MINISTRY OF EDUCATION AND SCIENCE OF THE REPUBLIC OF KAZAKHSTAN

СӘТБАЕВ УНИВЕРСИТЕТІ SATBAYEV UNIVERSITY

Institute of geology, petroleum and mining engineering

Department of Petroleum Engineering

Asauov A. A.

Solving the problem of limiting the height of the fracture during hydraulic fracturing with the use of special chemical reagents

DIPLOMA PROJECT

5B070800 – Oil and gas engineering

Almaty 2021

MINISTRY OF EDUCATION AND SCIENCE OF THE REPUBLIC OF KAZAKHSTAN

СӘТБАЕВ УНИВЕРСИТЕТІ SATBAYEV UNIVERSITY

Institute of geology, petroleum and mining engineering

Department of Petroleum Engineering

APPROVED FOR DEFENSE
Head of the Petroleum
Engineering Department
Dairov Zh. K.
____
____

DIPLOMA PROJECT

Topic: «Solving the problem of limiting the height of the fracture during hydraulic fracturing with the use of special chemical reagents»

5B070800 – Oil and gas engineering

Performed by Asauov A.

Academic adviser
MSc in in Reservoir Evaluation
and Management
Baibussinova Zh. B.
____

Almaty 2021

Метаданные

Название

Solving the problem of limiting the height of the fracture during hydraulic fracturing with the use of special chemical reagents

Автор	Научный руководитель
Асауов Асхат	**Жанар Байбусинова**

Подразделение

ИГНиГД

Список возможных попыток манипуляций с текстом

В этом разделе вы найдете информацию, касающуюся манипуляций в тексте, с целью изменить результаты проверки. Для того, кто оценивает работу на бумажном носителе или в электронном формате, манипуляции могут быть невидимы (может быть также целенаправленное вписывание ошибок). Следует оценить, являются ли изменения преднамеренными или нет.

Замена букв	ß	28
Интервалы	A→	0
Микропробелы		1
Белые знаки		0
Парафразы (SmartMarks)	a	8

Объем найденных подобий

Обратите внимание!Высокие значения коэффициентов не означают плагиат. Отчет должен быть проанализирован экспертом.

КП1	КП2	КЦ
1.07% / 1.07%	0.49% / 0.49%	0.50% / 0.50%

25	**16906**	**103374**
Длина фразы для коэффициента подобия 2	Количество слов	Количество символов

Подобия по списку источников

Просмотрите список и проанализируйте, в особенности, те фрагменты, которые превышают КП №2 (выделенные жирным шрифтом). Используйте ссылку «Обозначить фрагмент» и обратите внимание на то, являются ли выделенные фрагменты повторяющимися короткими фразами, разбросанными в документе (совпадающие сходства), многочисленными короткими фразами расположенные рядом друг с другом (парафразирование) или обширными фрагментами без указания источника ("криптоцитаты").

10 самых длинных фраз

Цвет текста

ПОРЯДКОВЫЙ НОМЕР	НАЗВАНИЕ И АДРЕС ИСТОЧНИКА URL (НАЗВАНИЕ БАЗЫ)	КОЛИЧЕСТВО ИДЕНТИЧНЫХ СЛОВ (ФРАГМЕНТОВ)	
1	https://oilcapital.ru/news/markets/20-11-2007/tehnologiya-j-frac-novyy-podhod-k-kontrolyu-rosta-treschiny-grp	82	0.49 %
2	https://www.daijiworld.com/news/newsDisplay?newsID=801940	20	0.12 %
3	https://www.sciencedaily.com/releases/2018/05/180501085545.htm	13	0.08 %
4	**Ways to enlarge vocabulary for the initial class** Абылгазина Анель Смагуловна **4/29/2019** University of Foreign Languages and Professional Languages (Учебный отдел)	11	0.07 %

5	**Development of a web portal for finding housing and roommates for students** Бибарыс Халмурзаев, Максат Мухамедгалиев **6/6/2019** International IT University (Компьютерная инженерия и информационная безопасность)	10	0.06 %
6	**Ways to enlarge vocabulary for the initial class** Абылгазина Анель Смагуловна **4/29/2019** University of Foreign Languages and Professional Languages (Учебный отдел)	10	0.06 %
7	**Камелов Алимжан.doc** Камелов Алимжан **5/30/2019** Atyrau State University named after Khalel Dosmukhamedov (Экология)	7	0.04 %
8	**Estimation of the height of the first interaction in gamma-ray showers observed by Cherenkov telescopes** Katarzyna Adamczyk,Dorota Sobczyńska,Julian Sitarek,Michał Szanecki,Konrad Bernlöhr;	7	0.04 %
9	**Камелов Алимжан.doc** Камелов Алимжан **5/30/2019** Atyrau State University named after Khalel Dosmukhamedov (Экология)	6	0.04 %
10	**“Impact of migrant remittances to the economy of the Kyrgyz Republic"** Kerimbekova Aizhan **6/11/2019** Kirgiz Economic University na M. Ryskulbekov (Кафедра экономической теории и мировой экономики)	5	0.03 %

из базы данных RefBooks (0.04 %)

ПОРЯДКОВЫЙ НОМЕР	НАЗВАНИЕ	КОЛИЧЕСТВО ИДЕНТИЧНЫХ СЛОВ (ФРАГМЕНТОВ)	
Источник: https://arxiv.org/			
1	**Estimation of the height of the first interaction in gamma-ray showers observed by Cherenkov telescopes** Katarzyna Adamczyk,Dorota Sobczyńska,Julian Sitarek,Michał Szanecki,Konrad Bernlöhr;	7 (1)	0.04 %

из домашней базы данных (0.00 %)

ПОРЯДКОВЫЙ НОМЕР	НАЗВАНИЕ	КОЛИЧЕСТВО ИДЕНТИЧНЫХ СЛОВ (ФРАГМЕНТОВ)

из программы обмена базами данных (0.35 %)

ПОРЯДКОВЫЙ НОМЕР	НАЗВАНИЕ	КОЛИЧЕСТВО ИДЕНТИЧНЫХ СЛОВ (ФРАГМЕНТОВ)	
1	**Ways to enlarge vocabulary for the initial class** Абылгазина Анель Смагуловна **4/29/2019** University of Foreign Languages and Professional Languages (Учебный отдел)	21 (2)	0.12 %
2	**Камелов Алимжан.doc** Камелов Алимжан **5/30/2019** Atyrau State University named after Khalel Dosmukhamedov (Экология)	18 (3)	0.11 %
3	**“Impact of migrant remittances to the economy of the Kyrgyz Republic"** Kerimbekova Aizhan **6/11/2019** Kirgiz Economic University na M. Ryskulbekov (Кафедра экономической теории и мировой экономики)	10 (2)	0.06 %
4	**Development of a web portal for finding housing and roommates for students** Бибарыс Халмурзаев, Максат Мухамедгалиев **6/6/2019** International IT University (Компьютерная инженерия и информационная безопасность)	10 (1)	0.06 %

из интернета (0.68 %)

ПОРЯДКОВЫЙ НОМЕР	ИСТОЧНИК URL	КОЛИЧЕСТВО ИДЕНТИЧНЫХ СЛОВ (ФРАГМЕНТОВ)	
1	https://oilcapital.ru/news/markets/20-11-2007/tehnologiya-j-frac-novyy-podhod-k-kontrolyu-rosta-treschiny-grp	82 (1)	0.49 %
2	https://www.daijiworld.com/news/newsDisplay?newsID=801940	20 (1)	0.12 %
3	https://www.sciencedaily.com/releases/2018/05/180501085545.htm	13 (1)	0.08 %

Список принятых фрагментов (нет принятых фрагментов)

ПОРЯДКОВЫЙ НОМЕР	СОДЕРЖАНИЕ	КОЛИЧЕСТВО ИДЕНТИЧНЫХ СЛОВ (ФРАГМЕНТОВ)

MINISTRY OF EDUCATION AND SCIENCE OF THE REPUBLIC OF KAZAKHSTAN

СӘТБАЕВ УНИВЕРСИТЕТІ SATBAYEV UNIVERSITY

School of geology, petroleum and mining engineering

Department of Petroleum Engineering

CONFIRM
Head of the Petroleum
Engineering Department
Dairov Zh. K.
____
____

TASK
For completing the diploma project

For student Asauov A.
Topic: « Solving the problem of limiting the height of the fracture during hydraulic fracturing with the use of special chemical reagents »
Approved by the order of university rector № 315-b from 15 feb 2021
Deadline for completion the work: 18.05.2021.
Initial data for the diploma project: well logging data, hydraulic fracturing reports.
Summary of the diploma project: The decision will be based on the results of field research, previous work, analysis of height restriction methods, and the results of past hydraulic fracturing work.
The list of issues to be developed in the diploma project:
a) Parameters of the crack height during hydraulic fracturing and methods of its limitation;
b) Hydraulic fracturing planning;
Recommended main literature:

1. Malyshev A. G. (2010). Features of well operation after hydraulic fracturing.
2. Michael Economides (2007). Unified fracturing design: from theory to practice.
3. Prud'homme A. (2013). Hydraulic Fracturing: What everyone needs to know.

SCHEDULE

for the diploma project preparation

Name of sections, list of issues being developed	Submission deadline to the Academic adviser	Notes
Introduction, methodology	14.02.2021	Task completed
Main part, database	14.03.2021	Task completed
Results	04.04.2021	Task completed
Recommendations, conclusion	28.04.2021	Task completed

SIGNATURES

Of consultants and standard controller for the completed diploma project, indicating the relevant sections of the work (project).

The section titles	Consultant name (academic degree, title)	Date	Signature
Introduction, methodology	MSc, Baibussinova Zh. B.	14.02.2021	
Main part, database	MSc, Baibussinova Zh. B.	14.03.2021	
Results	MSc, Baibussinova Zh. B.	04.04.2021	
Norm control	MSc, Baibussinova Zh. B.	28.04.2021	

Academic Adviser ________ Baibussinova Zh.

The task was accepted by student: Asauov A.

Date «9» May 2021

ANNOTATION

Failures to contain hydraulic fractures in the oil-saturated zone often lead to high water cutoff of products, premature work stoppages, which dramatically changes the payback time, the recovery rate of reserves, and the overall economic benefit of development. In the case of extracted water outside the area of interest, the problem can hardly be eliminated. At the same time, the operator is faced with the need to dispose of the extracted water, as well as with the problem of reduced oil inflow. By analogy, a break into a gas-saturated reservoir from above the producing oil reservoir also causes problems with the development of reserves from the zone of interest. Therefore, for many companies, it is important to limit the height of the crack in hydraulic fracturing (HF), at the present time, this problem is better solved with the help of chemical reagents.

To solve the problem of limiting the height of the crack during HF with the use of special chemical reagents, the field X was selected. At the field, some technologies of processing the bottom-hole zone, as well as perforation and joining of the lower and overlying layers were used simultaneously with HF. This work will include a deep analysis of all the main methods for limiting the height of the crack, the selection of a well for hydraulic fracturing, and the analysis of the main characteristics of the crack height. As a result, the most optimal method of limiting the height of the crack was the use of low-viscosity gels. Three models were developed to compare this method and evaluate hydraulic fracturing fracture geometries using FracPro software. The solution of the problem of limiting the height of the HF crack at field X by using low-viscosity gels showed the best result.

All data used in the study was derived from field records available from Field X.

Keywords: hydraulic fracturing, intensification, fracking, oil recovery, crack formation, ClearFrac, proppants, crack height, FracPro, frack height limit.

АННОТАЦИЯ

Неудачи при сдерживании гидравлической трещины в нефтенасыщенной зоне часто приводят к высокой обводненности продукции, преждевременным остановкам работ, что резко меняет время окупаемости работы, коэффициент извлечения запасов и в целом экономическую выгоду при разработке. В случае добываемой воды вне зоны интереса — проблема уже вряд ли может быть устранена. Оператор при этом сталкивается с необходимостью утилизации добываемой воды, а также с проблемой пониженного притока нефти. По аналогии, прорыв в газонасыщенный пласт сверху от добывающего нефтяного также вызывает проблемы с выработкой запасов из зоны интереса. Поэтому для многих компаний важно ограничить высоту трещины при гидравлическом разрыве пласта (ГРП), в нынешний момент такую проблему лучше решать с помощью химических реагентов.

На решение проблемы ограничения высоты трещины во время ГРП с помощью применения специальных химических реагентов выбрано месторождение X. На месторождении одновременно с ГРП применялись некоторые технологии обработки призабойной зоны, а также перфорации и приобщение ниже и вышележащих пластов. В этой работе будет глубокий анализ всех основных методов ограничения высоты трещины, подбор скважины для гидравлического разрыва пласта, также проведен анализ основных характеристик высоты трещины. По результату, самый оптимальный метод ограничения высоты трещины было применения низковязких гелей. Были разработаны три модели для сравнения этого метода и оценивания по критериям геометрий трещины гидравлического разрыва пласта с помощью программного обеспечения FracPro. Решение проблемы ограничения высоты трещины ГРП на месторождении X с помощью применения низковязких гелей показал наилучшую результат.

Все данные, использованные в исследовании, были получены из полевых записей, доступных из месторождения X.

Ключевые слова: гидроразрыв пласта, интенсификация, фрекинг, нефтеотдача, трещинообразование, ClearFrac, проппанты, высота трещины, FracPro, ограничения высоты трещины.

АҢДАТПА

Мұнайға қаныққан аймақтағы гидравликалық жарықшақты ұстап тұру кезіндегі сәтсіздіктер көбінесе өнімнің жоғары сулануына, жұмыстың мерзімінен бұрын тоқтатылуына әкеледі, бұл жұмыстың өтелу уақытын, қорларды алу коэффициентін және тұтастай алғанда дамудың экономикалық пайдасын күрт өзгертеді. Қызығушылық аймағынан тыс жерде алынған су жағдайында проблеманы шешу мүмкін емес. Бұл ретте Оператор өндірілетін суды кәдеге жарату қажеттілігіне, сондай-ақ мұнай ағынының төмендеу проблемасына тап болады. Осыған ұқсас, өндіруші мұнайдан жоғары газға қаныққан қабаттағы серпіліс қызығушылық аймағынан қорларды өндіруге де қиындық тудырады. Сондықтан көптеген компаниялар үшін гидравликалық сыну кезінде (гидравликалық сыну) жарықшақтың биіктігін шектеу керек, қазіргі уақытта мұндай мәселені химиялық реагенттердің көмегімен шешкен дұрыс.

Арнайы химиялық реагенттерді қолдану арқылы гидравликалық сыну кезінде жарықшақтың биіктігін шектеу мәселесін шешу үшін кен орны таңдалды.кен орнында гидравликалық сынумен бір уақытта төменгі шұңқыр аймағын өңдеудің кейбір технологиялары қолданылды, сонымен қатар төменгі және жоғарғы қабаттарды перфорациялау және біріктіру қолданылды. Бұл жұмыста жарықшақтың биіктігін шектеудің барлық негізгі әдістеріне терең талдау жасалады, гидравликалық сыну үшін ұңғыманы таңдау, сонымен қатар жарықшақтың биіктігінің негізгі сипаттамаларына талдау жасалады. Нәтижесінде жарықшақтың биіктігін шектеудің ең оңтайлы әдісі төмен тұтқыр гельдерді қолдану болды. Бұл әдісті салыстыру және FracPro бағдарламалық жасақтамасын қолдана отырып, гидравликалық сыну геометриясының критерийлері бойынша бағалау үшін үш модель жасалды. Төмен тұтқыр гельді қолдану арқылы х кен орнындағы ГРП жарығының биіктігін шектеу мәселесін шешу жақсы нәтиже көрсетті.

Зерттеуде пайдаланылған барлық мәліметтер х кен орнынан алынған далалық жазбалардан алынды.

Түйінді сөздер: гидравликалық сыну, қарқындылық, фрекинг, мұнай шығару, крекинг, ClearFrac, проппанттар, жарықшақтың биіктігі, FracPro, жарықшақтың биіктігін шектеу

TABLE OF CONTENT

List of figures:

List of tables:

ACKNOWLEDGEMENTS

This research was conducted with the support of several people, including department professors and company engineers.

First, I would like to thank my advisor Asanov Karim Balashevich, a representative of the Atyrau Branch of KMG Engineering LLP, who helped me from the very beginning to the end, and also shared a lot of valuable experience in the field of hydraulic fracturing.

I would also like to thank Zhanar Berikovna Baibusinova, a representative of Satpayev University, for her scientific guidance.

Special thanks to the head of the former Department of Petroleum Engineering Murat Syzdykov for the opportunity to participate in the KMG MinerSchool program.

Finally, I would also like to thank the Atyrau Branch of KMG Engineering LLP for providing me with the data for the study.

INTRODUCTION

1.1 Hydraulic fracturing

Hydraulic fracturing is one of the methods of intensifying the operation of oil and gas wells and increasing the attenuation of pumping wells. Widely used by oil and gas companies because of high profitability. The hydraulic fracturing method is that cracks are created in a productive reservoir at great depths, facilitating the pathway into the reservoir of water pumped into the pumping wells, or facilitating the flow of oil from the reservoir to operational wells.

When pumped into the well of a working liquid at high speed on it ret off creates high pressure. If it exceeds the horizontal component of mountain pressure, a vertical crack is formed. In case of excess of mountain pressure, a horizontal crack is formed. The network of created cracks improves hydraulic conduction of the rock of the reservoir and increases the drainage area of the well. This method leads to an intensification of the production of reserves, respectively, to achieve a higher final oil recovery and increase efficiency.

As a result, hydraulic fracturing multiplies the debit of extractive or receiving pumping wells by reducing hydraulic resistance in the filtration zone and increasing the filtration surface of the well, as well as increasing the final oil output by incorporating into the production of poorly drained zones and formation.

1.1.1. Crack height

The height of the crack is determined by the behavior of the crack, which means the analysis of the rupture pressure, and the design of hydraulic fracturing. As seen in the rechunk 1, the length of the crack is almost inversely proportional to the total height of the crack H_F. The length of the crack, and with it the expected increase in productivity is directly dependent on the height of the crack, the undesirable growth of which can cause a crack to penetrate the aquifer or gas cap and radically change the performance of the well.

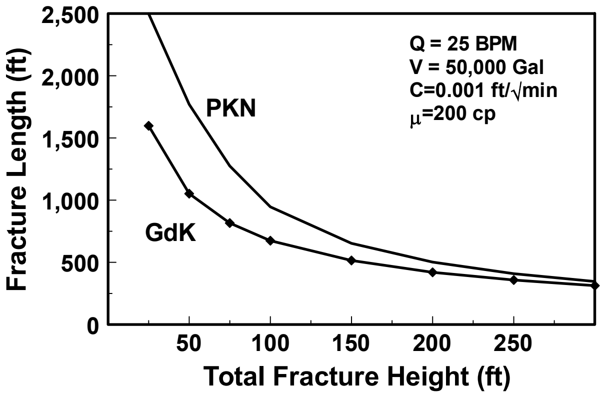


Figure 1 - H_F effect on length (if other parameters are unchanged)

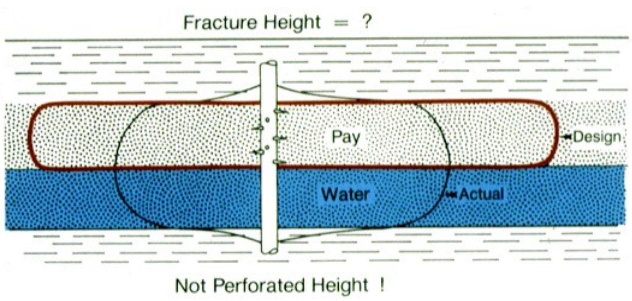


Figure 2 - "The Crack Grows Where It Wants To"

When viewed in Figure 2 illustrates the basic principle of determining the height of the crack - the crack grows, choosing the path of the least resistance.

