Acoustic Well Stimulation

of near-wellbore zone for enhanced oil recovery

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CUT SERVICE
CENTER OF ULTRASOUND TECHNOLOGY

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CUT SERVICE CENTER OF ULTRASOUND TECHNOLOGY

GROUP OF COMPANIES VIATECH

The group of companies specializes in the development of ultrasonic technology and software systems for enhanced oil recovery and own dozens of patents. Engineering company awarded with diplomas of Russian and international exhibitions.

LLC “Viatech” – R&D, manufacturing of ultrasonic equipment

LLC “Sonotech” – Services with permanent treatment solutions on territory of Tatarstan republic from 2014.

LLC «CUT-Services» - Services of ultrasonic treatment on territory of Russian Federation and International projects from 2010

HISTORY OF ULTRASONIC DEVELOPMENT IN VIATECH

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Abramov Oleg Vladimirovich (25.02.1936 – 25.09.2008)

Founder of AWS technology, one of first scientists in the world who implemented acoustic fields in the oil wells cleaning application

Scientific background:

1959 – 1975 Central research Institute of ferrous metallurgy

1975 – 1989 Institute of solid state physics, USSR Academy of Sciences

1990 – 2008 Institute of General and inorganic chemistry, Russian Academy of Sciences

His main area of research - the study the influence of power ultrasound to the substance, its practical use in metallurgy, engineering, chemistry for the intensification of heat and mass transfer processes and impact on the structure and properties of materials.

Oleg Abramov was a major, globally recognized expert in the field of interaction of ultrasound with matter. He published more than 250 scientific works, including 7 books and chapters in books (4 of them published abroad – in the United States, England, Germany, Slovakia), more than 220 papers and received more than 30 inventor's certificates. He was the head of the 25 graduate students who have defended PhD thesis, 4 of his students defended their doctoral dissertations.

HISTORY OF ULTRASONIC DEVELOPMENT IN VIATECH

CUT SERVICE CENTER OF ULTRASOUND TECHNOLOGY

Abramov Vladimir Olegovich

Lead scientist who driving ultrasonic research all his life.

Co-founder and co-owner of group of companies VIATECH

Scientific background:

1985 – 1993 Central research Institute of ferrous metallurgy

1993 – 1996 Germany, Max-Planck-Institut für Metallforschung, Institut für Werkstoffwissenschaft

From 1996 Institute of General and inorganic chemistry, Russian Academy of Sciences

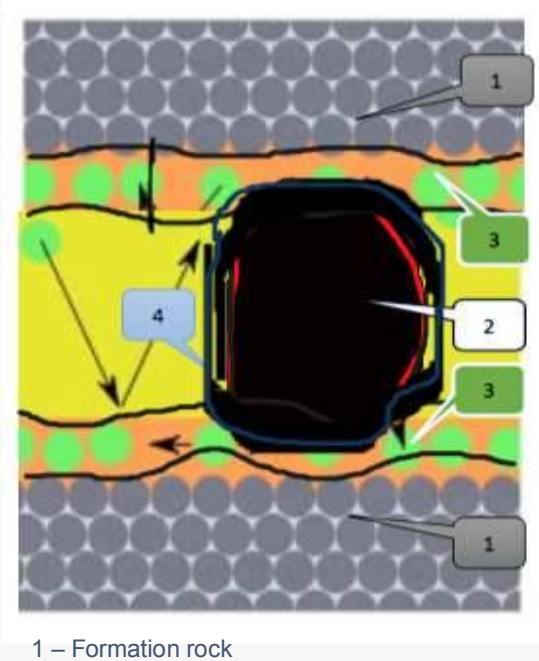
His main area of research – theory of ultrasonic vibrations, the introduction of ultrasound in metals and alloys, the effect of ultrasound on physico-chemical and technological processes, including wastewater treatment, recovery of oil wells, oil refining and chemical conversion to oil products.

Vladimir Abramov is the author of over 100 scientific publications and patents.

Ultrasonic equipment and technology cycles, developed under the leadership of Vladimir Abramov, implemented and are successfully functioning in Russia and more than 25 foreign countries.

TREATMENT OF WELLS WITH LIGHT OIL

NEAR-WELLBORE ZONE CLEANING



1 – Formation rock

2 – Foreign particle (mud filtrate, etc.)

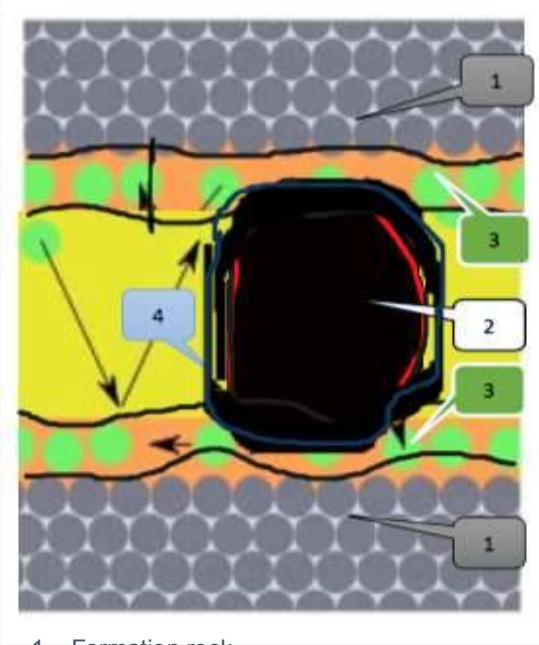
3 – Hydrocarbon boundary layer on formation pore

4 – Hydrocarbon boundary layer on foreign particle

Decrease the permeability of the near-wellbore zone may be caused by many factors, which depends both on the properties of the rock and the mode and technology of well operation, including the most common causes of declining productivity of wells can be:

- Mudding of a near-wellbore zone of the reservoir during drilling a well
- Mudding of a near-wellbore zone of the reservoir during well life (waxing, skin increase)
- Formation of crust in perforation channels after cumulative perforation
- Clogging of perforation channels and pores of rock during the process of killing the well and subsequent increase of pressure gradient between formation and the wellbore

NEAR-WELLBORE ZONE CLEANING



1 – Formation rock

2 – Foreign particle (mud filtrate, etc.)

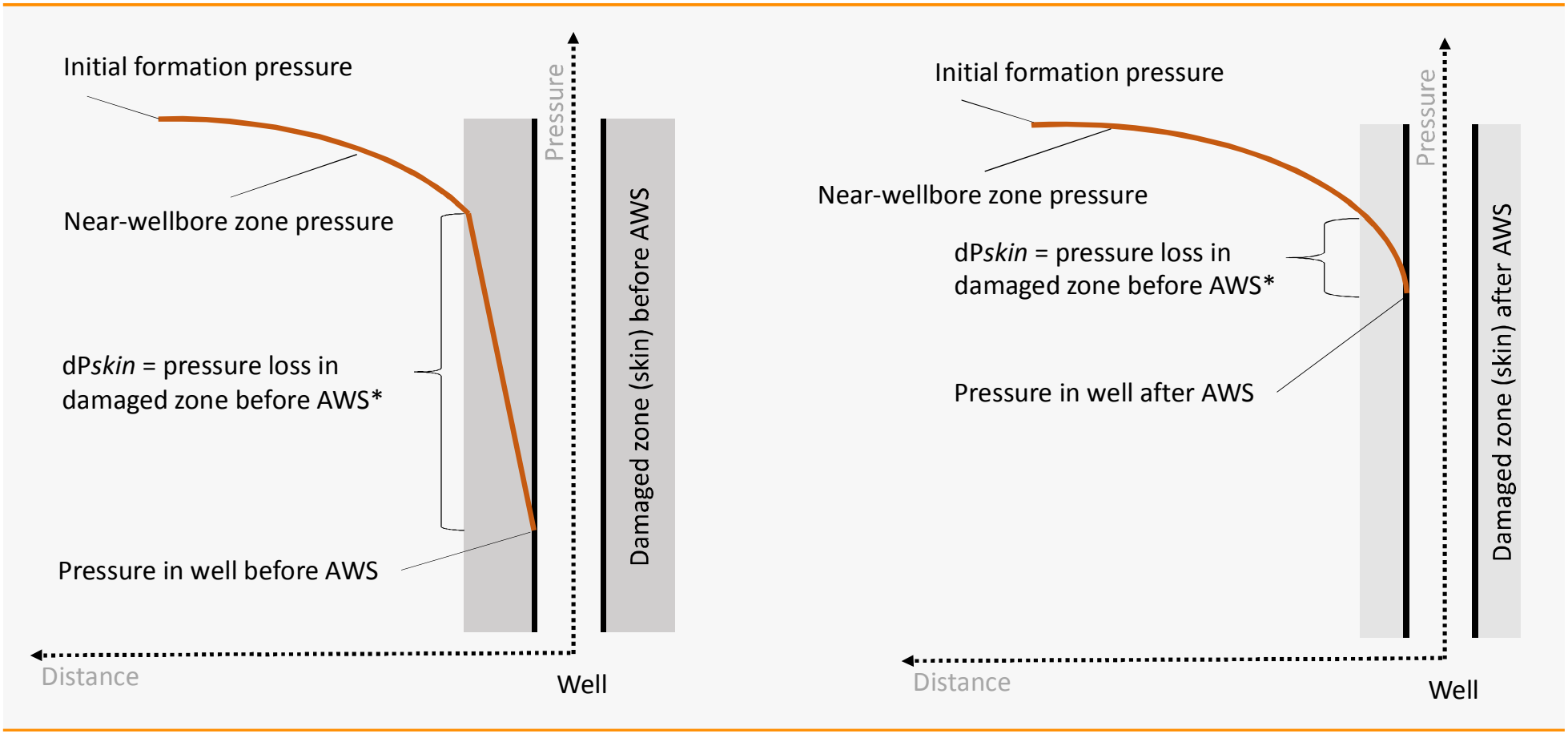
3 – Hydrocarbon boundary layer on formation pore

