Petrochemistry and Chemical Engineering

The use of an ultrasonic technology to increase the productivity of oil wells

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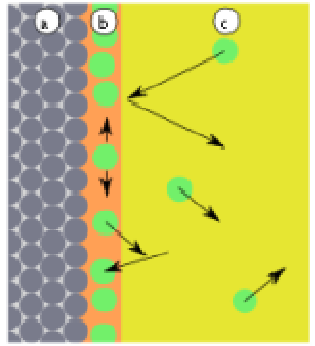
Introduction

- The efficiency of oil recovery is not satisfactory at the moment (the oil recovery is less than 40%).
- Existing technologies of enhanced oil recovery (EOR) are energy-intensive, labor-intensive and not environmentally safe.
- Most of the existing technologies of EOR are not applicable for horizontal wells
- Ultrasonic methods of EOR have shown promising results in the recent years

Theoretical background

Mechanism of pollution of the formation

On the surface between liquid oil and solid rock a interfacial layer is formed. It typically consists of asphaltenes, paraffins, resins and other surfactants. Thus, this layer has higher viscosity and higher critical shear stress. The thikness of this layer increases with time and it stabilises, leading to a drop of effective porosity of the formation. Interfacial layers form not only on the surfaces of the formation pores but also on lose solid particles, which also blocks the pores.



a) Rock (solid phase)

b) Interfacial layer

c) Oil (liquid phase)

Effects of ultrasound

- Nonlinear thixotropic change of the bulk properties of oil;
- Stimulation of oil mobility due to changes in the structure of the oil in the narrow zone of adhesion of oil and an oscillating solid surface;
- Change of the channel cross-section of the porous formation;
- Change in viscosity due to heating by the acoustic action;
- Acoustic cavitation effects;
- Sonocapillary effect.

Theoretical background

Treatment time

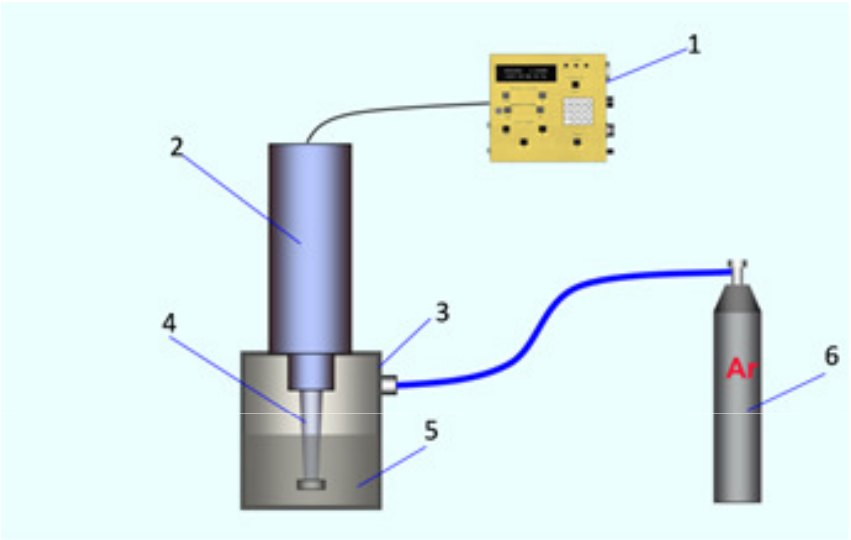
$$\tau_p = \tau_0 \exp\left\{\frac{E_0 - \gamma\,(\sigma_c + \sigma_u)}{kT}\right\}$$

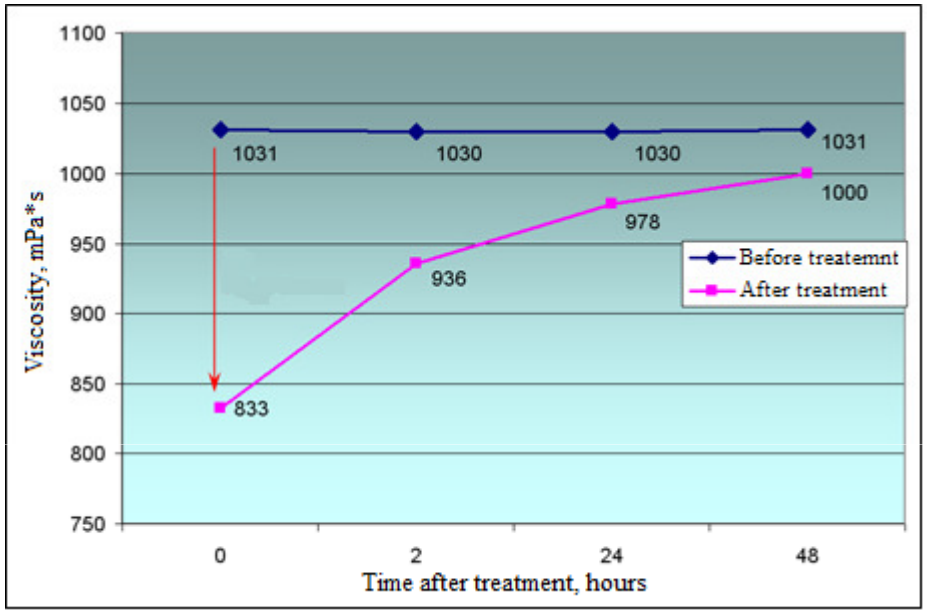
Destruction time of the intermolecular forces (formula of Ghurkov)

