшихся ухудшенными геолого-физическими характеристиками. Все вышеприведенные факторы привели к отставанию фактической годовой добычи нефти от проектной более чем на 14%.

В работе изучен механизм работы технологии выравнивания профиля приемистости. Повышение нефтеотдачи и интенсификация добычи нефти пластов при физико-химическом воздействии обусловлено доотмывом остаточной нефти, повышением охвата пластов заводнением, подключением в разработку недренируемых или слабодренируемых нефтенасыщенных интервалов и зон пласта. Все это достигается, как закачкой оторочек композиций хим.реагентов, способных выравнивать фронт вытеснения, перераспределять потоки нагнетаемой воды, увеличивать линейную скорость фильтрации воды и пластовой нефти, доотмывать остаточную нефть; так и воздействием на призабойную зону скважин с целью изоляции водопромытых и водоносных интервалов, внутриколонных и межпластовых перетоков; подключения в разработку недренируемых или слабодренируемых интервалов пластов. Одна из основных задач, которую следует решить – это скорректировать кинематику потоков нагнетаемого агента при помощи локализации системы высокопроницаемых пропластков и каналов и трещин автогрп с целью привлечения к процессу разработки запасов, находящихся в пропластках и местах, не охваченных выработкой. Достигнуть этого можно путем целенаправленного повышения гидравлического сопротивления в промытой части пласта с поддержанием давления нагнетания без инициирования трещин автогрп. В большинстве происходит отклонение(перераспределение) потоков, т.е. снижение фильтрационных характеристик высокопроводящих (высокопроницаемых) пропластков, а порой их полная изоляция и, как правило, подключение в работу ранее недренируемых интервалов пластов.

Для оценки эффективности ВПП разобрана методика. Расчет дополнительной добычи нефти выполняется по характеристикам вытеснения отдельно по каждой добывающей скважине окружения с последующим суммированием эффекта по всем реагирующим скважинам.

Расчет технологической эффективности ГТМ по скважинам учитывает особенности эксплуатации и геологии каждой скважины за счет:

индивидуального выбора для каждой добывающей скважины вида кривых: падения или обводнения;

индивидуального подбора для каждой добывающей скважины лучших базовых периодов и лучших характеристик по коэффициентам корреляции.

Расчет дополнительной добычи нефти выполняется по кривым падения, если в течение 6 месяцев непосредственно перед проведением ГТМ обводненность на реагирующей добывающей скважине была меньше 20%.

Эффективной обработкой ВПП будет являться та процедура, в которой происходит уменьшение текущей обводненности относительно базовой, рассчитанной по одной из характеристик вытеснения, указанной выше. Базовая обводненность рассчитывается на основе уже имеющейся обводненности скважины. Выбирается временной интервал не менее 6 меся на кривой обводенности и происходит адаптация модельной кривой и фактической.

На месторождении «Ω» был выбран участок из 4 скв, на котором проводилась оценка эффективности ВПП. Все обработанные скв по разным технологиям показали положительные результаты. Средний прирост по нефти составил около 4000 тонн на скважины и снижение обводненности до 20%

В целом на месторождении «Ω» проведено около 300 операций ВПП. Удельная добыча нефти составила 12000 тонн. Удельная добыча воды снизилась более чем на 11000 м^3. Из графика на рисунке 3.8 видно, что наибольшую добычу нефти принесли следующие технологии ВПП: волокнисто-дисперсионная система вязкоупругие системы поверхностно активное вещество, технология предусматривает в Полиамид Акрил с

Ацетатом Хрома в минерализованном растворе с последующей продавкой ПАВ . Средний эффект от одной операции ВПП составляет 6 месяцев.

Таким образом можно сказать, что в среднем на каждой нагнетательной скважине рекомендуется проводить повторную операцию по ВПП с периодичностью раз в 6 месяцев.

Если ранжировать технологии ВПП по относительному уменьшению обводенности скважинной продукции, то наиболее успешными являются следующие технологии: КТДД 2, ППС+ВУС+ПАВ, ДС+ВУПАС, Темпоскрин и ДЩПК+ПАВ.

Для данных расчетов по эффективности ВПП проведена экономическая оценка проводимых мероприятий по ВПП на месторождении Ω. Было отмечено, что скважины с обработкой дают более высокий ЧДД. Следует отметить, что уже после 4 лет эффект от операций ВПП падает, поэтому кривая ЧДД имеет перегиб. На этом можно сделать важный вывод, что на одной скважине следует делать несколько обработок ВПП. Проводимые операции по ВПП на месторождении «Ω» позволяют увечить чистый дисконтированный доход более 10 млн. руб от одной скв-операции.

Carrying out work on conformance control of voidage profiles, increasing flood area and changing the direction of the filtration streams

General Provisions

Enhancement of oil recovery and intensification of oil production in reservoirs under physico-chemical effects is due to pre-cleaning of residual oil, increased coverage of reservoirs by waterflooding, connection to the development of undrained or weakly drained oil-saturated intervals and zones of the formation. All this is achieved by pumping the finishes of compositions of chemical reagents capable of equalizing the displacement front, redistributing the flow of injected water, increasing the linear rate of filtration of water and reservoir oil, and removing the residual oil; And impact on the bottomhole zone of wells with the purpose of isolation of water-washed and water-bearing intervals, intracolumn and interplastic flows; Connection in the development of undrained or weakly drained intervals of beds.