4 – Hydrocarbon boundary layer on foreign particle

- Destruction of the boundary layer, confining globule mud filtrate and other particles in the rock pores
- Removal of contaminants from the rock
- Improving communication of well - formation system
- Improving well productivity from the first hours
- Preserving effect up to 2 years during continuous flow from the well

Reducing resistance of near-wellbore zone
=
Productivity increase

NEAR-WELLBORE ZONE CLEANING



CLEANING OF PERFORATION CHANNELS FROM THE DEBRIS AND CRUST

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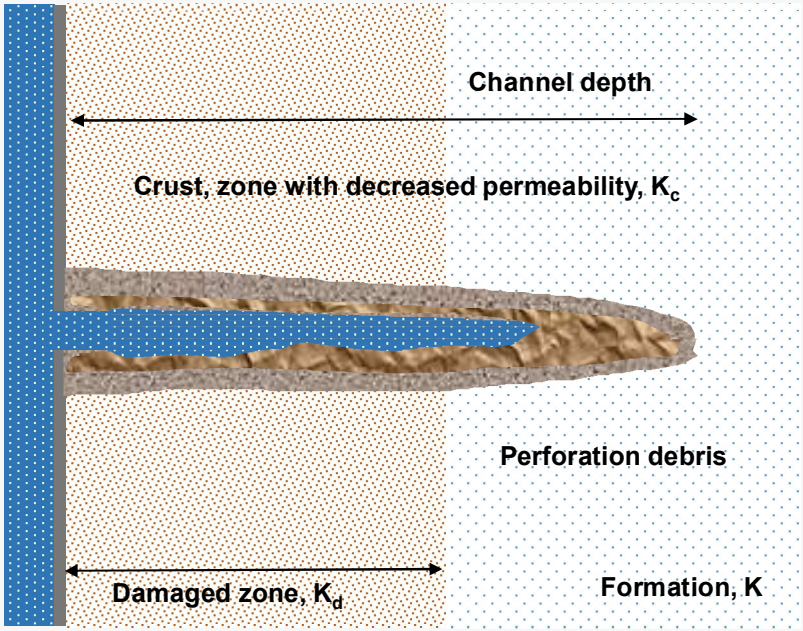
- Destruction of the boundary layer, confining particles of debris in the perforation channels
- Detachment crust formed by the cumulative jet, from the rock in the perforation channel
- Required to ensure well flowing during AWS to clean perforation channels from debris and crust
- Improving communication of well - formation system
- Improving well productivity from the first hours
- Preserving effect up to 2 years during continuous flow from the well

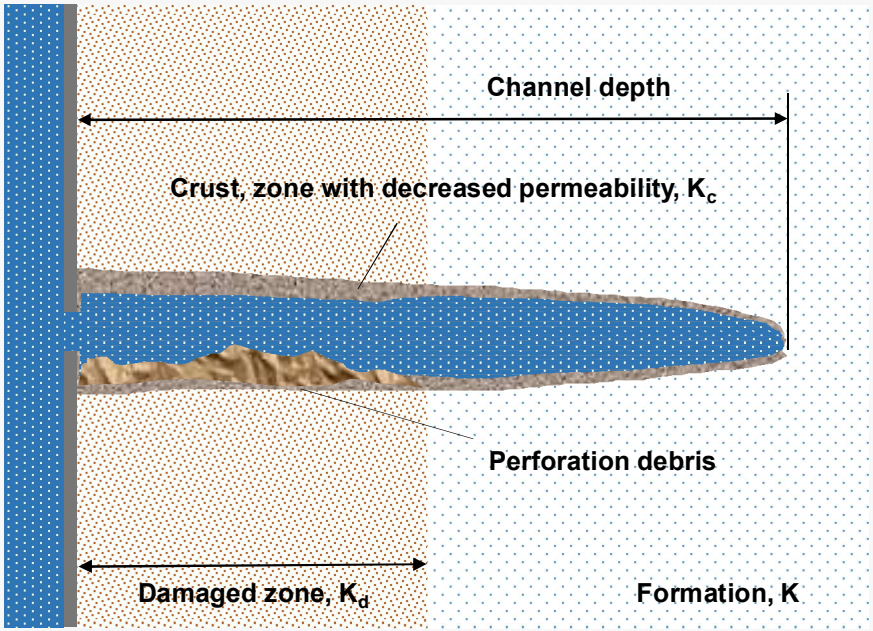
Reducing resistance on the boundary of perforation channels
=
Productivity increase

CLEANING OF PERFORATION CHANNELS FROM THE DEBRIS AND CRUST

Perforation channel after perforation



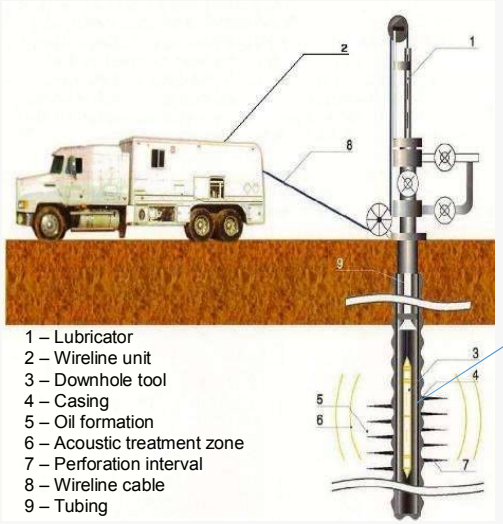
Perforation channel after AWS with underbalance



- A significant increase of the inflow area of perforation channels increasing well production
- In addition to the removal of the crust, there is a cleaning of the damaged zone of near-wellbore formation

TEMPORARY ACOUSTIC WELL STIMULATION SERVICES

- Operations on the wells with light and moderate oil
- AWS equipment contains surface ultrasonic generator and acoustic well oscillator connected by 3-wired cable.
- The main component of downhole tool is acoustic oscillator (magnetostrictive or piezoceramic), which transform electric power to mechanical vibrations in ultrasonic range.
- Diameter of downhole tool is 42 or 44 мм. Acoustic oscillator run in the well through tubing, power supply provided through wireline cable.



Advantages:

1. High commercial efficiency

2. Production growth 50% and higher

3. Quick operations

4. Environmental & ecological safety

5. Unlimited iterations on each well

6. Continuous effect from 6 to 24 month

CAPABILITIES OF ULTRASONIC TREATMENT

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EXAMPLE: Light oil

30 Bar underbalance, Liquid flowrate 30 m^3/day

Performing AWS after killing a well or long standby

Decreasing flowing pressure with saving production

25 Bar underbalance, Liquid flowrate 30 m^3/day

- Reducing the cost of oil recovery
- Increasing the life period of equipment
- More gentle reservoir development
- CAPEX and OPEX decreasing for field development
- Increasing cumulative production

Increasing production with same flowing pressure

30 Bar underbalance, **Liquid flowrate 50 m^3/day**

- Rapid development of the well/formation
- Short- and Mid- term production increase
- Decrease CAPEX и OPEX related to volume of produced oil

* - for clarity of the overall efficiency, the example shows approximate numbers

SERVICES FOR WELLS WITH LIGHT OIL

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WE ARE PROVIDING SERVICES IN DIFFERENT COMBINATION:

- Acoustic Well Stimulation of near-wellbore zone
- Acoustic Well Stimulation in combination with Chemical injection
- Acoustic Well Stimulation on Underbalance (Jet pump or Nitrogen unit)
- Combined treatment: AWS + Chemical injection + Underbalance

Client may chose and adopt type of services based on field development program and formation properties

TREATMENT OF WELLS

WITH HEAVY AND VISCOUS OIL

TREATMENT OF WELLS WITH HEAVY AND VISCOUS OIL

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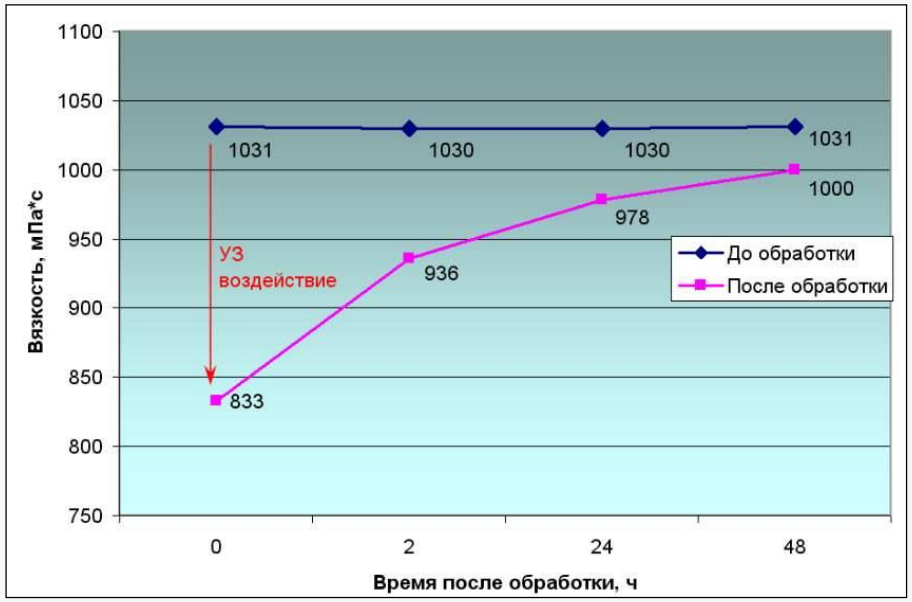
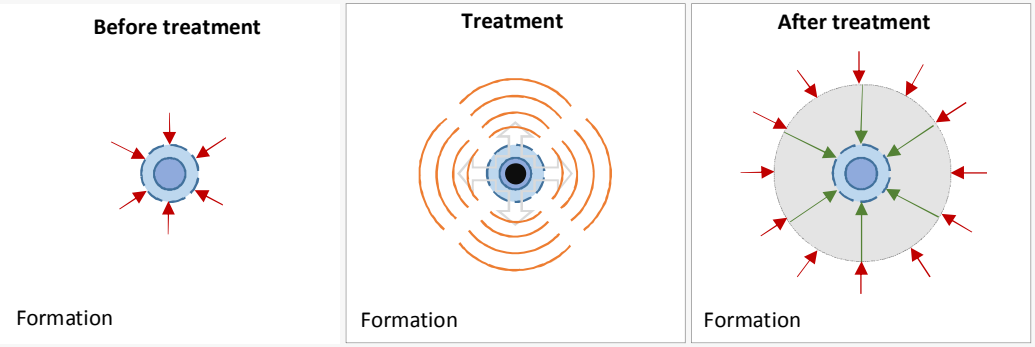
- High-viscosity, paraffin- and asphaltene- containing oil have a non-Newtonian viscoelastic properties
- Ultrasonic treatment changing the viscoelastic properties of oil and approaching fluid to the ideal Newtonian fluid
- The effect is achieved due to the impact at the molecular level and the destruction of intermolecular bonds
- The effect lasts up to 48 hours on treated oil
- In combination with demulsifiers effect may lasts up to 9 days on treated oil