1.2 Objectives of the study

The effectiveness of hydraulic fracturing depends on the geometry and conductivity of the crack created. These factors, in turn, depend on the characteristics of the materials used: hydraulic fracturing fluids and fixing agents (proppant). Failures in containing hydraulic fissures in the oil-saturated area often led to high watering, premature shutdowns, which dramatically changes the payback time, the recovery rate and the overall economic benefit in development. If the height of the crack is edified, the problem is unlikely to be fixed. Many oil and service companies have tried to use various technologies to prevent cracks from breaking through and limiting their vertical growth. Most of these attempts did not bring success. Therefore, the relevance of this problem in the world experience has extensive literature. The main goals of the work were:

1) To study all possible parameters affecting the height of the crack during hydraulic fracturing,
2) Analysis of the world's experiments limiting the height of cracks during hydraulic fracturing using the use of special chemical reagents.
3) Analysis of the suitable variant for the X field and analysis of hydraulic fracturing carried out with a limitation of the height of the crack in this field in order to select a well for the operation.
4) Calculation on the appropriate option for the optimal hydraulic fracturing with a height limit to design on FracPro software, which included models of mechanical and filtration properties of reservoirs, models of fracking, graphics of injection of liquids and proppant, a list of necessary equipment, chemical reagents, expected pressures, processing requirements, calculation of the growths of debits after hydraulic fracturing and description of the entire model.
5) Economic and environmental calculation of the alternative of optimal hydraulic fracturing with a limit on the height of the crack.
6) Recommend a detailed hydraulic fracturing with a limit on the height of the crack on the outcome of the entire project.

1.3 General information about the X field

In this work, it should be noted that the successful implementation of hydraulic fracturing at wells largely depends on the reliability of the information on the wells. The economy of the Territory is entirely focused on the oil industry and geological exploration. The agricultural sector is poorly developed and its development is hindered by the lack of land suitable for agricultural production and the complete lack of permanent sources of high-quality water resources. The climate of the area is sharply continental, with dry hot summers and little snow, cold winters. The vegetation cover is poor and characteristic of the semi-desert zone. There is no hydrographic network.

1.3.1 Geological structure of the deposit. Triassic system-T.

The roof of the triassic is marked by the appearance of moderately reddish-brown massive argillites at the top of this pack. The Triassic complex consists of often passing and passing into each other argillites, sandstones, less often limestone. Argillites are usually reddish-brown and light greenish-gray, occasionally very light gray and pale brownish. They are from soft to solid, dispersed, amorphous, sub-cutting, sometimes carbonic, from non-lime to slightly lime. Limestones from dirty white to very light gray, from soft to strong and dispersal. Limestones are different: from vacchi to grainy, sandy and turning into sandstone. Sandstones from light greenish-gray to light gray, look speckled. The breed is presented from poorly to moderately cemented, usually from fine - to coarse-grained and poorly sorted. Sand grains are usually sub-coaled to subrogated and from sub spheric to sub-length. The sandstones are grainy with lime-rich aleurite cement. Visible porosity is usually from bad to good and sometimes good. Sandstones mainly consist of quartz, lit clasts, pyrite, mica, glauconites and chlorite.

1.3.2 Characteristics of the thickness, reservoir properties of productive horizons and their heterogeneity.

The results of field-geophysical and hydrodynamic studies of wells, as well as laboratory studies of core samples, were used to determine the characteristics of thicknesses, collection properties of productive horizons and their heterogeneity. To determine the nature of the behavior of breed-collectors conducted a statistical analysis of effective thicknesses on neo-comical, Jurassic and Triassic productive horizons. Lithological productive layers are represented by alternating sandstones, clay aleurites and argillites. Collectors are mainly thin- and fine-grained clay sandstones, aleurites, to varying degrees cemented, aleurites, with layers of brick-red clays.

1.3.3 Analysis of the results of the core study.

For Triassic deposits, the core selection is 825.5 m, the core is taken out 514.06 m or 62.27% of the pass. The total passage of Triassic productive horizons (T-I, T-II, T-III, T-IV, T-V) is 456.78 m, core take-out is 292.2 m or 63.97% of the pass. The number of samples analyzed in The Triassic sediments is 350 samples, including 275 in productive horizons, 170 of which are air-conditioned samples.

1.3.4 The results of the analysis of geophysical studies of wells.

Species and volumes of GIS in a closed barrel. Definitions of the technical condition of the well and the study of the current oil saturation of the reservoirs were carried out in the following combination of modules: gamma logging, thermometry, gauge, barometric, magnetic detector, pulsed neutron logs, acoustic cement bond logging.

The condition of the cement stone clutch with the column and rock was assessed according to the acoustic cemetery of the acoustic cement bond logging. In order to determine the current oil saturation of the reservoir, in wells were measured pulsed neutron logs. Below are the lithological and capacitive filtration characteristics of productive horizons.

1) *Horizon T-IV.* According to the GIS, the porosity in the oil part of the horizon varies from 0.16 to 0.33 shares of units, on average 0.23 shares units, in the gas part from 0.18 to 0.31 shares units, on average 0.24 shares of oil saturation fluctuates in the range of 0.44÷0.82 shares of units, 0.45÷0.79 shares of core

porosity vary from 0.15 to 0.29 units, permeability - 0.0075-0.390 mkm^2, on average, 0.24 units and 0.109 mkm^2 respectively.

2) *Horizon T-V. According to fishing and* geophysical studies presented by collectors with porosity in the oil part on average 0.22 shares of units and varying within 0.13-0.33 shares of units, in the gas part with an average value of 0.19 shares and varying in the interval of 0.17-0.22 shares of the ed. For 51 conditioned core samples, porosity ranges from 0.15 to 0.34 units, permeability - 0.0012-0.679 $microns^2$, on average amounting to 0.218 shares and units. According to the 23 wells (37 definitions), the permeability varies from 0.00006 to 0.091 mkm^2 with an average of 0.020 mkm^2.

1.3.5 Oil properties in reservoir conditions.

On Triassic horizons T-I, T-III, T-IV, T-V the structure is divided into blocks, the characteristics of the plastic fluid of which differ. In particular, on the III block on the horizons of T-I-T-IV there is a gas cap, while on the rest of the oil deposits are presented as purely oil. At the same time, the bulk of deep samples were taken from oil deposits. By analyzing the measured parameters for samples, it can be established that some deep samples from wells №№ 61,64,73,76 were measured abnormal values of parameters of reservoir oil.

According to the new recombined samples, the measured parameters of the oil are located in the previously accepted range of representative depth samples. The data have a correlation, regardless of belonging to a particular formation or area, which gives the basis for the adoption of uniform parameters of oil for the Triassic horizons.

As part of the current project, when adopting a block structure for oil deposits, the parameters of oil are accepted based on the results of the studies of representative deep samples. It should be noted that when building a hydrodynamic model of the deposit on deposits with a gas cap (block III) took into account the phase state to the level of gas and oil contact with a saturated state of the reservoir fluid.

1.3.6 IV operational facilities.

As of the date of the project for the IV object, the actual accumulated production amounted to 1360.6 thousand tons of oil, 2212.9 thousand tons of liquid, 102.8 million m3 of associated gas, the accumulated injection reached 885.5 thousand m3 of water, with project accumulated volumes: 1354.3 thousand tons of oil, 2260.6 thousand tons of liquid, 143.5 million cubic meters of gas, pumping 896.2 thousand m3 of working agent. In 2018, 27.5 thousand tons were produced at the projected value of oil production. The actual well fund was 20 units, which is lower than the project fund by 2 units of oil debit below the project and is 3.0t/day at the project 4.1 tons per day. For 2019, 35.4 thousand tons were mined, with a projected 29.5 thousand tons. There is an excess of the actual level of oil production from the project. The current oil recovery factor is 0.339 shares, against the project 0.337 shares units. Inventory yield was 83.1% at a projected 82.7%.

1.4 Available data on hydraulic fracturing

According to the production plan of Field X in 2019-2021, it was planned to conduct hydraulic fracturing at 6 production wells with an efficiency of 5 t / day, the plan for accumulated additional production of 7.2 thousand tons. As of 01.04.2021, 6 hydraulic fracturing was carried out according to the plan with an efficiency of 9.57 t/day, the accumulated additional production was 20.4 thousand tons.

For the period of 2018-2019, one of the first hydraulic fracturing operations was carried out at two production wells № 104 and 136 for the first time at field X in order to intensify the flow of liquid to the well. The choice of the hydraulic fracturing method was determined by the low production rates of these wells, the low permeability of the Triassic horizons, and the extensive experience of hydraulic fracturing in similar fields.

As a result of the work carried out, the increase in oil flow rate for each well averaged 12.7 t/day, while for the period of 90 days after hydraulic fracturing, the average increase was 25.5 t/day. Additional oil production as of 20.08.2020 amounted to 12.3 thousand tons. Wells № 104 and 136 were selected for hydraulic fracturing as a result of a preliminary expert assessment of each well from the technical, technological and geological-field positions. For each well, the optimal fracturing technology was selected and designs were designed using FracPro software, which included models of the mechanical and filtration properties of the formations, models of fracturing fractures, schedules for pumping liquids and proppant, a list of necessary equipment, chemical reagents, expected pressures, processing requirements, and calculation of flow rates after fracturing.

On 29.11.2018, hydraulic fracturing was carried out at the T-V horizon at the perforation intervals of 1318-1322, 1325-1327 m, the interval of 1327-1340 m was isolated by filling with proppant in order to limit the development of the crack in height. In accordance with the approved design, 15 tons of 16/20 fraction proppant and 80 m3 of hydraulic fracturing fluid were injected. The proppant volume of 15 tons was chosen as the optimal and safe option, since there was a risk of crack development in water-saturated intervals below the depth of 1345 m. Figure 3 shows the profile of the fracture modeled in the FracPro software based on the actual data of the hydraulic fracturing performed. According to the simulation results, the crack development in the water-saturated intervals did not occur.

On 09.02.2019, hydraulic fracturing was carried out at well № 104 on the T-III and T-IV horizons in the perforation intervals of 1276-1281, 1286-1296 m. In accordance with the approved design, 40 tons of 16/20 fraction proppant and 120 m3 of hydraulic fracturing fluid were injected. There was no risk of a crack developing in the water-saturated intervals, so based on the effective oil-saturated capacity of the reservoirs, a tonnage of 40 tons was chosen as the optimal volume. Figure 4 shows the profile of the fracture modeled in the FracPro software based on the actual data of the hydraulic fracturing performed.

Wells № 104 and № 136 were among the first wells on the X field to conduct hydraulic fracturing. Further, during the period of 2020-2021, one of the first hydraulic fracturing operations was carried out at four production wells № 102, № 144, № 91 and № 121 at field X in order to intensify the flow of liquid to the well. The choice of the hydraulic fracturing method was determined by the low production rates of these wells, the low permeability of the Triassic horizons, and the extensive experience of hydraulic fracturing in similar fields.

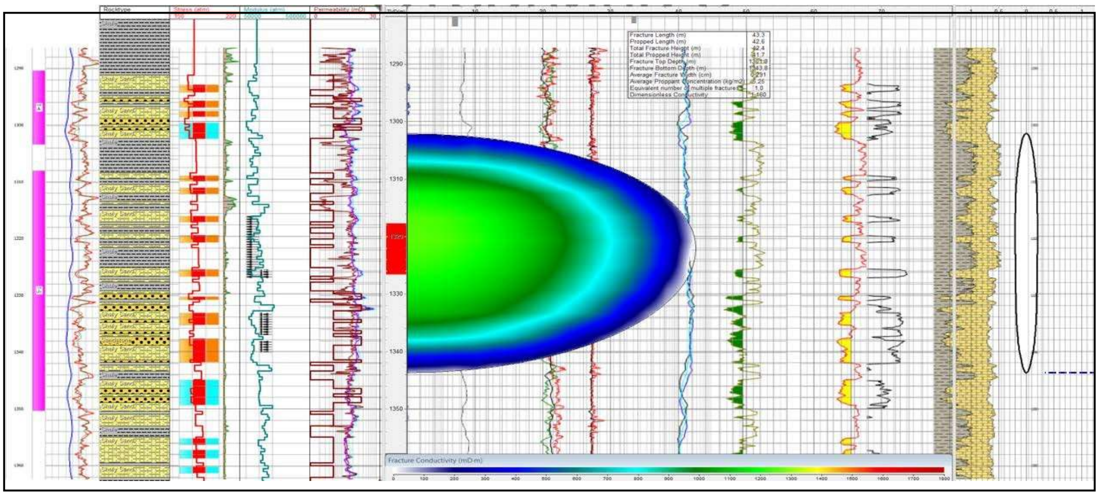


Figure 3 - Actual fracture profile of hydraulic fracturing at well № 136

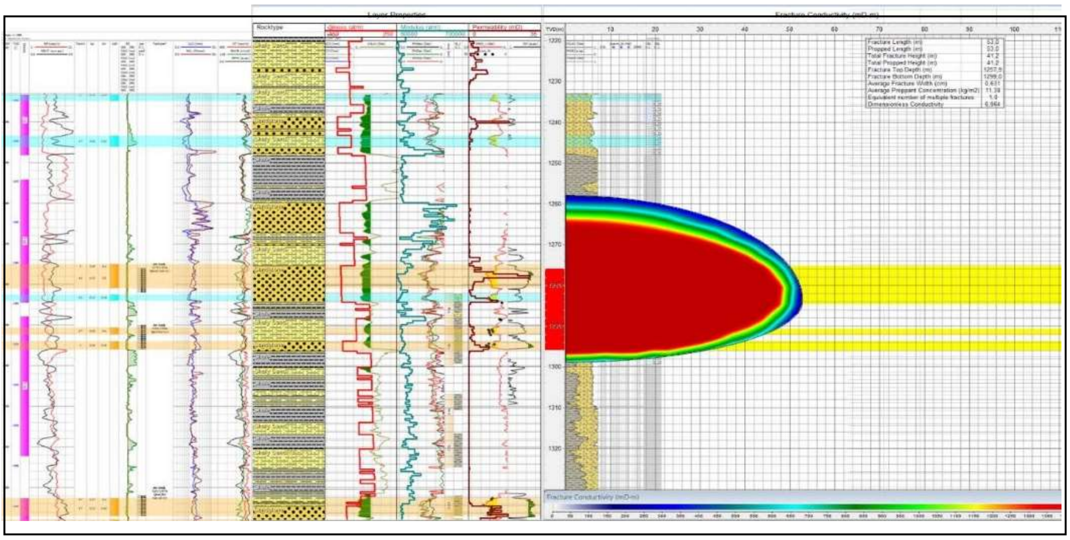


Figure 4 - Actual fracture profile of hydraulic fracturing at well № 104

6 wells worked an average of 59 days after hydraulic fracturing, of which 4 achieved the planned increase, 2 wells due to low pressure. Table 1 provides information on the effectiveness of hydraulic fracturing as of 01.03.2021.

1.4.1 Analysis of the reasons for the failure to achieve or lack of effect after hydraulic fracturing (wells № 91 and № 144)

Well №91 was commissioned on .c 30, 2007.c on the T-IV horizon. Prior to the hydraulic fracturing, the well was operated with the following indicators: 8.4 m3/day liquid debit, 3 t/day oil debit, 55% watering. The hydraulic fracturing was carried out on 23.10.2020 in perforation intervals 1308.5-1311.5,1317.5-1328 m of the T-IV horizon. 30 tons of proppant were pumped according to the design. The well was launched on 17.01.2021. As of 01.03.2021. worked 72 days with the following indicators: 25.45 m3/day liquid debit, 8.83 tons/day oil debit, 56.49% flooding. The increase in oil debit was 4.61 tons per day, thus the planned increase of 5 tons per day was not achieved.

Table 1 - Analysis of the efficiency of hydraulic fracturing performed as of 01.03.2021

№	Well	Launch date after HF	Time worked, day	Average performance before HF			Average performance after HF			Park growth, t / day				Average figures for the month (March 2021)			Acc. add. prod.	Reason for non-ach.
				Q_f, m^3/day	Water cut, %	Q_o, t/day	Q_f, m^3/day	Water cut, %	Q_o, t/day	Plan	Fact	Difference	% of achievement	Q_f, m^3/day	Water cut, %	Q_o, t/day	Park street, t	
1	136	03.01.2019	855	**2,07**	5,71	1,58	**20,86**	14,82	14,4	5	12,82	7,82	256,4	**24,71**	22,1	15,28	10233,18	-
2	104	10.03.2019	819	**2,65**	12,76	1,83	**16,06**	36,56	8,66	5	6,83	1,83	136,6	**14,51**	67,3	3,76	5226,49	-
3	102	14.10.2020	166	**5,94**	8,08	4,26	**27,7**	16,37	18,5	5	14,24	9,24	284,8	**21,73**	22,87	13,31	2264,69	-
4	144	31.10.2020	143	**9,5**	18,04	6,13	**17,28**	23,37	10,28	5	4,15	-0,85	83	**21,14**	19,14	13,54	685,04	Low Pr
5	91	17.01.2021	72	**12,92**	58,75	4,22	**25,45**	56,49	8,83	5	4,61	-0,39	92,2	**31,66**	55,2	11,27	609,88	Low Pr
6	121	20.01.2021	68	**8,08**	36,55	4,03	**36,01**	33,88	18,82	5	14,79	9,79	295,8	**33,68**	19,45	21,53	1388,28	-
Total			**353,83**	**6,86**	**23,32**	**3,675**	**23,89**	**30,25**	**13,25**	**5**	**9,57**	**4,57**	**191,5**	**24,57**	**34,34**	**13,12**	**20407,56**	

Intervention	Indicator	Plan	Fact	Difference	%
Hydraulic fracturing	**Quantity**	6	6	0	100
	Average growth, t /day	5	9,57	4,57	191,40
	Additional production, thousand tons	7,2	20,4	13,2	283,33
	Average time worked, day	150	353,8	203,8	235,87

Well № 144 was put into operation on 30.09.2020 by the fountain method on the T-IV horizon. Prior to hydraulic fracturing, the well was operated with the following indicators: liquid flow rate of 9.5 m3/day, oil flow rate of 6.13 t/day, water cut of 18.04%. Hydraulic fracturing was carried out on 23.10.2020 in the perforation intervals of 1256.3-1260, 1263.7-1265 m of the T-IV horizon. 30 tons of proppant were pumped according to the design.

