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ЭФФЕКТИВНОСТЬ МЕРОПРИЯТИЙ ПО УВЕЛИЧЕНИЮ ДОБЫЧИ ГАЗА И КОНДЕНСАТА НА ПРИМЕРЕ М ГАЗОКОНДЕНСАТНОГО МЕСТОРОЖДЕНИЯ (ЯНАО)

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ОГЛАВЛЕНИЕ

Введение

В настоящее время по результатам анализа эксплуатационного фонда газоконденсатных скважин становятся актуальными проблемы рентабельности и эффективности добычи углеводородов. Подтягивание конусов пластовой воды к нижним интервалам перфорации и постепенный подъем газоводяного контакта (ГВК) приводит к обводнению скважин. Форсированный режим отбора и эксплуатации скважин приводит к разрушению пласта-коллектора в результате чего происходит образование песчаных пробок в призабойной зоне пласта (далее ПЗП), приводящих к снижению продуктивности скважин, особенно при наличии жидкости на забое. Оба вышеизложенных фактора, а также уменьшение упругой энергии пласта приводит к так называемому эффекту «самозадавливания» скважин из-за нехватки скорости потока в лифтовой колонне для подъема скапливающейся воды на устье.

В качестве объекта, по которому проводится исследования выбрано М нефтегазоконденсатное месторождение, расположенное в Ямало-Ненецком автономном округе и являющееся в настоящее время одним из самых крупных по запасам природного газа и газового конденсата.

Научный интерес к изучаемому объекту вызван тем, что наряду с добычей природного газа добывается крупный объем попутного газового конденсата неокомских отложений с глубины 2800-3200 м, что осложняется добычей в условиях гидратного режима работы скважин.

Актуальность темы исследования определяется в вышеописанных условиях и заключается в оценке существующих мероприятий на месторождении по увеличению добываемого газа из скважин длительного срока эксплуатации, их экономической эффективности, а также разработка новых методов, направленных на оптимизацию и восстановление скважин, находящихся в простое и не удовлетворяющих нижнему пределу рентабельности.

Цель исследования: на основе полученных результатов исследования сделать вывод о будущем применении описанных методов и их эффективности на месторождении в условиях добычи валанжинского газа и неокомских отложений.

Задача исследования заключается анализе существующих методов, которые применяются или могут применяться на месторождении, в аналитическом решении и подборе модели для наиболее точной оценки и прогноза мероприятий по увеличению добычи газа и газового конденсата.

Выносимые защищаемые положения:

1. Алгоритм при проектировании зарезки боковых стволов и применение аналитических решений для оценки эффективности данного мероприятия в условиях добычи из газокоденсатных залежей скважин, не удовлетворяющих нижнему пределу рентабельности;
2. Компоновка скважины двухрядным концентрическим лифтом в условиях неокомских отложений газа и газового конденсата.

Практическая значимость работы заключается в информировании руководства газовых промыслов, отделов проектирования и разработки месторождения, а также производственного технического отдела (далее ПТО) о результатах, полученных в процессе выполнения выпускной квалификационной работы в целях улучшения и внедрения новых методов по оценке и прогнозированию способов по увеличению добываемого газа и газового конденсата, и их последующей реализации в рамках капитального ремонта скважин или плановых геолого-технических мероприятий, проводимых на месторождении.

Фактический материал: В основу исследования взяты материалы, полученные в результате газоконденсатных и геологических исследований скважин на различных режимах работы на диафрагменный измеритель критических течений с установкой шайб различных диаметров. Данные геофизических исследований о толщинах формаций скважин, основных показателей фильтрационно-емкостных характеристик. Использовались публикации по вопросам применения технологии эксплуатации скважин по концентрической лифтовой колонне (Медвежье месторождение, ЯНАО).

Аннотация

В настоящее время по результатам анализа эксплуатационного фонда газоконденсатных скважин становятся актуальными проблемы рентабельности и эффективности добычи углеводородов. Подтягивание конусов пластовой воды к нижним интервалам перфорации и постепенный подъем газоводяного контакта (ГВК) приводит к обводнению скважин. Форсированный режим отбора и эксплуатации скважин приводит к разрушению пласта-коллектора в результате чего происходит образование песчаных пробок в призабойной зоне пласта (далее ПЗП), приводящих к снижению продуктивности скважин, особенно при наличии жидкости на забое. Оба вышеизложенных фактора, а также уменьшение упругой энергии пласта приводит к так называемому эффекту «самозадавливания» скважин из-за нехватки скорости потока в лифтовой колонне для подъема скапливающейся воды на устье.

Данная выпускная квалификационная работа посвящена вопросу совершенствования методов по увеличению добычи газа и газового конденсата в осложненных условиях истощенных скважин, находящихся в простое, либо близкими к пределу, при котором не будут удовлетворять нижнему пределу рентабельности разработки. Работа состоит из следующих частей: общие сведения о месторождении и его геологическая характеристика, теоретические части, специальная часть, экономическая и социальная ответственность, часть на иностранном языке (анлийский).

В первой и второй главах работы описываются общие сведения о месторождении, его территориальное расположение и характерные особенности климата, геологофизические сведения, включающие тектонику и стратиграфию месторождения, запасы газа и газового конденсата, основные объекты разработки, текущее состояние разработки месторождения, количественное представление фонда добывающих скважин.

Третья глава описывает теоретическую составляющую технологии бурения боковых стволов (ЗБС) и настоящую актуальность применения

мероприятия в существующих условиях добычи углеводородов. Полностью раскрывается техника и технология зарезки боковых стволов, основные применяемые методы вскрытия окна обсадной колонны и применяемый в этом процессе буровой инструмент, подбор технологической оснастки для спуска хвостовика колонны и последующее цементирование пробуренного участка скважины.

В четвертой главе раскрывается один из методов борьбы с самозадавливанием скважины пластовой жидкостью: метод замены колонны насосно-компрессорных труб двухрядным лифтом. Излагается сущность метода и описан один из способов оценки возможности применения концентрической лифтовой колонны (КЛК) для газоконденсатных скважин.

Пятая глава рассматривается как исследовательская часть ВКР, в которой разбирается метод продувки скважины на горизонтальную факельную установку куста, как один из методов борьбы с образованием столба жидкости на забое вследствие истощения упругой энергии пласта и невозможности последующего подъема образовавшейся жидкости к устью. Построена диаграмма, отражающая термобарические параметры в процессе продувки и приводится описание их изменения на всем протяжении данного мероприятия.