Beneficial effect on oil fluidity and **improving well production** on the same regime of the well

TREATMENT OF WELLS WITH HEAVY AND VISCOUS OIL

Increase of drainage area and velocity of fluid inflow is an actual and operational solution for oil recovery increase for the wells with heavy and viscous oil



Inflow velocity before treatment

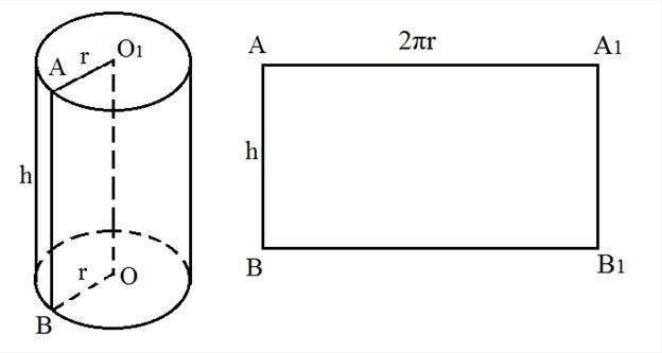
Inflow velocity after treatment

Area of increased fluid velocity

Calculation for 3-meter thickness of prod. interval:

*Initial **drainage area** (215mm drilling bit):*
2*3,1416*0,215*3
= **4,05 m²**

***Drainage area** After acoustic stimulation (Radius of impact - 1500mm):*
2*3,1416*1,5*3
= **28,27 m²**



Drainage area increase ⇒ **Productivity growth**

LATEST DEVELOPMENTS FOR MAXIMUM EFFICIENCY

A first combined tool was developed and produced in August 2016.
It's combine efficiency of physical and thermal EOR methods!

Advantages of thermo-acoustic oscillator:

- Breaking down waxes in formation in acoustic field
- Downhole heating of liquid hydrocarbons Нагрев нефти на забое preventing waxes disposition in tubing and surface oilfield equipment
- Significant viscosity decrease increase a lifetime of Sucker Rod Pumps and decrease electricity cost for oil recovery to the surface
- Growth of drainage area increasing hydrocarbons inflow to the well, increasing actual oil recovery
- Periodical powering of oscillator allow to avoid wax disposition in near-wellbore zone and keep increased productivity of the well

AWS SERVICES FOR WELLS WITH HEAVY AND VISCOUS OIL

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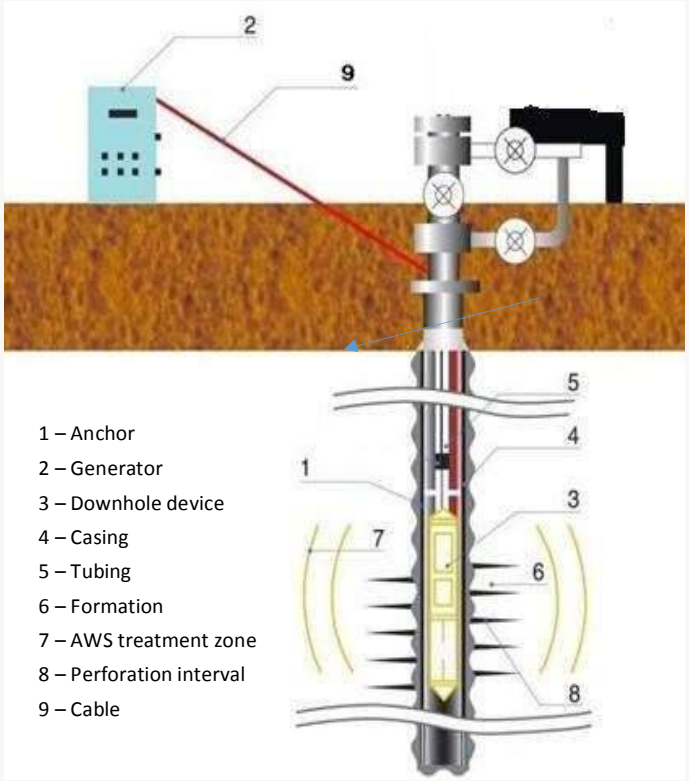
- Continuous AWS is intended to increase the flowrate of heavy oil
- The device is installed during workover operations on the well
- Downhole tool with diameter 102 mm is attached to the tubing
- Downhole tool remains in the well and operating periodically
- Device is controlled by ultrasonic generator from the surface
- Treatment efficiency can be enhanced by chemical injection into the treatment zone or using different frequencies

We are offering 3 main types of services:

- Continuous AWS
- Continuous AWS with injection of chemicals (own chemicals developed and patented)
- Continuous AWS in combination with heating



ACOUSTIC WELL STIMULATION CAPABILITIES

EXAMPLE: Heavy and viscous oil

Technology capabilities	Advantages for artificial lift	Advantages for field operator
Acoustic well stimulation of the wells with heavy and viscous oil	• Viscosity decrease • Increase of liquid flowrate (better cooling of the submersible pump) • More tender operating mode for equipment • Ability to use equipment with higher performance	• Increase of oil flowrate from the well • Decrease of oil viscosity • Decrease of oil lifting costs • Ecological & environmental safety

ACOUSTIC WELL STIMULATION CAPABILITIES

EXAMPLE: Heavy and viscous oil

SRP + AWS

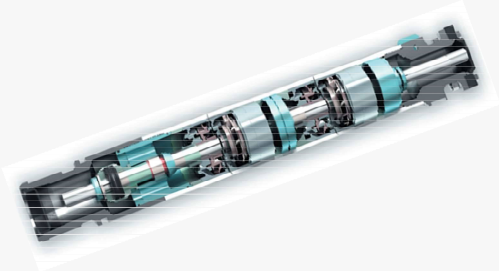
Operating experience:

- Russia: Republic of Tatarstan
- USA

Top Drive PCP + AWS

Same solution as SRP + AWS

Bottom-driven PCP/ESP + AWS

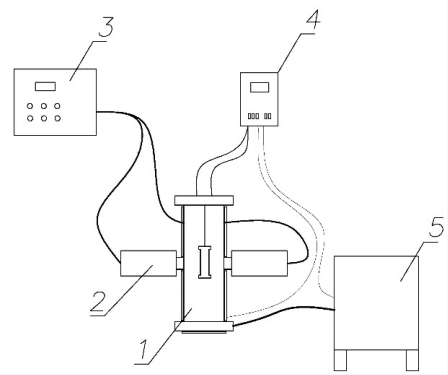


Ongoing development

CEMENT-FRIENDLY TREATMENT

CEMENT-FRIENDLY TREATMENT, PROVEN ON PRACTICE

Photograph and scheme of the experimental equipment used to check the impact of ultrasound on the cement under high pressure and temperature



№ of the sample set	Pressure, atm	Temperature, ^{0}C	Time of ultrasonic treatment, hrs	Bending strength, kGs/cm^2
1	1	20	Not	5,25
2	90	80	2	5,26
3	90	80	4	5,25

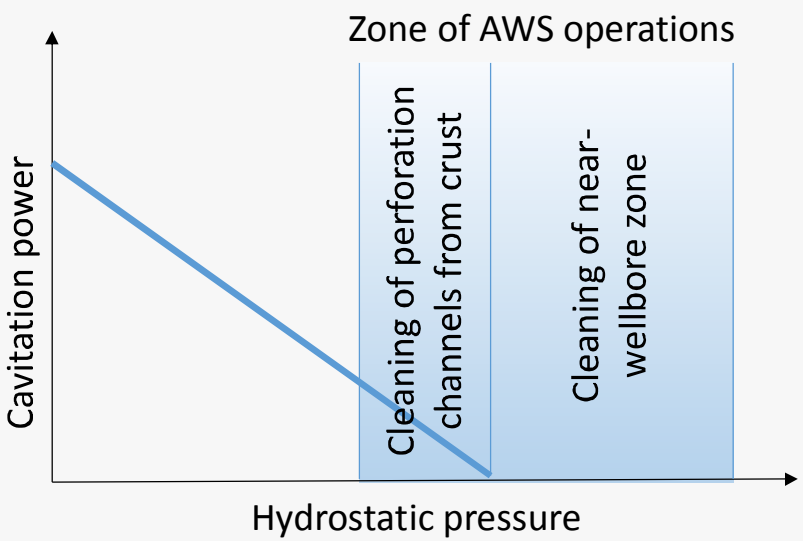
The experiments on the impact of ultrasound on samples of cement (conducted using the standard method GOST 1581-96 on the device MII-100) confirmed, that ***ultrasound with the intensity 10 times higher*** *than the intensity of used during treatment of wells* ***don't affect the integrity of the cement***