One of the main tasks that should be solved is to correct the kinematics of the injected agent flows by locating the system of highly permeable interlayers and channels and cracks in the autogrp in order to involve the development of reserves in interlayers and places not covered by production. This can be achieved by purposeful increase of the hydraulic resistance in the washed part of the formation with maintaining the discharge pressure without initiating the cracks in the autograss. In the majority there is a deviation (redistribution) of flows, i.e. Reduction of filtration characteristics of high-conductivity (high permeability) interlayers, and sometimes their complete isolation and, as a rule, connection to work of previously undrained intervals of layers [2].

As a result of optimization of development of deposits the following occurs:

• the most complete extraction of oil;

• stabilization, or reduction of water cut;

• reduction in the volume of water produced;

• maintenance of planned levels of oil production.

Methodology for selecting sites for flow deflecting EOR

Analysis of fishing information shows:

• Total oil recovery, all other things being equal, depends significantly on the permeability and macroinhomogeneity of the formation;

• to increase the oil recovery of heterogeneous reservoirs, it is advisable to establish average filtration rates in the range of 15-25 m / year with a viscosity ratio of oil and water of about 2-2.5;

• The experience of exploiting the studied reservoirs shows that the increase in the total oil recovery factor depends on the amount of water that rinses the reservoir, which obviously should not be below 1.5-2.0 pore volumes of the formation. Moreover, for more permeable reservoirs this value is less, for low permeable and inhomogeneous layers - this value is larger.

The results of the analysis of the obtained data and dependencies allowed us to single out the following regularities:

1. In the washing range up to 50% of the pore volume of the reservoir, 44–54% of recoverable reserves are selected. When the fluid was withdrawn in the range from 50 to 100% of the pore volume, the increase in CIN was 26–34%. With an increase in fluid extraction in the range from 100 to 150% of the pore volume, the average increase in CIN by fields is 11%.

2. Earlier, the decrease in the rate of fluid extraction during the main development period leads to imbalance of the development systems being implemented, to a deterioration in the structure of reserves, and the achievement of the oil recovery at these facilities, which is on the state balance, requires the adoption of adequate measures related to additional capital expenditures.

Optimal levels of accumulated fluid production are estimated in the range from 1.0 to 1.5 pore volumes.

In all types of reservoirs, the methods of non-stationary, cyclic waterflooding and changing the directions of filtration flows, as well as flow deflecting technologies, have positively proven themselves. These technologies:

• promote the coverage of the flooding process of stagnant zones, formed oil pillars;

• allow to intensify the extraction of oil from low permeable inclusions, zones, interlayers due to the mechanism of capillary absorption.

• The efficiency of these technologies is explained, first of all, by the increase in pressure gradients, rates of displacement in previously weakly drained zones of the formation.

In inhomogeneous layers, the effects of the limiting gradient are enhanced by the change in permeability and the limiting gradient from point i to the point of the medium. In this case, the increase in the rate of developmenti favorably affects the degree of coverage of the reservoir by embedding.

However, calculations for a layered reservoir show that an increase in the rate can increase the productivity and effective thickness of the formation, but it is not able to significantly increase the main technological indices - anhydrous and cobalt oil recovery. The analysis of results and data on oil recovery is determined by the interaction of active displacement of oil under the influence of hydrodynamic pressure drop and capillary impregnation process, which ensures the extraction of oil from weakly permeable areas, the necessary flow of water [3].

The coefficient of oil recovery in the water-pressure regime increases with the increase in the rate of fluid extraction. Reducing the rate of fluid withdrawal leads to the abandonment of oil in the reservoir, which is practically impossible to recover completely during the subsequent intensive selection of liquid.

Experience in the development of all oil fields indicates that the zonal layered inhomogeneity of reservoir properties, intermittent layers, lenticular structure are the main factors for the reduction of development efficiency, low CIN, and undesirable water cut.

When design development is carried out, there is usually no reliable data on the presence and parameters of the zone and layered heterogeneity of productive reservoirs. And experimental and experimental-industrial operation of wells and deposits are not particularly salvaged here. When industrial development begins, then all types of heterogeneity make themselves felt through earlier, intensive watering of well production. As a result, it is necessary to find and implement adequate measures to combat the corresponding heterogeneity of reservoir properties. Therefore, in the theory and practice of oil recovery, methods of intensive order have been applied, the purpose of which is to influence the filtration processes in the desired direction.

Basic requirements for wells to be selected for processing by flow control technologies

The mechanism for increasing the oil recovery factor using flow deflection technologies is based on increasing the formation coverage by means of the injection of water by increasing the filtration resistance of the washed channels of the formation. As a result, it is possible to regulate the movement of water through highly permeable channels to formations in order to limit filtration.

Requirements for candidates and ODA sites selected for injection of flow-deflecting liquids can be made on the basis of geological, physical, technical and technological considerations that take into account the processes of occurrence of protective barriers, as well as the state and characteristics of the workings of the heterogeneous formation both vertically and Lateral with the technical condition of injection wells and flooding.

For flow-diverting technologies, the objects of application can be layer-inhomogeneous reservoir-reservoirs, the permeability of individual interlayers, which have differences several times, developed as a whole object. Low-permeability channels should have a higher current oil saturation than high-permeability channels of the formation. Separate channels of the formation should be traced, for starters, to the nearest production wells and have a good hydrodynamic connection with the injection wells.

It should be noted that if a thin permeable layer (formation) is replaced by impenetrable rocks or wedged out, does not extend to the nearest production wells, and does not have lithological contacts at the boundary with a high permeable layer, then the positive effect of the application of technology and flow will be negligible. Similarly, it can occur with a high water saturation of rocks of a low-productive interlayer (interlayer).