Typical parameters of oil: E_D ~ 500 kJ/mol, ρ ~ 900 kg/m^3, c ~ 600 m /s, f = 20 kHz

Distance from the waveguide	Destruction time, min
0	2
0,5	7
1	19
1,5	54

Viscosity change of oil under the influence of ultrasound



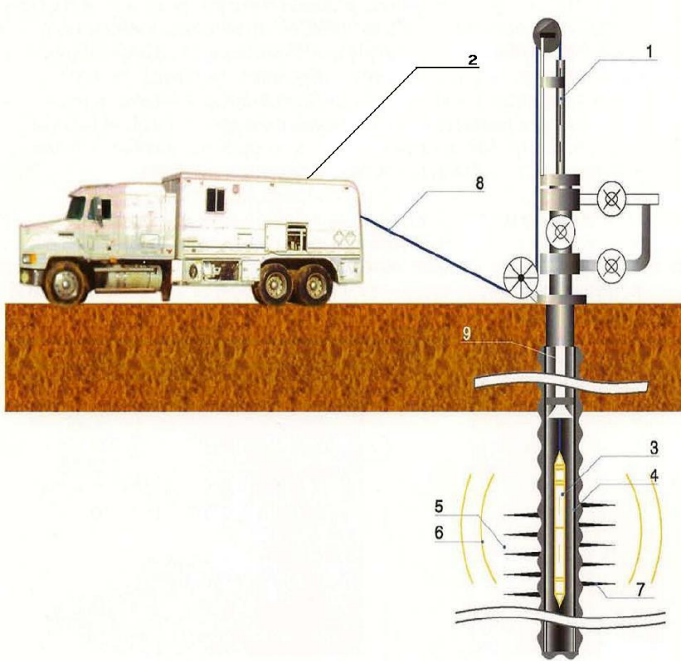


Density, g/cm³	Effective viscosity 20 °C, mPa*s	Freezing temperature, °C	Components, % mas.		
			Oils	Resins	Asphaltens
0,953	1014	-17	64,05	28,6	6,1

Treatment parameters:
Treatment time 3 min.
Frequency: 23,5 kHz, power: 1 kV

Equipment

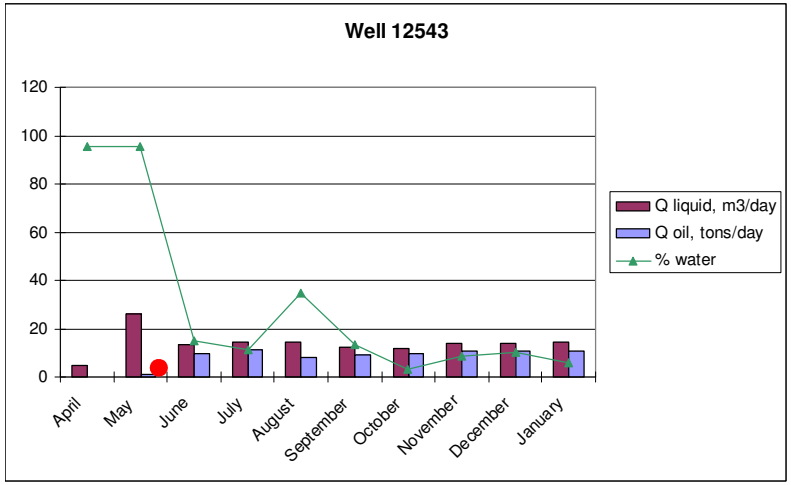
STS is used to enhance recovery of light crudes.
The equipment consists of an ultrasonic generator and a downhole tool connected with electric armoured cable.
The main element of the downhole tool is an electroacoustic transducer (piezoelectric or magnetostrictive) which transmits acoustic energy into the formation controlling the intensity of the ultrasonic field (determined by technical conditions).
The downhole tool for light and medium well treatment has a 42-44 mm diameter and can be used during capital and operational workover. It is lowered into the well through the tubing. Power is supplied through the cable.