The well was put into operation on 31.10.2020. As of 01.03.2021, it worked for 143 days with the following indicators: liquid flow rate of 17.28 m3/day, oil flow rate of 10.28 t/day, water cut of 23.37%. The increase in oil production was 4.15 t / day, so the planned increase of 5 t / day was not achieved.

The probable reason for the failure to achieve the planned effect in both wells is the reduced reservoir pressure in the area of the well location, in the vicinity of wells № 144 and № 91-this is well № 63. At well № 91, the pressure transient test study in December 2018 established the reservoir pressure at 82 atm. In October, 2020, a study of the buildup test was conducted, according to the results of which the P_r is about 80 atm. In order to clarify the current P_r, it is recommended to conduct additional well testing for wells № 144, 91 and 63.

1.4.2 Analysis of the causes of complications during hydraulic fracturing

As of 01.03.2020, 6 hydraulic fracturing operations were carried out at fields X, while no complications were received that would lead to a premature stop when the emergency “STOP” pump shutdown pressure was reached. However, only in 2 cases out of 6, the proppant was fully loaded according to the design. In 2 cases, there were failures in the operation of the equipment, which led to the fact that from 1 to 3 tons of proppant were not pumped out. Of these, in 1 case, the main cause was failures in the operation of the blender level gauge, in 1 case, failures in the operation of the proppant counters.

In the case of well № 121, 9 out of 10 tons of proppant were pumped due to a malfunction of the blender level gauge, as a result, 1 ton of proppant was not pumped. The tubing was lifted, and one pump-compressor pipe with a shank and a packer remained in the well. In the case of well № 91, 37 out of 40 tons of proppant were pumped due to a failure in the operation of the proppant meters, as a result, 3 tons of proppant were not pumped. This is a common cause of many complications. As a result of the resulting complications, with the total planned volume of injected proppant of 156 tons for all 6 wells, 152 tons of proppant were actually injected into the formations, which is 97.44%. According to the Hydraulic Fracturing Regulations of JSC NC "KazMunayGas", when more than 90% of the proppant is injected into the formation, the work can be considered completed successfully.

Table 2 - Information on getting complications during hydraulic fracturing

№	Well	Date of hydraulic fracturing	Planned volume of proppant, t	Pumped from the surface, t	Pumped into the reservoir, t	% of proppant in the formation	Note on complications
1	**136**	29.11.2018	15	15	15	**100**	Completed. Proppant uploaded in full
2	**104**	09.12.2019	40	40	40	**100**	Completed. Proppant uploaded in full
3	**121**	03.10.2020	10	9	9	**90**	Completed. 9 out of 10 tons of proppant were pumped due to a malfunction of the blender level gauge, as a result, 1 ton of proppant was not pumped. The tubing string is raised, 1 tubing string+packer+shank is left in the well.
4	**102**	05.10.2020	21	21	21	**100**	Completed. Proppant uploaded in full
5	**144**	23.10.2020	30	30	30	**100**	Completed. Proppant uploaded in full
6	**91**	28.12.2020	40	37	37	**92,5**	Completed. 37 out of 40 tons of proppant were pumped due to a failure in the operation of the proppant counters, as a result, 3 tons of proppant were under-pumped.
Total:			156	152	152	**97,44**	
Average data for 1 well:			26	19,2	19,2		

Prior to the main hydraulic fracturing, "bucket" tests of liquid and dry chemical feed pumps were performed at each well, which showed the complete serviceability of the equipment used. During the work, in case of failures of the proppant and chemical reagent supply meters, the specialists of the AF KMGI carried out control physical measurements, which showed that the chemical reagents and proppants were supplied with the planned concentration without deviations. Periodic sampling showed that the quality of the hydraulic fracturing fluid met the requirements. Table 2 provides information on obtaining complications during hydraulic fracturing for each well.

METHODOLOGY

2.1 World experience

Many companies use various technologies to prevent cracks from breaking into the unproductive zone and limit their vertical growth. Figure 5 shows a comparison of the development of the crack geometry according to the standard technology and according to the technology of limiting the growth of the crack in height. Let's consider several such methods:

1. The artificial wedge method (J-FRAC). Schlumberger's technology for controlling vertical crack growth. The technology is applied before the main hydraulic fracturing and uses selective injection of artificial barriers, as well as special fluid systems and injection schedules. The innovations are aimed at retaining the hydraulic fracturing crack inside the productive formation. This material is a mixture of a certain size of solid particles-selected in a special ratio for perfect packaging and minimal permeability.

The J-FRAC injection sequence consists of placing the J-FRAC mixture between the buffer stage and the proppant stages of the main work — with a small concentration of ~ 120 KgPA (~1kg / m3), then the planned hydraulic fracturing work is pumped. The purpose of the large particles in the mixture is to create a mechanical bridge on the clay barriers, and the two smaller fractions of the particles are used to eliminate leaks through the large ones. Without the fine particles, the fluid would pass through the large particles and continue to develop the crack in the vertical direction, creating a "closing zone", which leads to the hydraulic fracturing fluid breaking out of the zone of interest and often to an immediate stop of work ("stop"). As a rule, the consequences of this are the undesirable geometry of the crack, the well flow rate is lower than planned, additional costs for the work on the hydraulic fracturing zone and the need for repeated fracturing on the reservoir.

2. Low-viscosity gels (ClearFRAC) - allows you to limit the effective pressure of the crack with low-viscosity liquids; when compared with FiberFRAC, it uses under-crosslinked gel and other low-polymer liquids to limit the height of the crack. Hydraulic Fracturing Fluids Low-viscosity polymer-free gels have been developed specifically for wells that require additional backflow energy and the hydrostatic benefits of hydraulic sandstone with liquid CO_2.

Since the liquids are Low-viscosity gels designed in such a way as to avoid damage to the proppant package, crack production occurs unhindered. Even at low viscosities, the elastic properties of ClearFRAC fluids make them highly efficient when transporting proppant. The result is the ability to change the viscosity to better control the crack geometry without compromising transportability.

3. Proppant tonnage limitation is one of the main methods of limiting the crack height in practical applications. The method is to limit the oriented tonnage of the proppant to the minimum component that was calculated so as not to break the reservoir layer. This allows you to limit the effective height of the crack during hydraulic fracturing, but you need to understand that this is not economically feasible. Since during this method, the crack created will not only be limited in height, but also the distance of the length will be small. If the energy of the well formation is good, then limiting the tonnage of the proppant is not the best method for limiting the height of the crack.

4. Changing the fluid flow rate helps to effectively limit the height of the crack, which is also one of the practical methods in the field of hydraulic fracturing. Flow rate is the volume of liquid flowing through the cross-section of the flow per unit of time. This means that if its performance is reduced, the reservoir will be filled with liquid slowly and thus will help it to grow more easily in length.

5. Hydraulic fracturing fluids with the use of fibers (FiberFRAC). FiberFRAC technology consists in adding special self-destructing fibers to the hydraulic fracturing fluid, which create a reinforcing mesh inside the working fluid with the proppant, mechanically helping to hold and transfer the proppant in a suspended state during the operation. After the crack is closed and the well is started, the fibers are dissolved under the influence of the formation fluid and temperature. The time of dissolution depends on the reservoir temperature: for the conditions of the reservoir of the field, it is about 10 days. The decomposition products are carried out of the crack by the liquid flow.

Increasing the conductivity of the proppant pack is one of the most important tasks in hydraulic fracturing, as it affects the productivity of the well. The technology of hydraulic fracturing with the use of fibers solves this problem with the help of two mechanisms. The first is that FiberFRAC creates the possibility of reducing the loading of the gelatin agent due to the better ability to transfer the proppant at a reduced viscosity. A lower polymer concentration means less residual contamination of the proppant pack and greater residual conductivity compared to classical hydraulic fracturing. The second mechanism is the use of self-destructing fibers. Under the influence of reservoir temperature after hydraulic fracturing, they completely decompose in the crack. The technology was tested in 2010 at 12 new wells in the Urnenskoye field. Hydraulic fracturing was carried out in wells that opened the formation with the worst filtration and capacitance properties.

7. Limitations of the perforation interval. The perforation intervals are scheduled by the geological service of the oil and gas production department within a day after receiving the materials of the geophysical studies of the actual section of this well. Of course, the perforation interval and its density should be carefully justified. Therefore, all wells have a refined perforation height and when we want to limit it, we must show that the expected crack can break out into the aquifer. With the restriction, the fracture of the hydraulic fracturing may not reach the water-saturated reservoir, since its lower depth will be closed. There are two ways to do this: 1) We fill up from the bottom to the middle of the hole perforation with proppant; 2) We use an in-line packer.

8. Hybrid hydraulic fracturing. For hybrid hydraulic fracturing, specially selected combinations of various process fluids are used. As a result, a network of cracks is formed, resembling a spider web. Their length can reach 500 meters, which allows you to cover a larger volume of the reservoir. Hybrid hydraulic fracturing is a relatively new technology and is a combination of several fracturing techniques. The term "hybrid" itself has been used to describe various stimulation fluid systems consisting of combinations of "slip water", linear and crosslinked gels, foams, and others, for example: "slip water" + gel, foam + gel, CO_2 + gel, and so on.

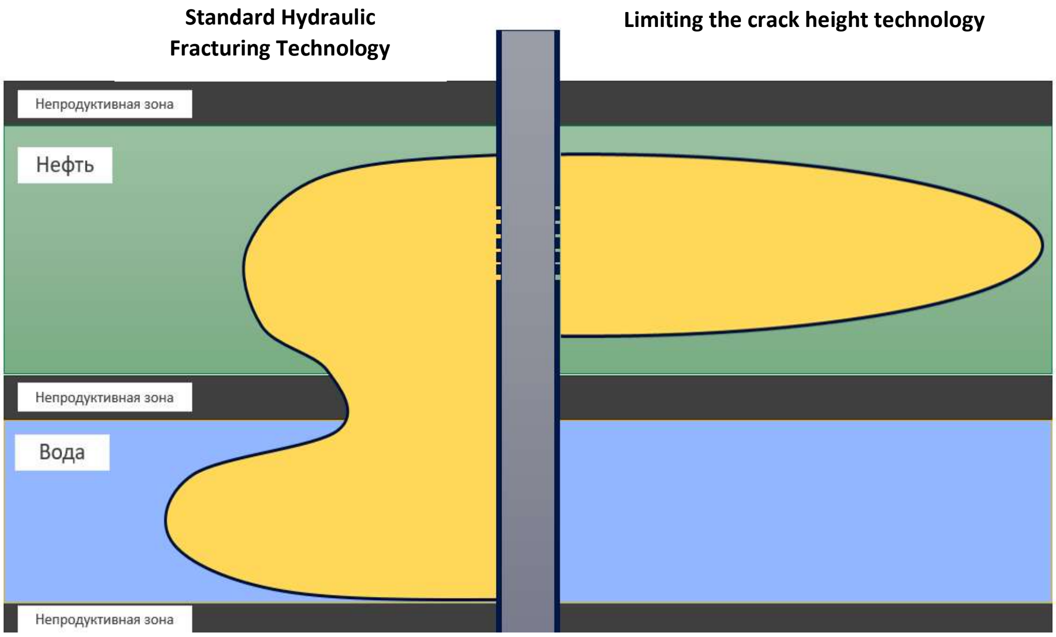


Figure 5. Comparison of hydraulic fracturing development in the application of various technologies

2.2 Analysis of these experiments

Modern methods of limiting the vertical height of the crack have their own interesting technologies. The crack height mainly depends on the stress ratio in the formation — more precisely, on the difference in the stress value in different lithological formations. More formally, in all these methods, the crack height is controlled by the ratio of the effective pressure in the crack and the difference in minimum stresses between the barrier and the formation. They all differ in some properties. For clarity, all these methods need to be analyzed using 5 criteria: 1. Relevance (importance, modernity), 2. Novelty (unusual), 3. Financial and economic justification (profitability), 4. The possibility of practical implementation (in production), 5. Practical results (for deposits in Kazakhstan). Table 3 provides information on a detailed analysis of crack restriction methods.

2.3 Analysis of the appropriate option and recommendations

The feasibility of hydraulic fracturing primarily depends on the overall condition and efficiency of the field development system. The condition for achieving the maximum effect of hydraulic fracturing is the reasonable selection of a specific well. In these methods we can observe that the first 5 have very good average estimates and I think they are all suitable for hydraulic fracturing in the field X.

In this work, we will focus on solving the problem of limiting the height of the crack during hydraulic fracturing by using special chemical reagents. A good option would be to use a hydraulic fracturing Fluid using fibers (FiberFRAC), but this method is not suitable for field X. This method is used when the reservoir temperature is above 60°C, the temperature indicators of the deposit X are equal to 43°C. Therefore, it is reasonable to apply the ClearFRAC method and compare it with the base model and with the proppant tonnage restriction model. As a result, we compare all 3 models and analyze the best option.

Table 3 - Detailed analysis of crack restriction methods

Score on a 10 scale (where 10 is good, 1 is very bad)							Average rating	Comment				
№	Method	Relevance	Novelty	Financial and economic justification	Possibility of practical implementation	Practical results		Year of opening	Strengths	Weaknesses	Threats	Technology
1	**Hybrid hydraulic fracturing**	10	8	10	10	10	**9,6**	2005	Does not require additional costs, Easy to use	Difficulty in calculating the required buffer size	Stop Risk	Combinations of various process fluids (lin. + cross-linked gel)
2	**Artificial Wedge Method (J-FRAC)**	9	9	9	9	8	**8,8**	2007	Efficiency, Ease of use	Requires additional costs	Stop Risk	Placing the mixture between the buffer stage with a small concentration
3	**Low-viscosity gels (ClearFRAC)**	10	10	8	8	8	**8,8**	2007	Min. contamination of the proppant packing	Insufficient knowledge of rheological properties	Stop Risk	Use viscoelastic hydraulic fracturing fluids (synthetic gels)
4	**Hydraulic fracturing fluids using fibers (FiberFRAC)**	9	10	7	8	8	**8,4**	2007	High residual conductivity	Requires additional information. costs, Limited application (at Tpl >60^{o}C)	Stop Risk	Adding special self-destructing fibers to the hydraulic fracturing fluid
5	**Lightweight propane**	10	8	8	8	8	**8,4**	2007	Min. contamination of the proppant packing	Complex production of propane, Requires additional equipment. costs,	Stop Risk	Light proppant allows you to use low-viscosity gels
6	**Limitations of the perforation interval**	9	5	8	10	9	**8,2**	1990	Efficiency, Ease of use	Requires additional costs	Technical risks	Restriction with a packer or proppant filling
7	**Liquid flow rate measurement**	8	5	10	10	8	**8,2**	1980	Easy to use	Slight effect on height	Technical risks	Reduced constant fluid flow during hydraulic fracturing
8	**Proppant tonnage limits**	8	5	10	10	8	**8,2**	1980	Reducing the cost of work	Suboptimal design	Technical risks	Proppant tonnage limit
Total		9,13	7,50	8,75	9,13	8,38	**8,58**					

MAIN PART

3.1 Crack Height Options

It is often difficult to give accurate quantitative calculations of the crack height, but it is possible to list the known key factors that control the height: The difference in closing stresses, the reservoir thickness, the" Pressure " of the rupture, the ratio of modules, the discharge of the layer plane (Possibly only at a small depth of occurrence), the plasticity of the rock, the stress/ pressure gradients of the liquid, the difference in strength (crack resistance). They should be taken into account when analyzing the minimum conditions for the growth of the crack height:

1) Lithological changes-since changes in closing stresses, changes in modulus or strength (i.e., crack resistance) are usually associated with changes in the composition of the rock;
2) Reduction of pore pressure-since a decrease in reservoir pressure will lead to a decrease in rock stress;
3) The thickness of the formation – since the adjacent bridging layers must be sufficiently powerful; and, finally,
4) Burst pressure-due to the tendency of the crack to grow out of the zone, the high treatment pressure is due to the crack closing stress, rock properties, or thickness.

Dependence on the closing stress.

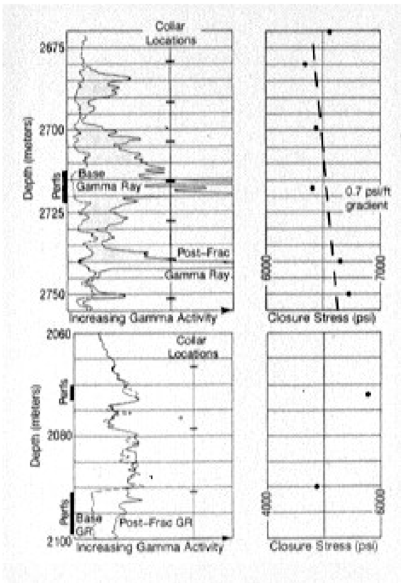
The dominant height parameter is the change in the closing stresses from zone to zone. Such changes are usually associated with changes in lithology or pore pressure. Figure 6 illustrates a case where a large stress difference was present in two different zones – the well logging data after hydraulic fracturing showed excellent height retention within the low-stress formation. The same diagram shows another case, without significant differences in stresses despite the change in lithology. Note that the height of the crack is not limited to the limits of the productive zone. Thus, lithological changes are a necessary, but not sufficient condition for changes in the closing stress-such changes that usually affect the growth of the crack height (the stress differences in Figure 6 give a gradient of 0.15 psi / ft, and 0.20 psi/ft is the approximate absolute possible maximum of the stress difference).

The dependence of the crack height on layers with different closing stresses is illustrated by the following example. Figure 7a shows a perfect example of sandstone, bounded above and below by powerful clays with higher stress. Formed in the sandstone, the crack quickly takes the shape of a round coin, as in the area " A " Figure 7b. With further injection, the crack increases in length, since clay layers with high stress serve as a barrier to the vertical growth of the crack. The effective hydraulic fracturing pressure (P_{net} = dynamic P_{downh} - $\sigma c1$) will increase in the "B" section in Figure 7, as the viscous fluid flow has to fill the increasingly increasing length of the crack. As the P_{Net} (P_{eff}) increases, the crack grows in height according to the pressure-height ratio in Figure 7a. For an ideal geometry with two stresses of three layers Figure 7a, this ratio will be.

$$P_{Net} = P - \sigma_{cl} = \frac{K_{Ic}}{\sqrt{\pi H_o}} \left[\frac{1}{H / H_o} - 1 \right] + \frac{2 \, \Delta\sigma_{cl}}{\pi} \times \cos^{-1} \left[\frac{1}{H / H_o} \right]$$

where K_{Ic} $\sqrt{inch}$ is the intensity of critical stresses, or the crack resistance of the rock.