Collectors, composed of one developed layer of sufficient thickness, the permeability of this layer varies significantly in thickness, and can also be objects of application of flow deflecting technologies to increase the oil recovery of heterogeneous reservoirs. It is worth noting that at the initial stage of fishing operations it is better to give preference to layered heterogeneous reservoirs.

To obtain a successful injection of solutions with chemical reagents into a highly permeable formation, the reservoir must be well drained and the well must have sufficient injectivity that meets the criteria of the technology.

Based on the above-mentioned, the areas for processing by flow-deflecting technologies are selected using the following criterion [3]:

• Productive seams (layers) of oil deposits should have a layered heterogeneity by hydrodynamically unbonded interlayers. It is necessary to distinguish the form of heterogeneity - macro-inhomogeneous formations with a thickness of low permeability layers of more than 1 m and microinhomogeneous layers with a thickness of low permeable interlayers of less than 1 m.

• The ratio of permeability of high permeability and low permeability of layers (interlayers) should not be less than 2.

• High-permeability and low-permeability interlayers of a heterogeneous formation along the vertical should have an area spread from injection to producing wells, at least up to the first production line. To establish the hydrodynamic connection between naked wells and to investigate the type of distribution of reservoirs, geol.profiles, collector distribution maps in the form of block diagrams, as well as the results of the GDI are used.

• The presence of interlayers (strata), not involved in the development and having an increased residual oil saturation in the section of the inhomogeneous reservoir in the injection wells. Such data can be obtained by analyzing the results of studies of injection wells by deep flow meters.

• Increased water cut of produced well fluid, indirectly indicates the signs of the development of stocks of watered interlayers and the formation of washed zones of the formation.

• Wells selected for injection must have the necessary injectivity, which meets the conditions of application of the technology.

• Low waterflood coverage due to high reservoir heterogeneity and variability in reservoir permeability.

• It is necessary to know the distribution of the injected water through the production wells, by plotting a map of total water abstractions; Based on the results of these work, the basic direction of movement of water is identified in the layers or in the whole group of layers.

• Then, the graphs of the change in the water cut of the production and the schedules of changes in well production over time are plotted.

• Study of the technical condition of wells for stabbing circulations.

• After grouping the results, conclusions are made about the suitability of the analyzed sections of the formation for processing.

Analytical dependencies

We agree with the indices "н", "ж" and "в" to denote the quantities characterizing the extraction of oil, liquid and water, respectively.

The average daily production rate of an individual oil well qn and liquid qzh is defined as the ratio of the oil produced per month, (liquid) to the number of hours worked, multiplied by 24:

;;

$$q_H = 24 \cdot \frac{Q_H}{t_m} \qquad q_б = 24 \cdot \frac{Q_б}{t_m} \quad (1),$$

Where tm is the number of hours actually worked by the well in a month.

The average daily water flow is defined as the difference between the daily average flow rate and the average daily oil production rate.

The average daily production rate of one active well of the qn section is defined as the ratio of oil production Qn by area to the total number of days worked by all wells in the section:

$$q_H = \frac{Q_H}{(\frac{t_m}{24})} = 24 \cdot \frac{Q_H}{t_m} \quad (2)$$

Similarly, the average daily production rate of one well per fluid is determined.

$$q_б = 24 \cdot \frac{Q_б}{t_m} \quad (3)$$

The average daily production rate of one well by water is defined as the difference between the average daily production rate of one well by liquid and by oil.

$$q_В = q_Ж - q_Н , \quad (4)$$

The operating factor of the well is denoted by QB and is defined as the ratio of hours worked to the total number of hours in a month:

$$K_e = \frac{t_m}{24 \cdot n_{сут}}, \quad (5)$$

Where nsut is the number of days in a month.

The average well service factor of the site can be calculated from the formula

$$K_e^y = \frac{\sum_{i=1}^{N} t_{mi}}{24 \cdot N \cdot n_{cym}}, \qquad (6)$$

Where N is the number of wells in the section, tmi is the hour worked by the i-th well in the given month.

Average daily daily flow rates of oil, fluid and water cut wells are calculated separately for highly watered and low-water well groups.

Description of technologies for enhanced oil recovery

SPS technology

Crosslinked polymeric or viscoelastic systems are hydrogels based on water-soluble polymers, in particular polyamide acrylic, they are formed as a result of the chemical cross-linking reaction of polymer macromolecules in its aqueous solution with the help of special cross-linking reagents. Hydrogels based on polyamide acrylic can be obtained by chemical cross-linking of an aqueous solution of polyamide with acrylic aldehydes or cations of polyvalent metals.

Decrease in water consumption in washed high permeability layers with very high rate of production of stocks, decrease in liquid production and increase of depressions in the reservoir in producing wells occurs as a result of temporary puncturing of the most permeable interlayers of the productive section. It involves oil-saturated and interstitial layers of reduced permeability and water cuts that were not previously covered or poorly flooded by increasing the pressure gradient and between the injection zone and the sampling zone and changing the directions of the filtration flows in the formation in the process of producing reserves.

As a result of the work performed, the coverage of the productive strata increases, which leads to an increase in the current and final oil recovery.