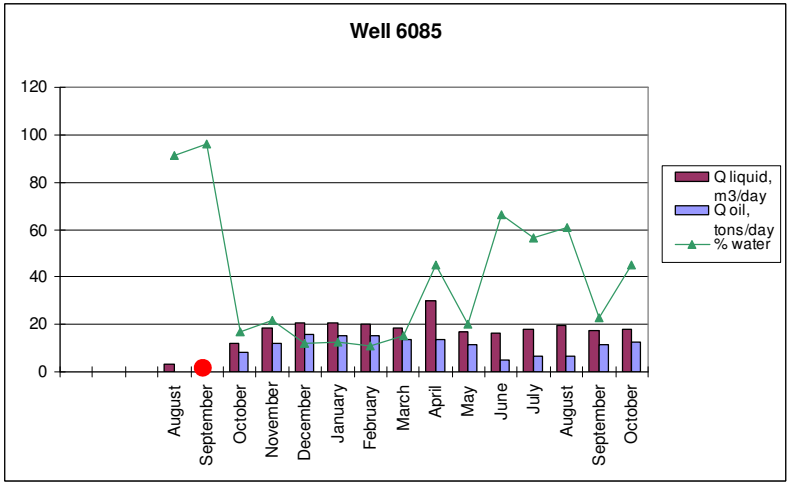


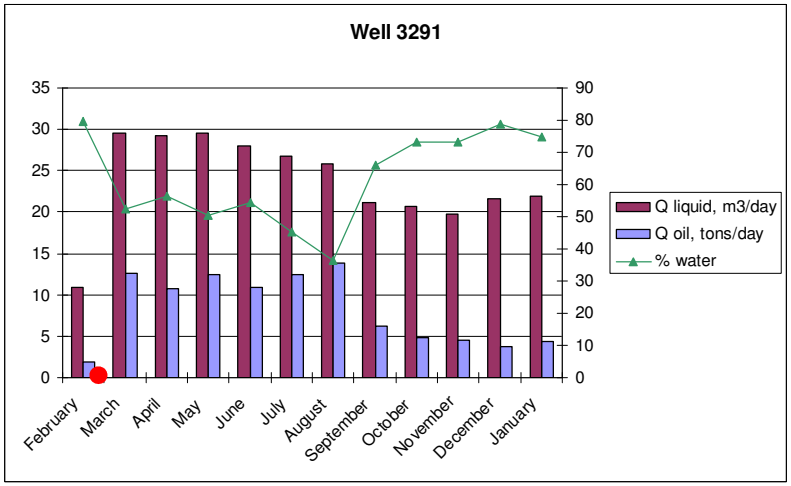
1 - Lubricator
2 – Wire line truck
3 - Downhole tool (42 mm)
4 – Casing
5 - Oil-bearing formation layer
6 - Area of acoustic impact
7 – Perforation zone
8 - Logging cable
9 - Tubing

