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Paper Title
ОРРНЭО Technology (single commingle development of several production zones) Introduction Experience On Oil Fields in Western Siberia

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Abstract

The paper presents the problem of the usage of "intelligent wells" with multi packer arrangement. The "intelligent well" with multi packer systems enable companies - operators to adjust parameters of a reservoir in a mode of real time and to provide selective operation of particular deposits through the section without running the well.

The multihorizon oil fields are effectively developed by such wells on Western Siberian oil fields. It is possible simultaneously-separately or alternately to withdrawal and inject into several exploited objects and also to keep account and the control of extraction of a fluid and injected agent through one lift. Simultaneous -separate development of multihorizon oil fields using multi packer arrangement is a new direction in development and perfection of the theory and practice of oil production

At the optimization of oil recovery [1] process both current production maximization and oil recovery maximization of all reservoirs under development are implemented as a criterion. It is obvious that the more production zones are allocated the higher oil recovery can be obtained per total number of reservoirs. However, regardless of oil recovery enhancement at zones subdivision this approach is restrained by economic limitation, first of all, by a number of drilled wells. There is another alternative method of subdivision of development zones without drilling additional wells (several commingled zones for separate zones or several interlayers for separate interlayers) without drilling of additional wells. This way, the contradiction between economic side and conservation of mineral resources when choosing operational objects can be resolved using the single-commingle technology [2].

Geological simulation is performed by applying a software package using seismic surveys data, field geophysics (logs), core analysis and taking into consideration of a theory on formation features of a reservoir under review [1]

Traditional approach of geological model parameters determination (porosity, permeability, net pay thickness, OWC location, rock water-retaining capacity, volumetric shaliness, etc.) as per logging data (SP, apparent resistivity, induction, nuclear, acoustic logging, MRIL, etc.) in reservoirs with complicated structure not always give open-ended answers. For example, due to polymineral rock composition and forming of deep zones of process liquids penetration into the zone while evaluation of saturation properties. While determination of fluid loss properties of reservoir rocks upon logging surveys data considering lithologic and petrophysical core studies except functional correlation between porosity, permeability and reservoir saturation, correlations between the following parameters are also determined: permeability and horizon effective net pay; residual water saturation and permeability; initial oil saturation and hypsometric offset from OWC; permeability and diffusion-adsorption activity, etc.

2D and 3D **seismic** is widely used for revealing geological structure and productive reservoirs faults and 4D seismic (3D seismic within some period of time) – for determination of interphases movement between fluids and stagnation zone borders, which are not covered with filtration.

Geochemical methods are applied more and more during hydrocarbon deposits surveys. Particularly, oil system basic elements – source rock, migration ways, reservoirs, covers, traps are defined with the help of geochemical correlation using modern analytical data base – Rock-Eval kerogen pyrolysis, gas chromatography, chromatography-mass spectrometry, isotop-mass spectrometry. Upon maximum concentration of hetero-organic compounds (asphaltenes, tars, sulphur and nitrogen-organic compounds, paraphines, high-molecular aromatic hydrocarbons, etc.) the sources location of oil ingress into a deposit are determined. the additional of these sources are: the higher initial production rates, formation pressures and temperature and also net pay thicknesses of the section and number of oil saturated productive layers.

There are different software sets used for hydrodynamic modeling. At that the model is created and adjusted on the basis of geophysical, hydrodynamic, tracer (indicated) and chemical surveys considering formation pressure dynamics, water injection, fluid and oil production in wells. This model already includes accumulation of technological information taking into account changes within the time (4D).

The most difficult problem while creating reservoir model is acquiring of the qualitative initial data and the most important for model adjustment is an information on metering characteristics for separate layers – reservoir fluid recovery and water injection into them.

The primary source of geological-geophysical and technological basic information on development process and place of applied process management is the well. But for study of spacing between the wells, pressure interference test data and surveys using injection of indicated agents are applied. The quality of the studies is much higher when the ОРРНЭО technology is used [3].

The more efficient method of hydrodynamic model adaptation is the comparison of calculated and actual indices and their correlation by means of changes integration into parameters of the initial model and secondary hydrodynamic calculation.

Permeability values determined upon the results of direct core measurements, upon logging surveys and hydrodynamic surveys can vary significantly. Of course, permeabilities acquired based on hydrodynamic surveys are considered to be more reliable for the hydrodynamic model. But the values of the last can also significantly vary, particularly, due to its performance in wells, which produce at unstable modes. Moreover, hydrodynamic surveys provide with permeability, which is averaged for the whole perforation interval (layer) and do not consider vertical heterogeneity of the zone.