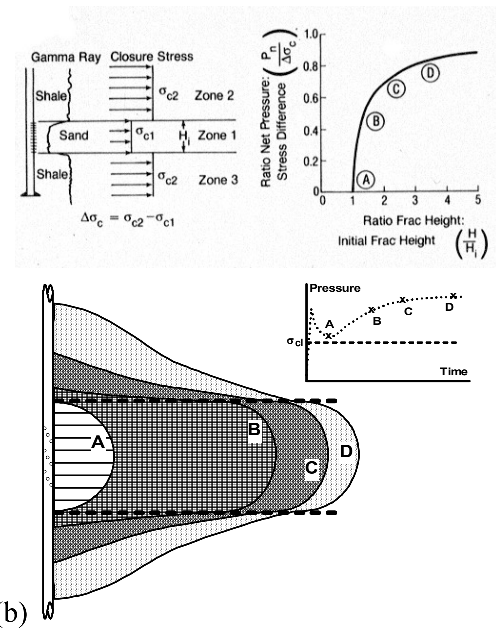
$$P_{Net} = P - \sigma_{cl} = \frac{2 \, \Delta\sigma_{cl}}{\pi} \times \cos^{-1} \left[\frac{1}{H / H_o} \right]$$



4b

4a

Figure 7 – Lithological changes with and without closing stress differences



(a)

(b)

Figure 6 – Effect of different stresses on height, example with three layers

Thus, as the crack length increases, the P_{Net} increases, and the crack height will increase until the effective P_{Net} pressure is 75-80% of the stress difference-point "C" in Figure 7. Exceeding this pressure leads to a significant increase in the crack height and a slowdown in the rate of length increase, or to its termination, in Figure 7"D". When the P_{Net} reaches this level, there is an uncontrolled increase in the height of the crack outside the zone, and subsequent increases in injection volumes lead to significant uneconomical costs.

For the case under consideration, assume that the stress difference between sandstone and clay rocks is 1,000 psi. Then, for the moment "A", the effective pressure is P_{Net} = 500 psi (or $P_{Net}/\Delta\sigma_{CL} = 0.5$). In this case, the height will increase by 20% of the "base" height – by 10% up and 10% down, as shown. As the injection continues, the crack length increases, and the pressure continues to increase until "B". P_{Net} can be 700 psi ($P_{Net}/\Delta\sigma_{CL} = 0.7$). This effectively doubles the height: 50% of the power of the main zone up and 50% down. There is clearly an excessive height increase, which in total exceeds the capacity of the productive interval by two times. However, the main height increase is observed near the borehole, and in addition, the crack width in the above and below clay layers is very small. In this regard, the main injected fluid enters the" main " part of the crack, and from the point of view of the material balance (and the design of the hydraulic fracturing), the described case is still an example of a good localization of the crack height!

Finally, after continued injection, the crack grows to the point "D". At this point, the P_{Net} can reach 800 psi ($P_{Net}/\Delta\sigma_{CL}$ = 0.8), and the crack height increases three times – up by the thickness of the productive zone and down by the same amount. More importantly, the pressure / height ratio is equalized, and an additional extensive height increase will be observed even with a very small increase in P_{Net}. In addition, the crack geometry undergoes fundamental changes. Now the crack is turning into a radial one " “with a nose”!

In order to calculate whether the height will be localized within the zone, you need to have some idea of the stresses of the layers that cause the crack to close. If the voltage difference is 500-600 psi, then an uncontrolled height increase will occur at an effective hydraulic fracturing pressure of about 450 psi. If such a low effective pressure does not ensure the creation of the design length, then it is necessary to design a design that takes into account the significant increase in height. In other cases, with large values of the stress difference, at 1,000 psi, as described above, it is possible to create almost any length of the crack until the" significant " height increases (taking into account that the height of the crack can easily double without being considered "significant").

The effect of hydraulic fracturing and reservoirpower.

The power of the reservoir has an effect on the height of the crack in two main ways. First, the power of the productive interval determines the effective pressure of hydraulic fracturing (assuming the absence of significant height growth), hence the power is determined by the strength of the barrier limiting the height growth. In addition, the adjacent layers should be powerful enough to prevent the development of crack height.

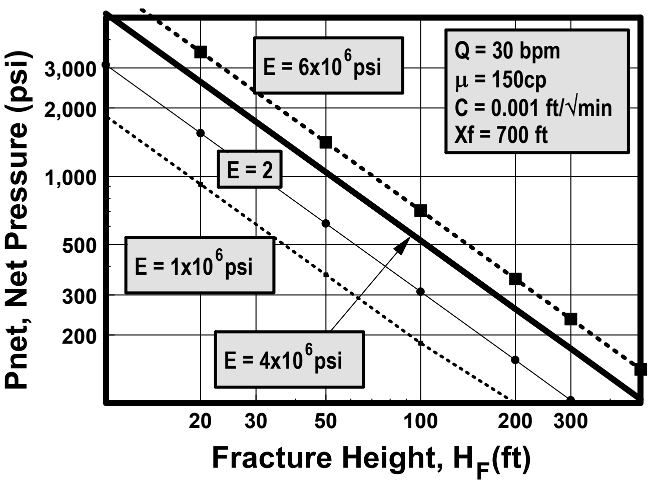


Figure 8 - Dependence of P_{Net} on the general

Influence *Productive zone power* illustrated by figure 8 where the effective pressure needed to create a 700 length is given feet (half-length crack) at different crack height (and module values). Obviously, a "limit degree" sufficient to hold a crack at a 200-foot interval would not prevent the height from rising beyond the 50-foot reservoir. There is also a focus on very high pressures in areas with low thicker within less than 20 to 25 feet. It is almost impossible to limit such pressures, and it is not possible to maintain height within such small intervals (except in the case of rocks with very low modules, which are often found in hydraulic fracturing with the installation of a mesh filter - "frac packs»). While the height of the crack has a major effect on effective pressure, other variables, such as the module, fluid viscosity and, in some cases, rock strength, can also determine the required pressure of hydraulic fracturing. In general, whatever parameters are controlled by effective pressure, the higher the pressure, the greater the limitation is required to localize the gap, respectively, and the probability of rising beyond the productive zone is much higher.

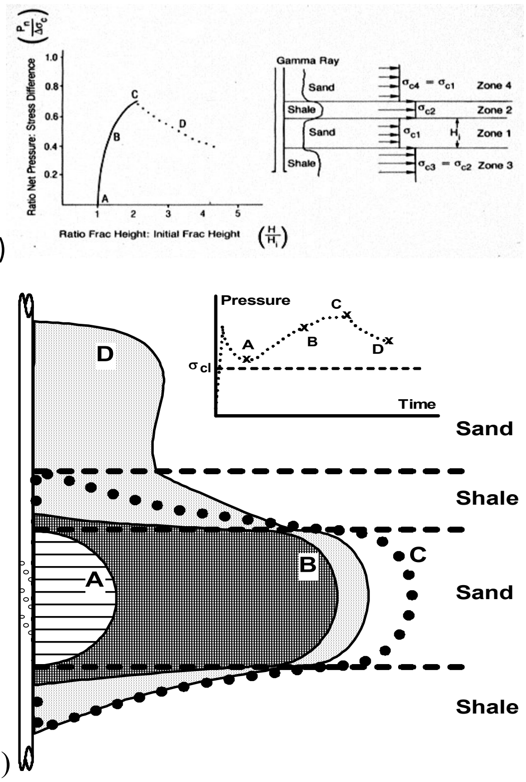
The thickness of the adjacent layers plays an important role, since the final thickness of the adjacent layers is necessary for the rational retention of the crack within the productive zone. If we take the extreme case, based on the fact that a 5-foot clay interval is not able to limit a crack in the sandstone with a thickness of 50 feet, then, compared to the sandstone, it is quite obvious that the thickness of the clays is not significant. However, outside of such extreme cases, it is difficult to conclude how powerful the adjacent reservoir should be. One practical rule is that the thickness of the adjacent layers should not be less than the thickness of the productive layer. However, this largely depends on the absolute value of the capacity of the productive zone, the difference in the stresses of the productive formation and neighboring layers, as well as on the properties of the rocks, as a module. For each specific case, it is necessary to perform calculations.

Figure 8 shows the height of the crack for the ideal case with infinite adjacent layers. However, such situations are rare. In general, the thickness of the formation, along with the stress difference, determines the permissible hydraulic fracturing pressure (and, consequently, the permissible crack length) until a significant transverse crack growth occurs. This is clearly shown in the example in Figure 9. with more layered deposits. Compared to the previously discussed simple 3-layer geology, in this case, the simple pressure / crack height equations are no longer applicable. However, the order of analysis is similar, and the pressure / height relationship can be constructed, as shown in Figure 9a. Figure 7b shows the crack growth. Again, as soon as a crack is formed, it quickly takes on a radial geometry, as we considered in the case of "A".

Then the crack length begins to increase, as the thin clay bridge acts as a barrier for a short period of time, the crack geometry reaches the moment "B" and "C". At the moment "C", the crack penetrates through the clay bridge, into the upper-lying sandstone with less stress. At this point, the treatment pressure may decrease as the crack penetrates into a new preferred low-stress zone, in fact, it is possible to reduce the crack length, as in the "D" moment. Due to this decrease in pressure, it is possible to reverse the flow of liquid into the barrel, with the probability of causing a premature "stop".

The impact of module relationships on height growth.

In general, the actual pressure of hydraulic fracturing, which is necessary to create a given crack length, the difference in the stresses of different deposits and the relative power of the reservoirs - these are the parameters that control the height growth. However, height may depend on other breeds, although, except in extreme cases, other properties rarely affect its growth.

(a)


(b)

Figure 9 - Height growth dependence on clay power

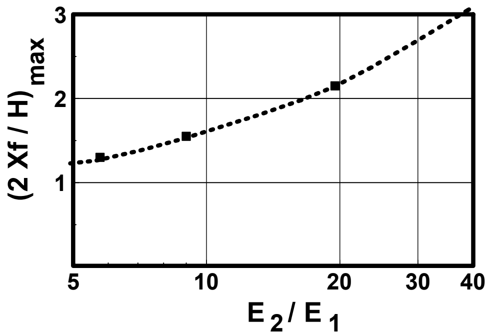


Figure 10 - Height dependence on module ratio

These properties include the Jung module, and the ratio of modules can influence the height of the crack. If the adjacent layers have a higher module value (i.e., they are tougher), they slow down the growth of the crack outside the zone. However, the calculations presented by Van Ikelen (as in fig. 10) show that the degree of height limit by the ratio of modules is small, i.e., the acceptable relationship is only a little more than one.

Other variables that affect height growth

In certain situations, the height of the crack can be controlled by other parameters. The main number is the shift of the boundaries of the top/bottom of the crack. It is most likely at shallow depths, either for deposits with abnormally high plastic pressure or increased natural fissures, as in coal seams.

This is an example of a strong, almost perfect obstacle to height growth. However, the available evidence proves that it is not among the common factors of fracking in oil and gas wells. This is explained by the findings of Toifel's laboratory studies, see the riceof the unc. 11. These experiments (and similar tests on Andersen) indicate that shifts in the boundaries of the section or planes of the plate are unlikely for depths below 1,000 to 2,000 feet (300 - 600 m).

Another variable that can influence height growth without discussed in the above examples, you can call gradients Stress in different layers (and gradient of hydrostatic pressure of hydraulic fracturing fluid). The height of the crack is associated with their difference, and this difference is usually small. For example, water-based liquid (0.43 psi/foot) and the normal gradient of mountain stresses this difference is 0.27 psi/foot; or only 27 psi 100 feet high. cm. Illustration 6. Typically, pressure/stress differences, as in this case, are dismissively small, and fluid pressure stresss and gradients are not the main parameters influencing altitude growth if the height of the crack is not too high. As a result, fracking with a significant height it can turn out to be more than 200 feet. At this value, due to the difference in gradients, effective pressure at the top of the crack can be 50 - 100 psi higher than the bottom.

Such is the value of effective pressure within the order of the typical end pressure of crack growth; at this point of difference, gradients begin to control the growth of geometry (with the corresponding growth of the crack, usually directed upwards). The three-dimensional hydraulic fracturing models in question at the source, in most cases show a crack that retains geometry close to the present conditions radial, with migrating up the trunk center of the crack coin-shape.

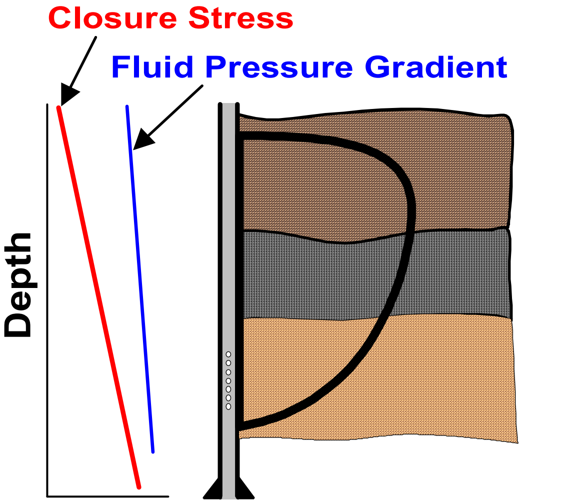


Figure 11 - Pressure/stress gradients

3.2 Selection of a well for hydraulic fracturing with a limited crack height

In accordance with the data of field X, 5 main candidate wells were selected, among which 1 candidate for hydraulic fracturing with a limit on the crack height was identified. For the selection of wells, all wells operating on the Triassic horizons of the X fields were considered.

The factors that determine the success of hydraulic fracturing are the correct choice of the object for operations, the competent selection of wells for processing and the use of the optimal hydraulic fracturing technology for each specific well.

The main factors for selecting candidates were:

- Current state of wells (idle, idle, periodic operation);
- Low production rates (low oil production rate);
- Low water content of products and low risks of increased water content after hydraulic fracturing;
- Adjacent wells where hydraulic fracturing was performed;
- New wells drilled in low-permeable deposits.

Table 4 shows a list of the main candidate wells for hydraulic fracturing at Field X. During the selection, cards of three wells № 12, № 63, № 54 were prepared for a good overview. As a result of the analysis, № 108 and № 20, there were potentials for conducting conventional hydraulic fracturing in the Triassic horizon T-IV+T-V.

Well № 54 was drilled and put into operation in 1998. It is operated in a mechanized way with the help of sucker rod pump on the horizon PT-V (IV object) with perforation intervals of 1320-1324 and 1331.5-1334m. As of 01.03.2021, the well is in operation with average monthly indicators: liquid flow rate of 6.46 m3/day, oil flow rate of 4.55 t / day with 11.25% water cut. The accumulated oil production is 26.25 thousand tons.

According to the Well logging data of 16.09.2019, the interval 1299.2-1313.2 m is identified as water-saturated, this interval will be covered during hydraulic fracturing, so there is a risk of increased water content after hydraulic fracturing. According to well logging tech. status of 16.09.2019 (before the transition to object IV) in the range of 826.4-842 m, there is a backflow of the column. In the intervals 790-792,6, 1318-

1319,6, there is a violation of the integrity of the e/k. According to the Ministry of Foreign Affairs, the alleged violations of the integrity of the e/c are highlighted in the intervals 786,9-788, 790-791,8, 1318,2-1318,8 m, e/c wear is noted in the intervals of 1314.7-1318.2, 1318.8-1321.7 m. According to the sonic logging, the contact with the column is 19.8% solid, and the contact with the rock is 12.9% solid. Taking into account the age of the well, several transitions between objects with the implementation of acoustic cement bong log, unsatisfactory technical condition of the well before the transition to object IV, hydraulic fracturing can be complicated by the occurrence of emergency situations, as well as an increase in water cut, in this regard, it is not recommended to conduct hydraulic fracturing on this well.

Well № 63 was drilled and put into operation on April 23, 1998. It is operated in a mechanized way with the help of sucker rod pump on the horizon PT-V (IV object) with perforation intervals 1231,0-1235,0; 1270,0-1274,0; 1304,0-1306,0; 1309,0-1312,0; 1315,0-1328,0 m. As of 01.03.2021, the well is in operation with average monthly indicators: liquid flow rate of 53.4 m3/day, oil flow rate of 11.79 t / day with 72.16% water cut. The accumulated oil production is 57,834 thousand tons. Hydraulic fracturing on the T-V horizon in the perforation intervals of 1315-1328 m.

The interval of 1304-1312 and 1315-1328 m is separated from the main SP, which complicates the hydraulic fracturing due to the formation of undesirable multi-cracks and uncontrolled leakage of hydraulic fracturing fluid, and is also located near the underlying water-saturated layers of the T-V horizon (1338.5 m). For these reasons, it is recommended to lower the packer to a depth in the region of 1280-1282m for temporary isolation of perforation intervals 1231-1274 m. Approximate tonnage of 10 tons.

Well № 12 was drilled and put into operation on June 8, 1994. It is operated in a mechanized way with the help of sucker rod pump on the horizon PT-I (object III) with perforation intervals of 974.0-977.0 m. As of 01.03.2021, the well is in operation with average monthly indicators: liquid flow rate of 42.11 m3/day, oil flow rate of 11.06 t / day with 66.33% water cut. The accumulated oil production is 37,335 thousand tons. The recommended hydraulic fracturing at the T-V horizon in the perforation intervals of 1323-1328 m. Taking into account the age of the well, several transitions between objects with the implementation of acoustic cement bong log, unsatisfactory technical condition of the well before the transition to object IV, hydraulic fracturing can be complicated by the occurrence of emergency situations, as well as an increase in water cut, in this regard, it is not recommended to conduct hydraulic fracturing on this well.

According to the wells, it can be understood that the best option for conducting hydraulic fracturing with a limited crack height will be № 63. The well production profile and well logging plate are shown in Figures 12 and 13, respectively.