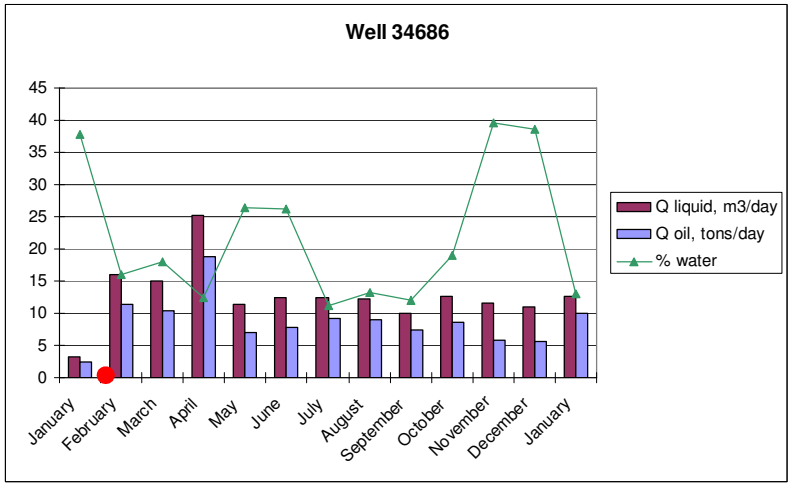


STS – treatment results







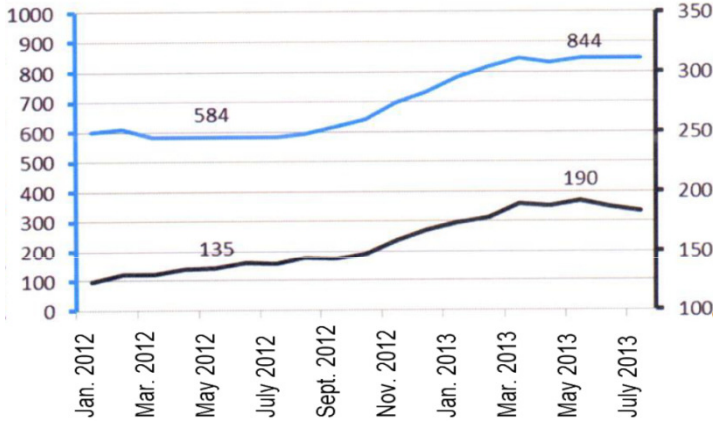


- STS

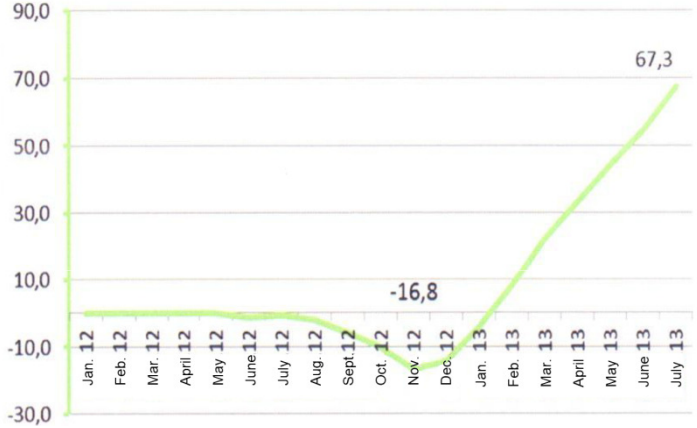
STS – treatment results

STS is a proven technology, in use since 2010 in the Samartlor field, Siberia (results of 01.2012 – 07.2013)

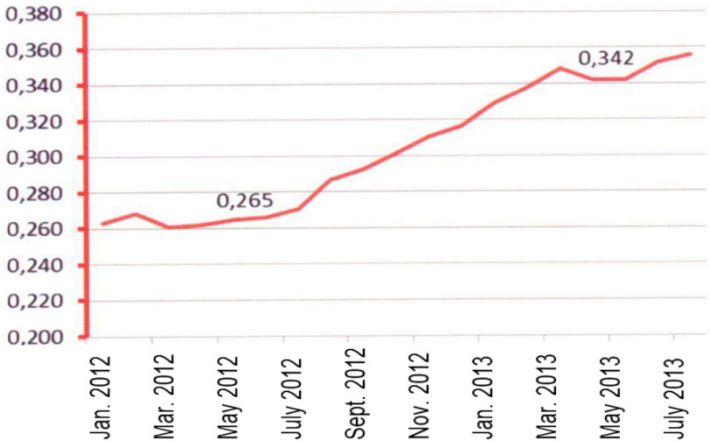
Changes of the oil and fluid production



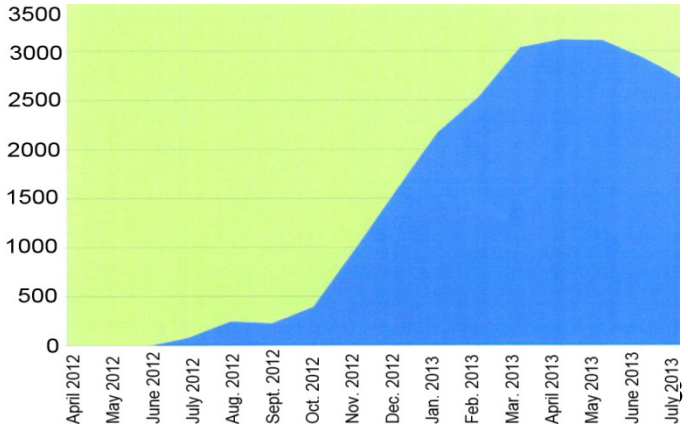
CF (mln. rubles)