Шестая глава относится к специальной части диссертационной работы, и здесь рассматриваются основные аналитические решения для проведения прогноза прироста добычи после проведения ЗБС. Каждое решение представляет собой зависимость, отражающую модель притока газа к горизонтальной (субгоризонтальной) скважине. Проведен расчет по каждой модели на основе исходных данных из промысловых исследований. Сделан вывод о наиболее подходящей для условий залегания газа в неокомских отложениях. В этой же главе описывается апробация мероприятия зарезки боковых стволов и анализируется его эффективность на основе данных до и после ЗБС. Сделан вывод о применимости данной технологии на М НГКМ.

Седьмая глава также относится к специальной расчетной части выпускной квалификационной работы. В ней проводится оценка возможности применения концентрической лифтовой колонны на одной из специально-подобранных скважин-кандидатов, отличающаяся высоким содержанием газового конденсата и жидкости в целом. Оценка и аналитическое решение строится на основе метода узлового анализа, при котором в системе пласт-забой-скважина-устье выбирается точка относительно которой строятся кривые притока и оттока к этой точке. С помощью программного обеспечения PipeSim была выстроена данная система, а качестве узловой точки выбран забой скважины. На основе полученных результатов дан ответ о том, стоит ли применять данную технологию в условиях добычи валанжинского газоконденсата, и действительно ли это позволит стабилизировать добычу из самозадавливающихся скважин.

В восьмой главе диссертационной работы проводится анализ экономической эффективности проведения зарезки боковых стволов на основе одного из реализованных проектов на месторождении. Расчеты основываются на стоимостной оценке мероприятия от компании-подрядчика, занимающейся услугами в сфере бурения боковых стволов. Рассчитана чистая дисконтированная стоимость зарезки и чувствительность текущего проекта к рискам.

Девятая глава ВКР описывает социальную ответственность оператора добычи нефти и газа. Она основана на производственных инструкциях и технологическом регламенте газового промысла. Рассмотрены вредные и опасные производственные факторы, с которыми может столкнуться работник в процессе выполнения непосредственных своих производственных обязанностей на кусту газовых скважин. Описаны возможные вредные воздействия на окружающую среду в пределах месторождения. Также раскрываются действия при чрезвычайных ситуациях.

Десятая глава на иностранном языке посвящена обзору применения зарезки боковых стволов на выработанных месторождения по всему миру. Также рассматривается актуальность применения данной технологии и требования к ней. Описаны основные методы бурения боковых стволов и способы вырезки окна в обсадной колонне.

GAS WELL SIDETRACKING IN MATURE FIELDS

1. Introduction

The oil and gas industry today, as in a number of other instances in the past, is faced with the problem of falling oil prices which has led to the shutting down of a number of oil rigs around the world and a tremendous loss of jobs especially in the upstream sector. Explorations for oil and drilling of new wells have become in large part, of less economic gain and companies are downscaling in these areas. Hopes are, that oil price bounces back at some point and activities once again peaks in these areas.

However, in the meantime and indeed not just now, enhancing oil recovery from mature fields is and will likely continue to be a scientific challenge to the petroleum engineer.

While exploration for new oil fields and drilling new wells in mature fields are good, the cost of these projects are very high and not of great economic gain in the present situation of the industry. Sidetracking a number of wells of mature fields can help recover an additional percentage of un-swept residual oil. This percentage in large parts will be dependent on a number of factors ranging from the drilling practice to the production practice applied on the field. Considering the amount of mature fields around the world some of which have been plugged and some others on their third stage of production, usually characterized by a falling output of oil and an increasing water production, and the fact that oil recovery is never hundred percent, sidetracking the wells of these fields will greatly increase the world’s total output at a low cost while preserving new oil fields for the energy needs of the future.

The oil industry does not give a strict definition to the term mature field but it could be any oil field regardless of its location that falls into any of the categories described by Hull in his 2012 paper ‘What is a Mature field?’. He writes that, the term “mature field” has no single definition. Often, engineers consider fields mature when they have declined in production by more than 50% of their plateau rate [1]. Different companies might apply their own specific definitions though. For example, Total considers the surface and the subsurface. For the subsurface, they consider a field mature when the cumulative production has reached 50% of the initial 2P (proved plus probable) reserves. And for the surface, they consider a field mature after 10 years of production. They use other criteria, but these are the main ones. Halliburton defines a mature field as “one where production has reached its peak and has started to decline [1]. These kinds of fields abound around the world. About two-thirds of the world’s daily oil production comes from mature fields [2].

The industry, having grown in technology and innovation, now stands a better chance of reentering wells of these mature fields which in many cases were drilled using older technologies. Newer technologies have improved the chances of hitting targets that were hitherto unpenetrated and getting their reserves to surface.

The industry has over the years developed a number of enhanced oil recovery methods such as the water alternating gas method, gas injection method, chemical treatment of the reservoir as well as hydraulic fracturing of the reservoir among others. These have, and continue to play great roles in petroleum extraction today. However, in dealing with mature fields, these methods have a certain limitation that is common to them all. Neither of the methods promises to or is able to reposition the bottom of an oil well and as such they are unable to connect untapped reserves. This limitation is comprehensively taken care of by sidetracking the wells of mature fields on which the above methods can still be applied for a yet higher oil recovery ratio.

Sidetracking is the drilling of a new lateral from an existing well that has poor or no productivity due to mechanical damage to the well or depleted hydrocarbons at that particular site [3]. It may also be defined as the term used for drilling a directional hole to bypass an obstruction in the well that cannot be removed or damage to the well, such as collapsed casing that cannot be repaired. Other applications of sidetracking are deepening a well or relocating the bottom of the well in a more productive zone [4].

There are many reasons for sidetracking: the casing is damaged or collapsed, junk may be lost in the hole, the production zone may have been damaged in the original well, or to tap into another less-depleted drainage area [5]. The process today is increasingly being employed, for the purpose of enhanced and sometimes accelerated recovery form mature oil fields. The initial primary purpose of sidetracking was however, to bypass around an unrecoverable fish.

Drilling of sidetracks reduces the cost of construction of horizontal wells. Besides increasing of well productivity, sidetracking allows to select hydrocarbons from reservoirs that haven't been previously developed. Multihole branching of existing wells improves the conditions of opening of the reservoir. Small isolated deposits of oil or gas can be opened by a wellbore with deviation from the vertical including multi-holes. Productivity of horizontal wells exceeds vertical wells 3-4 times, and in some cases it is 17 times greater. In addition, if there is a gas cap or underlying water or both of them, horizontal wells produce significant increase in recoverable reserves.