Enhancement of hydrodynamic model reliability requires rock (interlayers) differentiation of one zone per permeability to locate zones with low and high productivity, determination of productivity indices for each of the interlayers and selection of the most effective filtration direction [4].

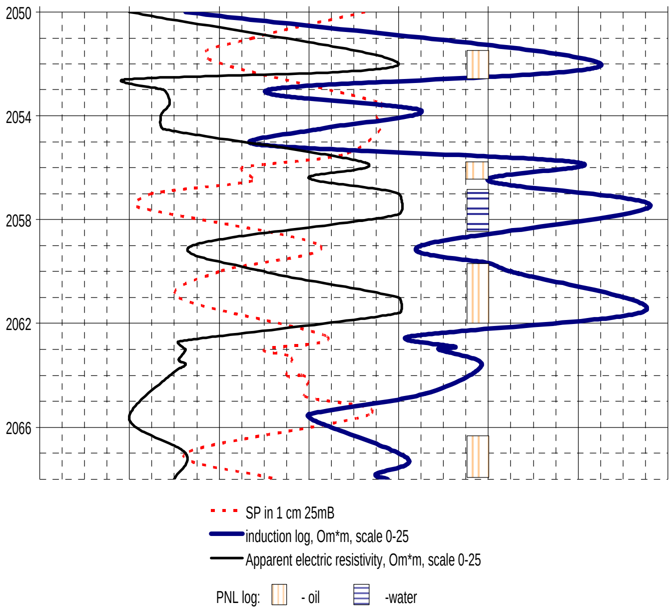
The most informative indices are the following: inflow and injectivity profiles; radionuclide nuclear logging; forecast of development process at different adjusting procedures and workover/maintenance procedures; fluid, oil and gas rates on wells, bottomhole pressures, formation pressures; interacting through reservoir and interlayers of the well.

The more reliable for reservoir model setting is the information on distribution flows between reservoirs, merged in one zone of development and between interlayers of one reservoir with different permeability acquired from injectivity profile from producing wells and injectivity (absorption) profile of injection wells. However, injectivity profiles give different distribution of production at various draw down pressure. The same concerns the injectivity profiles – distribution of water injection changes at the various repression.

Analysis run on core data, geophysical and hydrodynamic surveys on West Siberian field deposits indicated that sections of the majority of the reservoirs there are interlayers with different fluid loss properties. Besides, reservoirs and non-reservoirs, sections of the majority of the reservoirs there are interlayers, conductivity of which dos not conform with Darcy's law. This causes significant problems at hydrodynamic modeling, i.e. moel should be changes in time, in particular, in depending on formation pressure change and draw down pressure to the formation.

Hydrodynamic features of the zone such as adjusted rate, average unit productivity, relative permeability are reduced with testing interval increase. This is specified by hydrodynamic interrelation of separate interlayers with different permeability in the zone under review, i.e. superposition principle is violated. For example, permeability index, determined by hydrodynamic survey data can be reduced few times at exposed thickness of the same productive layer, at that the total production rate of the well increases disproportionately to the thickness exposed.

At the control over reservoir development and individual interlayers, the largest preference (more than a half of total amount) is given to surveys by means of **pulse neutron logging**. The results of pulse neutron logging characterize depletion and drowning (saturation distribution) of a productive zone per thickness (Picture 1). As one can see from the picture, there are highly permeable intervals of premature water breakthrough, which can be possibly characterized with high velocities of the injected water laterally. PNL data allow mapping of water saturated thicknesses in segments, based on which production forecasts can be made.



Picture 1 Results of well surveys per depth (well 547, B_3 reservoir)

The distribution along the thickness of the intervals producing oil, water with oil and water determined based on injectivity profile often do not correspond with saturation distribution per PNL. The reasons of such nonconformance can be measurements happening at different times and with different modes; presence of annular circulation at intrastratal and interstartal cross flows.

Extent of layers (interlayers) involving in production per thickness depends on the reservoir type (i.e. reservoir interconnectivity in the section of offset wells with the injectivity line). At that it increases from the non-continuous reservoir (2-20%) to the hydrodynamically bonded reservoirs (10-50%).

Great number of developed reservoirs experience shows that the initial ideas about the deposits are too far from reality and downhole equipment technical capabilities do not allow providing optimum performance for the developed accumulation. In order to enhance development process management it is necessary greatly expand adjustment capabilities of producing and injection wells. The capabilities will rise steeply only in case of providing differentiated recoveries and injection into different interlayers of the developed zone at a different time of its exploitation.