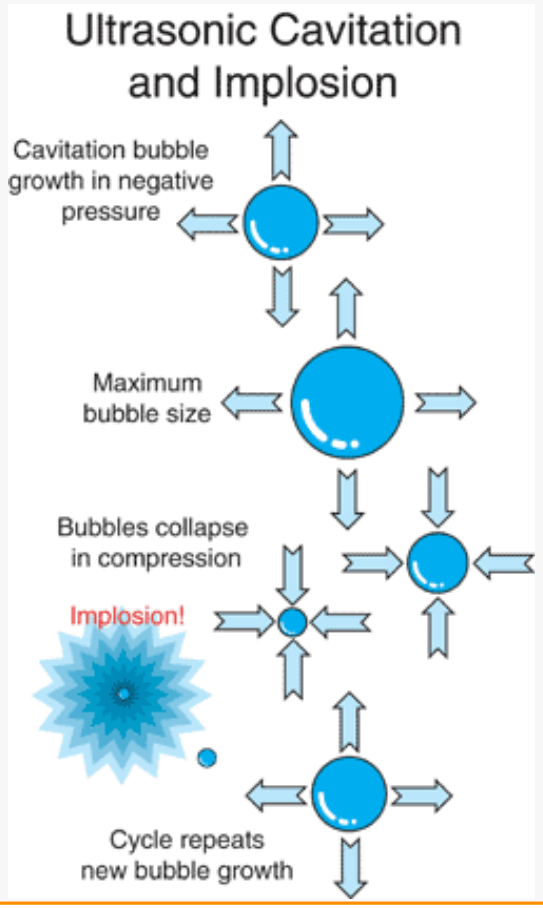
Samples before and after the experiments

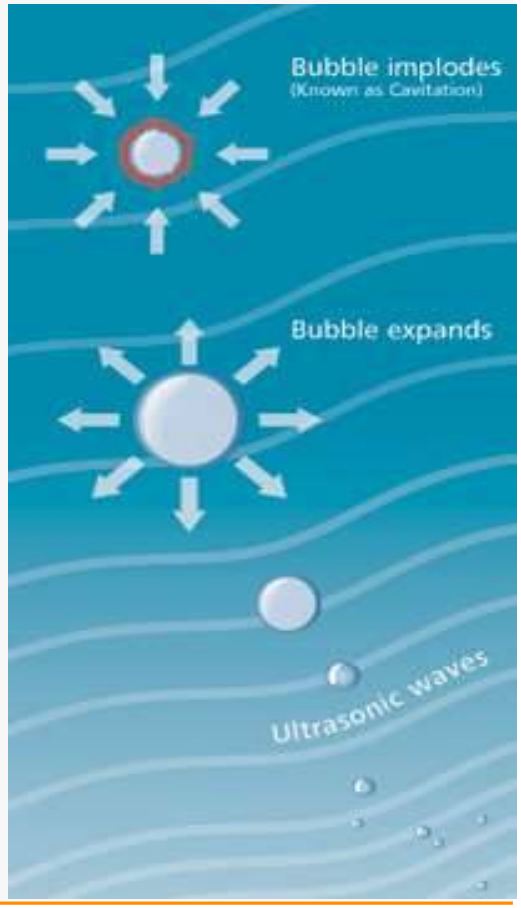
PHYSICAL PROPERTIES OF ULTRASONIC EXPOSURE

PHYSICAL PROPERTIES OF ULTRASONIC EXPOSURE
1. Cavitation

Ultrasonic cavitation — the formation and activity of gas bubbles in the area exposed to ultrasound, as well as effects arising from their interaction with the environment and acoustic field.





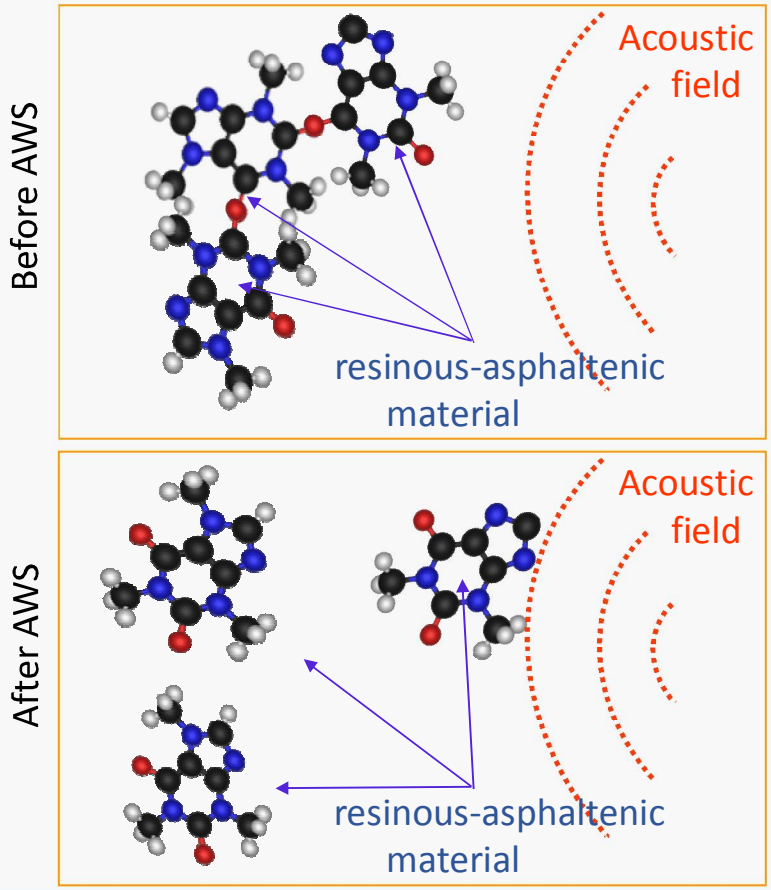


PHYSICAL PROPERTIES OF ULTRASONIC EXPOSURE
2. Sono-capillary effect

If the liquid in the capillary tube oscillates under the influence of the source of ultrasound, the capillary effect increases dramatically: the height of the liquid column increases several tens of times significantly increases the speed of recovery. Experimentally proven that the fluid is pushing up not by the radiation pressure and the capillary force, but by a standing ultrasonic wave. The ultrasound again and again compress the liquid column and picks it up.

(Discovered by academician E. G. Konovalov, 1961)

PHYSICAL PROPERTIES OF ULTRASONIC EXPOSURE
3. Destruction of intermolecular bonds



During AWS each molecule of liquid is exposed to time-dependent tension:

$$\sigma(t) = \sigma 0 \sin\omega t$$

If the exposure duration exceeds the time, then there is a rupture of intermolecular bonds

$$\tau p = Np / \omega; \qquad N_p = \frac{\sigma_T}{\sigma_0} - \frac{kT}{\gamma\sigma_0} \ln\left\{\frac{\sigma_T}{\sigma_0}\right\}$$

Legend:

σ_T – *breaking stress for current type of intermolecular bonds,*

γ – *characteristic for current type of intermolecular bonds,*

K – Boltsman constant,

T – temperature.

PHYSICAL PROPERTIES OF ULTRASONIC EXPOSURE SUMMARY

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Physical property	Cavitation	Sono-capillary effect	Destruction of intermolecular bonds
Application	**Cleaning of perforation channels**	**Heavy oil**	**Cleaning of near-wellbore zone**
Principle of impact	Detaching crust from boundary of perforation channel	Increase speed of inflow from pores in formation and lead to increase drainage area of the well	Decrease of skin effect by breaking boundary layer on mud filtrate and other foreign particles that lead to easy removal of such particles from formation pores
Specific notes	Serious requirements to cement quality	For permanent applications	For temporary treatment during workover operations

TECHNOLOGY ADVANTAGES

CUT SERVICE CENTER OF ULTRASOUND TECHNOLOGY

- ✓ COMBINATION WITH EXISTED METHODS OF ENHANCED OIL RECOVERY
- ✓ EFFECTIVE TREATMENT ON WELLS WITH LOW AND ZERO FLOWRATES
- ✓ ABSENCE OF NEGATIVE EFFECT TO ENVIRONMENT AND FORMATION
- ✓ HIGH PERFORMANCE INDICATOR OF TREATMENTS
- ✓ MAXIMUM GENERATED POWER UP TO 10 KW
- ✓ COMPACT EQUIPMENT AND MOBILE TEAMS
- ✓ UNLIMITED ITERATIONS ON EACH WELL
- ✓ NO DAMAGE TO CEMENT OR CASING
- ✓ A STRONG SCIENTIFIC BACKGROUND
- ✓ HIGH PERFORMANCE ON HEAVY OIL

CONFIFMATION OF EFFICINCY

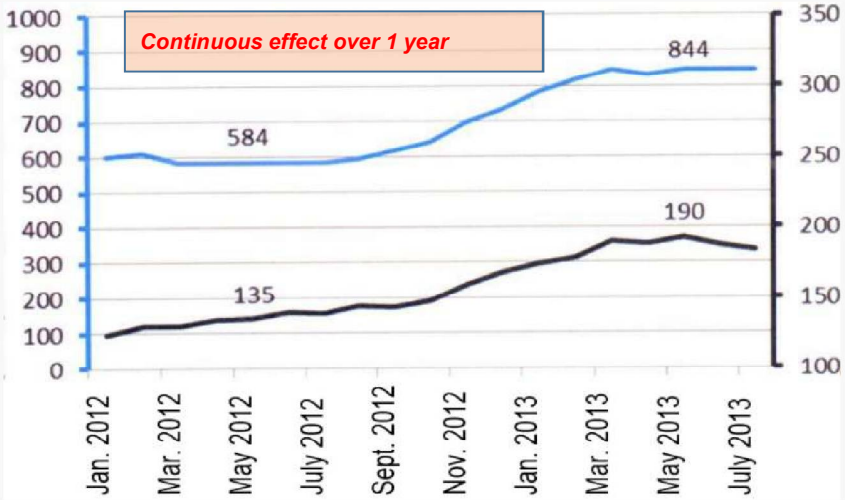
CONFIRMATION OF EFFICIENCY
Treatments in 2011-2013