2. Literature review and success of sidetracking on mature fields around the world

The practice of sidetracking on mature oil fields for enhanced recovery has been carried out successfully in a number of oil fields around the world. Most countries where oil production started more than fifty years ago have either sidetracked a number of wells on their mature fields or have mature fields with un-swept reserves waiting to be tapped. Mature fields occur throughout the world. Onshore North America and the Gulf of Mexico continental shelf have many fields that are late in their lives. Many oil fields in the North Sea have passed their production peak, and the potential in Russia's older fields is large. Other areas, including China, India, Australia and Argentina, contain significant numbers of mature fields. Many parts of the world that are still developing their resources also have fields that are moving into the late production plateau including Mexico, Thailand, Nigeria and Egypt [6].

Reports of increased recovery and decreased water production after sidetracking a number of wells in some mature fields of a number of the countries listed above, signal a possible positive result should the sidetracking technology be applied to other mature fields of other countries.

A Russian oil Company drilled sidetracks at 224 wells in 2010 and gave average daily flow of 19.7 tonnes. In 2010 this company drilled a total of 12 sidetracks in Urevskoye field and eight sidetracks in Unvinskoye field. In Pamyatno-Sasovskoye field, which is one of the largest in the Volga region, total additional oil production achieved by drilling of sidetracks was 67.300 tonnes [7]. Another Russian oil company has operation rights on 1000 wells on the Sakhalin Island. These wells are un-active with proven Reserves, but the wells have been drilled over a period of half a century. Implementation of new technology such as extended reach sidetracks into these mature oilfields would increase production significantly [8].

A joint venture of three companies managed to drill a 650-m horizontal sidetrack with a complex 3D profile to improve productivity and to maximize reserves recovery in a mature Chinese oil field. The target was a low-quality clastic reservoir with very thin oil pockets of 1.5 m thickness [9]. Due to the apparent thin oil column in Gunung Kembang Field in the South Sumatera Extension area of Medco E&P Indonesia working areas, three horizontal wells,GK-1 HW, GK-3 HW and GK-6 HW, were executed in 2004 by side-tracking existing vertical wells, GK-1, GK-3, GK-6 [10]. This improved both the amount of recoverable oil and had a highly positive effect on field development operations. Through sidetracking the reserve of PuCheng oil field had increased by 5.1×104t, water drive reserves had increased by 130×104 t, and recoverable reserves had increased by 50×104t. Sidetracking well, to a certain extent, slowed the decline of production

3.The technology of sidetracking

To sidetrack a cased well, a window has to be cut through one of the well’s casings, depending on the depth of either the fish being bypassed or the location of the targeted oil reserve. In most instances of sidetracking wells of mature fields for increased recovery, the window is cut on the production casing. In other situations, the sidetrack might start from an open section of the parent well.

To kick off the sidetrack, a cement plug or whipstock is commonly used to start bit deviation along the desired trajectory. Cement plugging has a number of disadvantages when compared to the use of whipstock and these include but not limited to the following:

1.The need to wait for proper cement curing and hardening before sidetracking can start which is an additional cost in rig time,

2.The cement plug may not gain enough hardness to start a sidetrack in casings of high hardness and such formations as granite which can force the bit to drill through the cement plug itself or any other path of lower resistance,

3.A layer of residual mud or oil may prevent proper bonding between the cement plug and the wellbore.

While sidetracking to bypass a fish is a much similar process to sidetracking on wells of mature fields, the later requires a number of considerations and stages for quality result. These stages cover the processes of milling out a window on an old well, the actual drilling of a sidetrack well and the well's completion. The stages can be summarized as follows:

1.Choosing the candidate wells for sidetracking: In this process the operator identifies the wells to be sidetracked considering the production history of the field and the field's geology.

2.Geophysical testing of the chosen wells: After a well or some wells have been chosen as candidates for possible sidetracking, geophysical test and logging should be carried out on the well(s) to ascertain their exact state of strength and to enable the driller make the proper choice of the kick off point as well as well trajectory.

3.Drilling the sidetrack: This includes the process of cement plugging the well or setting the whipstock in place, milling a window and the proper drilling of the directional sidetrack well. The standard drill stem of drill pipes or coil tubing technology may be used; both having their own special applications and advantages.

4.The final stage is well completion: The sidetracked well as any other oil well may have open completion or be cased at the production zone depending on a number of factors which includes formation strength.

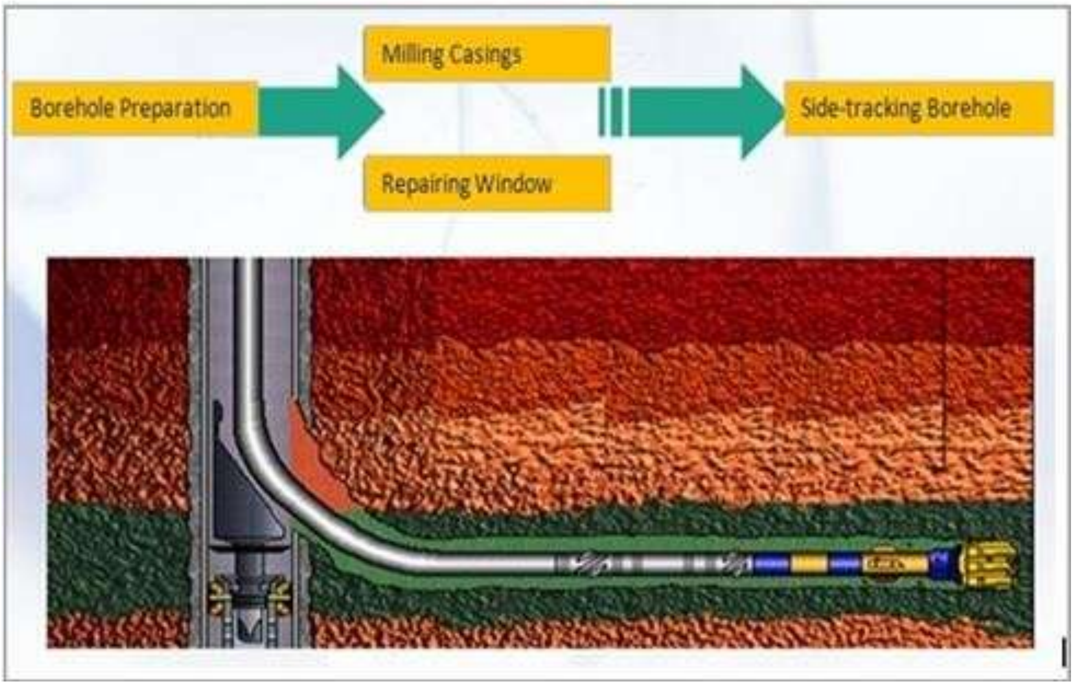

Figure 1 - Profile of a sidetracked well showing the various stages of the sidetracking process