Optimum development process [5] can be presented as a controlled process of water injection in various interlayers of injection wells, its movement inside reservoir and merging of separated reservoir fluids from different interlayers in producing wells. At the same time all interlayers can be divided into covered and uncovered by displacement that in its turn is defined by repression and drawdown pressure ratio between various interlayers.

Complete coverage of the deposit by the impact of injection and recovery is possible only in case of water flow in every injection well will be distributed to all oil-saturated interlayers, and in each producing well from each interlayer controlled oil recovery will be made. For maximum coverage of all interlayers by injection and recovery, it is necessary to implement differentiated exposure to each interlayer, where the intensity and duration of injection and recovery must be adequate to characteristics (permeability, mobility) of the corresponding interlayers.

Water cut increase of individual intervals (interlayers) of the reservoir exposed by the well occurs faster if:

- the distance to OWC is less;
- the distance to the injection well (injection line) is less;
- SP value is more;
- draw down pressure is less;
- repression in interconnected injection wells is higher;

There are only two controlled (changeable) properties (draw down pressure and repression to the appropriate interlayers) among enumerated geological/field properties.

For example, for **B3 zone** in the injection wells all 3 sand intervals accept injected water in equal proportions. At that maximum injectivity falls on the bottom of each interval and the involving extent of the reservoir on thickness is from 8 to 55%. The largest percentage of water flooding coverage is typical for marginal zones.

While development of the multilayer fields there are series of additional problems, the main problem can be formulated in the following way – how to provide the largest oil recovery of the reservoirs having the limited reserves (number of wells)?

Commingled development practices has a number of negative moments:

- oil recovery decrease due to reduction of coverage with stimulation;
- oil production decrease since while commingled production rate of several reservoirs for 30-50% less than amount of their production rates while single exploitation;
- loss of information on actual product recoveries from each of the reservoirs and consequently on remaining oil reserves.

Before 1995 [1] the directional wells drilled had 3- and 4-interval trajectories with drilling of directional wellbores at the depth from 500 m to 1500 m, depending on displacement. However, experience indicated that such trajectories are inefficient in conditions of multilayered oil field, when there is a necessity to develop upper horizons with the wells drilled to the lower horizons. With such trajectories, TDs are “concentrated” close to the pad projection.

New trajectory provides with two target areas - one for return top and the other – at the top of the target. Both of them are located vertically above each other. Such type of trajectory allows increasing the distance between reservoir crossing and cover a larger field zone with less number of wells for all productive horizons. In the result of this the total number of wells required for field development decreases and efficiency of drilled wells significantly grows and also conditions for quality of production casing cementing improves

It is known [6], that the bottom hole zone status and activity play the significant role in the reservoir oil recovery enhancement. It is necessary to assure the maximum coverage of the reservoir by the impact, both for perforated interval thickness (involving of the low-permeable interlayers) and remote part of the reservoir (lateral migration of oil) and along the area of the drainage reservoir.

Status of bottomhole productive formation zone is determined by quality of: drilling, well casing, cementing, perforation, well killing, completion, hydraulic fracturing, water isolation, gas isolation and other physical-chemical treatments.

To involve difficult-to-recover reserves into development it is necessary to improve processes of drilling, wellbore casing and cementing, drilling in and development of zones keeping their natural productivity and oil production at operation modes that prevent from complications in a reservoir and in a wellbore.

Table (see Table 1) shows concrete examples of effective performance of reservoir per well surveys data (inflow profile determination) in Van-Yogan field wells with relatively good status of bottomhole zone. Tentatively these wells can be divided into new and old, which are different in drilling and reservoir exposing technologies. As one can see from the table in wells 669, 1123, 6050, drilled and exposed with implementation of new (Western) technologies, all the perforated interlayers are producing regardless of their lithologic properties.

For wells drilled per given technologies, skin factor averagely decreased more than 3 times and was 4,3 for new wells in stead of 15,7 for old wells.

In wells 617 and 692, drilled and exposed with traditional (Russian) methodics, only individual intervals of perforated reservoir are producing.

Effective bed thickness ratio also depends on geologic factors. See table 2.

Due to the fact that company has considerable “old” well stock built with old technologies there is a necessity in creation and implementation of technology set “to reanimate” old wells in those zones, where appreciable, remaining reserves still exist.