More than 100 wells treated during period from 2011 till 2013 on the territory of Russian Federation:

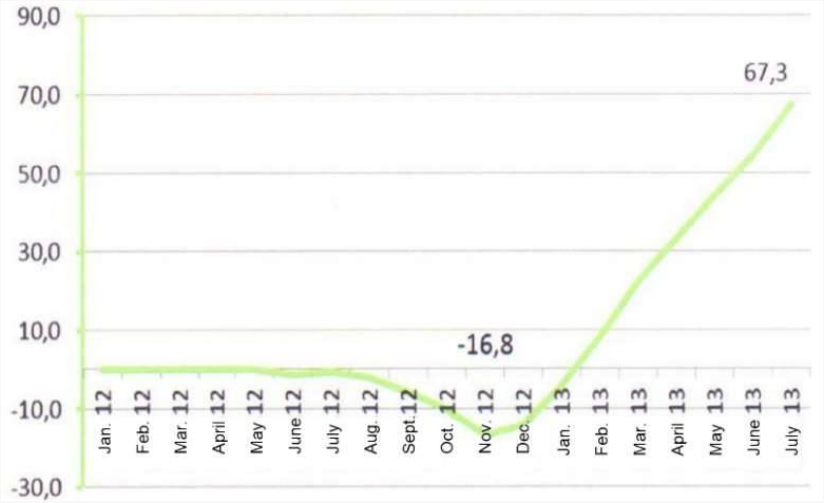
- *Average oil production growth – from 4,2 m³/day to 8,4 m³/day (100%)*
- *Success rate 90%*
- *Duration of effect from 6 to 24 month*

Average results of treatment for one of Clients in Western Siberia:

Liquid and oil flowrate history



Commercial effect, cumulative (mln.rub)



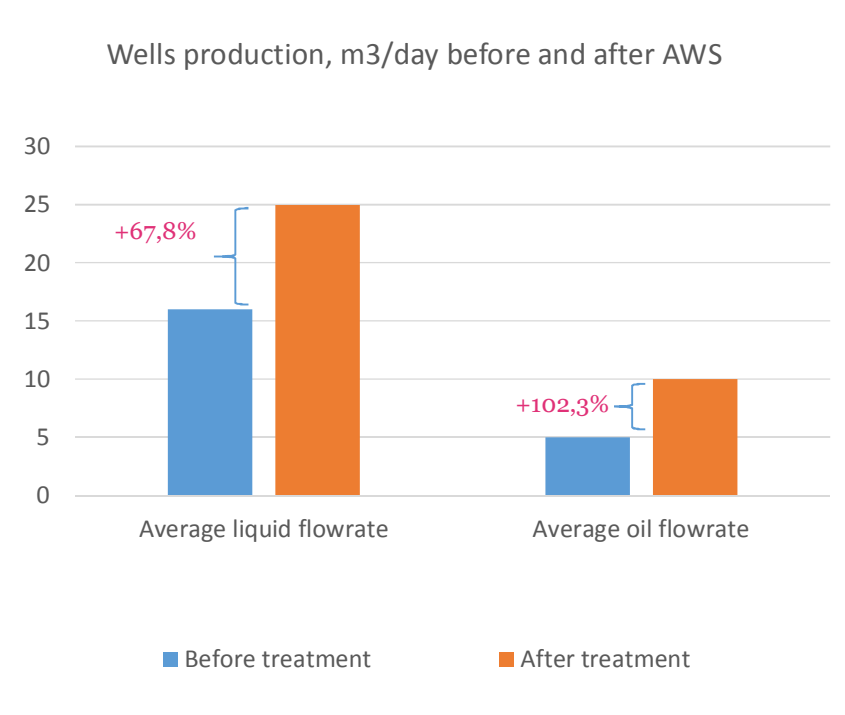
CONFIRMATION OF EFFICIENCY

Treatments in 2013-2015

More than 100 wells treated during period from 2013 till 2015 on the territory of Russian Federation:

- *Liquid flowrate on wells:*
  before treatment 0 – 36 m^3/day,
  after treatment 4 – 63 m^3/day,
- *Average oil production growth 102,3%*
- *Success rate 82%*
- *Duration of effect from 3 to 24 month*

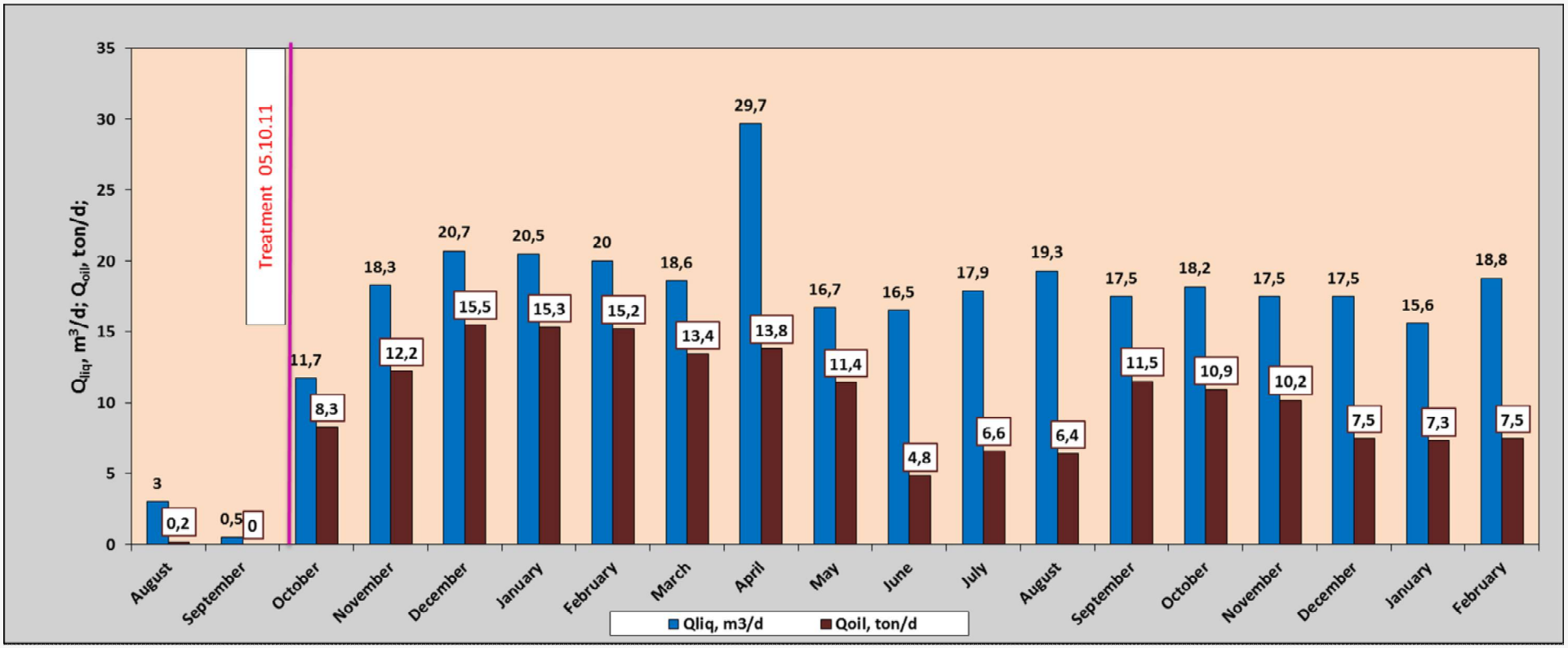
At the same time, wells were not exposed to the damage by acidizing and multiple perforation that helped to preserve the original borehole conditions and the properties of the near-wellbore formation, in this way, unlimited multiplication of ultrasonic treatment and the absence of negative effects is certainly a unique feature of the technology.



CONFIRMATION OF EFFICIENCY

CUT SERVICE CENTER OF ULTRASOUND TECHNOLOGY

Production history of well 1 (actual number is confidential) from Samotlorneftegaz before and after treatment