4. The challenges of sidetracking wells of mature fields

While the prospect of increased recovery which means more petro dollar, from sidetracking mature fields is high, it is very important to note the following challenges which are associated with sidetracking on mature fields. They include:

1.Geological and stratigraphic uncertainties: While we can always have geophysical and drilling log data of the field from previous wells to consult, the geology of the environment as well as it’s stratigraphy after many years of drilling and production does in large part differ from the data obtained while drilling the earlier wells on the field. This brings certain degree of uncertainty into the drilling process and special attention must therefore be paid to this. Depleted reservoirs will have a varied pressure condition and a varied stress pattern from previous wells.

2.Abrasive metallic particles from the window milling process: When the kick of point of a sidetrack well is not in an open hole, a window has to be created through a metallic casing. This process produces metallic particles which the drilling fluid picks up to the surface. If not immediately taken care of, these can cause abrasive damage to the mud cleaning equipment.

3.Limited choice of well diameter: The diameter of a sidetrack well on wells of mature fields is dictated by the diameter of the open hole or casing located at the kick off point, restricting its diameter to less than that of the casing through which the window is milled. This way, the drilling string will be in much closer contact with the wellbore which can lead to well bore instability issues. This calls for increased attention to the type and properties of the drilling fluid to be used; especially, it's lubricating property among others as well as its water loss property. Formation of a thick mud cake will usually have an increased negative consequence in this case. In situations of lost circulation, the level of the drilling fluid could decrease tremendously, which means, an enormous instantaneous decrease in hydrostatic pressure with a possibility of catastrophic blow out. This calls for adequate preparation with measures put in place to possibly avoid lost circulation in such wells or at least bring them under immediate control should they occur. It is important also, to note that mature fields have depleted reservoirs, where formation pressure are much lower than they used to be; such are possible lost circulation zones.

4.Wellbore stability issues: Sidetrack wells usually show a tendency for high instability around the kick of point where instability is a consequence of both instability in the main well and the sidetrack well. The type of the stress regime and the orientation of the principal stresses have no or negligible effect on the stability of the sidetrack compared to sidetrack inclination and therefore it cannot be generally considered as a factor affecting the bend stability. On the other hand, the sidetrack deviation angle from the vertical main well plays the major role in the stability of the bend area. It is predictable that by the increase of the deviation angle the bend area become more unstable. This factor has a more significant impact when the sidetrack is near the vertical position, 0°-15°. Then by the increase of the deviation angle the needed mud pressure increases with a lower rate and even in some cases no changes can be seen in the required mud pressure, especially when the deviation angle differs from 45°to 60.

5. Sidetracking methods

In recent years, new technology, such as three-dimensional (3D) seismic, has stimulated renewed exploration and development of mature oil fields. The ability to locate and produce previously undiscovered hydrocarbons in mature fields has led to increased drilling activity using sidetracking methods. In mature fields, plugging and sidetracking an existing wellbore is often more cost effective than drilling a new well. Offshore, the limited number of unused slots on a platform makes sidetracking the only feasible way to redevelop a field in many cases. Developments in tools and methods have also made sidetracking an economic alternative to conventional fishing jobs, and operators are choosing sidetracking over fishing more frequently than before.

When considering any type of reentry for sidetracking (Figure 2), be it whipstock, section mill, pilot mill, or cut-and-pull for slot recovery, it is important to communicate with the fishing-tool company, mud company, directional-drilling company, and wireline company for proper prejob planning. During well planning, communication between the fluid supplier and milling company is essential for an efficient milling operation that leaves a wellbore free of metal cuttings. Milling-fluid requirements vary widely between window-cutting, section-milling, and pilot-milling applications. Compared to window cutting, for example, pilot and section milling produce larger volumes of cuttings for removal by the mud system, so surface equipment must have larger flow lines, with a minimum of bends and irregularities, and should include centrifuges for pH control. Higher yield points, greater viscosity, and higher annular velocities are also required during section and pilot milling, creating the need for high-volume pumps. Effective preplanning for milling operations will ensure efficient removal of cuttings while keeping the volumetric ratio of cuttings to mud at an absolute minimum.