Table 4 - List of major fracking wells

Well information												Recommendation for hydraulic fracturing							Risks
№	Well	Object	Horizon	Condition	Operating method	Effective perforation interval	Bottomhole, fact.	Accumulated oil production	**Qf**	**Water cut**	**Qo**	**Horizon**	**Perforation intervals for hydraulic fracturing**	**h eff**	**Proppant, t**			**Comments**	**Risks**
						m	m	t	**m3/day**	**%**	**t/day**		**m**	**m**	**16/20**	**12/18**	**Total**		
1	108	II	I J2	In work	Sucker rod pump	781,0-784,0 786,0-790,0	1205	18940	**35,15**	**91,576**	**2,51**	T-V	**1328-1335**	7	22	8	**30**	There is a potential for conducting conventional hydraulic fracturing in the Triassic horizon T-IV+T-V	No
2	12	III	I PT	In work	Sucker rod pump	974,0-977,0	977	37335,94	**42,11**	**66,33**	**11,06**	T-V	**1323-1328**	5	8	5	**13**	Good flow rate (higher than 10 t / day)	The risk of a crack breaking into water-saturated layers below the depth of 1341,5 m
3	54	IV	V-PT	In work	Sucker rod pump	1320,0-1324,0 1331,5-1334,0	854	26250,1	**6,46**	**11,25**	**4,55**	T-V	**1320-1324** **1331,5-1334**	6,5	10	5	**15**	Poor technical condition of the well	No
4	63	IV	V-PT	In work	Sucker rod pump	1231,0-1235,0 1270,0-1274,0 1304,0-1306,0 1309,0-1312,0 1315,0-1328,0	1377	57834,15	**53,40**	**72,16**	**11,79**	T-V	**1315-1328**	13	7	3	**10**	A good candidate to consider limiting the crack height	The risk of a crack breaking into water-saturated layers below the depth of 1338.5 m
5	20	Chargebacks	III-PT	In work	Sucker rod pump	1226,0-1231,0	1250	49998,17	**29,86**	**83,31**	**3,94**	T-V	**1304-1308** **1313-1318** **1321-1328**	16	40	10	**50**	There is a potential for conducting conventional hydraulic fracturing in the Triassic horizon T-IV+T-V	No

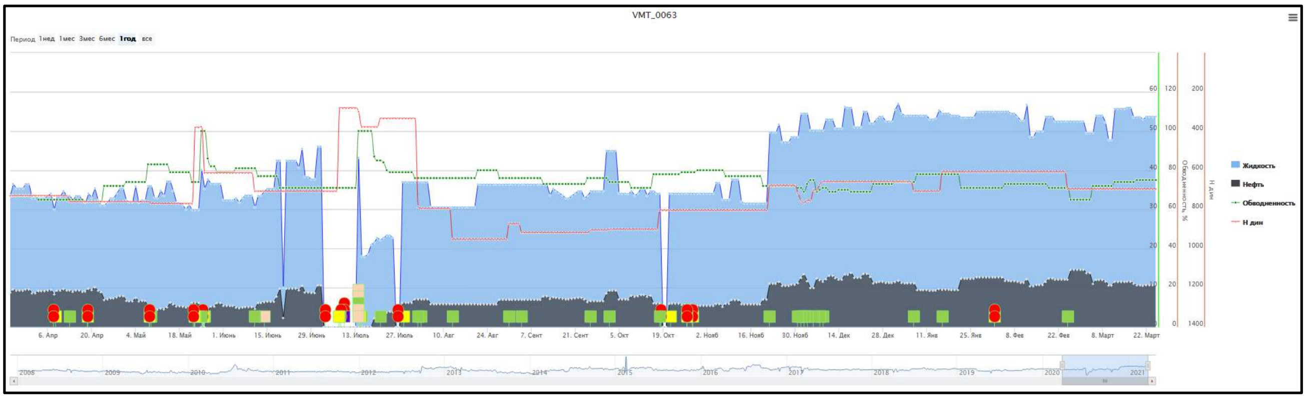


Figure 12 - Production profile №63 of the X field

3.3 FracPro Hydraulic Fracturing Simulation

FracPro is a hydraulic fracturing simulator, an industrial software for mathematical modeling and analysis of the fracturing process during hydraulic fracturing. The hydraulic fracturing simulator is designed to solve a number of applied problems related to modeling the propagation of a hydraulic fracturing crack in a formation, taking into account the geological structure of the formation, the geomechanically properties of the composing rocks, the dynamics of the flow of the fracturing fluid and the transport of proppant. Hydraulic fracturing modeling software is used in the oil and gas industry in the planning, monitoring and analysis of the application of hydraulic fracturing technology.

Import of well data. Initially, to create a hydraulic fracturing design, you need to import data about the well design and information about the well and processing:

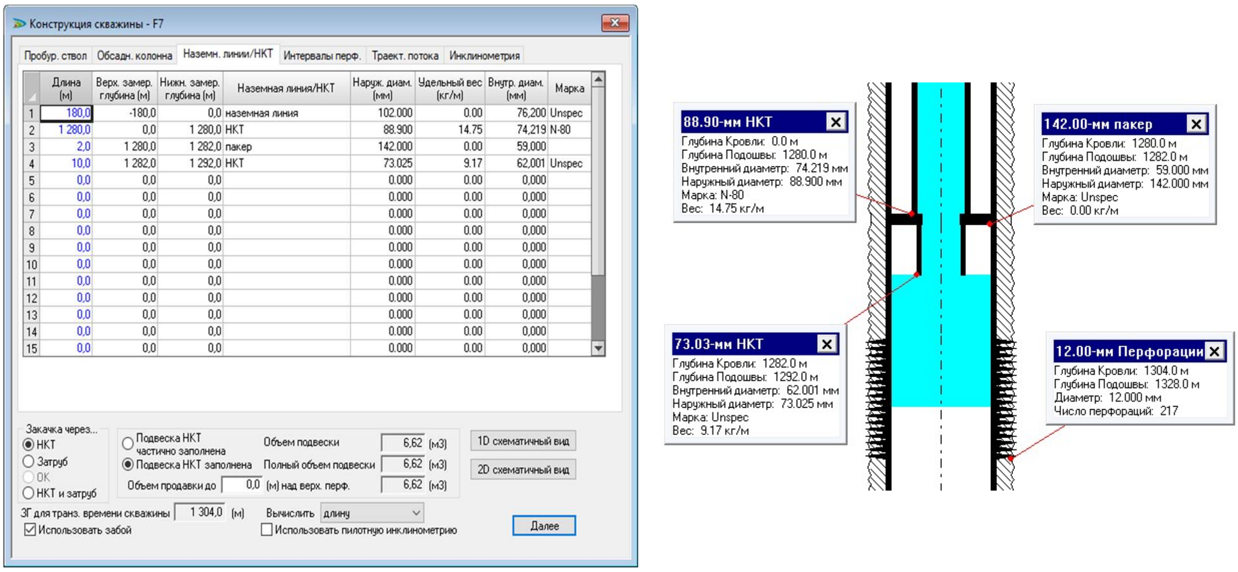


Figure 13 - Construction of the well №63 of the field X

The acts of the general design of wells were used and the depth of the projected hydraulic fracturing with the help of the well logging was included in the program (Fig. 14). Due to the lack of data on inclinometers, the column under the appropriate name was not filled, however, according to available information, well 63 is vertical. Also, the parameters of the heat transfer of the reservoir were taken from the data on the field.

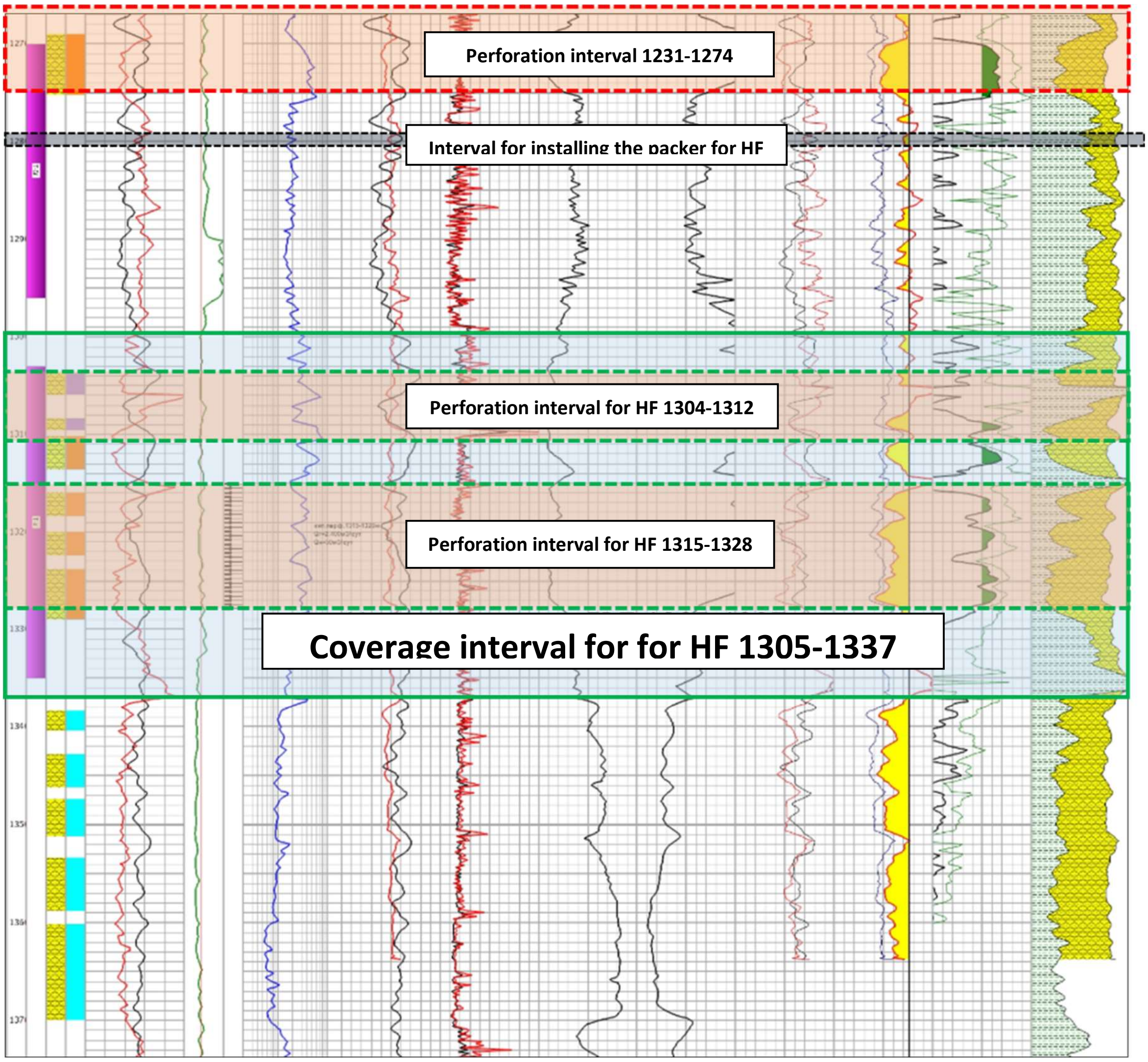


Figure 14 - Tablet logging of the open borehole № 63 of the field X

Importing reservoir data. The next step is to enter data about the reservoir, namely, about the filtration-capacity and geomechanical properties of rocks. The main parameters of the reservoir are porosity, permeability, oil saturation and thickness. The data entry technique was based on lithologies. This means that we first imported the data from the geophysical survey of the well and selected the base in the rock library. The basic mechanical, chemical, and thermophysical properties of the rocks were hammered into the properties of the rocks. For the correctness of all the parameters, we used the data that was found out from the hydraulic fracturing that was in well № 91, since they are located at close distances. Additional properties included drainage area, compressibility, viscosity, porosity, reservoir pressure, permeation ratio, and average crack pressure.

Selection of liquids and proppants. The next step is to select the fluid and proppant for the planned hydraulic fracturing design and take into account the expected geometric structure of the formation. Proppants are used to fix cracks created during hydraulic fracturing. It is a similar-sized pellet with a typical diameter of 0.5 to 1.2 mm. This design uses the typical proppant values for this deposit, which are BorProp 16/20 and BorProp12/18. Such proppants have a bauxite base, are characterized by a homogeneous structure and uniform crystallization of the material.

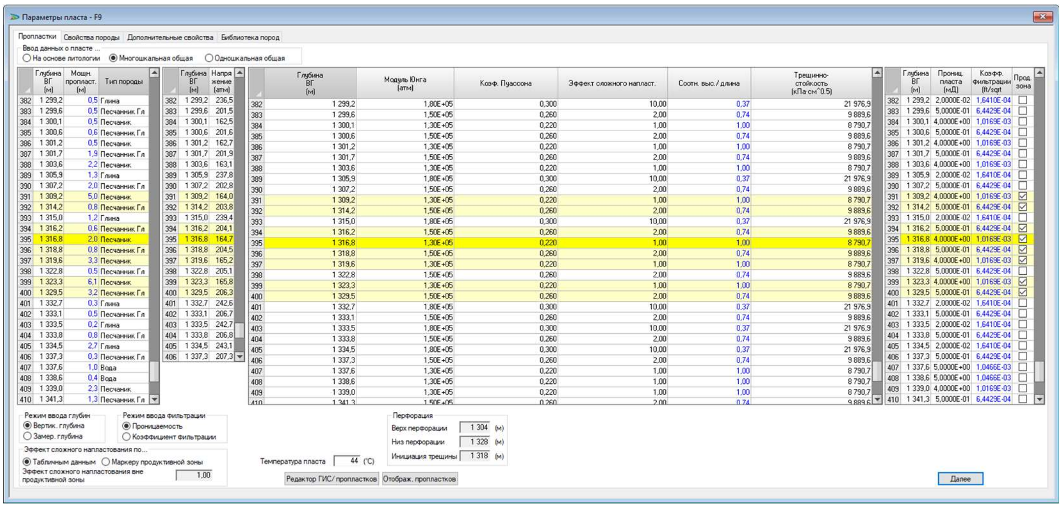


Figure 15 - Formation parameters of well №63 of field X

When selecting the hydraulic fracturing fluid, we used the Crosslinked Gel #25 (Delta Frac 140 30 lb/Mgal gel 2% KCl) and Linear Gel #25 (Water Frac G (WG – 19) 30 lb/Mgal gel) available in the Halliburton fluid database. For convergence with the actual hydraulic fracturing fluid used at field X, the rheological parameters n' and K' were changed using laboratory studies of the hydraulic fracturing fluid.

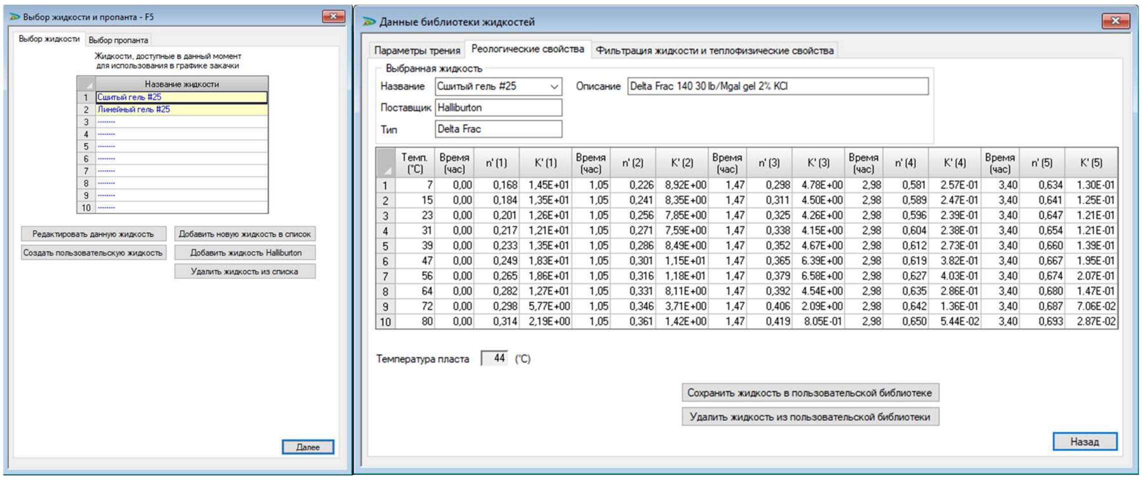


Figure 16a - Selection of liquid № 63 field X

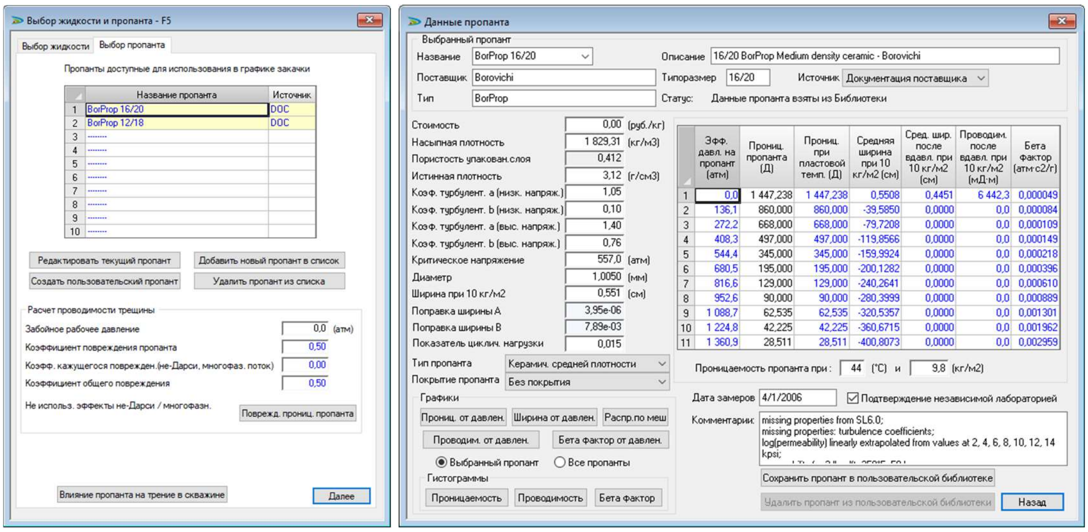


Figure 16b - Selection of proppant № 63 field X

The schedule of hydraulic fracturing. While the ultimate goal of well stimulation is to increase its productivity using cost-effective activities and materials, the challenge of hydraulic fracturing design and analysis is to create optimal pumping schedules showing the volumes and concentrations of propant portions. The pumping schedule was similar to the neighboring well 91: consumption 1 and 2, propane concentration 1 and 2.