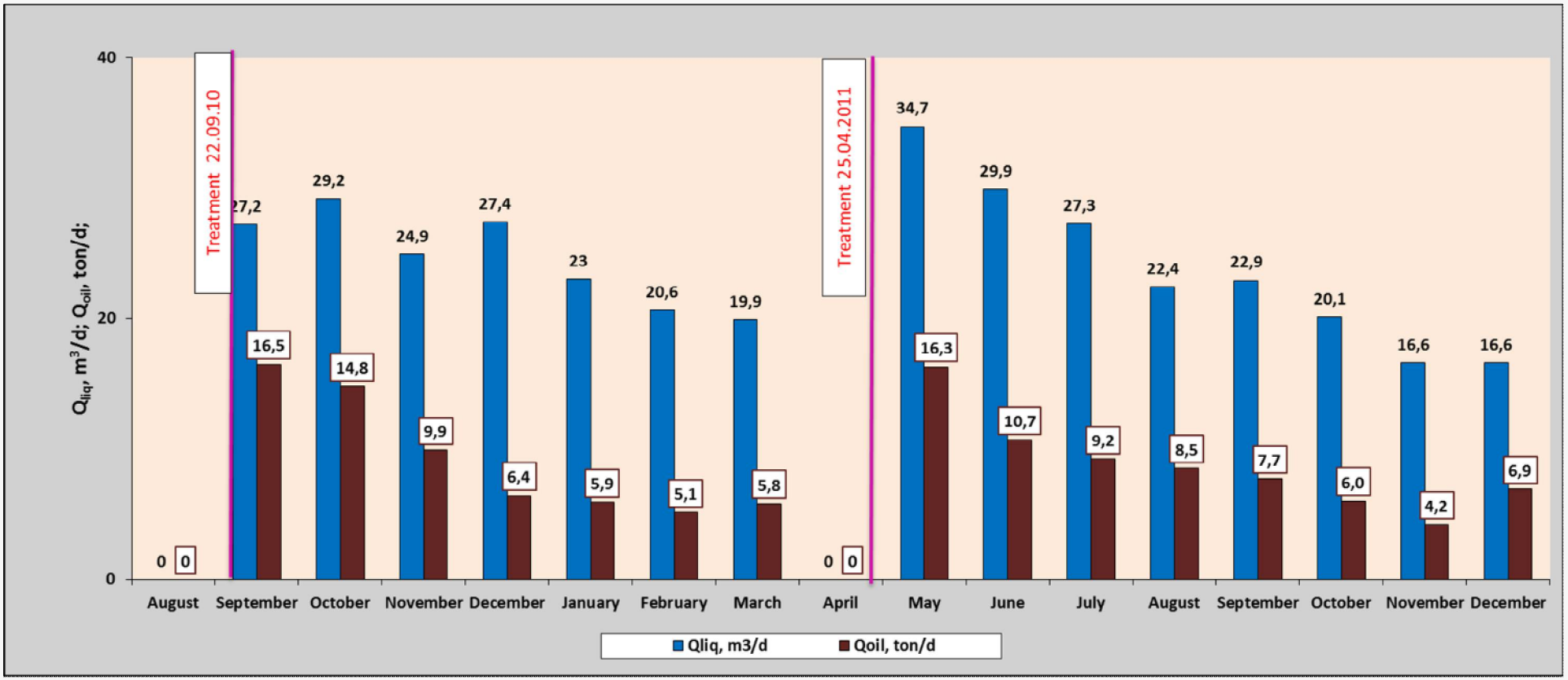


385 days in operations, average increase on oil rate 11 ton/day, productivity index grew from 0,007 to 0,277.

CONFIRMATION OF EFFICIENCY

CUT SERVICE CENTER OF ULTRASOUND TECHNOLOGY

Production history of well 2 (actual number is confidential) from Samotlorneftegaz before and after treatment

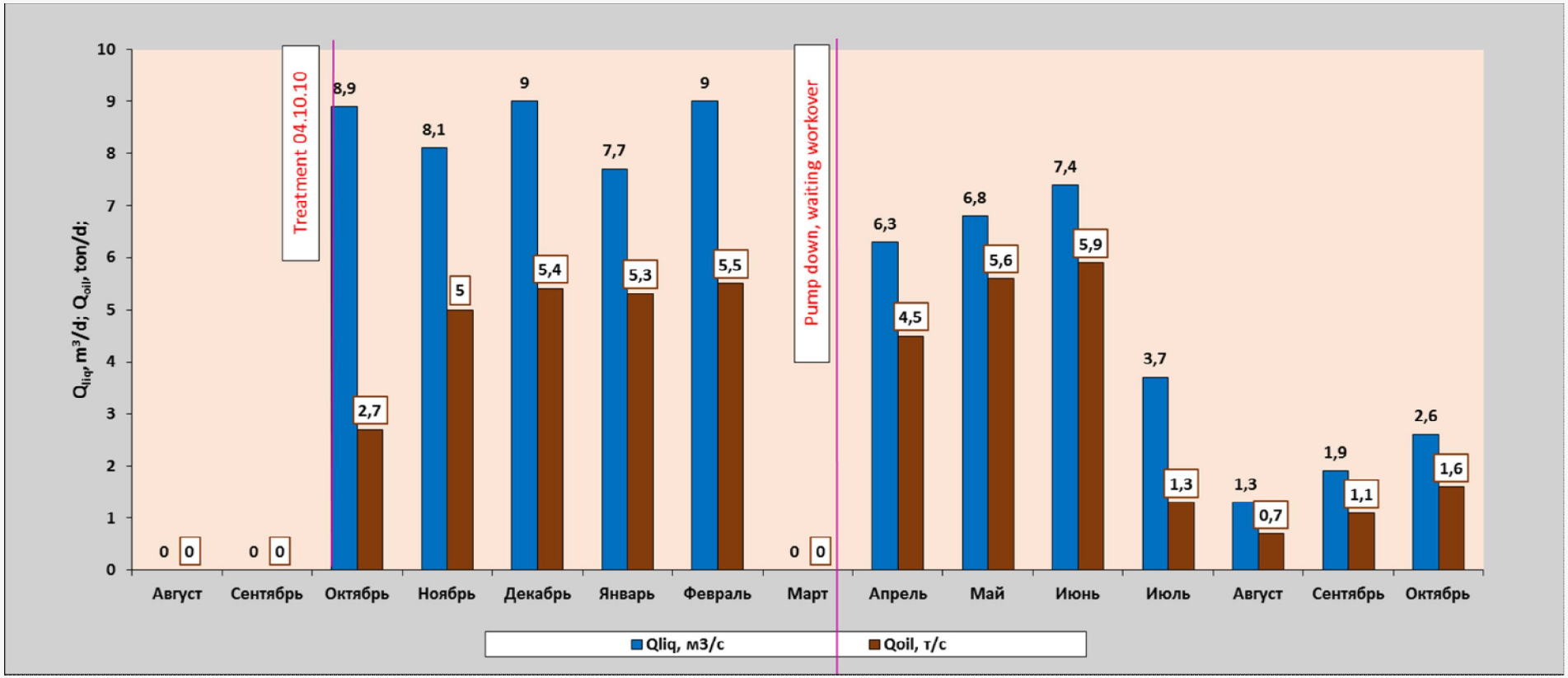


1st treatment: 220 days in operations, average increase on oil rate 9,2 ton/day, 2nd treatment: 244 days in operations, average increase on oil rate 8,7 ton/day

CONFIRMATION OF EFFICIENCY

CUT SERVICE CENTER OF ULTRASOUND TECHNOLOGY

Production history of well 3 (actual number is confidential) from Samotlorneftegaz before and after treatment

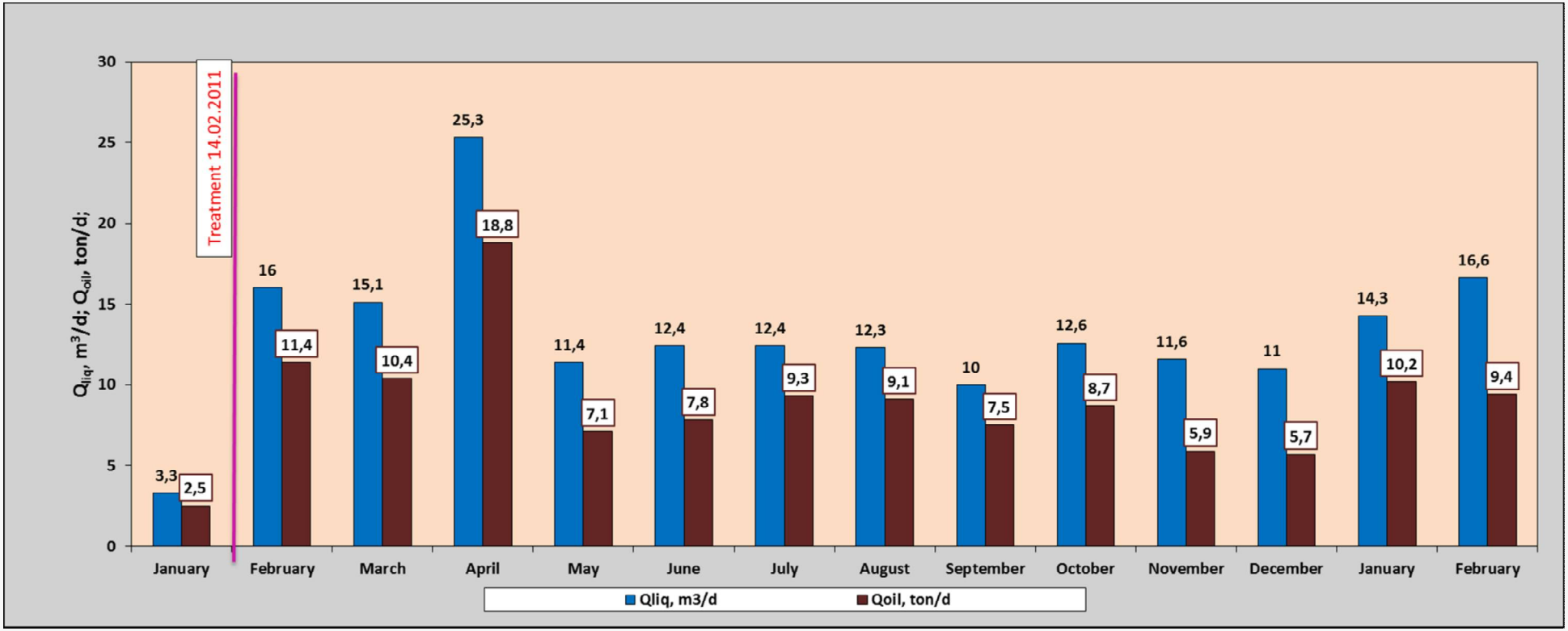


325 days in operations, average increase on oil rate 3,7 ton/day from 0

CONFIRMATION OF EFFICIENCY

CUT SERVICE CENTER OF ULTRASOUND TECHNOLOGY

Production history of well 4 (actual number is confidential) from Samotlorneftegaz before and after treatment