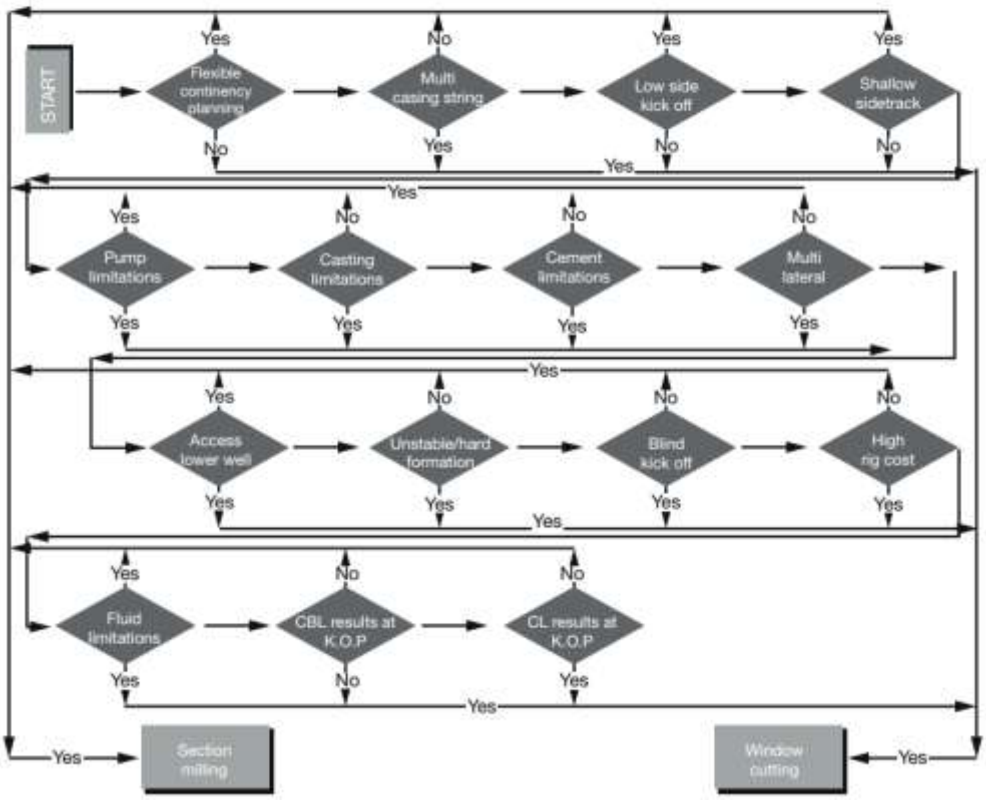

Figure 2 - Identifying the appropriate sidetrack option

5.1 WHIPSTOCK SYSTEMS AND ANCHORS

Whipstocks are used to sidetrack a wellbore when reentering an existing wellbore as a cost-effective alternative to fishing a drilling bottom-hole assembly (BHA) that has become stuck, to address severe formation or drilling problems, to change the direction of a wellbore, or to drill multiple exits (multilateral wells) from a single wellbore. Whipstocks are available in permanent and retrievable versions.

5.2 HOLE CONDITIONS

To set a whipstock and sidetrack through casing, a good cement bond is critical. A cement-bond log should be run at the point of the proposed sidetrack. If the cement bond is poor, the casing could move during the milling operation, with unacceptable results. If the bond is inadequate, then the casing should be perforated and cement squeezed around it. An alternate depth can be chosen where an adequate bond is found if doing this is practical and fits overall drilling objectives. It is also recommended that an anchor device be set 4 ft. above the casing collar to ensure that there is no attempt to mill through the collar. The casing collar can be found with a casing-collar locator run on wireline.

5.3 WHIPSTOCK-FACE ORIENTATION

Infrequently, an operator will have no preference as to the direction of a sidetrack, but for most sidetrack operations, proper whipstock-face orientation is a must. At the kickoff (K.O.P) point, if the wellbore has more than 2.5° of inclination, the whipstock should be oriented relative to the high side of the hole. Normal orientation of the whipstock face is recommended only within 60° to the left or right of the high side. Orienting the face outside this window increases the risk of window failure.

A whipstock assembly can be oriented using two methods: measurement while drilling (MWD) and a bypass sub. The MWD method can be used only in wellbores with an inclination of more than 5°. Also, a wireline surveying device, such as a surface-readout gyroscope (Figure 3) or steering tool, and a universal bottom-hole orienting (UBHO) sub can be used.

Figure 3 - Surface-readout gyroscope

5.4 CLEANLINESS OF CASING WALL

In some wellbores, especially those with high-temperature mud systems that have a tendency to settle out or cause corrosion, or those with older wells, the casing wall may not be clean. It is normally necessary to run a bit and scraper to below the packer/bottom-trip anchor setting depth to scrape the wall clean. When it is not clear that a casing scraper will clean the casing wall thoroughly, it may be necessary to use two or three full-gauge string mills to clean the casing at the kickoff point and allow proper packer/bottom-trip anchor slip setting. In cases where a whipstock packer will be set on wireline, run a wireline-gauge ring and junk basket to below packer-setting depth to ensure that the casing is full gauge.

5.5 FORMATION

The type of formation at the kickoff point can be a factor in the selection of milling equipment. Although most current milling systems can mill the window and drill the pilot hole in one trip, it is important to understand the formation at the kickoff point. When the window mill leaves the whipstock face, it leaves the milling mode, enters the drilling mode, and acts like a drill bit. In some formations, the mill does not drill the formation very efficiently, which requires another trip so that the pilot hole can be finished with a drill bit instead of the window mill. To prevent this extra trip, it is best to avoid very difficult formations whenever possible. Formations such as chert, some types of limestone, depleted sands, and granite can cause problems that result in an extra trip.

5.6 BOTTOM-SET ANCHOR

A bottom-set anchor (Figure 4) is used to anchor a whipstock in place in the wellbore. It is an alternative to the packer/anchor assembly. The bottom-set anchor attaches to the lower end of the whipstock with a drill-pipe connection. It can be used with a one-trip or two-trip milling system. To activate the setting sequence, only a bottom restriction is required. This can be a permanent or retrievable bridge plug, top of cement, liner top, production packer, etc. When using a bottom-set anchor, either the UHBO or MWD orientation method can be used.

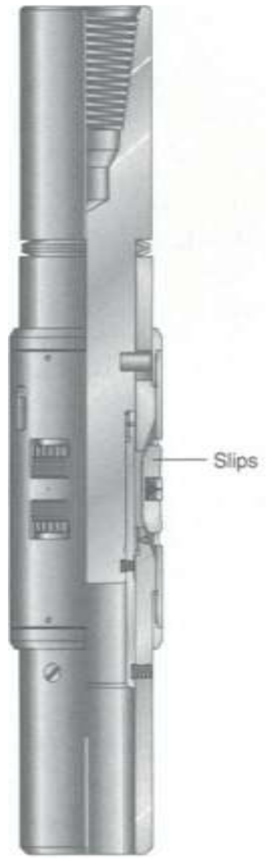

Figure 4 - Bottom-set anchor

5.7 TWO-TRIP MILLING SYSTEMS

The two-trip milling, or window-cutting, system is an efficient way to exit casing and provide a window suitable for running drilling BHAs, liners, and completion equipment. It is one of the most reliable systems in use, with thousands of successful field runs. The window is normally achieved in two round trips with drill pipe. The first trip lands the whipstock and makes a starting cut. The second trip completes the window and drills a pilot hole for the drilling BHA. When run with a whipstock packer, and if whipstock-face orientation is necessary, one MWD run or two electric-line runs are required to obtain the correct orientation.

The whipstock is run while pinned to the starting mill with a shear pin (Figure 5). The mill is made with a stinger, which serves two purposes. The stinger holds the whipstock, and it also guides the starting mill by keeping it inside the casing. This causes it to cut a long window instead of merely cutting a hole and going outside. Most shear pins are made to shear with approximately 20.000–45.000 lbs. of weight after the whipstock has been set. Once the pin has been sheared, rotation and circulation can begin, and the first phase of cutting the window is accomplished. The starting cut is usually around 12–24 in., depending on the design and size of casing to be cut. Mills used for this purpose are usually made with crushed carbide, insert carbide disks, or a combination of the two. Most operators do not run any drill collars with the starting mill because it should follow the taper of the whipstock.