Table 1. Reservoir production evaluation based on the analysis of geophysical surveys (inflow profile determination) at Van-Yogan field

№ Well		669	1123	6050	692	617
№ Pad		42 Б	40 Б	16	40	7
Drilling date		11.93	10.93	02.93	04.91	12.87
Drilling and reservoir exposure technique		New	New	New	Old	Old
Reservoir		БВ$_6$	БВ$_6$	БВ$_6$	БВ$_6$	БВ$_6$
Saturation character		Oil	Oil	Oil	Oil	Oil
Exposed net pay	m	14,4	6,4	4,4	11,6	9,8
	Interlayer count	4	1	2	5	6
	average αSP, fraction	0.57	0.8	0.77	0.76	0.59
Perforated thickness, m		10,5	5,0	3,4	13,5	14,4
Produ-cing	thickness, m	14,4	6,4	3,4	7,8	5,5
	interlayers	I-IV	V	I-II	IV-V	IV-VI
Gross thickness of oil saturated layer	m	3,6	1,0	2,5	5,5	1,6
	interlayers	I,II,I V	V	I-II	V	VI
Effective bed thicknes		100	100	77	67	56

Table 2. Effective bed thickness ratio also depends on geologic factors.

Geologic Factor		Average capacity factor for wells drilled using:	
Name	Deviation	New technologies	Traditional methods
Shaliness	αПС more 0.6	71%	34%
	αПС less 0.6	36%	24%
Strike thinkness	less 2.5 m	77%;	28%
	more 2.5 m	40%	21%

When the pressure in annulus is lower than in the reservoir, gas migrates into reservoir with less formation pressure. Gas migrate through the channels of remained drilling mud at the border between rock and cement or cement – casing and through fractures formed while cement shrinkage and also during changing of thermobaric conditions. That’s why plugging material properties (density, fluid loss, shrinkage, free water content) is selected in such a way that the pressure would be between formation pressure and hydraulic frac pressure values during cementing and hydration of cement.

Implementation of two-stage cementing and plugging material with lowered fluid loss property allowed eliminating dependency of bond quality from the depth that proves the minimum impact to productive layers.

Implementation of this technology permitted to enhance quality of cementing, f.e. for intermediate casing strings:

- good bondage increases to 30% in average;
- partial bondage increases to 5%;
- poor bondage decreases to 35%.

In general, satisfactory bondage increases from 34% to 73 % of cementing interval.

It is worth mentioning tah the best quality has been obtained in the zone of Cenomanian deposits, which significantly decreases risk of gas migration.

Observation of wells performance, which have been drilled as per new technology, shows total absence gas-water cross-flows.

Well logging data showed that the ratio of producing intervals to the perforated intervals does not exceed one third and an average depth factor of mud filtrate penetration is more than 3 diameters of a well. As per hydrodynamic surveys well productivity decreases more than twice.

Initial exposing influences more than perforation quality on a well perfection. However, only secondary exposing of a layer can be changed.

The basic factors, which define well hydrodynamic perfection during the secondary exposing, are the following:

- properties of fluid, which fills a wellbore during perforation;
- perforation gun type;
- perforation density;
- conditions of perforation performance (at draw down pressure or repression).

The main reason of low factors of productivity is nonconformance of working fluid properties and modes of different operation performance in a well, geological-and-physical reservoir characteristics and physicochemical properties of saturation fluids.

Significant decrease in oil inflow from a reservoir to the well while cased hole completion occurs with application of water based perforation fluids. Reservoir permeability on oil in the area of its saturation with perforation fluid is reduced to 35% in average at the total increase of fluid invasion zone radius up to 2 meters;

Implementation of the cased hole design does not provide with a high enough hydrodynamic well perfection per exposure type:

0,85 for ПКС-8 (12 holes/1 rm);

0,7 for ПС 112 (5 holes/1 rm);

0,75 for ПР 43 (with draw down pressure).

For perforation with draw down pressure, the wellbore can be filled in with oil. At this the value of draw down pressure is limited by strength of productive layer and cement bond. Draw down pressure stimulates filtrate and drilled rock recovery from the polluted zone of bottomhole formation zone into the wellbore. For perforation with draw down pressure TCP should run.

Summarized logging material indicates on increase of producing thickness of the reservoir in wells drilled and exposed considering suggested techniques more than 30%, that is adequate to oil recovery enhancement to 12-15%.

Analysis well perforation with different types of perforation guns showed [7] that the efficiency of the secondary exposure grows in the following order:

- water based and brine based perforation (4% of all well operations);
- hydrophobic solution or oil based perforation (without repression) with lowered level (63%);
- draw down pressure perforation with interpenetrating charges (33%).