The technology using SPS is based on injection into a non-uniform permeability and oil saturation polymer solution containing a cross-linking agent. Under the influence of chemical transformations, transverse bridges are formed between individual polymer molecules and a spatial structure (grid) is formed, filled with a solvent, i.e. Water - polymer hydrogel. The principal difference between gels and polymer solutions is the presence of static shear stress (SNS). At stresses less than SNS, the gel behaves like an elastic (Guke) body, reversibly deformed. When the SNA is exceeded, the structure breaks down and its current begins. Gels are permeable to water, but create increased resistance when it is filtered - so-called. Residual resistance factor.

GOS-1 technology (with composite fillers)

To reduce or stabilize watering, increase oil production and oil recovery, it is recommended to pump injection wells reinforced with various additives of polymer systems. At the same time, the injectivity of the injector well decreases drastically, the injectivity profile changes, new interlayers are included in the work, and consequently difficult-to-recover reserves are involved in the development, thereby increasing the oil recovery of the formation. This technology is not expensive enough and technological.

When GOS-1 (SC) is injected in the high-permeability part of the formation, a partial colmatation of the washed high-permeability layers of the formation occurs, a feature of this technology is injection into the injection well alternately of the polymer composition followed by injection of the disperse phase (chalk, clay, wood flour) . As a result of this injection, each solution chooses the permeability layer proper for its selectivity and clogs it.

The technology of GOS (VUS)

The main components of the technology are a water-soluble polymer - polyacrylamide (PAA) and a crosslinker (chromium compounds or formaldehyde).

Viscoelastic compositions are prepared by crosslinking polymer macromolecules in solution. After a certain period of time (gelation period), an elastic gel with a wide range of strength and insulating characteristics is formed. Moreover, the formation of the gel takes place predominantly in highly permeable water-washed intervals, which leads to a redistribution of the filtration streams of injected water and the connection to the development of previously undrained oil-saturated reservoir intervals . The addition of surfactants to the solution and the drilling fluid promotes pre-washing of the oil from the water-washed intervals in which the oil is in the film state and the washing of oil from the low permeable interlayers.

LNG technology (with selective waterproofing)

The main components of the technology are sodium silicate (liquid glass), Polyamide acrylic and hydrochloric acid (or $CaCl_2$).

The essence of the method consists in the sequential injection of an aqueous solution of sodium silicate with the addition of polymers and hydrochloric acid (or $CaCl_2$), which are forced into the formation by the rims of the water. The gel is formed from sodium silicate in an acidic medium. In this case, the gel is formed exclusively in the water-washed intervals, which leads to a redistribution of the injected water flows and the connection to the development of previously undrained oil-saturated intervals and stagnant zones of the formation. Addition of Polyamide acrylic promotes greater stability and stabilization of the gel in reservoir conditions.

Thermogel technology

The physicochemical nature of the use of gel-forming systems is based on the formation of an aluminum hydroxide gel in an oil reservoir that isolates oil-free, highly permeable areas, and thereby facilitates the connection of low-permeability sections of the formation and interlayers. On the other hand, the ammonium salts (NH_4CL) formed as a result of reaction react with the oil components to form complex complex compounds, which leads to a reduction in interfacial tension, destruction of asphaltene structures, thereby increasing oil recovery.

The resulting gels isolate the formation rock selectively, only high-conductivity pores and channels, and non-insulated low-permeability pores and channels sealed with asphaltenes and resins are exposed by ammonia and ammonium chloride. The selective decrease in the permeability of highly conductive layers occurs by one or two orders of magnitude. Recommended for use in high-temperature strata of the Jurassic deposits.

ES technology (has selective waterproofing)

The technology of enhanced oil recovery with the use of emulsion compositions consists in pumping through the injection wells or BKNS into the stratum of the emulsifier rim. Inverted emulsions stabilized by Ringo EM containing formation water, oil and calcium chloride are water droplets that are closely adhered to each other, surrounded by armor shells consisting of a hydrocarbon solution of Ringo EM.

Since the external phase of such emulsions is a hydrocarbon, these emulsions readily solubilize the residual oil, creating on the front of displacement of the zone with increased content of oil, and transferring the oil to production wells.

Emulsion systems based on Ringo EM are resistant to high temperatures and do not exfoliate to a temperature of 80 ° C. Partially clogging the most permeable interlayers, they redistribute the flow of injected water into the interlayers with low permeability, involving or increasing the share of their participation in the development. In addition, some components of the emulsion composition, adsorbed on the surface of the rock, hydrophobicize it, thereby reducing the phase permeability of water in the flooded areas of the reservoir, which also contributes to the redistribution of the injected water flow and, accordingly, limits the flow of water into producing wells.

The VDPS technology (from the category of hard technologies)

The technology of fibrous disperse systems is based on wood flour + a polymer fixed with chromium acetate and subsequent rim of the clay solution, which is insulating, protecting the gel composition from destruction.

The technology of fibrous dispersion - polymer composition is practically suitable for any reservoir temperatures. The preferred reservoir temperature can be considered from 15 to 85 ° C.

The injected water can be both slightly mineralized to 20 g / l, and fresh according to GOST 2874-82 mass fraction of potassium ions up to 40 g / cm3, magnesium ions up to 10 g / cm3, density 1000 g / cm3, pH 7 - 8.

The injectivity of injection wells does not have the upper limit. It is inadmissible to use the VDPS technology on wells with an acceptance rate of up to 400 m3 / day. Preference is given to the wells with an acceptance rate of 500 m3 / day. Up to 1000 m3 / day.

CCC technology

Sediment-forming composition based on sodium sulfate is designed to limit the inflow of formation water and equalize the injectivity profile of injection wells.