Figure 5 - Starting mill pinned to the whipstock

The window in the casing is completed with a window mill, string mill, watermelon mill, or a combination of these (Figure 6). Cutting material is dressed on both the bottom and the sides of the mill. These mills are usually designed to ride alongside the face of the whipstock. An additional hole should be cut in the formation with this assembly so that the new hole is guided away from the old hole. The rule of thumb on any whipstock job is that after pulling the window, string, and watermelon mills from the hole, the outside diameter (OD) of the mills should be measured. If it is within the recommended gauge OD, drilling operations can begin. If the mills are under the recommended gauge, an additional milling run should be made to continue to open the window in the casing.

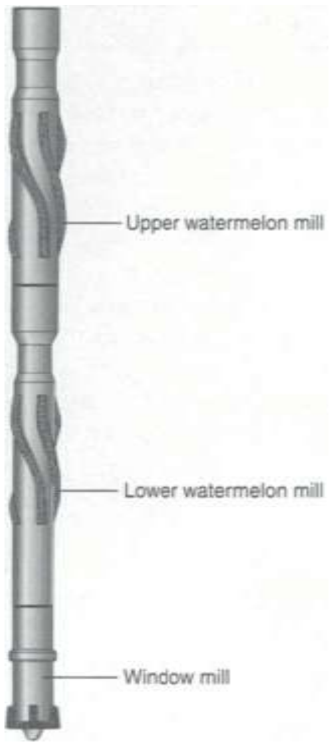

Figure 6 - Window-milling mills

5.8 HYDRAULIC-SET WHIPSTOCK ANCHOR

The hydraulic, one-trip window-cutting system is used to exit casing efficiently and provide a window. The complete window is normally accomplished in one round trip with drill pipe. If a hole angle of 5° or greater exists at the kickoff point, an MWD tool can be used to orient the whipstock face. A bypass valve is required between the MWD tool and the whipstock. The valve allows flow to the annulus for MWD readings. Once the whipstock is properly oriented, the bypass valve can be closed hydraulically. As the valve stops flow to the annulus, it simultaneously provides fluid passage to the window mill. The hydraulic whipstock includes a steel tube inserted into the window mill that provides a means to apply hydraulic pressure to a packer. The packer can now be set hydraulically, without manipulating the drill string. The packer includes a rupture disc to prevent accidental release. Once the packer is set, the window mill is released from the whipstock by shearing down and then pulling off of the steel tube. Then the milling process can be started.

5.9 ONE-TRIP MILLING SYSTEM

The one-trip milling, or window-cutting, system (Figure 7) is used to exit casing efficiently and provide a window suitable for running drilling BHAs, liners, and completion equipment. The complete window is normally accomplished in one round trip with drill pipe. In one trip, the starting cut is made, the window milled, and a pilot hole drilled for the subsequent drilling BHA.

When run with a whipstock packer, and if whipstock-face orientation is necessary, two electric-line runs are normally required. The first is to set the packer, and the second is to determine the direction of the orientation key located inside the packer. When run with a bottom-trip anchor, only one electric-line trip is normally required. This is typically an electric-line gyroscope tool run through the drill pipe and into a UBHO sub located above the milling BHA, with its internal key previously lined up with the whipstock face. The desired whipstock-face orientation in this case is obtained by drill-pipe manipulation.

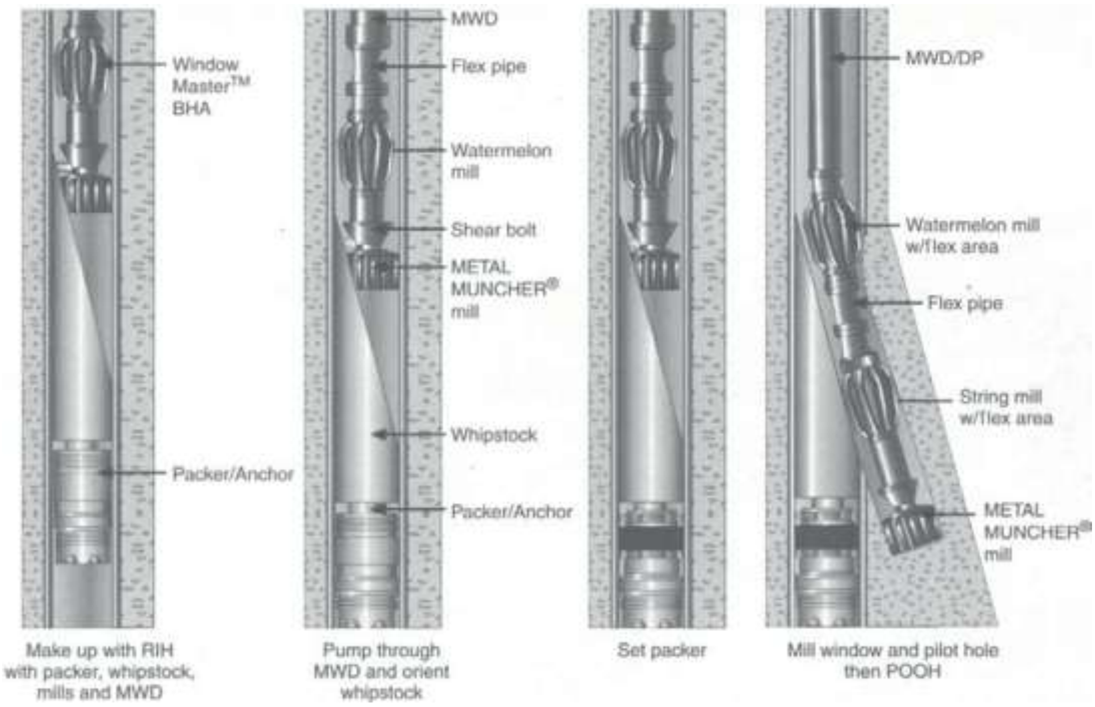

Figure 7 - One-trip window-milling system

When using the bottom-trip anchor, if an MWD tool is available and the hole angle is 5° or greater at the kickoff point, the use of electric line can be completely eliminated. Instead, run the MWD tool in place of the UBHO, with its tool face previously lined up with the whipstock face. Pump flow through the

MWD tool then will provide the whipstock face direction at the surface. In this case, only one drill-pipe trip is necessary to run in, orient, and anchor the tool; mill the window; and drill the pilot hole, making it the most desirable method when applicable.