Changes of the prod. coefficient

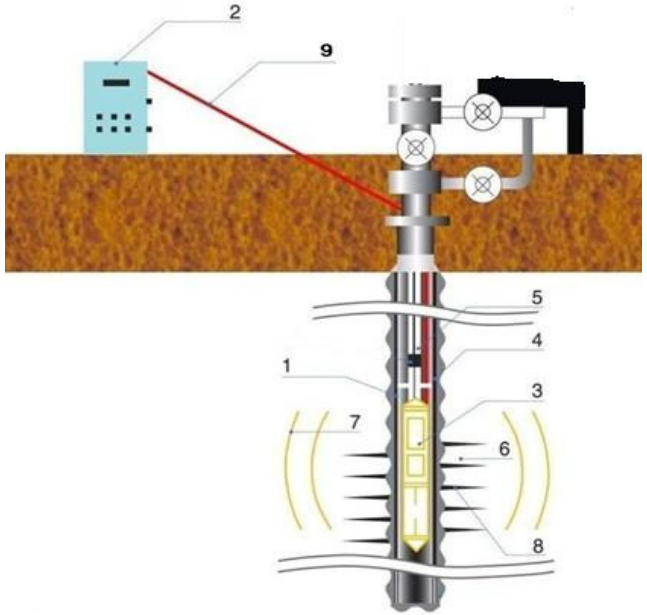


Level of additional oil production, tons



LTD – general description

LTD is designed to increase production in heavy crudes, this system is deployed during a maintenance workover by means of a rig truck. The downhole tool has a 102 mm diameter and is attached to the tubing. It is left operating in the well and operates continuously for periods between workovers. Its operation can be regulated by means of the ultrasonic generator at the surface.

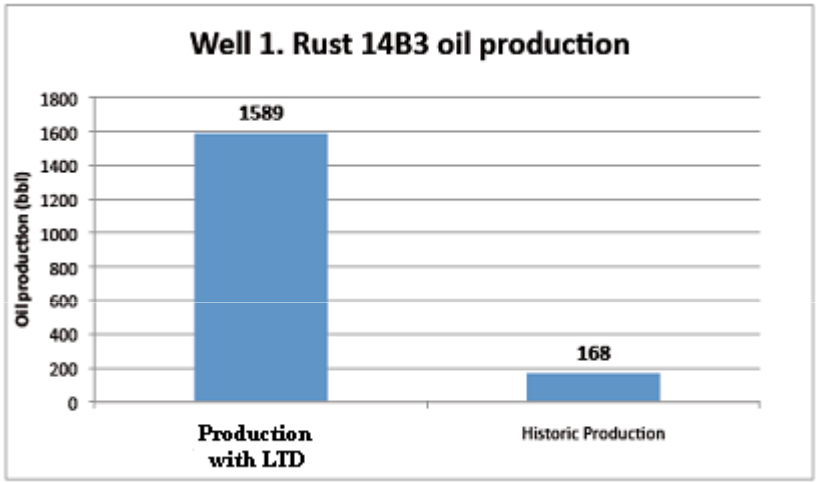


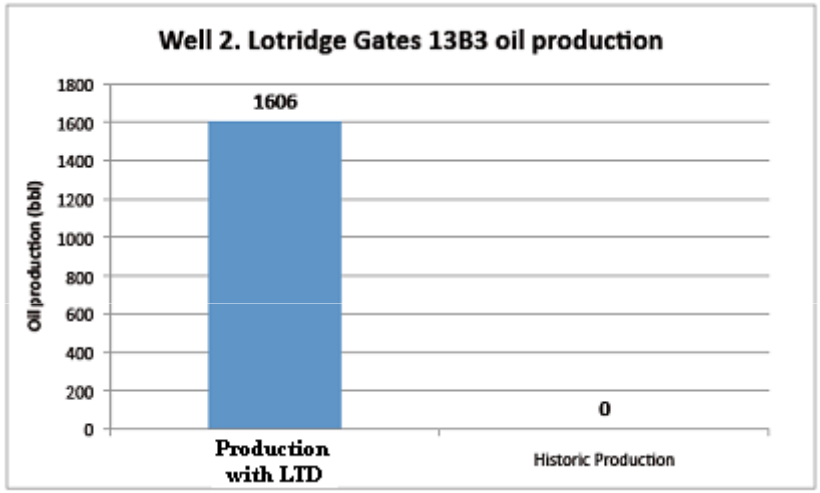
1. - Anchor
2. - Ultrasonic generator
3. - Downhole tool (102 mm diameter)
4. - Casing
5. - Tubing
6. - Reservoir
7. - Area of acoustic impact
8. - Perforation zone
9. - Cable