The essence of the method for limiting the inflow of formation water (OPW), including the injection of the precipitating composition, is as follows. In the oil reservoir, one or more rims of an aqueous solution of sodium sulphate or a composition based on it are pumped through the injection wells. Then a solution of calcium chloride is pumped. The injection of these reagent solutions into the formation ensures the formation of a crystalline calcium sulphate precipitate in the high permeability intervals, which reduces the permeability of water-washed intervals without their isolation and increases the filtration resistance to the injected water. This makes it possible to redistribute the filtration streams and to connect to the development the sections and intervals of the reservoir that were not previously flooded. Geophysical studies show that in a number of cases, using the sludge-forming composition, it is possible to connect to the development all perforated intervals of the formation.

The main components of the technology are sodium sulfate and calcium chloride.

The essence of the technology - in the oil reservoir is initially pumped a solution of sodium sulfate or the compositions containing it, and then a solution of calcium chloride. The following reactions occur:

1. $Na2SO4$ (p-p) + $CaCl2$ (min water) = $CaSO4$¯ + 2 NaCl (p-p)
2. $Na2SO4$ (p-p) + $CaCl2$ (p-p) = $CaSO4$¯ + 2 NaCl

The increase in oil recovery is due to the blocking of water-saturated and water-washed intervals of the formation, because the precipitate of calcium sulphate is formed exclusively in the water-washed zones.

Technology of KRES, KROES

The main components of the technology are silicone emulsion and sediment-forming reagents. The technology is designed to equalize the injectivity profile of the injection wells and increase the formation coverage of the formation. The silicone emulsion provides hydrophobization of rocks both near the PZP injection well and in the reservoir volume due to the reversible adsorption of the silicone polymer. At the same time, hydrophobization of the rock leads to redistribution of filtration flows (CRES technology). The injection of sediment-forming reagents (in particular sodium sulphate with calcium chloride - KROES technology) enhances the effect of redistribution of filtration flows, and the injection of a hydrocarbon solvent contributes to the intensification of oil inflow. Due to the high thermal stability of all components of the composition, this technology can be applied to high-temperature non-uniform permeability strata. (In particular, on the Jurassic deposits).

Carbohydrate Reagents (DOC)

Carbon-based reagents (UCPR) contain sodium salts of humic acids, dispersed carbonaceous and inorganic particles, resins and wax. The technology is environmentally safe, the reagent is approved for use by Gosgortechnadzor. As a result of injection of the DFR into the formation, the permeability of the water-conducting channels of the formation decreases due to the formation of colloidal sediments and gels, which results in equalization of the oil displacement front and involvement in the development of weakly drained sections of the formation.

Reagents used:

Coal crumb (brown coal) - 35-40% - TU 0324-008-00164399;

Caustic (sodium hydroxide) - 40-45% - TU-6-01-1306-85 [2];

Calcium chloride - 30% - GOST 450-77 [3];

Pumping water

The essence of the technology lies in the injection into the reservoir of a solution of the alkali metal reagent (DIC) and then the solution of calcium chloride (precipitant).

In-Depth Fluid Diversion

The recovery factor of all enhanced recovery operations in heterogeneous reservoirs with high permeability streaks can be increased by the application of gelled polymer systems. In contrast to near wellbore treatments applications, polymer gels are applied in injector wells through in-depth fluid diversion (IFD) to increase reservoir scale sweep efficiency. Novel gel systems allows multichoice range solutions from weak gels to sequential injection for in situ gels, colloidal dispersion gels, preformed gels and microgels. The objective of an IFD process is to modify reservoir inflow profile for significant reduction of thief zones effective permeability to prevent the water uptake.

Since the 1990s, IFD research has gained momentum and new gel systems have been investigated to handle the problem of unswept zones.

Depth of the propagation and strength of the formed immobile gel structure are major factors influencing the success of such treatments.

Polymer gel injection can be classified as either bulk gel injection (surface produced) or sequential injection (in-situ). Each of these two injection mechanisms has key disadvantages and benefits. Bulk injection involves the injection of a homogeneous gel solution, formulated at the surface before the injection process takes place. This homogeneous gel solution, injected into the formation, quickly becomes a strong gel in-situ and predominantly affects the near-wellbore region. Bulk injection can result in weaker gels as result of shear degradation. By contrast, sequential injection can be used. This involves in turn injection of polymer and crosslinker. It enables in-depth placement of gels, as there is not much chance for crosslinking until both the polymer and crosslinker are present in the formation. Only then will the crosslinking take place yielding a strong gel capable of varying a zone's permeability. The disadvantage of sequential injection, however, is the added difficulty associated with the obvious loss of control. The polymer and crosslinker slugs may not even come into contact with each other if they flood different reservoir zones/strata8.

Summarizing the information presented above the bulk gel injection gives a weak gel due to shear degradation; by contrast sequential injection gives a strong gel but has a risk of control risk.

Gel Strength

Sydansk has defined a gel strength code (Codes A through J) to evaluate gels strength. In proposed scale a Code B gel is classified as a highly flowing gel (i.e. weak gel). As an alternate measure Han and Li1 have proposed a rheological parameter, the storage modulus (G'). A gel is classified as a weak gel when G' is less than 1dyne per square centimeter (dyne/cm2).

Because weak polymer gels are commonly used when it is important to keep gels or gel particles as a flowing fluid, this is sometimes referred to as a flowing gel process.