Unlike conventional and two-trip systems, the one-trip milling system can start, mill, and ream the window without requiring a change in BHAs. A preliminary “starting-mill” run is not required. The result is a complete, full-gauge window in one milling trip. The one-trip milling system can be used with most currently available anchoring systems.

5.10 COILED TUBING SIDETRACKING

Coiled tubing drilling can be used when it is not economically feasible to utilize the main platform rig or mobilize a drilling rig. Advances in seismic and reservoir modeling are also helping to target smaller pockets of oil, further enhancing the economics of coiled tubing use. One of the operations essential for a successful and cost-effective coiled tubing sidetrack is the casing exit, discussed next.

5.11 CASING EXITS

Coiled tubing casing exits do not require the well to be killed and can be conducted in underbalanced conditions. The operation uses the existing completion to produce the well, including safety valves. In addition, smaller volumes of drilling fluids are required, and little formation damage is caused.

Currently, two coiled tubing casing-exit methods exist, which depend on the completion configuration; through unrestricted monobore completions and thru-tubing casing exits.

The monobore whipstock, also referred to as an in-tubing whipstock, can be set inside the tubing or in a monobore liner and the sidetrack performed by milling a window in the liner or through the tubing and outer casing. This method uses a traditional combination of packer and oriented- whipstock ramp. By contrast, the thru-tubing whipstock (Figure 8) is run through the tubing, and the whipstock is set in the larger casing or liner below it. It has no packer, allowing it to be set in a single trip.

The sidetrack is usually performed in a single milling run using a tungsten carbide or diamond window-milling assembly.

Both systems have been used successfully in a range of applications, with the whipstock deployed on either coiled tubing or electric line.

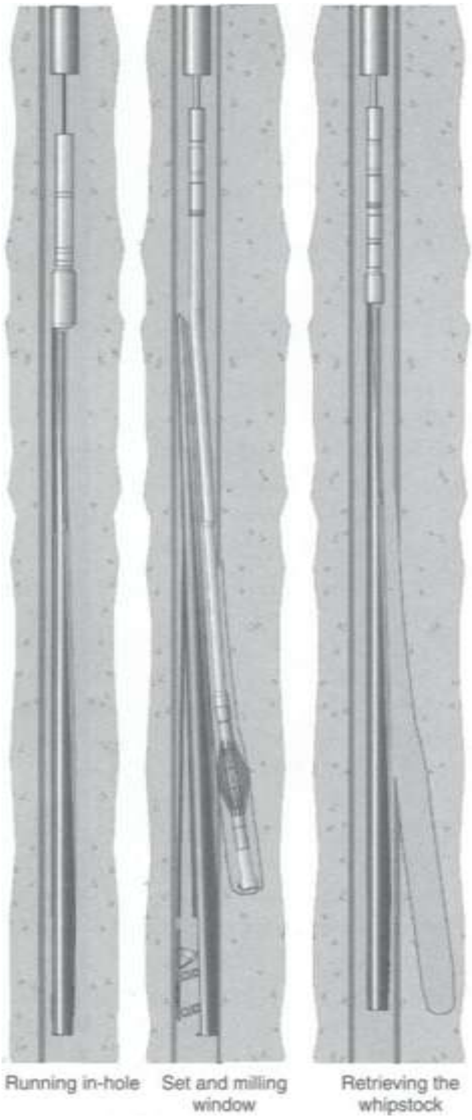

Figure 8 - Thru-tubing whipstock system

6. Improvement sidetracking technologies

Ways of the sidetrack construction technology improvement have been suggested. The necessity of increasing the diameter of the sidetracks and change in the construction of the first wells has been proved. The impact of casing perforation methods of productive formation on cement stone safety have been assessed and abrasive jet perforation (AJP) has been offered as a gentle method of casing perforation. Sidetrack drilling from previously drilled wells is among the most promising methods of the well reconstruction. This method allows drilling in the oil- saturated deposits. It is becoming increasingly important as a method of enhanced oil recovery with different state-of-the-art navigation equipment, reliable hard-wearing rock-breaking tools, drilling technologies and accessories.

However, satisfactory quality of sidetrack construction from previously drilled wells has not been provided, as such technology is not properly developed. That is why, its improvement is vital, and it can be realized with the following technical and technological solutions [1]:

1.Changing the sidetrack design.

Small diameters of sidetrack account for a thin cement sheath in the bore-hole annulus of sidetrack, which reduces the cement sheath integrity and durability; there is a danger of a complete contact deficiency of the cement stone between the casing and wellbore walls, the effect appears especially at extending and reducing zenith intervals, and the cement stone can be destructed by casing perforation.

The 4 7/8" bit is used for drilling sidetracks from the 5 3/4" first well casing, and 4" – for sidetracks. Thus, there is 7/8" gap for cement slurry.

The majority of earlier drilled wells (about 85 %) were constructed with 5 3/4" casing string in Perm region. A similar situation is in other oil regions of Russia. The required quality cannot be achieved by the traditional casing technologies in these conditions. To increase the sidetracks diameter is possible with bicentric bits. In that way, 5 3/16" well can be drilled with a bicentric bit from 5 3/4" casing string.

We deem it necessary to change the design of the first well and thereby obtain the possibility of sidetrack construction with a larger diameter in the future. In total, it is possible to use a 7" casing string for the well that was drilled with a 8 1/2" bit without changing the well design, instead of 6 5/8" and 5 3/4" casing strings. This diameter replacement does not lead to a substantial increase of the well construction cost, because surface casing and intermediate casing are the same; moreover, bit diameters for each casing string are not changed.

Thus, a 6" bit for drilling a sidetrack with 4 1/2" casing string makes 3/4" gaps on each side, and the use of the same bit with 4" casing string makes 1" gaps on each side. Moreover, a 7" casing pipe for the first well provides a "reserve" diameter, and also allows using the well safety valve during well operation, which excludes the necessity to kill a well during workover.

Furthermore, implementation of the proposed technological solutions will improve the quality of 7" casing string cementing, enhancing the upstream speed by 2 times without increasing the number of cementing units, as well as reduce the risk of complications and accidents, both during sidetrack drilling, its cementing and operation.

2.Increasing the strength of the cement stone [2].

Addition of ultrafine mineral supplement to cement slurry is the most promising method to increase the strength of the cement stone that meets the conditions and technologies of well cementing. The floured mineral supplements can actively participate in the structural processes and fill the space between the cement grains, thereby sealing the structure.