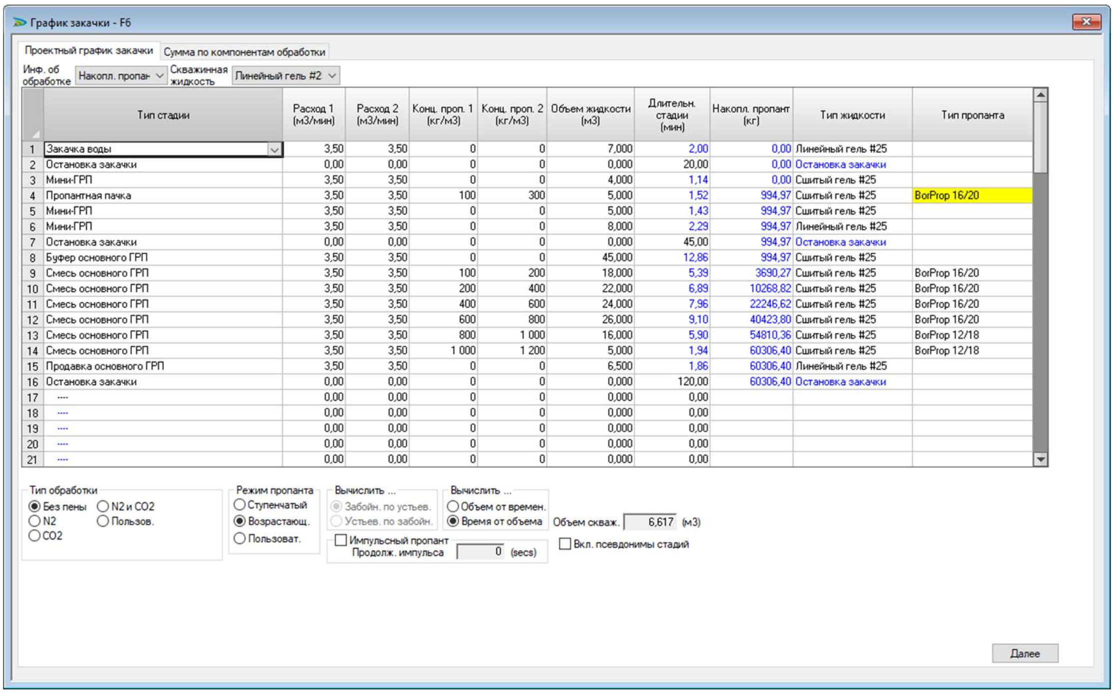


График закачки - F6

Проектный график закачки | Сумма по компонентам обработки

Инф. об обработке: Накопл. пропан · Скважинная жидкость: Линейный гель #2

	Тип стадии	Расход 1 (м3/мин)	Расход 2 (м3/мин)	Конц. проп. 1 (кг/м3)	Конц. проп. 2 (кг/м3)	Объем жидкости (м3)	Длительн. стадии (мин)	Накопл. пропант (кг)	Тип жидкости	Тип пропанта
1	Закачка воды	3,50	3,50	0	0	7,000	2,00	0,00	Линейный гель #25	
2	Остановка закачки	0,00	0,00	0	0	0,000	20,00	0,00	Остановка закачки	
3	Мини-ГРП	3,50	3,50	0	0	4,000	1,14	0,00	Сшитый гель #25	
4	Пропантная пачка	3,50	3,50	100	300	5,000	1,52	994,97	Сшитый гель #25	BorProp 16/20
5	Мини-ГРП	3,50	3,50	0	0	5,000	1,43	994,97	Сшитый гель #25	
6	Мини-ГРП	3,50	3,50	0	0	8,000	2,29	994,97	Линейный гель #25	
7	Остановка закачки	0,00	0,00	0	0	0,000	45,00	994,97	Остановка закачки	
8	Буфер основного ГРП	3,50	3,50	0	0	45,000	12,86	994,97	Сшитый гель #25	
9	Смесь основного ГРП	3,50	3,50	100	200	18,000	5,39	3690,27	Сшитый гель #25	BorProp 16/20
10	Смесь основного ГРП	3,50	3,50	200	400	22,000	6,89	10268,82	Сшитый гель #25	BorProp 16/20
11	Смесь основного ГРП	3,50	3,50	400	600	24,000	7,96	22246,62	Сшитый гель #25	BorProp 16/20
12	Смесь основного ГРП	3,50	3,50	600	800	26,000	9,10	40423,80	Сшитый гель #25	BorProp 16/20
13	Смесь основного ГРП	3,50	3,50	800	1 000	16,000	5,90	54810,36	Сшитый гель #25	BorProp 12/18
14	Смесь основного ГРП	3,50	3,50	1 000	1 200	5,000	1,94	60306,40	Сшитый гель #25	BorProp 12/18
15	Продавка основного ГРП	3,50	3,50	0	0	6,500	1,86	60306,40	Линейный гель #25	
16	Остановка закачки	0,00	0,00	0	0	0,000	120,00	60306,40	Остановка закачки	
17	----	0,00	0,00	0	0	0,000	0,00			
18	----	0,00	0,00	0	0	0,000	0,00			
19	----	0,00	0,00	0	0	0,000	0,00			
20	----	0,00	0,00	0	0	0,000	0,00			
21	----	0,00	0,00	0	0	0,000	0,00			

Тип обработки: Без пены; N2 и CO2; N2; Пользов.; CO2

Режим пропанта: Ступенчатый; Возрастающ.; Пользоват.

Вычислить ...: Забойн. по устьев.; Устьев. по забойн.

Вычислить ...: Объем от времен.; Время от объема

Объем скваж. 6,617 (м3)

Импульсный пропант · Продолж. импульса 0 (secs)

Вкл. псевдонимы стадий

Далее

Figure 17 - Download schedule of № 63

At the end of the simulation, the profile of the cracked hydraulic fracturing well № 63. The profile of the crack shows the different parameters of the final model and the cracked hydraulic fracturing (Figure 18).

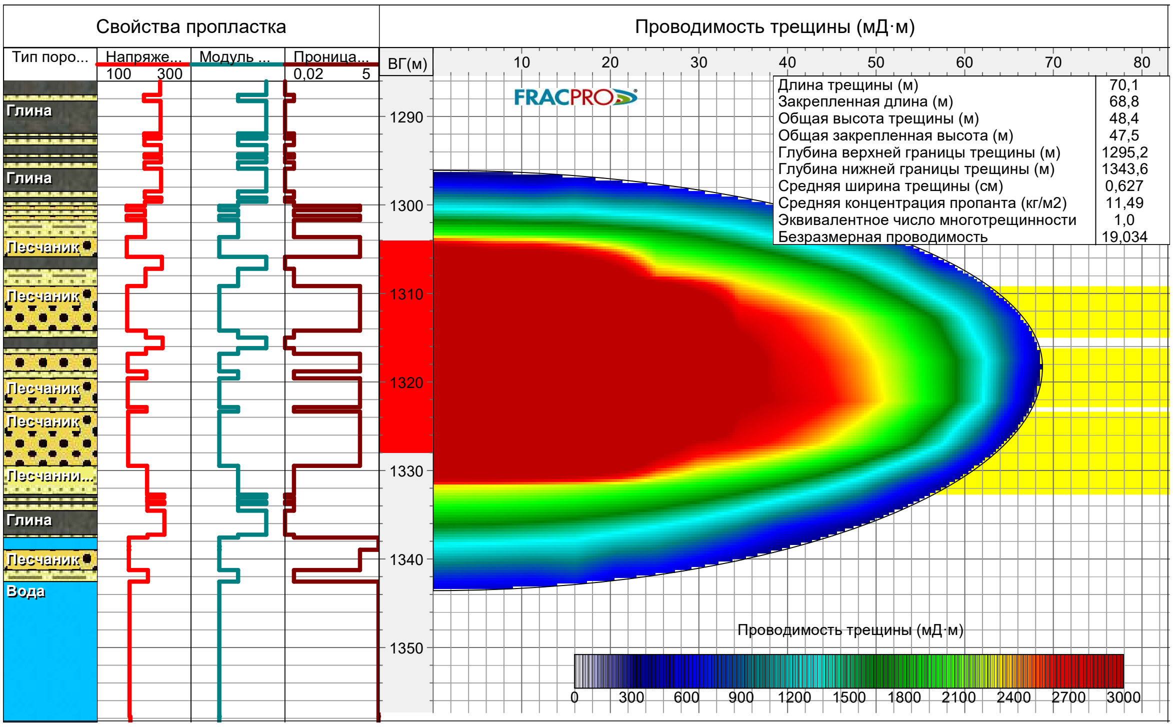


Figure 18 - Crack profile №63 (1-model)

RESULTS

4.1 Model Details

This paper describes in detail all the possible parameters that affect the height of the crack during hydraulic fracturing and the world experiments of limiting the height of the crack during hydraulic fracturing using special chemical reagents. According to the analysis of a suitable option at field X for hydraulic fracturing with a limited crack height, the most effective method was identified, it turned out to be Viscoelastic hydraulic Fracturing Fluid (ClearFrac). For a detailed analysis and visual view of the crack height, it was reasonable to compare three different models: the Basic Model, the Proppant Tonnage Limitation Model, and the Viscoelastic Fluid Utilization Model. It should be noted that all models have common parameters, such as the Well Design and Reservoir Data.

4.1.1 First Model

The first Model (the Basic Model) is the originally designed hydraulic fracturing at well № 63, which was injected with 60 tons of propane. In Figure 18, it is clearly visible that the crack has reached the water layer and from the geometry of the crack, you can see that the height of the sound is high.

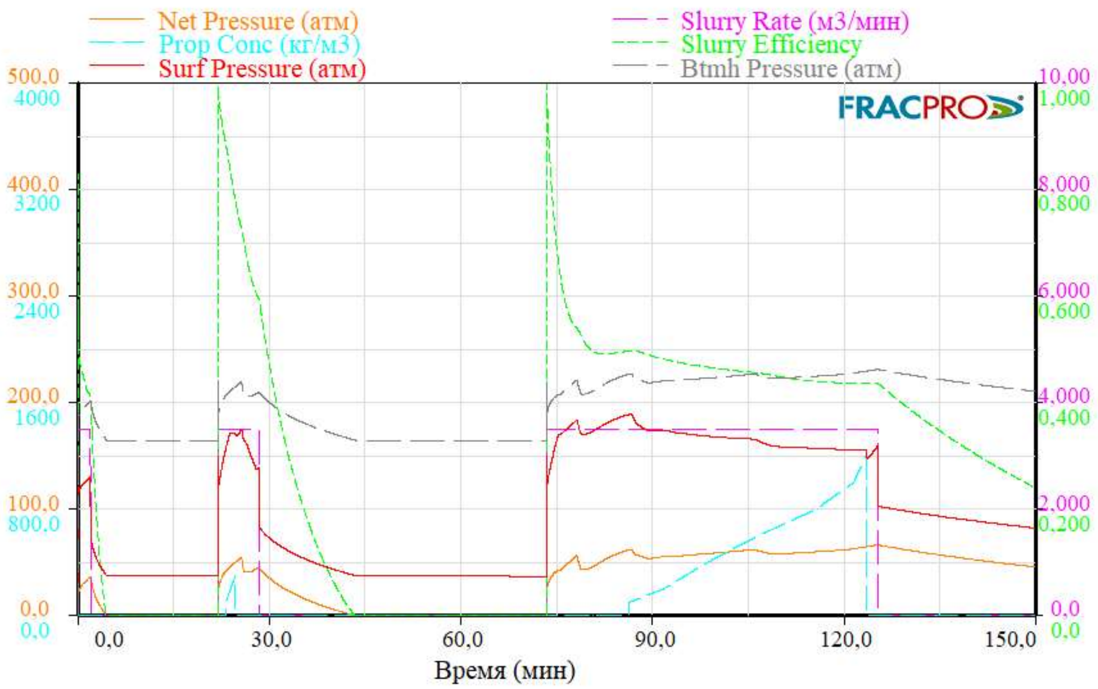


Figure 19. Planned hydraulic fracturing schedule (1-model)

4.1.2 Second Model

The second Model (the Model of Limiting the tonnage of proppant) is the reduction of the accumulated proppant to a minimum in which the created crack will be located in the zone of oil layers. According to the model it can be observed that the tonnage of proppant was reduced from 60 tons to 50 tons. Figure 20 shows that the crack did not reach the water layer and compared to the Basic Model, it is limited in height.

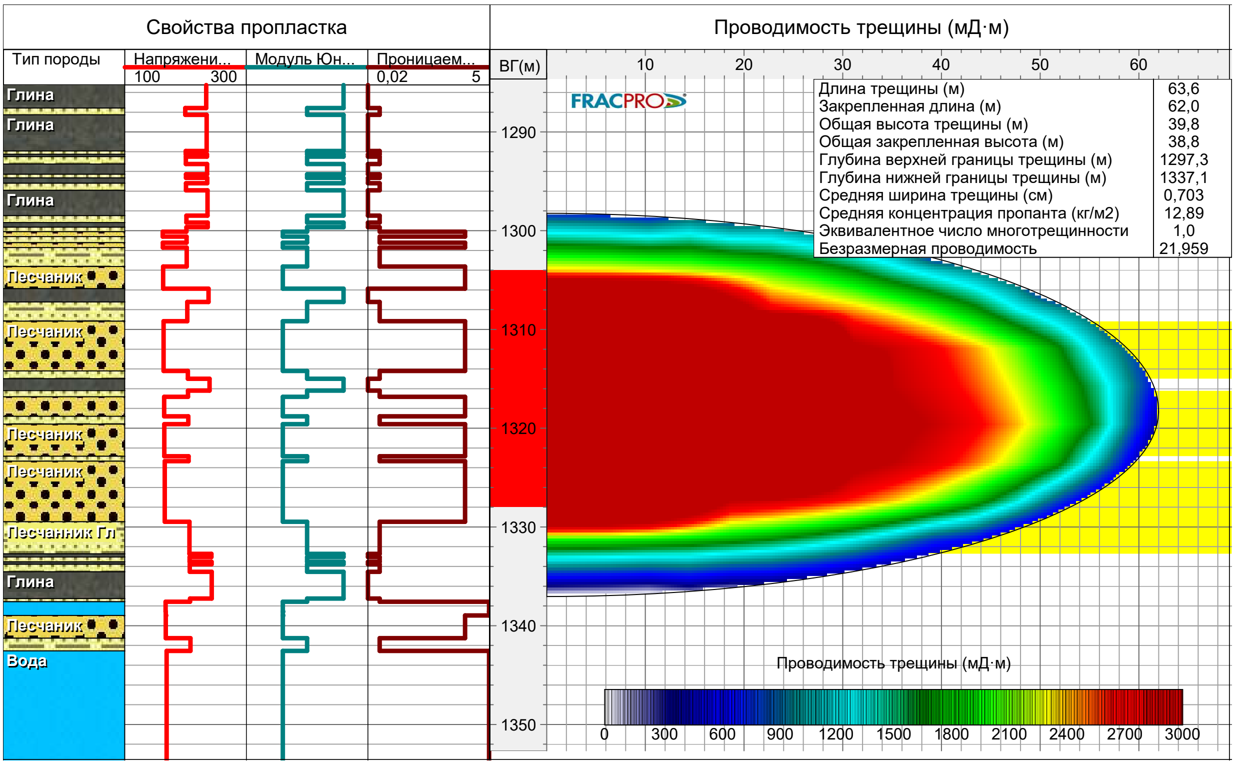


Figure 20. Crack profile №63 (2-model)

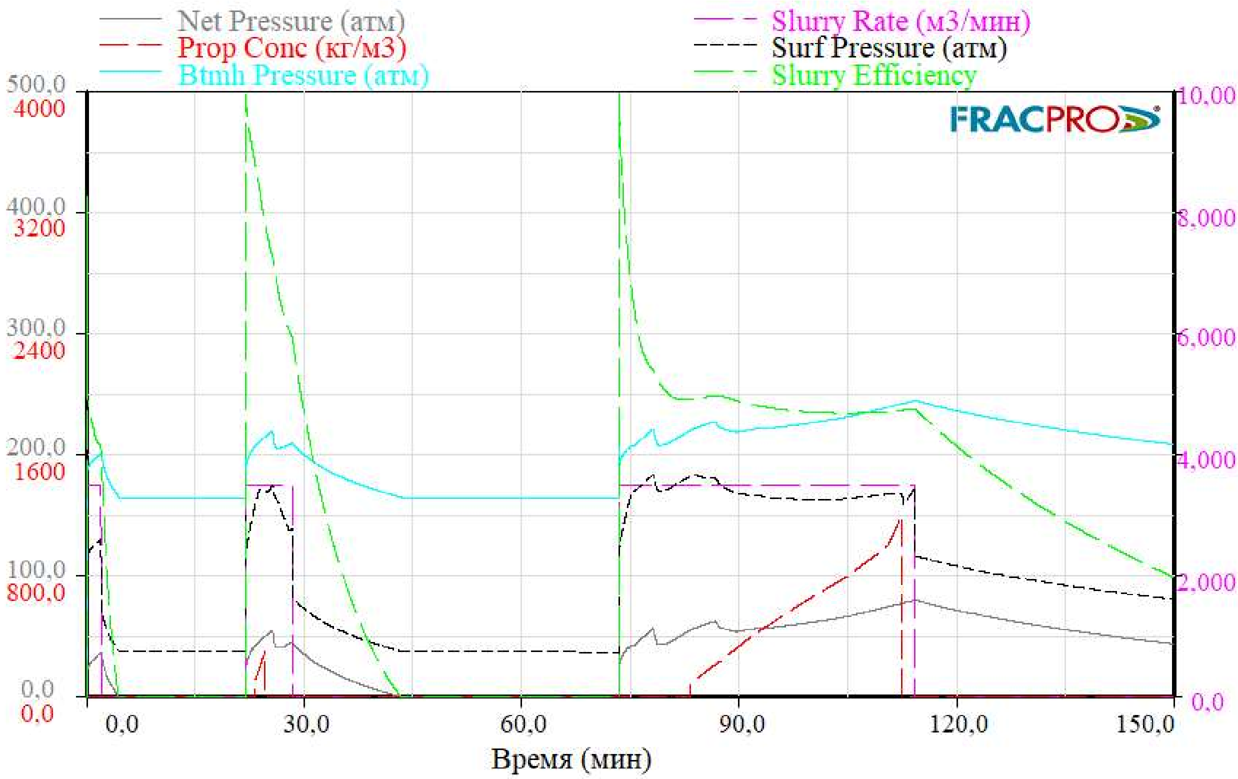


Figure 21. Planned hydraulic fracturing schedule (2-model)

4.1.3 Third Model

The third Model (The model with the use of Low-viscosity gels) is due to a change in the hydraulic fracturing fluid supplied. Hydraulic fracturing with the use of Low-viscosity gels (ClearFrac) – differs only in the type of liquids used. As we remember, in conventional hydraulic fracturing, there are concepts like Linear and Crosslinked gels. In this Model, we use approximately this kind of gels, but the rheology of the liquids is changed. In the ClearFrac method, you need to take two liquids: WF and 2% J508W. The first is water-based, and the second is also water-based with 4% Cs content and 2% concentration of the total liquid. Finally, a model with a limited crack height is obtained.