Weak gel injection selectively penetrates farther into high permeability zones and in the subsequent waterflood or chemical flood, it can be gradually pushed even deeper into the formation. In this process, fine gel particles migrate into pore throats, some of them squeeze through the throats, propagating forward, while others are trapped, effectively blocking further flow. This blockage plugs divert the subsequent water injection into unswept low permeability zones.

This paper presents an experimental study of nanogel which allows combining the advanatges of gels used in bulk and sequential injection. Addition of light metal nanopartciles subsequently increase the gel system strength while crosslinking, but has no effect on flow ability before it. The very weak gels form near the wellbore region, but continue to propagate into the reservoir. Adjustable crosslinking time allows on opportunity to be sure that gel bank placed exactly in thief zone and strong in-situ gel is not formed unpredictably. The subsequent injection of fluids, either water or chemical solutions, will redirect the predominant flow paths to unswept reservoir zones, which improves oil sweep efficiency by waterflood (or chemical flood), therefore leading to enhanced oil recovery (EOR). The surface of the gel is rough in nature.

Nanogel Strenght Evaluation Experiments

Nondestructive ultrasound-based analysis of gelation is applied in based on chronometry of ultrasonic signal transmission through the specimen, the rate of ultrasonic signal increases herewith alongside with the specimen thickening. The advantage of the methods lies in registrability of the whole gelation process without destruction of the test specimen. In compare with other methods it allows on objective valuation of gels compressive strength.

Tests were conducted as follows: 5% aqueous solution of polymer (CMC) was prepared for the experiment. Then nanoparticles were added and at constant stirring the crosslinking agent was introduced. To eliminate the effect of entrapped air on a specimen minimal pressure up to 3.4MPa (500 psi) was supplied. Tests were conducted at 62°C. The experiment result was a plot of gel strength evaluation versus time.

Kamcel 1000 grade CarboxyMethylCellulose with degree of substitution of carboxymethyl groups 80–90 and degree of polymerization of 1050–1150 was used as polymer. Nanoparticles supplied by Advanced Powder Technology (Tomsk, Russia), aluminum, were used. We used polyvalent metal salt as crosslinking agent. Crosslinking time of the polymer solution has adjustable range from 1 hour up to 10 days. Dynamics of changes in gel strength with and without addition of nanoparticles is shown in Figure 1. The gel with concentration of nanoparticles 0.0125 wt% was selected for the experiments due to increase of gel strength up to 65% (here and after referred as nanogel).

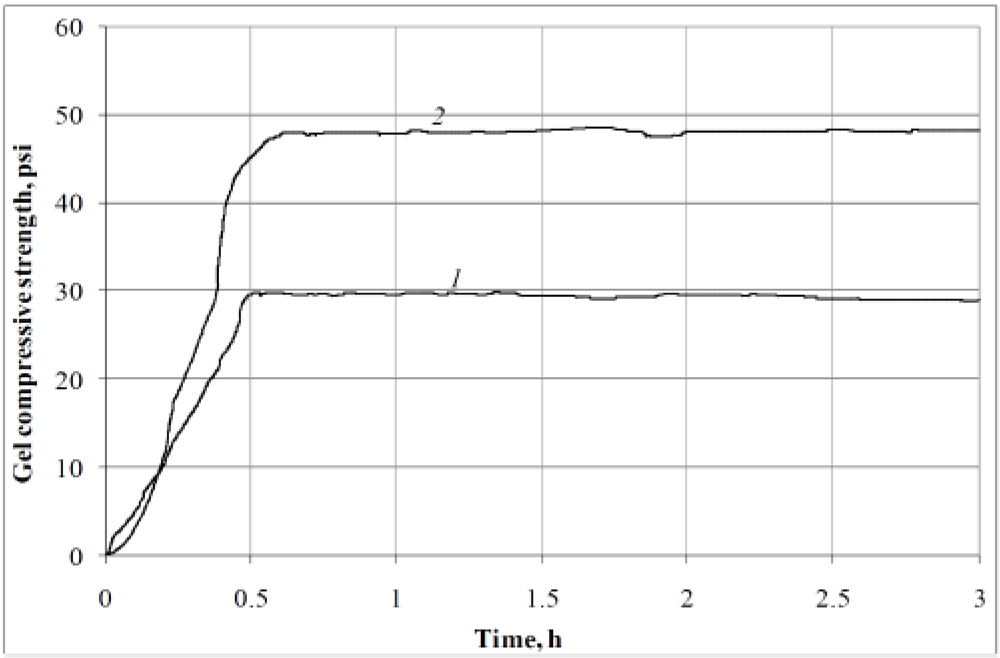

Figure 1 – Gel compressive strength changes: 1: gel without addition of nanoparticles; 2: gel contains 0.0125 wt% of nanoparticles.

Kinetic Mechanism of Gelation in the Presence of Nanofillers

Study and comparison of gelation curves in the presence and absence of nanoparticles allows the process mechanism to be explained In the presence of nanofillers, we can visually identify an inflection point on the graph (Figure 1). This circumstance allows us to speak about two simultaneous processes: cross-linking of the polymer system and reinforcement of gel by metallic nanoparticles. Nanoparticles are evenly distributed within the gel, thus increasing the surface area of the filler, which is accompanied by gel strength increase. However, after exceeding a threshold concentration (0.0125 %) it decreases. This can be explained by aggregation of nanoparticles (and possibly coalescence) that leads to a decrease of nanofillers surface area, which finally reduces reinforcing effect. To confirm our arguments we have to prove the existence of an inflection point on gelation curve in presence of nanoparticles in the system Proposed kinetic mechanism of the observed phenomena was proved by percolation task formulated for a continuous medium on the basis of gel electrical properties changes.