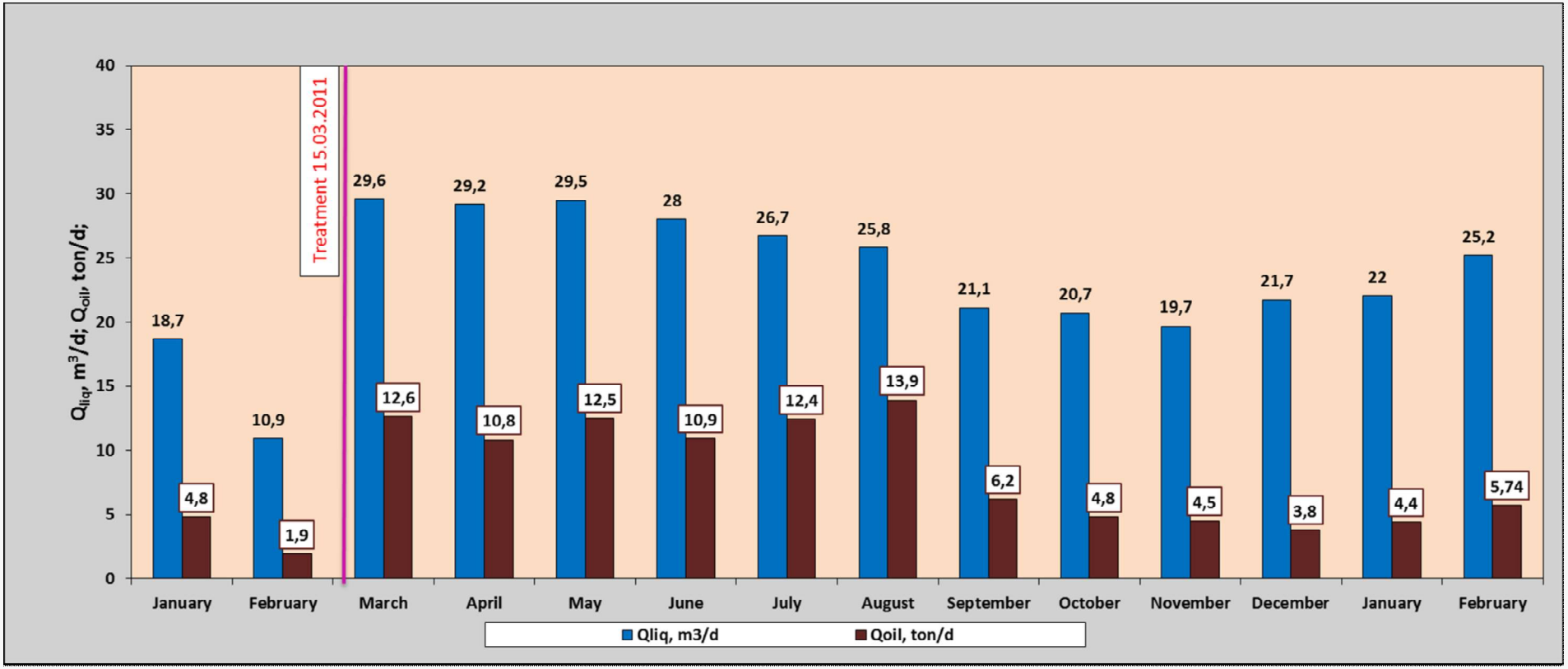


398 days in operations, average increase on oil rate 6,3 ton/day

CONFIRMATION OF EFFICIENCY

CUT SERVICE CENTER OF ULTRASOUND TECHNOLOGY

Production history of well 5 (actual number is confidential) from Samotlorneftegaz before and after treatment

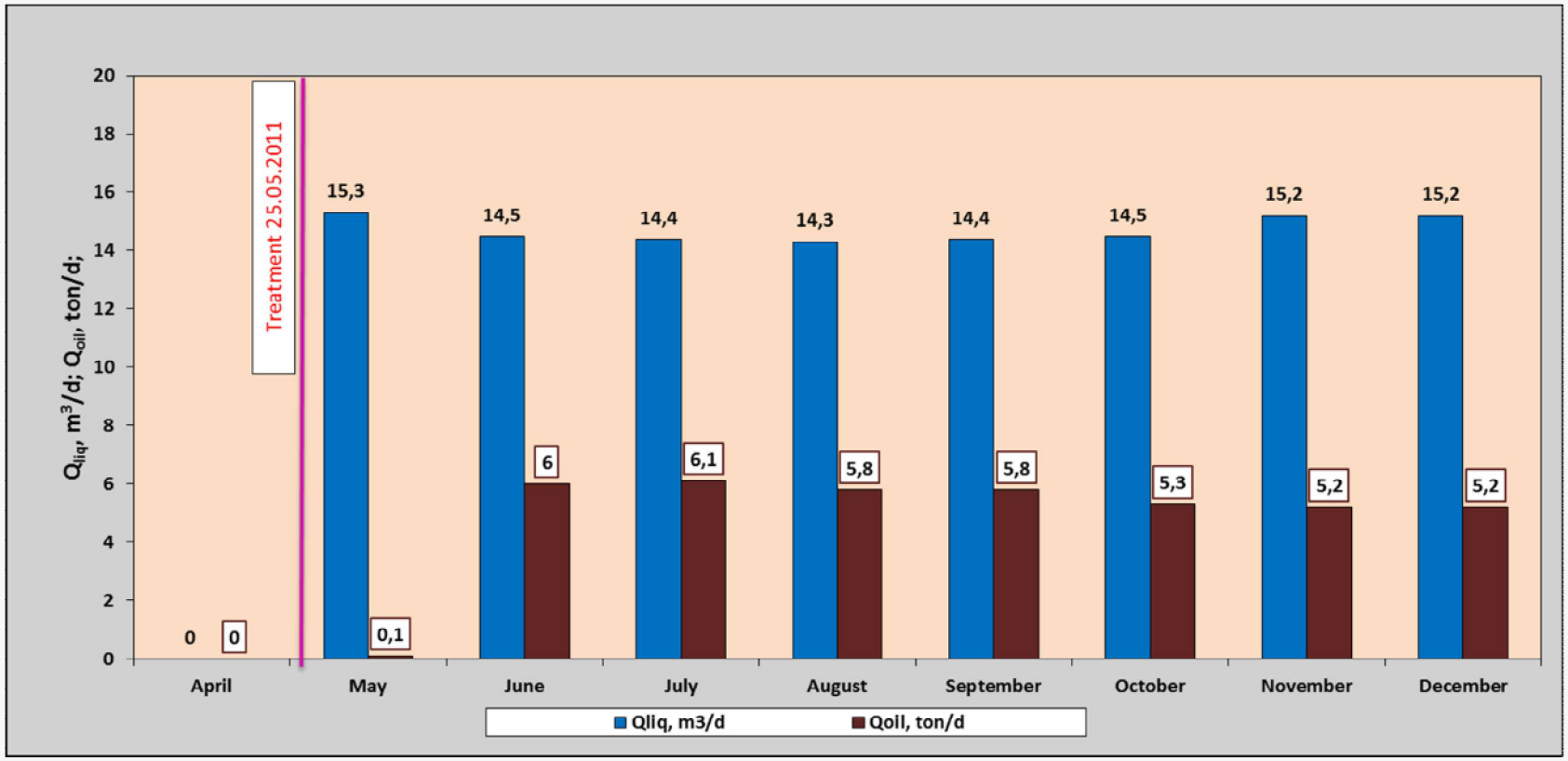


345 days in operations, average increase on oil rate 5,15 ton/day

CONFIRMATION OF EFFICIENCY

CUT SERVICE CENTER OF ULTRASOUND TECHNOLOGY

Production history of well 6 (actual number is confidential) from Samotlorneftegaz before and after treatment



218 days in operations, average increase on oil rate 5,6 ton/day

CONFIRMATION OF EFFICIENCY ON HEAVY AND VISCOUS OIL

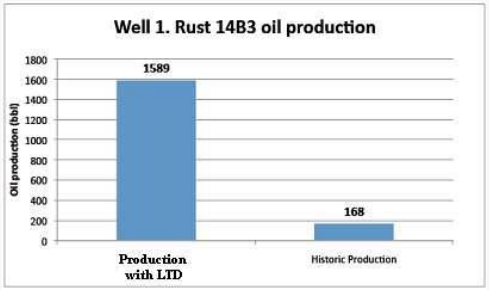
CUT SERVICE CENTER OF ULTRASOUND TECHNOLOGY

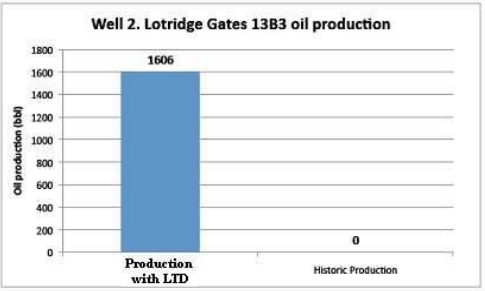
- Continuous AWS has been tested at low producing wells of Green River Formation, USA in 2008.
- This field was selected for pilot tests because represent traditional hard-to-recover oil deposits

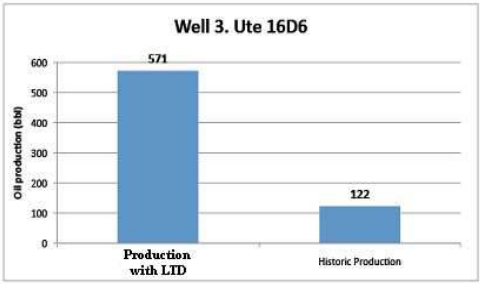
By results of pilot test of technology of ultrasonic treatment, US Department of Energy made following conclusion:

«… If the (AWS) technology becomes widely adapted in the United States and throughout the oil and gas industry, there may be a large increase in production of hydrocarbon fluids. The resulting increase in domestic production could decrease the dependency of the United States on foreign oil» ©

From 2014 this type of services provided by Joint Venture with Nanocentre of Tatarstan Republic (ROSNANO entity) – LLC “SONOTECH”