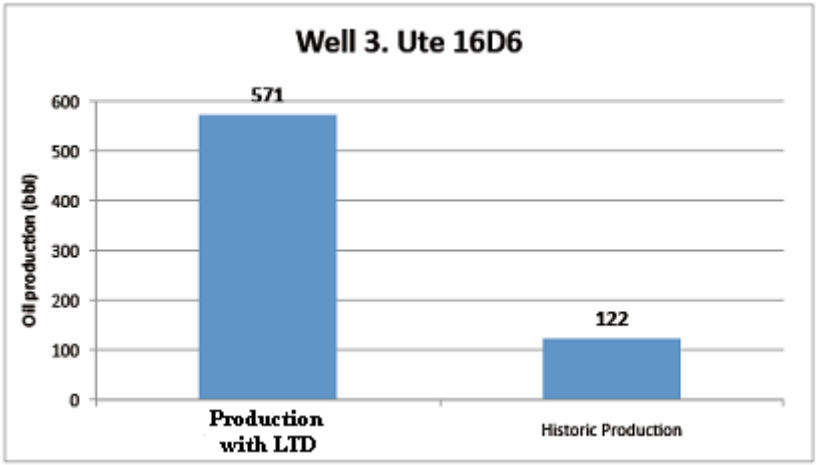


LTD – treatment results

LTD has been tested on low-production oil wells in the Green River formation, USA. This reservoir was chosen for testing because it is clearly representative of accumulation of non conventional deposits.







Equipment – for treatment of horizontal wells

Main principles:

- It is important to determine the intervals for treatment prior to the treatment, this can be done if preliminary geological studies are carried out
- In order to decrease the treatment time chemical and acoustic treatment should be combined
- The delivery of chemicals during the treatment should be possible
- The chemicals should be delivered to the zone where the efficiency of the acoustical treatment is maximal



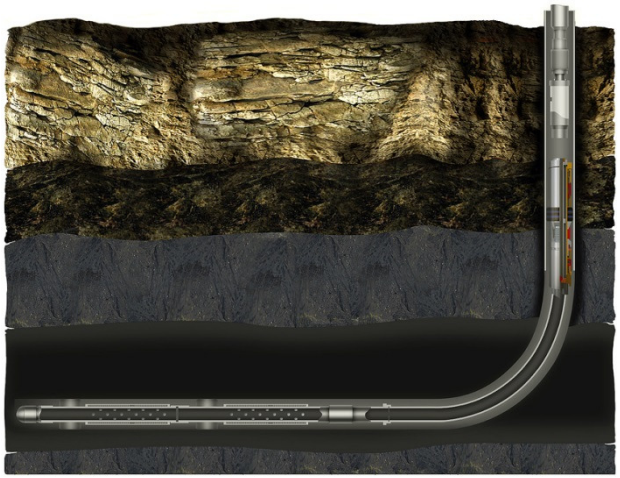
Equipment – for treatment of horizontal wells

The downhole equipment includes a sonotrode, a system for injection of chemicals and a registrator of geophysical data (temperature, pressure, flow).