However, the last one, the most effective perforation type, is possible only for the methods of production with open lift, i.e. for flowing and gas lift methods of well exploitation.

Repeated well killing for workovers (downhole equipment replacement), at which man-caused impact on productive reservoir usually occurs, have a significant influence on reservoir production capabilities. That’s why the number of subsurface repairs should be as less as possible (overhaul period as long as possible) not only to maximize exploitation factor but to minimize oil production decline rate and water cut rate increase. Therefore it is preferable to have well operation with greater overhaul period. For an example, gas lift wells overhaul life is 5-7 times longer than for ESP wells [8].

In well killing the following fluids are used in ascending order:

- hydrophobic solution based on reverse water-oil emulsion with adjustable density and rheologic properties;
- 2% KCl solution with addition of 1% in volume of MISOL
- “alien” oil;
- brine.

At that the following is used as well killing efficiency criteria:

- ratio between oil rate after killing with oil rate before killing;
- time of putting a well into the stable rate of oil production.

When using hydrophobic solution based on reverse water-oil emulsion (regardless of the time to put a well into the previous fluid rate extended for 2 days – 15 days in stead of 17 days) time of putting a well into the stable initial rate in comparison with water based solutions is reduced to 9 days in average (19 days in stead of 28 days), at that while killing with water based fluids initial oil rate existed before killing was often not reached at all, i.e. well 664 oil rate before killing was 28 tpd but after killing it was 19 tpd.

Purpose of the well completion is to maintain absolute link between a productive oil saturated reservoir and a well. Poor completion is one of the reasons of flow limitation at the bottomhole zone.

Well completion can be performed by means of displacement of a fluid in a wellbore for lighter fluid by gassing of fluid column, lowering the column level by swabbing or pumping out of a fluid.

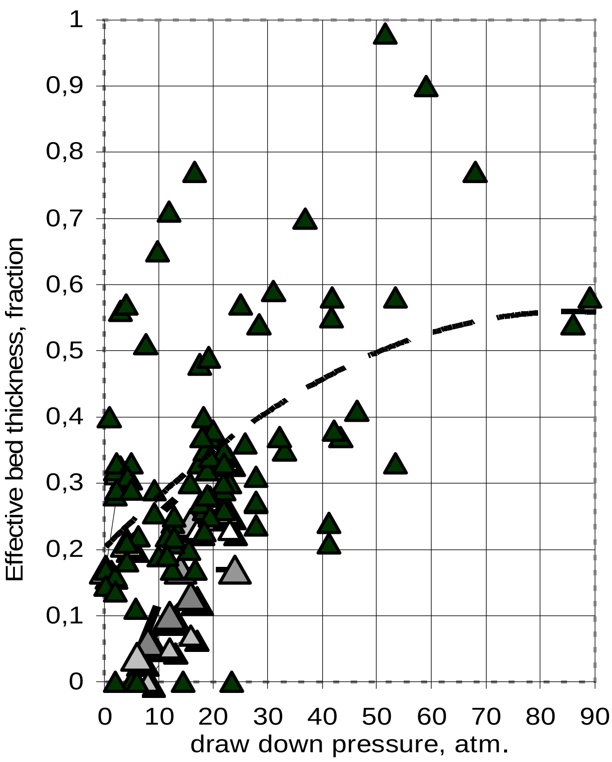
To prevent from cement bond destruction behind the casing, the process of completion should be run smoothly and adjusted by reduction of backpressure to the formation. Well completing with swabbing and with gas lift method, which gradually increases draw down pressure by stage gas consumption growth, meets requirements fuller.

Selection of an optimum assumes provision with a maximum coverage both per capacity (including low permeable interlayers) of a perforated formation interval and per area of drained reservoir (side oil migration from lower permeable to higher permeable interlayers) without gas and water coning.

Upon the results of surveys in gas lift wells, it was observed the influence of the draw down pressure to the effective formation thickness factor of the perforated intervals in the individual reservoirs. The coverage of the reservoirs on the thickness in the bottom hole at the different draw down pressures can be determined (fluid movement profile record) only in gas lift wells, because the pumps blocks the well bore and in the flowing wells the draw down pressure can not be adjusted within the wide range at the optimum operational modes. That is, this optimization type that increases coverage of reservoir with stimulation has significant limitations and possible only for gas lift way of well exploitation, which partially explains the reason of higher values of oil recovery ratio in the areas of deposits developed with gas lift wells.