Laboratory tests were conducted with the following mineral supplements: silica flour (SF 0.05), diabase flour, metakaolin (MetaCem 85C), microsilica suspension (MS-85), and fine silica powder (FCS).

Tests were conducted with oil-well portland cement 1-G with high sulfate resistance (SCP Limited liability company). The mineral supplements were added into the cement at about 1, 1.5, 2, 3, 5, 7, and 10 % of its weight. The cement stone strength tests were conducted on 20×20×80 mm prism samples which had been maintained at 75 and 158 °F in a bath of fresh water, after 24, 48 and 72 hours. The cement stone strength was determined by the test results as the average of the three best results out of the four (table).

The mineral supplements effect on the cement stone strength was revealed according to the laboratory work. The cement stone with 5 % fine silica powder has the best strength characteristics for low temperatures (75 °F). Moreover, the cement stone with 10 % fine silica powder has the best strength characteristics for moderate temperatures (158 °F). This mineral supplement participates in the structural processes and forms the fine texture which significantly increases the strength of cement stone.

Changes in cement stone strength relative to the base structure at the optimum mineral supplement concentration

The supplement	Temperature, °F	The supplement ratio, %	Strength increase, %
Silica flour	75	1	8.2
	158	2	23.7
Diabase flour	75	1.5	-0.6
	158	1	10.9
Metakaolin	75	7	21.4
	158	10	22.6
MS-85	75	10	10.1
	158	3	9.1
Fine silica powder	75	5	39.1
	158	10	50.4

3.Using gentle perforation methods, which excludes high pressure on the cement stone [3].

The cement stone safety depends very heavily on the choice of casing perforation methods, because of high pressure on the casing string and cement stone during the process. So it is necessary to apply gentle casing perforation methods and enhanced oil recovery of reservoirs avoiding the possibility of cement stone destruction. The standard jet perforation method is not acceptable for sidetrack casing perforation as it causes a very high pressure of 70–100 MPa in the perforation interval and in the range of 50 m above and below it. Due to so high pressure the casing string diameter increases and a thin cement ring is destructed so that contact density between the casing string and cement stone is broken. The latter is due to the elastic properties of casing string, i.e. restitution, but the cement stone does not possess such properties, so it is destructed during jet perforation. As a result, channels between the cement stone, casing string and the well walls are formed, which leads to the behind-the-casing flows; water enters the hole from the underlying water saturated formations, because of the lower formation water viscosity in comparison with the oil one.

In order to avoid high pressure pulses during sidetrack casing perforation of productive layers abrasive jet perforation or other alternative methods are suggested. The former has the following advantages: 1) creating new percolation paths by reducing the stress state of bottomhole formation zone; 2) increasing filtration area 2-8 times compared to other casing perforation methods,

3)recovering potential rates of the oil production well and a significant increase of the main injection wells stimulation methods effectiveness.

To sum up, suggested technical and technological solutions will provide durable wells' cement stone, increase interrepair time and enhance oil production.

Заключение

В результате выполненной работы были выбраны основные методы, которые на текущий момент применяются или могут применятся на месторождении в качестве мероприятий по увеличению добычи газа и газового конденсата. Это продувка скважин на горизонтальную факельную установку куста (ГФУ), зарезка боковых стволов и предлагаемый реализуемый в будущем метод замены колонны насосно-компрессорных труб на двухрядный лифт (концентрическая лифтовая колонна).

В результате исследования метода продувки был сделан вывод о том, что данное мероприятие характеризуется нестабильными отборами газа и является лишь временным решением проблемы самозадавливания скважин (работа скважины в шлейф составляет 2-3 дня в среднем), после чего жидкость снова накапливается на забое и общий дебит снижается на 20-30%, после чего в результате снижения температуры гидрат откладывается по ходу газа в НКТ, либо на устье скважины, образуя гидратную пробку. Данная процедура повторяется с затратой времени, человекоресурсов и ингибитора гидратообразования. Также побочным эффектом данного метода является то, что в результате создаваемых частых высоких депрессий на пласт, забой скважины разрушается, начинается пескопроявление вплоть до осыпки забоя с последующим выводом скважины в ремонт. Следует отказаться от данного метода в пользу иных мероприятий, имеющих более эффективный ресурс.

Бурение боковых стволов при качественном проектировании сейчас является наиболее высокоэффективным методом для скважин с низкими термобарическими параметрами. В ВКР приведены основные модели аналитического расчета эффективности данного мероприятия, подобрана наиболее подходящая (box-shape модель Babu и Odeh) для текущего объекта исследования (М НГКМ). Проведена апробация метода на одной из скважин-кандидатов. В результате дебит при работе в шлейф возрос в полтора раза и составил 195000 м3/сут. Однако наиболее важными параметрами стоит выделить давление и температуру. До ЗБС скважина не могла работать в шлейф в виду ее постоянного гидратного режима работы (температура 8-10 С), а низкое давление (менее 60 атм) не позволяло работать ей в общий газосборочный коллектор с соседними скважинами куста. После проведения ЗБС термобарические параметры возросли: температура 24 С и давление 75 атм, что позволило вновь ее запустить в эксплуатацию с более высоким суточным дебитом. Экономическая оценка данного мероприятия дала положительный результат: ЗБС окупается в первый год после его проведения. ЧТС составил на конец четвертого квартала 54млн рублей.

В качестве замены способа продувки скважин на ГФУ предложен метод спуска в скважину концентрической лифтовой колонны. В работе смоделирована одна из скважин месторождения с установленной в ней НКТ 114мм. В настоящий момент на ней периодически (раз в двое суток) проводятся продувки для ее эксплуатации. Предлагается спуск дополнительной НКТ диаметром 60мм в качестве центральной лифтовой колонны для очистки забоя скважины от накопившейся жидкости. Модель пласт-забой-скважина-устье построена в ПО PipeSim с узловой точкой на забое. В результате расчетов было выявлено, что применение ЦЛК диаметром 60 мм позволит полноценный вынос капельной жидкости, а общий дебит газа без жидкости по колонне составит 125000 м3/сут. Данный метод не только позволяет увеличить дебит на 10000м3/сут, но самое главное стабилизировать отборы газа без применения продувки, без простоев и постоянных создаваемых перепадов депрессий на пласт, что продлит эксплуатационный период скважины при нормированном режиме ее технического обслуживания.