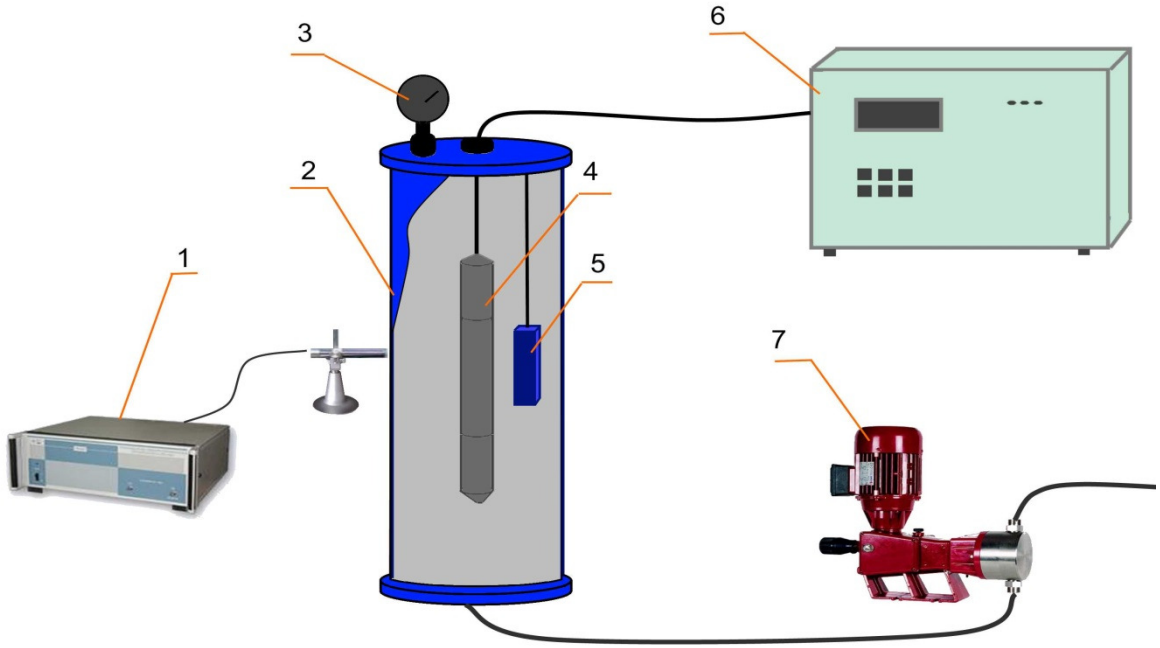


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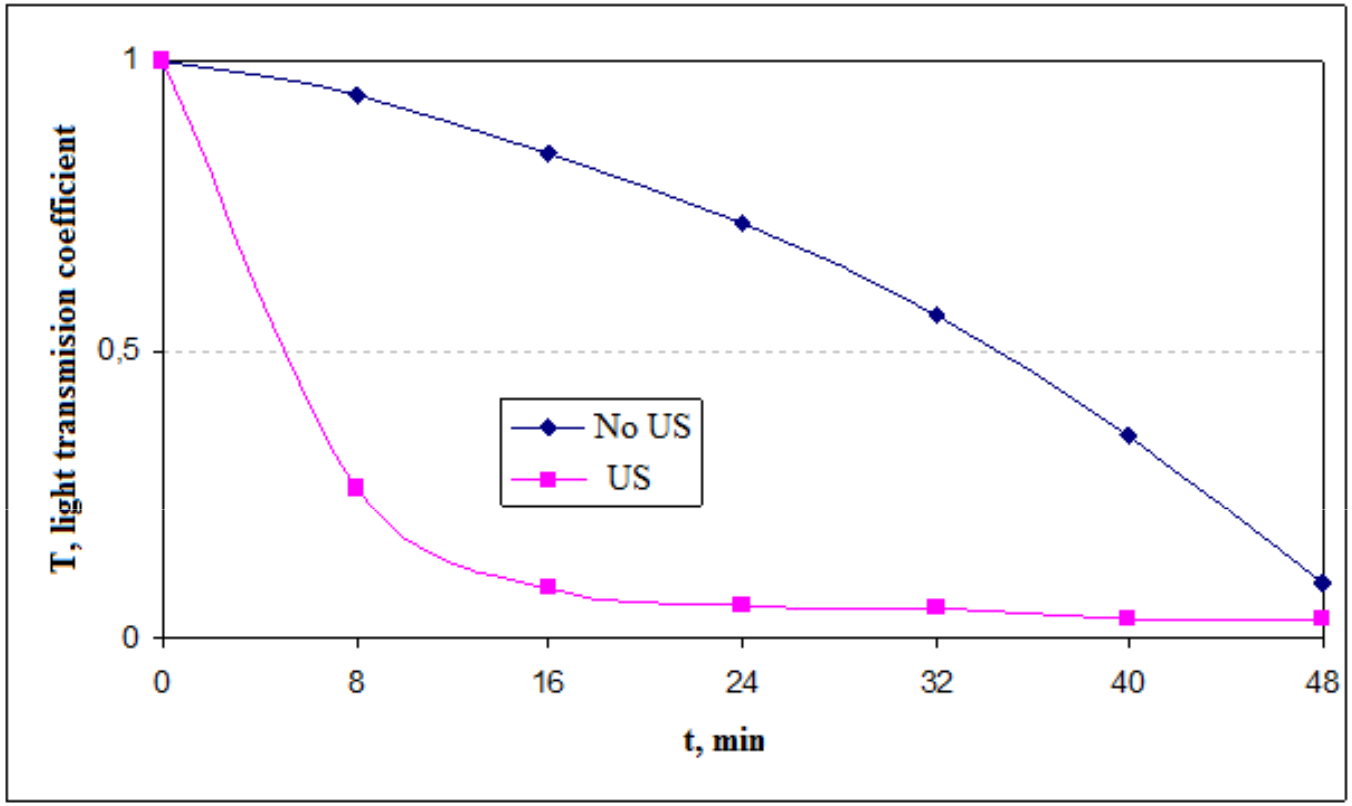
Ultrasonic method
of enhanced oil recovery