In flowing wells and gas lift wells significant impact of draw down pressure to effective bed thickness index of perforated intervals of some reservoirs has been observed (Picture 2).

If it is not possible to create the optimum draw down pressure on undeveloped oil-saturated intervals because of operating high water-cut and highly productive intervals, then it is necessary to isolate the latter or limit the water flow, using a packer assembly, for an example.



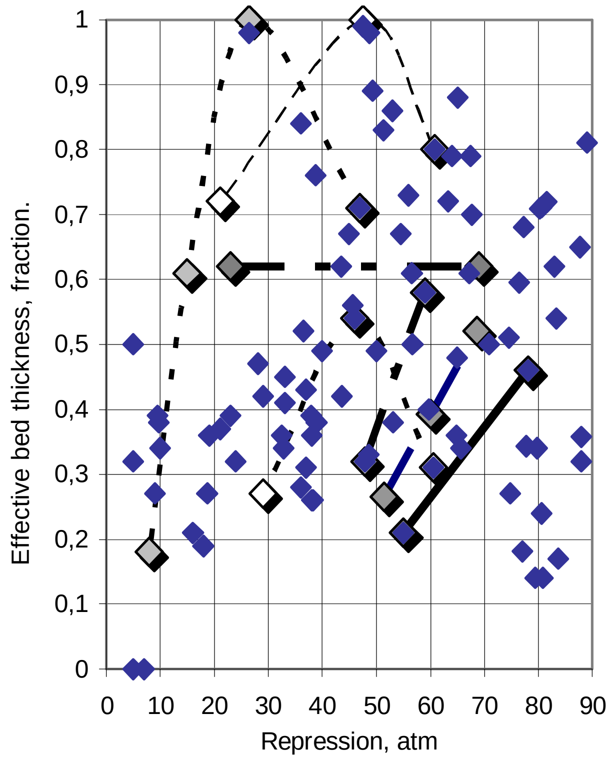
Picture 2. Coverage of Van-Yogan field reservoirs with stimulation per individual producing wells.

Active and flexible change of the draw down pressure to the formation in the more broad range without downhole assemblies replacement in producing wells, which allows changing well mode while variation of structure and reservoir parameters (hydraulic fracs, water conformance) and at deviation of actual development indices from optimum indices (designed) is possible only in gas lift wells [8].

There is significant dependence of operating interval on repression is observed in injection wells (Picture 3).

In the table 3 provided there are results of researches of injection wells at joint operation of several formations.

For a successful performance of workover/maintenance procedures in particular water conformance procedures , it is required to obtain profile and composition of fluid inflow from each layer and desirably with different draw down pressure. It is obvious that in wells with a lift blocked by ESP it is practically impossible to do it. Besides, after performance of workover/maintenance procedures (i.e. squeeze job) it is required a secondary running of the set of logging and hydrodynamic surveys in a producing well that allows getting data on intensity of reservoir performance, inflow composition, well productivity and fluid loss properties of the reservoirs and select the optimum draw down pressure for well exploitation. For example, among 225 inflow profiles analyzed by the author, only one is run for the well producing with ESP before running the subsequent ESP by means of a special device for well geophysical surveys. All the rest surveys on getting inflow profile were run either in flowing (91%) or in gas lift wells (9%). That's why it is very important that the method of well exploitation would allow to flexibly adjusting operating mode within the wide range of production rates with the simultaneous capability to survey reservoir properties.



Picture 3. Coverage of Van-Yogan field reservoirs with stimulation per individual injection wells.

Table 3. Results of injection wells surveys at commingle exploitation of several reservoirs

Well	534						536				
breaking in date	16.10.2000						25.06.1999				
research date	29.05.2001						29.09.2000				
Reservoir	БВ$_3$			БВ$_4$			БВ$_3$			БВ$_5$	
Type of reservoir	III			II			II			II	
Perforation interval (injectivity)	2064-2067	2065.6-2067.2	2071.6-2073	2076-2077	2079-2081	2083.5-2089	2132-2135	2138.5-2142	2144-2149	2175-2179.5	2181-2187
Water consumption among the perforation intervals m^3/day	39.2	100	24	225			120 0			136.1	
Water distribution among the perforation intervals %	24,0	61.3	14,7	100,0			46.8 0			53.1	
Total water consum-ption in the reservoir conditions m^3/day	163.2			225.2			120			136.1	
Well total consum-ption m$^{3/}$day	338.4						256.1				
% of consum-ption per well	42,0			58,0			46.8			53.2	
$K_{охв.зав}$	1.0			0.17			0.52			0.81	
Water flooded thickness within the perforated interval	3,6			7,2			5,6			9,6	
Pres, MPa	262.6			263.6			266.1			270.3	
ΔP, MPa	49.5			49.5			61.2			61.2	