Resistance Factor and Residual Resistance Factor

The resistance factor, residual resistance factor and their change trend to test time are shown in Figure 2. The standart testing procedure was used during the experiments. Tests were conducted at 62°C. Artifical core samples with 470 md permeability were used for experiments.

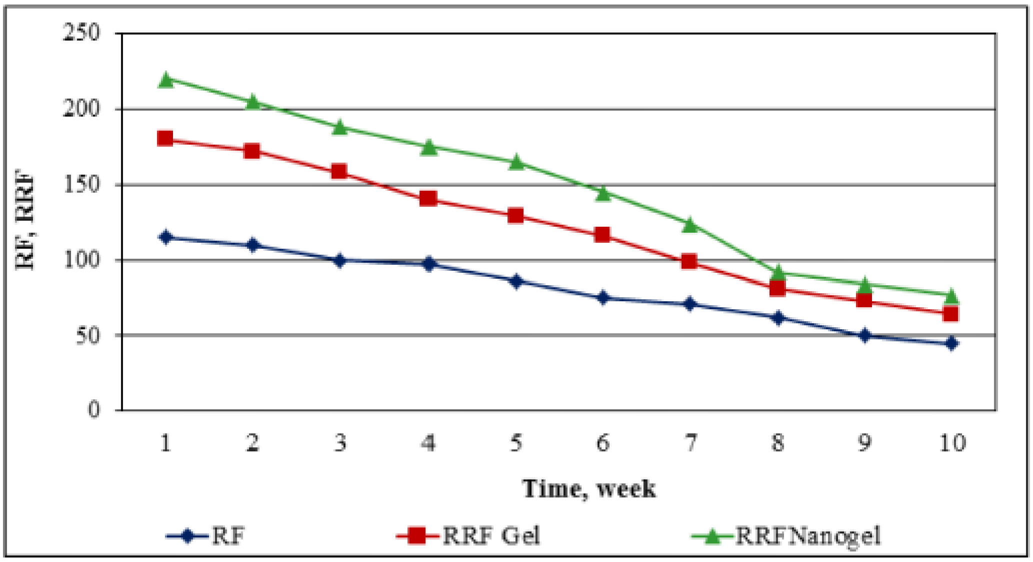

Figure 2 – Relationship between RF, RRF and test time

Core Preparation and Test Procedure

A two different artifical core sample from quartz sand were used to reproduce a confined homogeneous or a simply stratified heterogenious porous media (Table 1). The dry core samples was evacuated and saturated with formation brine under vacuum by standard procedures16,17. Porosity and pore volume were calculated from weight difference between wet and dry core. The core was mounted in a core holder and at least 15 PV of the same formation brine was injected into the core to reach a stabilized pH at the outlet and also a constant pressure drop across the core. After determining the permeability of formation brine by the porous plate method16 residual water saturation was 14%. Further, the core sample is placed back in the core holder, with simulated reservoir conditions: formation pressure 16MPa and 26MPa overburden pressure, temperature 62°C. The core sample was saturated by the live crude oil recombined from separator oil and synthetic separator gas and after the constant differential pressure achieved oil permeability of the sample was measured. The core samples were aged in live crude oil for a period of two weeks. During the ageing period the live crude was replaced by fresh crude oil three times. A minimum of two pore volume was injected and sufficient amount was used to achieve a constant GOR.

Gel Treatment

The modeling study presented by Entov shows that oil recovery is significantly greater if the flow is blocked in the neighborhood of the producing well as compared with blocking near an injection well or deep in the reservoir. It also shows that the crossflow between the layers of a layered reservoir plays an important role in achieving a gain in oil recovery. It is obvious that core treatment experiments without crossflow between the core samples could not accurately represent the fluid deep diversion. There in the gel bank act part more as plunger than blockage system because of its impermeability. Therefore the treatment experiments with crossflow betweencore samples were conducted at experimental setup shown in Figure 3. It has injection vertex, but separate production lines which allows on accurate monitoring of oil produced.

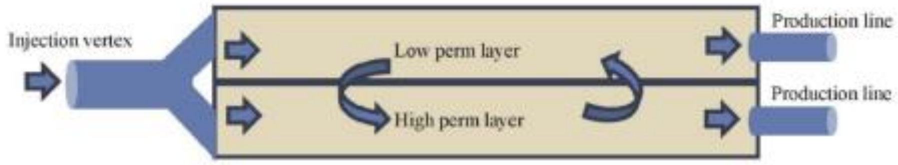

Figure 3 Artifical core crossflow scheme

Unsteady state displacement were performed at full reservoir conditions at a nominal flow rate of 5 PV.

d. All experimental plans and procedures were as follows:

1. Saturating brine and experimental oil;
2. Syntetich Caspian Sea water flooding until to 98% water cut;
3. Gel flooding with 10% PV;
4. Subsequent water flooding to 98% water cut.

It were condcuted six flooding experiments with gel and nanogelat different gel bank in-situ positioning. To test the impact of gel bank positioning on diverted perfomance of the gel three different positions of gel bank were selected (Figure 4). The volumes of produced water and oil were recorded at intervals, and the oil recovery factor was calculated as percent of original oil in place (%OOIP).