Laboratory experiments





Laboratory experiments

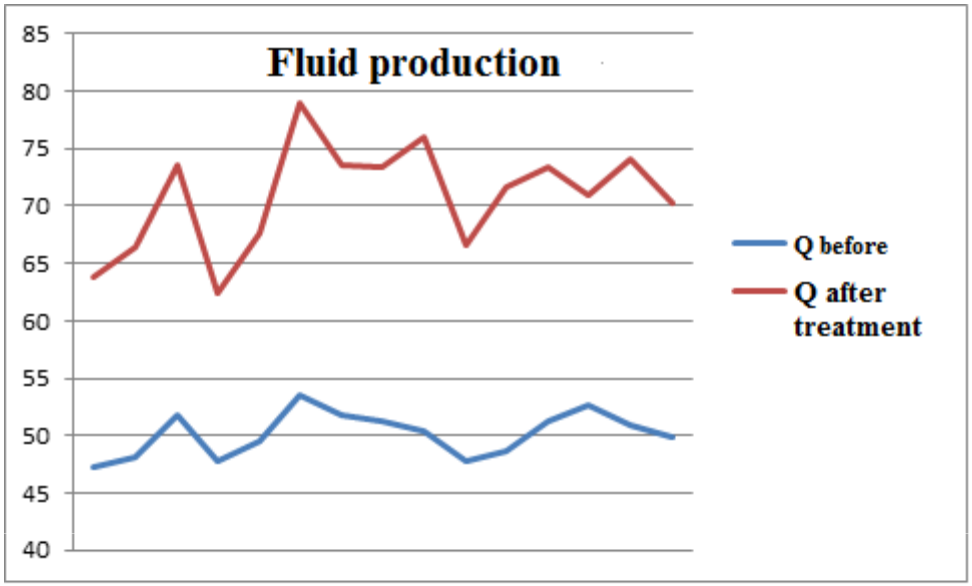


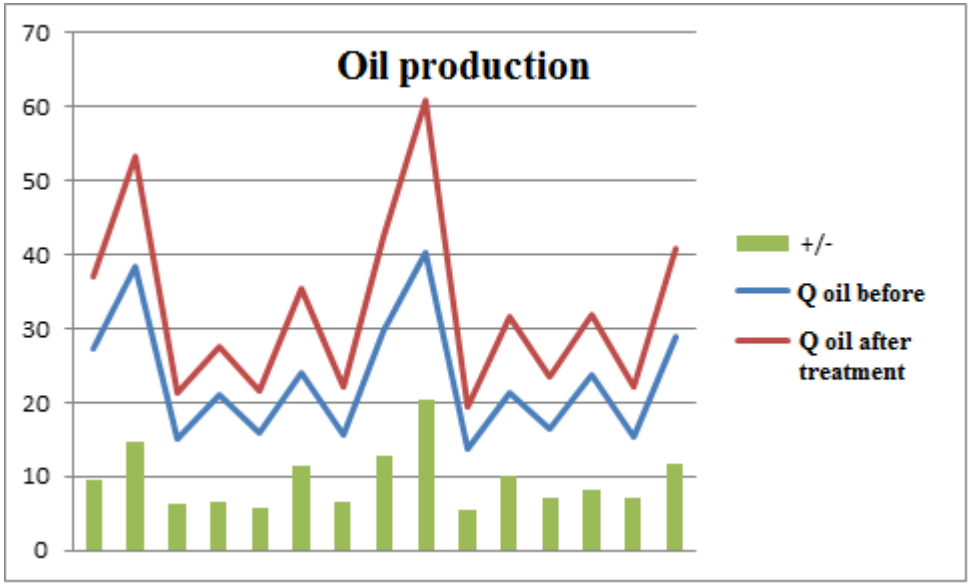
$$T = (I - I_t)/(I_k - I_t)$$

Field tests

Region	Type of treatment	Before treatment	After treatment	3 month after treatment
Western Syberia	Sonochemical	3.92	9.1	8.4
	Ultrasonic	3.92	8.32	7.7
Samara region	Sonochemical	8.4	19.8	15.8
	Ultrasonic	8.4	18.6	11.5

Field tests – horizontal well





Field tests – analysis

- Normally ultrasonic and sonochemical treatment is done during capital workover of the well, it is often accompanied by optimization of the pumping equipment.

- Ultrasonic treatment leads to an increase of the productivity factor by 39% and decrease of the water cut of the well by 5% in average.
-
- In wells where only the optimization of pumping equipment was carried out a drop of the productivity factor of 5.6% and an increase in the water cut of 1.5% were observed.

- Thus, the effects achieved can be fully attributed to sonochemical or ultrasonic treatment.

Conclusions

- The tests indicated that the success rate of the sonochemical method reaches 90% and the increase in oil production is in the range of 40-100%
- One of the main advantages of this approach is the possibility to use this EOR method in horizontal wells
- Special equipment has been developed for this purpose
- Field tests on a horizontal well revealed the potential of this technology
- An oil production increase of 40% in average was achieved after sonochemical treatment of a horizontal well

References

[1] Abramov V.**,** Mullakaev M., Abramova A. et al. *Ultrasonics Sonochemistry,* 20(5): 1289 -1295. **2013**
[2] Abramov V., Mullakaev M., Bayazitov V. et al. *Petroleum Engineering* (in Russian), 6: 26-31. **2013**
[3] Alhomadhi E., Amro M., Almobarky M. *Journal of King Saud University – Engineering Siences,* 26: 103-110. **2014**

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Thank you for your attention!