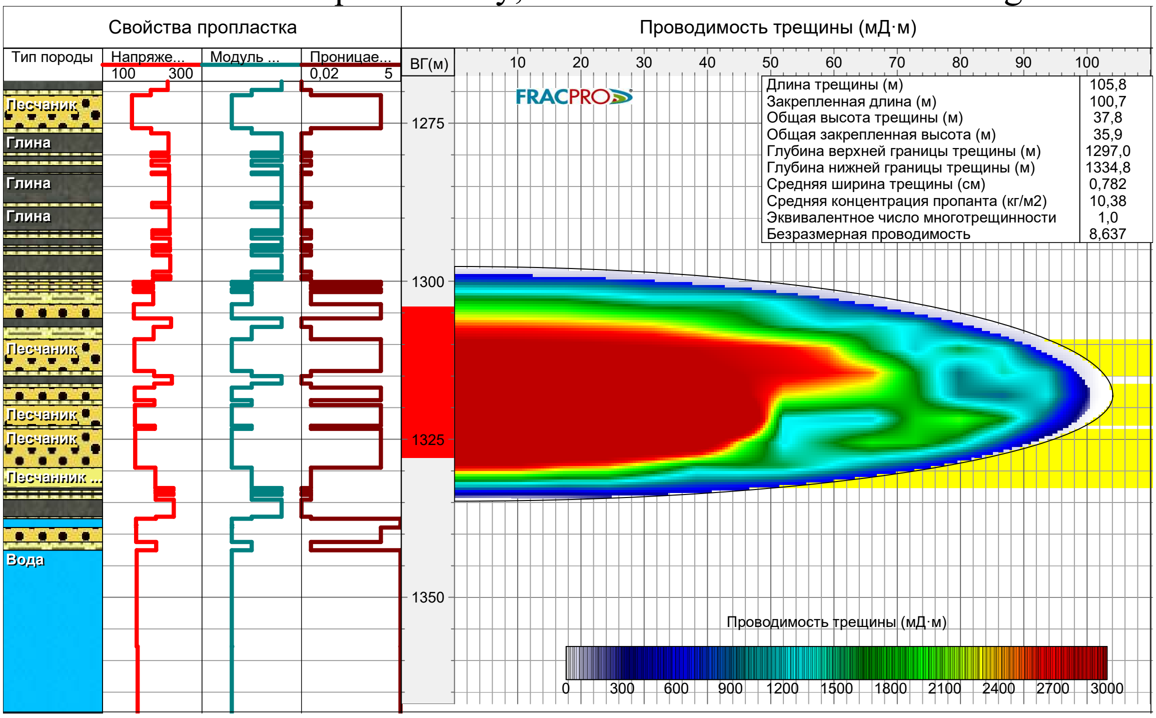


Figure 22. Crack profile №63 (3-model)

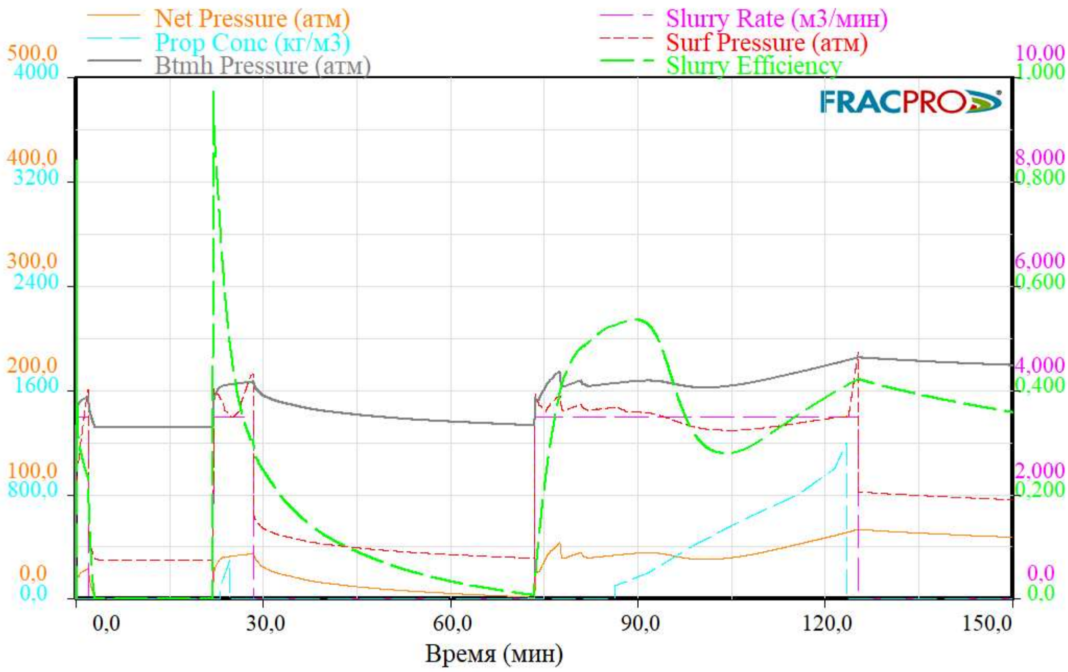


Figure 23. Planned hydraulic fracturing schedule (3-model)

4.2 End Analysis

In the final analysis, all the fracture profiles of the hydraulic fracturing were placed on the main plate of the geophysical study of well № 63. The scale of all models is the same, and for clarity of the picture, the line of the water oil contact is visualized. The data on the deposit explains that it has a low permeability and high water cut. Therefore, the most effective crack will be the one that has more coverage across the reservoir. Also, the crack should have good indicators for height, width and flow rate increase. Naturally, the height should be more limited than the others.

Each hydraulic fracturing operation must be accompanied by a calculation of the increase in flow rate after hydraulic fracturing. This is done on the usual calculated Excel file that was made in the company where I did my internship. This file contains the basic formulas of production technologies and techniques, as well as all the indicators before and after hydraulic fracturing. This indicator shows how cost-effective our hydraulic fracturing operation is. You can add these conclusions in the economic calculation of the project. The calculation of the increase in flow rate after hydraulic fracturing and the total additional production for 1 year are shown in Table 11. A detailed calculation of the total additional production for 1 year is described in the economic part of the project.

To give arguments other than visual, we can mathematically show which model is optimal. To do this, based on the above observations, we set the indicators of the height, width, length of the crack and the flow rate of the optimal model and take them into account by 100%. The full calculation of the optimal model is shown in Table 6.

Table 5 - Calculation of additional production

Model		**1-Model**		**2-Model**		**3-Model**	
Tons		**60**		**50**		**60**	
Filter mode	Pseudo-installed	**Before HF**	**After HF**	**Before HF**	**After HF**	**Before HF**	**After HF**
Liquid flow rate	**(Q_{liq})** [m3/day]	47,9	169,7	47,9	160,8	47,9	201,1
Water flow rate	**(Q_w)** [m3/day]	34,5	122,2	34,5	115,8	34,5	144,8
Oil flow rate	**(Q_o)** [t/day]	10,6	37,6	10,6	35,7	10,6	44,6
Water cut	**(f_w)** [%]	72,0	80,0	72,0	72,0	72,0	72,0
Increase in oil production rate	**(ΔQ_o)** [t/day]		**13,7**		**25,1**		**34,0**

1-Model	Cumulative additional production for 1 year	Q, t	4150,415
2-Model			7604,045
3-Model			10300,3

Table 6 - Calculating the optimal model

Parameters	1-Model	2-Model	3-Model	Optimal model
Length, m	70,10	63,60	105,80	**110,00**
Height, m	48,40	39,80	37,80	**37,00**
Width, mm	0,63	0,70	0,78	**0,80**
Increase in the flow rate, t/day	27,00	25,10	34,00	**35,00**
Length, %	63,73	57,82	96,18	
Height, %	76,45	92,96	97,88	
Width, %	78,75	87,50	97,50	
Increase in the flow rate, %	77,14	71,71	97,14	
Total	74,02	77,50	**97,18**	

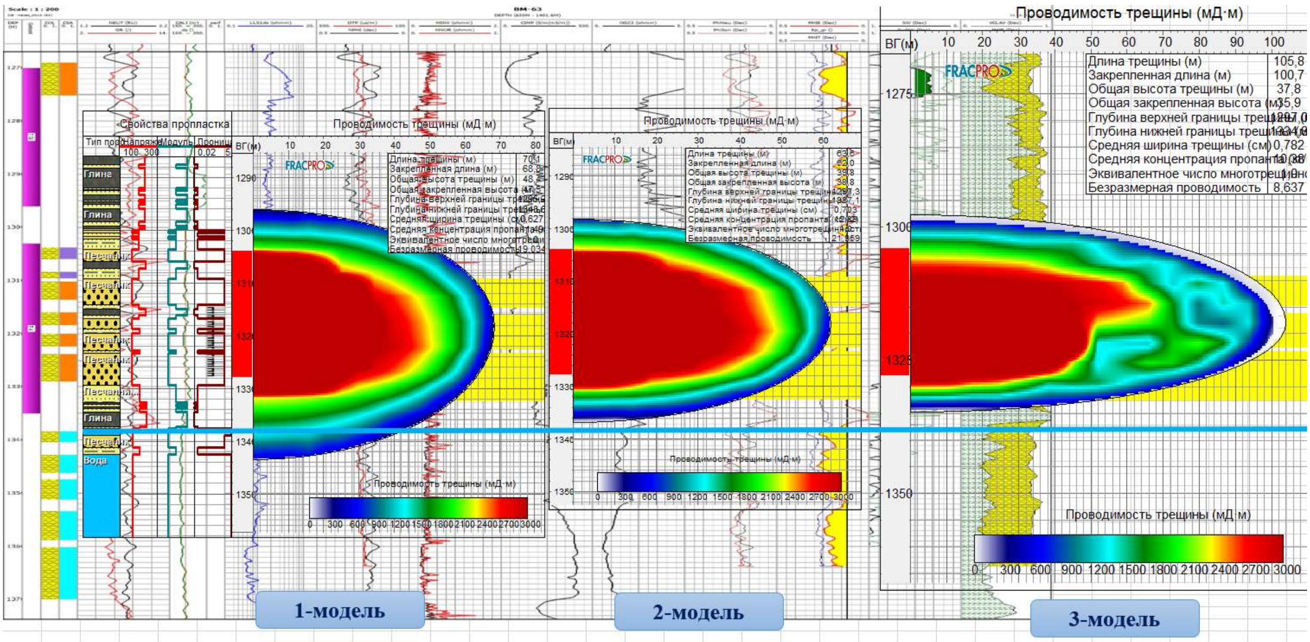


Figure 24. Comparison of Models

It can be observed from Figure 24 that the 3-model has good indicators than the others and it is more optimal. According to the 1 - model, we see that it breaks through into the water-saturated layer, which means that after hydraulic fracturing, its water content will increase and this will no longer be profitable. Further, the 2-model does not break through, but it is in height, width and length behind the 3-model. In the end, we can say with confidence that the 3-model, which uses the method of limiting the height of the hydraulic fracturing crack with the use of special chemical reagents, namely Low-viscosity gels, showed a good result and this model is optimal for well 63 at field X.

4.3 History matching

Model calibration for us is the fitting of the model, carried out in order to ensure the best agreement of the model output data with the measurement results. In order for us to trust the model, we initially used real hydraulic fracturing data in the neighboring well № 91 before modeling. Therefore, we can compare the design for the well № 91 with the same fracturing fluid and propane that was in the 1-model. As we can see in Figure 25, these models are similar and have similar crack conductivities. As a result, based on the above observations, we can trust this model.

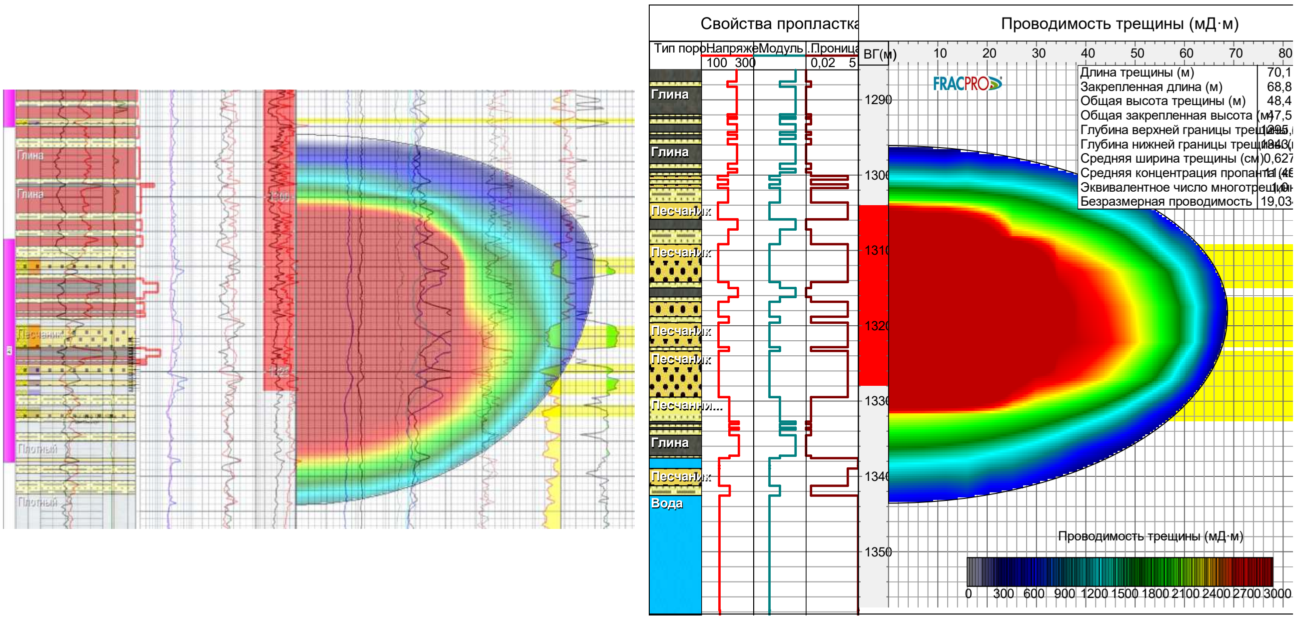


Figure 25. History matching (1-model)

ECONOMIC AND ENVIRONMENTAL PART

5.1 Economic part

The huge increase in hydrocarbon productivity due to the creation of an extensive network of fractures in the hydraulic fracturing process is an indicator of the economic feasibility for the oil and gas industry to use huge hydrocarbon resources in previously undeveloped low-permeable unconventional reservoirs.

Any relatively large project proposed for implementation in the energy sector of the economy needs a thorough preliminary assessment of its development opportunities, primarily from the point of view of investors, that is, companies (companies) interested in participating in the project and counting on a profitable investment of their money in the project.

In this project, for the economic assessment of the technological indicators of the field development options, the change in income due to the use of oil development and production technologies (increase in oil production) is estimated. At the same time, the following parameters are analyzed: the additional volume of oil production, the period of reaching the economic limit, the payback period of investments, capital investments, operating costs, net profit, accumulated cash flow and economic indicators. The analysis of the financial profitability of the project is based on modeling the flows of real money that develop over the entire period of its implementation.

We will calculate the economic efficiency of hydraulic fracturing carried out in the 3-model from field X in order to better understand how much it is advisable to conduct hydraulic fracturing not only from the technological side, but also from the economic side.

Table 7 - Baseline averaged for a single well (3 model)

Indicators	Esle. I mean.	It's ed. Izm.	Values
The amount of daily production rates for wells before hydraulic fracturing	$\sum q_1$	T/day	10,6
The amount of daily production rates for wells after hydraulic fracturing	$\sum q_2$	T/day	44,6
Operating ratio	Kr	-	0,83
Average cost per well processing	K	Tg.	50 000 000
Number of wells being processed	W	-	1
Number of treatments per well	n	-	1
Cost of production of 1 ton of oil to hydraulic fracturing	C_1	Tg.	6480

The calculation of additional oil production from hydraulic fracturing is shown in Table 11, but is not detailed.

$$\Delta Q = \left(\sum q_2 - \sum q_1\right) \times 365 \times K_{\mathrm{r}}$$

Where the q is an additional annual production; 365 - the number of days of work.

After hydraulic fracturing, the well increased its productivity by 4 times, respectively, we get:

$$\Delta Q = (\sum q_2 - \sum q_1) \times 365 \times K_{\mathrm{r}} = (44{,}6 - 10{,}6) \cdot 365 \cdot 0{,}83 = 10300{,}3 \text{ t.}$$

This type of processing, as well as additional annual oil production, entails additional costs. Thus, knowingthecost of one processing, as well as the number of effective days of work, we calculate the total size of capital investments according to the following formula:

$$\Delta CI = K * W * n$$

where ΔCI - the total capital investment of Tg.

Taking into account that one well has made one treatment in one well, we get:

$$\Delta CI = KWn = 50\,000\,000 \cdot 1 \cdot 1 = 50\,000\,000 \text{ Tg.}$$

The amount of additional operating costs is calculated by the number of conditional variables costing one ton of oil for an additional annual oil production. Conditional variables include those articles and calculations of the cost of oil, the costs of which directly depend on the amount of oil extracted.

These articles are:
1. The cost of energy spent on the extraction of 1 ton of oil - ΔEE, 480 tons;
2. The cost of artificial impact on the seam - ΔAI, 540 tg.;
3. Oil and gas collection and transportation costs - ΔGaT, 480 tg;
4. The cost of oil preparation is - ΔOP, 600 tg;
5. The cost of maintaining and operating the equipment is - ΔMaO, 600 tg.

The amount of operating expenses (additional) is calculated by the following formula:

$$\Delta E = (\Delta\text{EE} + \Delta\text{AI} + \Delta\text{GaT} + \Delta\text{OP} + \Delta\text{MaO}) \times \Delta Q, \text{tg}$$

where, ΔE - the amount of additional operating expenses (tg).

The amount of conditional-variable articles expensing the cost of one ton of oil to hydraulic fracturing (tg):

$$\Delta\text{EE} + \Delta\text{AI} + \Delta\text{GaT} + \Delta\text{OP} + \Delta\text{MaO} = 2700 \text{ tg}$$

$$\Delta\text{E} = 2700 \times 10300{,}3 = 27\ 810\ 810 \text{ tg.}$$

We calculate the cost change according to the following formula:

$$\Delta C = C_1 - C_2$$

where, $\Delta C$is the change in the cost of tg.; C_1 is the cost of oil production before fracking = 6480 tg.; C_2 is the cost of one ton of oil after fracking tg. In turn, the cost of one ton of oil after hydraulic fracturing is found by the formula:

$$\text{C}_2 = \frac{\Sigma\text{E} + \Delta\text{E} + \Delta\text{C}I}{Q_1 + \Delta Q}$$

where, ∑E - the full expenses of gross oil production before the event. Q_1 - annual oil production before the event, we find according to the formula:

$$Q_1 = \sum q_1 \times 365 \times K_\text{r} = 10.6 \cdot 365 \cdot 0{,}83 = 3211{,}27 \text{ t.}$$

The full expenses of gross oil production to hydraulic fracturing is found according to the formula:

$$\sum\text{E} = Q_1 \times P_1 = 3211{,}27 \cdot 6480 = 20\ 809\ 029{,}6 \text{ tg.}$$

Then, the cost of one ton of oil after the hydraulic fracturing:

$$\text{C}_2 = \frac{20\ 809\ 029{,}6 + 27\ 810\ 810 + 50\ 000\ 000}{3211{,}27 + 1\quad 300{,}3} = 7298{,}92 \text{ tg.}$$

Annual oil production after hydraulic fracturing is found similarly to annual production before hydraulic fracturing.

$$Q_2 = \sum q_2 \times 365 \times K_э = 44{,}6 \cdot 365 \cdot 0{,}83 = 13511{,}57 \text{ т.}$$

Table 8 - Indicators of economic efficiency after the event (3-model)

Indicators	Before the event was introduced	After the event was introduced	Rejection absolute
Oil production, thousands of tons	3211,27	13511,57	+10300,3
Average daily debit of wells, t/day	10,6	44,6	+34
Cost of 1 ton of oil, tg.	6480	7298,92	+818,92
Economic effect, thousands of tg.	20 809 029,6	98 619 868,5	77 810 838,9
The profit growth remaining at the company's disposal is thousands of tons.	-	77 810 838,9	77 810 838,9

After analyzing the received values, we can conclude that the economic efficiency of hydraulic fracturing is very high during the calculated year. after the hydraulic fracturing was 98,619,868.5 tenge, that is more than 4 times the justification for the use of hydraulic fracturing on this well is economically feasible.

5.2 Environmental Part

As a result of hydraulic fracturing, the groundwater may be contaminated with chemicals. 1% of the hydraulic fracturing fluid is a helium solution based on chemical additives that allow you to create cracks. If the proppant is relatively harmless, then chemical additives are quite toxic substances. In the United States, hydraulic fracturing is so developed that the damage from it is also noticeable.

When viewing the analysis of the current state of surface and underground waters, in hydrogeological terms, the considered territory of the deposit is located within the Buzachinsky artesian basin of the second order, which is part of the Caspian Artesian basin. According to the nature of flooding and the common lithological-facies composition of water-bearing rocks, aquifers and complexes of Quaternary, Cretaceous, Jurassic and Permian-Triassic sediments are distinguished in the basin.

In the best 3-model, we see that our crack does not reach the depth of the ground water and also the lower aquifer. Therefore, based on the application of hydraulic fracturing at a given well, it is environmentally appropriate.