Regardless type of impact either physical or chemical (thermal, acoustic, vibrotreatment, etc.) an extremely important condition for efficiency is possibility to perform and simultaneous drawdown pressure impact on a zone and desirably without lift pull over. An obligatory condition for a technology success is sufficient drawdown pressure (for breaking down of an adhesive film) on bottomhole zone at the moment of impact, which can be performed without significant problems only at gas lift well operation. For instance, surveys in several wells, which produce high viscosity oil, as per acoustic impact on bottomhole zone of PK deposits at VY field, revealed possibility to restore well productivity.

The same condition is necessary for efficiency of gas-impulse, low-frequency implosion and thermal impact on bottomhole formation zone.

During the last 3-5 years the fracturing modifications are being widely implemented in West Siberian oil fields. Just for 2005 the fracturing quantity is more than 1000 operations.

Fracturing is a method of oil production intensification, but also leads to downturn than to increase of reservoir recovery.

One of the perspective directions in advancing the development technology is the use of systems of joint development of several operational objects (reservoirs) using a method with the use of multi-packer sector assembly. The method includes the organization of simultaneous-separate production and simultaneously-separate injection on multizone reservoirs. Field development with use of systems of joint reservoir operation without creation of a reliable monitoring system and regulation of processes of reserve recovery on each reservoir is a gross violation of the mountain legislation and the development design rules. Intelligent wells with multi-packer assemblies in the underground equipment enable to control reservoir data of the operating system "reservoir bed" in a real time mode.

The simultaneous-separate production and the simultaneously-separate injection are new technologies that include use of intelligent wells with multi-packer sector assemblies, intended for separate production and differentiated injection in geologically different operational objects.

It is known, that combined injection of water in several reservoirs that have heterogeneous permeability, leads to non-uniform water flood. Thus accelerated frontal advance of oil by water on high-permeability reservoir leads to water breakthrough to operating well bottom and, as a consequence, to increase of expenses for the oil injection and production. In the best case scenario, it leads to increase of the oil production cost price, and in the worst case scenario - to decommissioning of water-producing well combined with loss undeveloped oil reserves remaining in low-permeability reservoirs. Practice of combined water injection to several reservoirs also leads to loss of the information on actual volumes of water injection in each of the reservoirs separately.

The *ОРРНЭО* technology is very different from existing technologies because the consecutive divided assembly installations for single-commingle production considerably raises reliability of packer pressure test implementation (from the top and the bottom), and consequently, reliability of formation segregation. This also increases the probability of successful tear-down after long operation of a well. Thus the technological process of installation does not limit the quantity of sections installed. Each section is installed on a separate productive reservoir. The base case of a packer section includes: packer, string disconnector, and a regulator - bean (cutoff valve). The multi-packer assembly can operate as many reservoirs as it is necessary according to a project.

The multi-packer sections of the Russian assemblies do not interlock solidly with each other; they use string disconnector and telescope joints. It is possible to divide sections and to organize a zone flush above a packer through a string disconnector. There is a high accident rate noticed when removing foreign assemblies in cases when behind-the packer zone in the bottom of an assembly is dusted with base sediment, and the zone cannot be flushed. The section method of assembly installation allows the crew to use Current Workover Rig A-50 not only during the installation works, but also during tear-down: the packer thrust stress up to 18 tons plus the weight of a string CNL for deep wells (3000 m) up to 26 tons. For failure of import configurations Using A-50 for foreign assembly thrust is insufficient and problematic because of maximum loads.

Single-commingle production and single-commingle injection technologies allow to simultaneously develop several reservoirs dramatically different in their collecting properties, fluid make-up and occurrence depth. In some wells, it is possible to use gas from gassy seams or gas caps for transportation of fluid from producing intervals with a much decreased reservoir pressure. Multi-packer assembly is an ideal match when organizing natural downhole gaslift.

Rational use of gas during oil production from gas caps can raise not only oil production rate, but also lower associated gas carryover. For this purpose it is enough to divide a gas part of reservoir (a gas cap) from an oil part (oil fringe) using double packer assembly. After that install flow plugs on separate regulation of gas consumption (the flow bean in diameter 0,5-4 mm) and fluid production (the flow bean in diameter in diameter 5-9 mm and other). During the operation process, it is possible to correct and change the downhole gaslift operating modes using wireline operation, gaslift technology and “Gaslift” software packages.