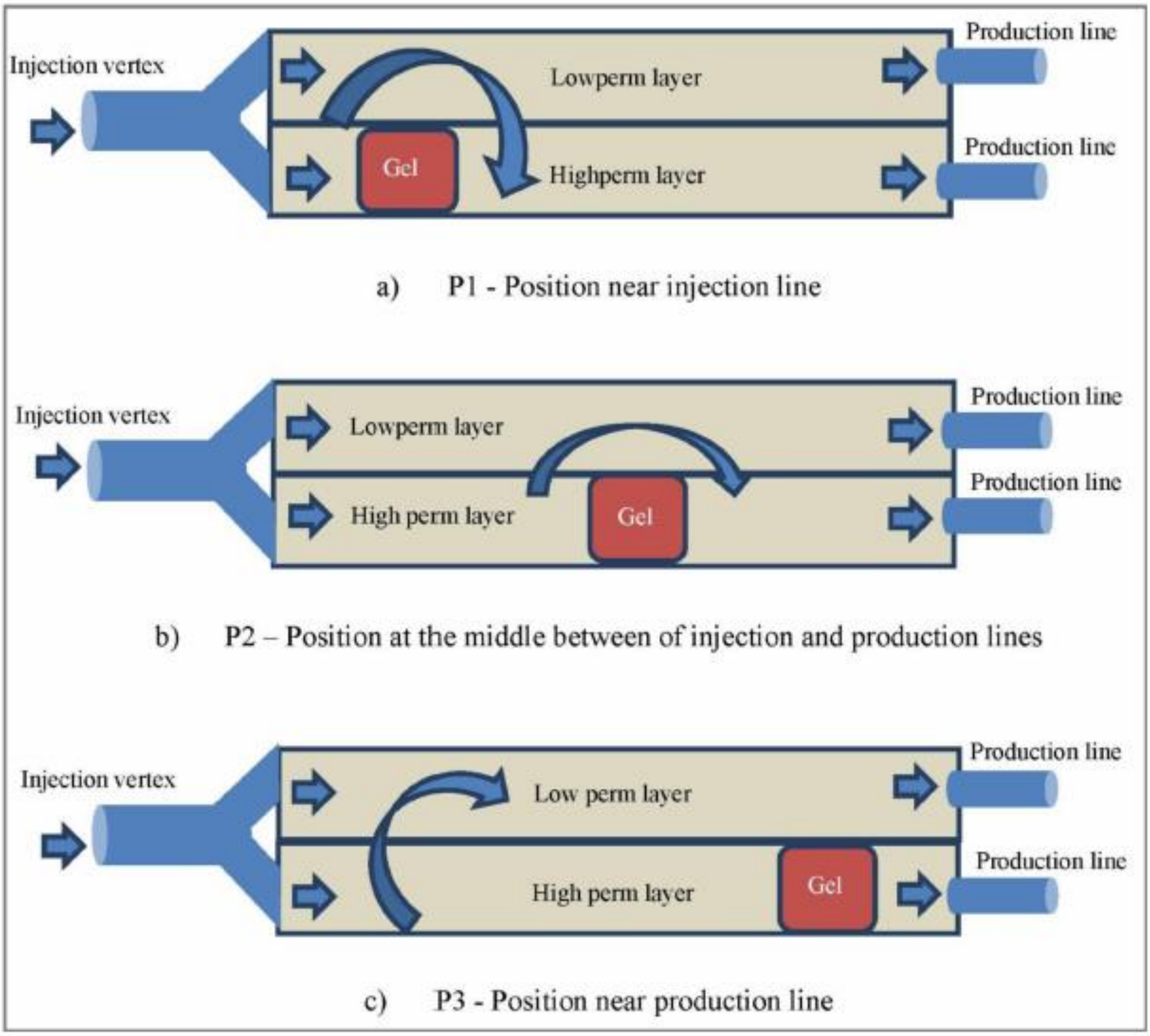

Figure 4 Gel bank positions

All the experiments were done at 62°C temperature.

Заключение

В ходе выпускной квалификационной работы были выполнены все поставленные задачи.

Ω нефтяное месторождение имеет сложное геологическое строение. Многопластовые залежи представлены в основном песчано-алевритовой разностью, в результате чего наблюдается высокая латеральная и вертикальная неоднородность пластов коллекторов..

Текущее состояние разработки месторождения соответствует проектным документам, которые были разработаны для этой цели. Удалось даже превысить плановые показатели по бурению скважин н на 2% и повысить коэффициент эксплуатации на 0,02% против проектного.

В работе рассмотрены и проанализированы различные методики по выравниванию профиля приемистости. Проведен их сравнительный анализ и выявлены лучшие подходы для ВПП на месторождении Ω это: ВДС+ВУС+ПАВ, КТДД2 и АС-CSE+ПАВ.

Разобран подход по оценке эффективности проведенных операций ВПП. Разобранная методика позволила оценить с достаточной точностью эффект от ВПП. На всех рассматриваемых скважинах наблюдался эффект от ВПП, который в среднем составил около 5000 тонн нефти за год. Также рассмотрено месторождение в целом по обработкам ВПП. Наилучшие показатели по приростам нефти показала методика ДС+ВУС+ПАВ в среднем 1260 тонн дополнительного прироста по нефти и снижение обводненности на 7%.

Также была рассчитана экономическая эффективность от проведенных ВПП, которая показала значительное увеличение прибыли компании в виде чистого дисконтированного дохода более 10 млн руб.

В главе социальная ответственность рассмотрены вредные факторы, влияющие на окружающую среду и меры безопасности по работе с химреагентами, а также меры по предотвращению попадания химических веществ в водоемы и почву.