CONCLUSION AND RECOMMENDATIONS

6.1 Conclusion

At the field, some technologies of processing the bottom-hole zone, as well as perforation and joining of the lower and overlying layers were used simultaneously with hydraulic fracturing. In the forecast, an attempt is made to remove the obvious effects of the increase in the flow rate of wells that are not associated with the use of hydraulic fracturing.

The X field is well suited for hydraulic fracturing due to its low-permeability rocks. It should be added that field X has a problem of high-water content and the water-saturated zone is close to the perforation zone of many wells, thus it was decided to use methods to limit the height of the crack. The selection of wells was made, taking into account the previous hydraulic fracturing operations of 2019-2021, the most suitable for performing hydraulic fracturing was well № 63.

The analysis of the main characteristics of the crack height and methods of its limitation is carried out. As a result, the most optimal method of limiting the height of the crack was the use of special chemical reagents, or rather low-viscosity gels (ClearFRAC). Three different models were developed to compare this method and evaluate hydraulic fracturing fracture geometries by criteria. The solution of the problem of limiting the height of the hydraulic fracturing crack at field X by using special chemical reagents showed the best optimality (97.2%).

Analysis of the technological efficiency of hydraulic fracturing, which shows an increase in productivity by an average of 4 times. The efficiency of the proposed hydraulic fracturing technologies in producing wells is economically and environmentally justified.

6.2 Recommendations

Based on the results of solving the problem of limiting the height of the hydraulic fracturing crack at field X by using special chemical reagents in 2021, the following is recommended:

1) It is recommended to use the hydraulic fracturing method of limiting the crack height using low-viscosity gels (ClearFRAC) on the № 63 well, since it showed the best result according to the optimality of the model.

2) In order to eliminate waterlogging in field X, it is recommended to use methods for limiting the height of the crack on several horizons.

3) It is recommended to consider the use of technologies aimed at physical measurement of the height of cracks in order to improve the accuracy of model calibration and optimize the design of hydraulic fracturing, such as micro seismic monitoring, injection of special marked proppants with the well logging method of pulsed neutron-neutron logging before and after hydraulic fracturing, thermometry after hydraulic fracturing, acoustic broadband logging before and after hydraulic fracturing, the use of depth gauges during hydraulic fracturing.

4) In order to make practical use of the above recommendations, it is necessary to include them in the technical specifications for hydraulic fracturing contractors.

GLOSSARY

Accumulated mining	Reflects the amount of oil and extracted from the field since the launch of the first extracting well.
Bottom hole pressure	Oil pressure (fluid) on the ret off (bottom) of the well.
Capital investment	Capital expenditures are the investment activities of the company, investments in the purchase of equipment, buildings and facilities, construction, etc.
Core	A cylindrical rock sample obtained from the well when it is drilled using a special core receiver.
Filter-capacity properties (FCP)	The filter-capacity properties of the rocks are determined by the basic physical parameters - porosity, permeability and water saturation.
Hydraulic fracturing	A way to intensify oil production in the field. It is that under high pressure in the layer pumped a mixture of liquid and a special snuck agent (proppant).

Logging	The general name of the methods of geophysical research of the well, carried out by the descent and lifting of the geophysical research probe.
Oil Recovery (Rf)	One of the basic indicators of the efficiency of oil production. This is the ratio of the amount of recoverable reserves to the size of geological reserves.
Production (extracting) well	Designed for oil and gas production.
Productive thickness	The thickness of the layer, measured by the shortest distance between its roof and sole.
Propant	A granular material that is used in the oil industry to improve the efficiency of well recoil using hydraulic fracturing technology.
Rate	The rate of wells is the volume of oil or gas coming into the unit of time from a natural or artificial source.
Reservoir	The oil and gas reservoir is a rock capable of accommodating liquid, gaseous hydrocarbons and giving them away during the development of deposits.
Viscosity	The most important technological property of the oil system. Characterizes the force of friction (internal resistance) that occurs between two adjacent layers inside a liquid or gas per surface unit as they move mutually. The viscosity of oil depends on its fractional composition, as well as on the temperature.
Water cut	The water cut of the stingray is the content of water in the well's production, defined as the ratio of water debit to the amount of oil and water rates.
Water-oil contact	The conditional surface separating the oil deposits in the oil deposit area of oil and reservoir water.
Well logging (WL)	A set of methods used to study rocks in near-important and inter-important spaces, as well as to monitor the technical condition of wells.
Well Testing (WT)	A combination of various measures aimed at measuring certain parameters (pressure, temperature, fluid level, debit, etc.) and sampling of reservoir fluids (oil, water, gas and gas condensate) in working or stopped wells and their registration over time.

ABBREVIATIONS

∑q1	The amount of daily production rates for wells before hydraulic fracturing
∑q2	The amount of daily production rates for wells after hydraulic fracturing
CI	Capital Investment
ft	Feet
HF	Hydraulic Fracturing
K	Average cost per well processing
Kr	Operating ratio
LLP	Limited Liability Partnership
m	Meter
MD	Measured depth
MPa	Mega (x106) Pascals
n	Number of treatments per well
P	Price
Pnet	Net pressure
Pp	Formation pressure
ppg	Pounds per gallon
psi	Pounds per square inch
W	Number of wells being processed
ΔP	Change in Formation Pressure
ν	Poisson's ratio
C1	Cost of production of 1 ton of oil to hydraulic fracturing

REFERENCES

1. A., P. (2013). *Hydrofracking: What Everyone Needs to Know.* Oxford University Press.

2. Carbodirect.com. (2010). *FRACPRO fracture design and analysis software.* Texas.

3. Center, U. o. (2018). *Fracking the immune system: Study links fracking chemicals to immune imbalance* . ScienceDaily.

4. Economides, M. (2007). *Unified fracturing design: from theory to practice.* Moscow: Orsa Press Alvin.

5. G., M. A. (2010). *Features of well operation after hydraulic fracturing.* Moscow: LLP VNIIOENG .

APPENDIX A

Table 9A - Project download schedule (1-model)

The Dia №	Stage type	past It's time min:sec	type Liquid	volume Liquid (m3)	Coarant concentration 1 (kg/m3)	Propane concentration 2 (kg/m3)	Propant Stage (kg)	Consumption of mixture 1 (m3/min)	Consumption of the mixture 2 (m3/min)	type propagon
	Fluid in the well		#25 linear gel	6,617						
1	Pumping water	1:59	#25 linear gel	7,000	0	0	0,0	3,50	3,50	
2	Stop downloading	22:00	STOP DOWNLOADING	0,000	0	0	0,0	0,00	0,00	
3	Mini-hydraulic fracturing	23:08	Sewn #25 gel	4,000	0	0	0,0	3,50	3,50	
4	Proped tutu	24:39	Sewn #25 gel	5,000	100	300	995,0	3,50	3,50	BorProp 16/20
5	Mini-hydraulic fracturing	26:05	Sewn #25 gel	5,000	0	0	0,0	3,50	3,50	
6	Mini-hydraulic fracturing	28:22	#25 linear gel	8,000	0	0	0,0	3,50	3,50	
7	Stop downloading	73:22	STOP DOWNLOADING	0,000	0	0	0,0	0,00	0,00	
8	Main hydraulic fracturing buffer	86:14	Sewn #25 gel	45,000	0	0	0,0	3,50	3,50	
9	A mixture of basic hydraulic fracturing	91:37	Sewn #25 gel	18,000	100	200	2 695,3	3,50	3,50	BorProp 16/20
10	A mixture of basic hydraulic fracturing	98:30	Sewn #25 gel	22,000	200	400	6 578,6	3,50	3,50	BorProp 16/20
11	A mixture of basic hydraulic fracturing	106:28	Sewn #25 gel	24,000	400	600	11 977,8	3,50	3,50	BorProp 16/20
12	A mixture of basic hydraulic fracturing	115:33	Sewn #25 gel	26,000	600	800	18 177,2	3,50	3,50	BorProp 16/20
13	A mixture of basic hydraulic fracturing	121:28	Sewn #25 gel	16,000	800	1 000	14 386,6	3,50	3,50	BorProp 12/18
14	A mixture of basic hydraulic fracturing	123:24	Sewn #25 gel	5,000	1 000	1 200	5 496,0	3,50	3,50	BorProp 12/18
15	The sale of the main hydraulic fracturing	125:15	#25 linear gel	6,500	0	0	0,0	3,50	3,50	
16	Stop downloading	245:15	STOP DOWNLOADING	0,000	0	0	0,0	0,00	0,00	

Project Fluid Volume (m3)191.50Proproject Propant (kg)60 306.4
Project Volume of Mix (m3)210.92

Table 10A - Information on crack geometry (1-model)

Half-length of the crack (m)	70	**Fixed half-length (m)**	69
Total crack height (m)	48	**Total fixed height (m)**	47
Vertical depth to the upper edge of the crack (m)	1 295	**Vertical depth to the upper boundary of the fixed crack (m)**	1 296
Vertical depth to the bottom of the crack (m)	1 344	**Vertical depth to the lower boundary of the fixed crack (m)**	1 344
Equivalent number of formed cracks	1,0	**Maximum crack width (see)**	1,01
The effectiveness of the fracking mixture	0,44	**Medium crack width (see)**	0,63
		Average propane concentration (kg/m2)	11,49
Average conductivity	4 096,2	**Medium crack width (closed on propane) (see)**	0,623
Immeasurable conductivity	19,03	**Relative permeability of the reservoir (MD)**	3,13
Propane damage factor	0,50	**Permeability of undamaged propane under stress (MD)**	1 152 132
The apparent damage factor	0,00	**Permeability of propane, taking into account damage to propane (MD)**	576 066
General damage factor	0,50	**Permeability of propane, taking into account the total damage (MD)**	576 066
Effective fixed length (m)	69	**Pressure of propane (mm)**	0,580
Effective pressure of the model	66,5	**The pressure of fracking at the boae (atm)**	164,7
Actual Effective Pressure (Atm)	0,0	**The grade of the pressure of the bow (atm/m)**	0,1250
Hydrostatic pressure (atm)	128,1	**Medium pressure on the mouth (atm)**	166,8
Plastic pressure (atm)	95,0	**Maximum pressure on the mouth (atm)**	189,6

Table 11A - Project Download Schedule (2-model)

The Dia №	**Stage type**	**past It's time min:sec**	**type Liquid**	**volume Liquid (m3)**	**Coarant concentration 1 (kg/m3)**	**Propane concentration 2 (kg/m3)**	**Propant Stage (kg)**	**Consumption of mixture 1 (m3/min)**	**Consumption of the mixture 2 (m3/min)**	**type propagon**
Fluid in the well			#25 linear gel	6,617						
1	Pumping water	1:59	#25 linear gel	7,000	0	0	0,0	3,50	3,50	
2	Stop downloading	22:00	Aboutthe pumping machine	0,000	0	0	0,0	0,00	0,00	
3	Mini-hydraulic fracturing	23:08	Sewn #25 gel	4,000	0	0	0,0	3,50	3,50	
4	Proped tutu	24:39	Sewn #25 gel	5,000	100	300	995,0	3,50	3,50	BorProp 16/20
5	Mini-hydraulic fracturing	26:05	Sewn #25 gel	5,000	0	0	0,0	3,50	3,50	
6	Mini-hydraulic fracturing	28:22	#25 linear gel	8,000	0	0	0,0	3,50	3,50	
7	Stop downloading	73:22	Aboutthe pumping machine	0,000	0	0	0,0	0,00	0,00	
8	Main hydraulic fracturing buffer	83:22	Sewn #25 gel	35,000	0	0	0,0	3,50	3,50	
9	A mixture of basic hydraulic fracturing	86:22	Sewn #25 gel	10,000	100	200	1 497,4	3,50	3,50	BorProp 16/20
10	A mixture of basic hydraulic fracturing	91:41	Sewn #25 gel	17,000	200	400	5 083,4	3,50	3,50	BorProp 16/20
11	A mixture of basic hydraulic fracturing	97:59	Sewn #25 gel	19,000	400	600	9 482,4	3,50	3,50	BorProp 16/20

The Dia №	Stage type	past It's time min:sec	type Liquid	volume Liquid (m3)	Coarant concentration 1 (kg/m3)	Propane concentration 2 (kg/m3)	Propant Stage (kg)	Consumption of mixture 1 (m3/min)	Consumption of the mixture 2 (m3/min)	type propagon
12	A mixture of basic hydraulic fracturing	104:59	Sewn #25 gel	20,000	600	800	13 982,4	3,50	3,50	BorProp 16/20
13	A mixture of basic hydraulic fracturing	110:31	Sewn #25 gel	15,000	800	1 000	13 487,4	3,50	3,50	BorProp 12/18
14	A mixture of basic hydraulic fracturing	112:27	Sewn #25 gel	5,000	1 000	1 200	5 496,0	3,50	3,50	BorProp 12/18
15	The sale of the main hydraulic fracturing	114:19	#25 linear gel	6,500	0	0	0,0	3,50	3,50	
16	Stop downloading	234:19	Aboutthe pumping machine	0,000	0	0	0,0	0,00	0,00	

Project Fluid Volume (m3)156.50Proproject Propant (kg)50 024.1
Project Volume of mix (m3)172.61

Table 12A - Information on crack geometry (2-model)

Half-length of the crack (m)	64	**Fixed half-length (m)**	62
Total crack height (m)	40	**Total fixed height (m)**	39
Vertical depth to the upper edge of the crack (m)	1 297	**Vertical depth to the upper boundary of the fixed crack (m)**	1 298
Vertical depth to the bottom of the crack (m)	1 337	**Vertical depth to the lower boundary of the fixed crack (m)**	1 337
Equivalent number of formed cracks	1,0	**Maximum crack width (see)**	1,08
The effectiveness of the fracking mixture	0,48	**Medium crack width (see)**	0,70
		Average propane concentration (kg/m2)	12,89
Average conductivity	4 259,7	**Medium crack width (closed on propane) (see)**	0,699
Immeasurable conductivity	21,96	**Relative permeability of the reservoir (MD)**	3,13
Propane damage factor	0,50	**Permeability of undamaged propane under stress (MD)**	1 203 665
The apparent damage factor	0,00	**Permeability of propane, taking into account damage to propane (MD)**	601 833
General damage factor	0,50	**Permeability of propane, taking into account the total damage (MD)**	601 833
Effective fixed length (m)	62	**Pressure of propane (mm)**	0,588
Effective pressure of the model	80,1	**The pressure of fracking at the boae (atm)**	164,7
Actual Effective Pressure (Atm)	0,0	**The grade of the pressure of the bow (atm/m)**	0,1250
Hydrostatic pressure (atm)	127,9	**Medium pressure on the mouth (atm)**	168,2
Plastic pressure (atm)	95,0	**Maximum pressure on the mouth (atm)**	183,6

Table 13A - Project Download Schedule (3-Model)

The Dia №	Stage type	past It's time min:sec	type Liquid	volume Liquid (m3)	Coarant concentration 1 (kg/m3)	Propane concentration 2 (kg/m3)	Propant Stage (kg)	Consumption of mixture 1 (m3/min)	Consumption of the mixture 2 (m3/min)	type propagon
Fluid in the well			#25 linear gel	6,617						
1	Pumping water	1:59	WF120 w/0.001563 1	7,000	0	0	0,0	3,50	3,50	
2	Stop downloading	22:00	STOP DOWNLOADING	0,000	0	0	0,0	0,00	0,00	
3	Mini-hydraulic fracturing	23:08	2.0% J508W in 4% 2	4,000	0	0	0,0	3,50	3,50	
4	Proped tutu	24:39	2.0% J508W in 4% 2	5,000	100	300	995,0	3,50	3,50	BorProp 16/20
5	Mini-hydraulic fracturing	26:05	2.0% J508W in 4% 2	5,000	0	0	0,0	3,50	3,50	
6	Mini-hydraulic fracturing	28:22	WF120 w/0.001563 1	8,000	0	0	0,0	3,50	3,50	
7	Stop downloading	73:22	STOP DOWNLOADING	0,000	0	0	0,0	0,00	0,00	
8	Main hydraulic fracturing buffer	86:14	2.0% J508W in 4% 2	45,000	0	0	0,0	3,50	3,50	
9	A mixture of basic hydraulic fracturing	91:37	2.0% J508W in 4% 2	18,000	100	200	2 695,3	3,50	3,50	BorProp 16/20
10	A mixture of basic hydraulic fracturing	98:30	2.0% J508W in 4% 2	22,000	200	400	6 578,6	3,50	3,50	BorProp 16/20
11	A mixture of basic hydraulic fracturing	106:28	2.0% J508W in 4% 2	24,000	400	600	11 977,8	3,50	3,50	BorProp 16/20
12	A mixture of basic hydraulic fracturing	115:33	2.0% J508W in 4% 2	26,000	600	800	18 177,2	3,50	3,50	BorProp 16/20
13	A mixture of basic hydraulic fracturing	121:28	2.0% J508W in 4% 2	16,000	800	1 000	14 386,6	3,50	3,50	BorProp 12/18
14	A mixture of basic hydraulic fracturing	123:24	2.0% J508W in 4% 2	5,000	1 000	1 200	5 496,0	3,50	3,50	BorProp 12/18
15	The sale of the main hydraulic fracturing	125:15	WF120 w/0.001563 1	6,500	0	0	0,0	3,50	3,50	
16	Stop downloading	245:15	STOP DOWNLOADING	0,000	0	0	0,0	0,00	0,00	

Project Fluid Volume (m3)191.50Proproject Propant (kg)60 306.4
Project Volume of Mix (m3)210.92

Table 14A - Information on crack *geometry (3-Model)*

Half-length of the crack (m)	106	**Fixed half-length (m)**	101
Total crack height (m)	38	**Total fixed height (m)**	36
Vertical depth to the upper edge of the crack (m)	1 297	**Vertical depth to the upper boundary of the fixed crack (m)**	1 299
Vertical depth to the bottom of the crack (m)	1 335	**Vertical depth to the lower boundary of the fixed crack (m)**	1 335
Equivalent number of formed cracks	1,0	**Maximum crack width (see)**	1,21
The effectiveness of the fracking mixture	0,42	**Medium crack width (see)**	0,78
		Average propane concentration (kg/m2)	10,38
Average conductivity	2 719,6	**Medium crack width (closed on propane) (see)**	0,526
Immeasurable conductivity	8,64	**Relative permeability of the reservoir (MD)**	3,13
Propane damage factor	0,50	**Permeability of undamaged propane under stress (MD)**	1 152 122
The apparent damage factor	0,00	**Permeability of propane, taking into account damage to propane (MD)**	576 061
General damage factor	0,50	**Permeability of propane, taking into account the total damage (MD)**	576 061
Effective fixed length (m)	101	**Pressure of propane (mm)**	0,580
Effective pressure of the model	66,7	**The pressure of fracking at the boae (atm)**	164,7
Actual Effective Pressure (Atm)	0,0	**The grade of the pressure of the bow (atm/m)**	0,1250
Hydrostatic pressure (atm)	128,5	**Medium pressure on the mouth (atm)**	174,3
Plastic pressure (atm)	95,0	**Maximum pressure on the mouth (atm)**	236,8