CONFIRMATION OF EFFICIENCY ON HEAVY AND VISCOUS OIL

CUT SERVICE CENTER OF ULTRASOUND TECHNOLOGY

- Outstanding results on extra-low rates heavy oil wells in Canada in 2016

Date	12.04.2016	19.04.2016	26.04.2016	03.05.2016	10.05.2016	11.05.2016	12.05.2016	13.05.2016	17.05.2016
Average daily flowrate, bbl/day									
Well #1	1,08	1,00	0,71	0,71	0,86	7,00	3,00	2,00	1,25
Well #2	1,00	0,57	0,00	0,00	0,86	5,00	3,00	1,00	0,75
Well #3	1,00	0,71	0,71	0,71	0,86	1,00	1,50	2,00	1,00
Well #4	0,83	0,71	0,71	0,71	0,86	6,50	5,50	5,00	1,25
					-->	<-- AWS treatment			

Relative productivity growth					
Days after treatment ->	0	1	2	3	7
Well #1	100%	817%	350%	233%	146%
Well #2	100%	583%	350%	117%	88%
Well #3	100%	117%	175%	233%	117%
Well #4	100%	758%	642%	583%	146%

Instant productivity growth **> 800%**
Effect duration – up to **7 days**

Single stimulation proved that installation of oscillators for continuous operations will allow to keep productivity rate at level of 700-800% from initial and will require to power up oscillators just for 30 minutes daily

Project status: ongoing discussions on Phase 2 details – introduction of AWS equipment for permanent installation

CONFIRMATION OF EFFICIENCY ON HEAVY AND VISCOUS OIL

CUT SERVICE CENTER OF ULTRASOUND TECHNOLOGY

- **SC «TATEX», Republic of Tatarstan, Russian Federation**

Treatment of 2 wells of Demkinskoe field in 2015:

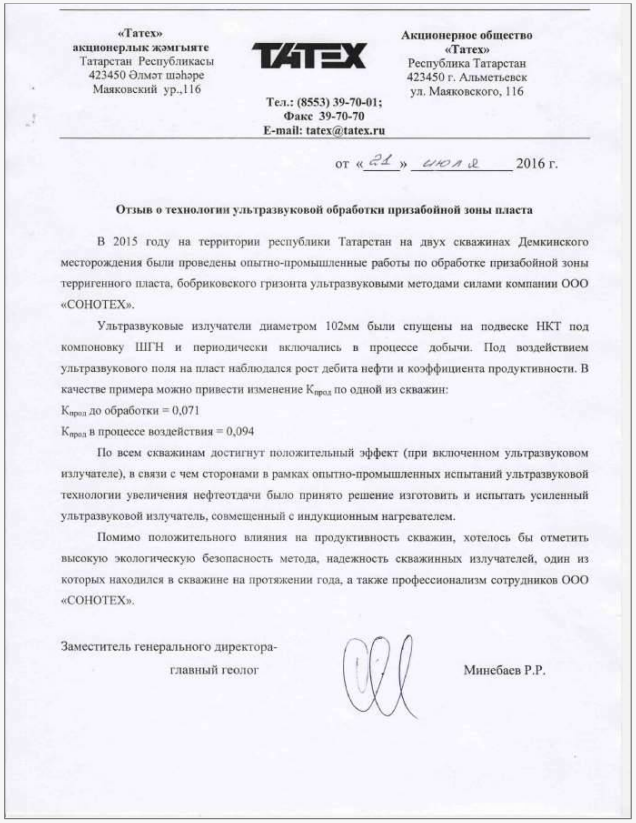
Descroption	WELL 1	WELL 2
Instant oil flowrate growth	+ 15%	+ 30%
Effect duration	3 days	3 days

Trial job proved technology efficiency in the formation conditions

On Well #1 equipment was removed after the treatment
On Well #2 equipment kept in the well for the continuous monitoring for 1 year

Project status: ongoing selection of 3-5 wells for the treatment with thermo-acoustic oscillator in 2017.

Recognition letter:



«Татех»
акционерлык жәмгыяте
Татарстан Республикасы
423450 Әлмәт шәһәре
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Акционерное общество
«Татех»
Республика Татарстан
423450 г. Альметьевск
ул. Маяковского, 116

от «21» июля 2016 г.

Отзыв о технологии ультразвуковой обработки призабойной зоны пласта

В 2015 году на территории республики Татарстан на двух скважинах Демкинского месторождения были проведены опытно-промышленные работы по обработке призабойной зоны терригенного пласта, бобриковского гризонта ультразвуковыми методами силами компании ООО «СОНОТЕХ».

Ультразвуковые излучатели диаметром 102мм были спущены на подвеске НКТ под компоновку ШГН и периодически включались в процессе добычи. Под воздействием ультразвукового поля на пласт наблюдался рост дебита нефти и коэффициента продуктивности. В качестве примера можно привести изменение $K_{прод}$ по одной из скважин:

$K_{прод}$ до обработки = 0,071

$K_{прод}$ в процессе воздействия = 0,094

По всем скважинам достигнут положительный эффект (при включенном ультразвуковом излучателе), в связи с чем сторонами в рамках опытно-промышленных испытаний ультразвуковой технологии увеличения нефтеотдачи было принято решение изготовить и испытать усиленный ультразвуковой излучатель, совмещенный с индукционным нагревателем.

Помимо положительного влияния на продуктивность скважин, хотелось бы отметить высокую экологическую безопасность метода, надежность скважинных излучателей, один из которых находился в скважине на протяжении года, а также профессионализм сотрудников ООО «СОНОТЕХ».

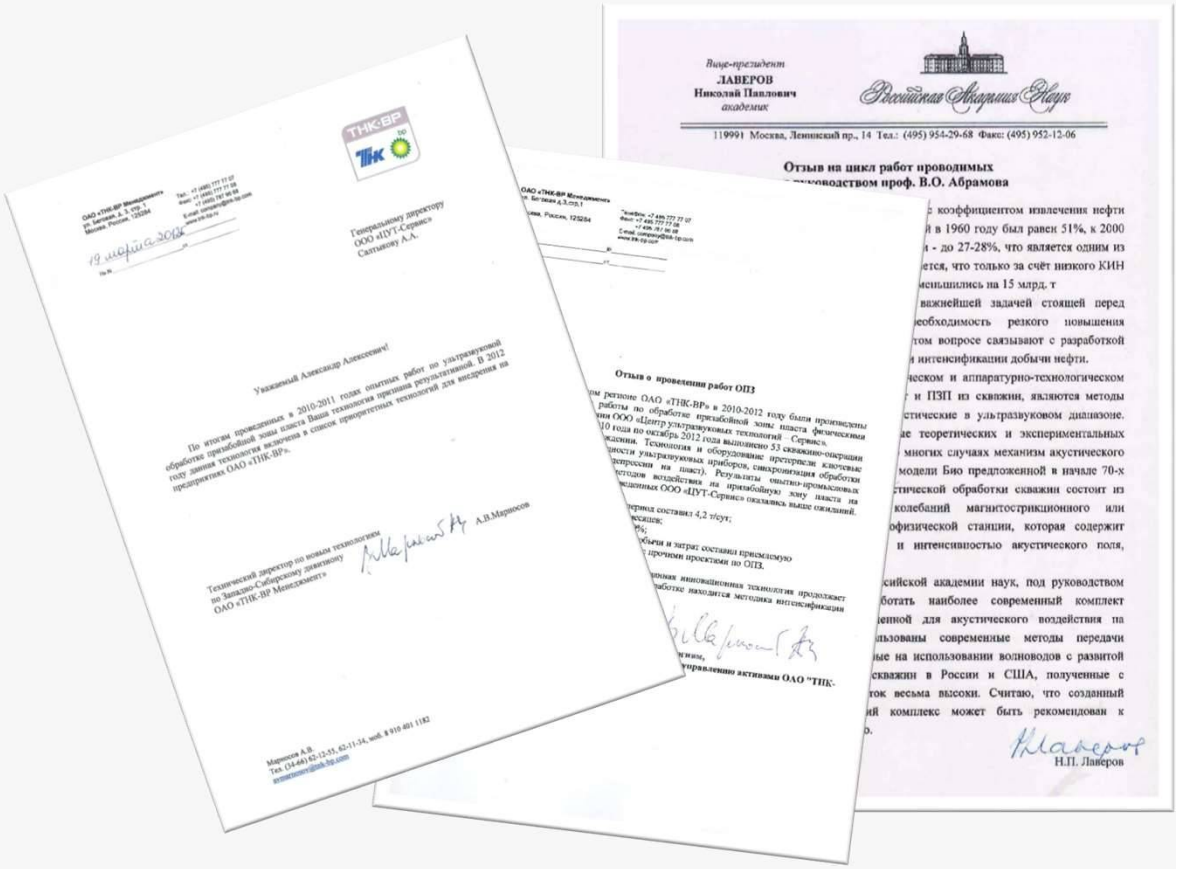
Заместитель генерального директора-
главный геолог Минебаев Р.Р.

CONFIRMATION OF EFFICIENCY

Recognition letters

Technology went through all levels of field trials from 2010 until 2012 and was added to the list of priority technologies to deployment in TNK-BP by HQ Management.

From 2012 technology fully commercialized in Russian Federation



Вице-президент
ЛАВЕРОВ
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Отзыв на цикл работ проводимых
руководством проф. В.О. Абрамова

Н.П. Лаверов

Генеральному директору
ООО «ЦУТ-Сервис»
Сяткину А.А.

Уважаемый Александр Алексеевич!

Технический директор по новым технологиям
по Западно-Сибирскому дивизиону
ОАО «ТНК-ВР Менеджмент»

А.В.Марков

Отзыв о проведении работ ОПЗ

CUT SERVICE CENTER OF ULTRASOUND TECHNOLOGY

QUESTIONS