One of the significant moments in introduction of single-commingle production and single-commingle injection is that it is possible to transfer lamine with undeveloped remaining reserves on separate operation. Even when shale barriers reach 1 meter between interlayers , and distance between perforation intervals is up to 2 meters, it is sufficient for packer seat. The level of development of the single-commingle production technology allows to install a packer section for each reservoir; and to regulate and supervise oil and gas deposit development by changing flow-breakers, flow plugs or pressure regulators.

Intelligent wells using single-commingle production form integrated control systems of fluid movement at packer section division of development objects. Service maintenance of the wells includes a combination of measuring and operating functions on a bottom hole for the automatic control and regulation of production of oil, gas and differentiated waters injection. At the present time the following tools have been developed and tested: pressure controller, flow controller, flow breaker of bottomhole formation zone from a well, the valve for open flow prevention, the valve of periodic gaslift, the valve for automatic start of gaslift well, mandrels with retractable double bean regulators of fluid consumption.

The technology with multi packer section assemblies allows to efficiently develop water-flooded and drown-out oil reservoirs until they reach the target production rate and at the same time allow to include new water free reservoirs in the single-commingle production. With the help of flow breaker regulation, the production and injection in several oil reservoirs is conducted simultaneously-separately or periodically and, at the same time, fluid production and injection of working agent accounting and control is conducted. Economic efficiency is reached due to restriction of highly watery liquid inflow from a base reservoir, and involvement of a new reservoir, that allows to receive an additional oil production and cut down the expenses on the reservoir preparation.

In some cases it is possible to conduct serial development of various oil reservoirs by transferring the whole stack of wells from base reservoir to a different reservoir for some time interval. After restoration and stabilization of gravitational and hydrodynamical balance in the depleted reservoir, it is possible to make the wells ready for the further development of remaining reserves on base reservoir. This technology can be especially useful during existence of flow production, compressor and non-compressor gaslift or jet operation. Thus using wireline technique flow breakers are installed in mandrels of one reservoir, and corresponding bottomhole flow beans are installed in others. Shut-down valve application prevents consequences of harmful influence of killing a well on bottomhole formation zone.

During a well operation process, it is not unusual when a capital string’s seal is broken. The use of multi-packer assemblies allows to avoid such situations and continue well operation.

Regulation of well operation with pumping fluid production becomes complicated and has a number of the restrictions connected with avoidance of uncontrolled fluid extraction at its simultaneous selection from various oil reservoirs. It is required to approach the process with more attention: well research, selection of operation modes, and installation of underground equipment (flow breakers). This way it would be possible to get reliable information such as production rate and watercut. Serially, intercepting one reservoir after another, it is possible to conduct direct production and watercut measurements in the mouth in real time mode, without dropping the equipment to intelligent well and thus without use of deep measurements.

Surface regulation and measurements (by means of electric devices) of reservoir parameters, operating single-commingle production mode can be carried out with application multi-packer assembly, where there is at least one mechanical packer with cable entry is used.

Mass introduction of single-commingle production with use of intelligent wells [2, 9, 10 ,11] with multi packer sections will allow:

– To raise oil recovery factor and production rate due to additional involvement of low permeable seams in the development.
– To increase the depth and exploration intensity of multiple zone field, by separate involvement of separate thin multi permeable seams;
– To reduce capital investments of well drilling;
– To intensify process of selection and injection regulation in time and well column;
– To increase profitable term of a field development;
– To lower operational expenses;
– To account for production and injected work agent from every reservoir;
– Manage reservoir pressure and regulate direction and speed of reservoir fluid filtration.
– To prevent harmful influence of solutions of killing a well on bottomhole formation zone;
– Decrease the possibility of hydrating complications, asphaltene, tar and paraffine deposits, high temperatures, gas factor, water content and viscosity of production [4], increased content of solids, salt, scrape and corrosive-active components;

– To maintain a well with a broken seal in capital string;

– To use gas from a gas cap or gassy seams for the organization natural pressure or downhole gaslift;

– To develop bottom water-drive reservoir, preventing water cone formation.

Impact upon the zone under development by means of pressure redistribution in it, results in speed and direction change of formation fluid flows as well as ratio of dimensions and interdisposition of differently saturated parts of accumulation. The main indexes of oilfield development depend on the efficiency of this impact, including oil recovery ratio.

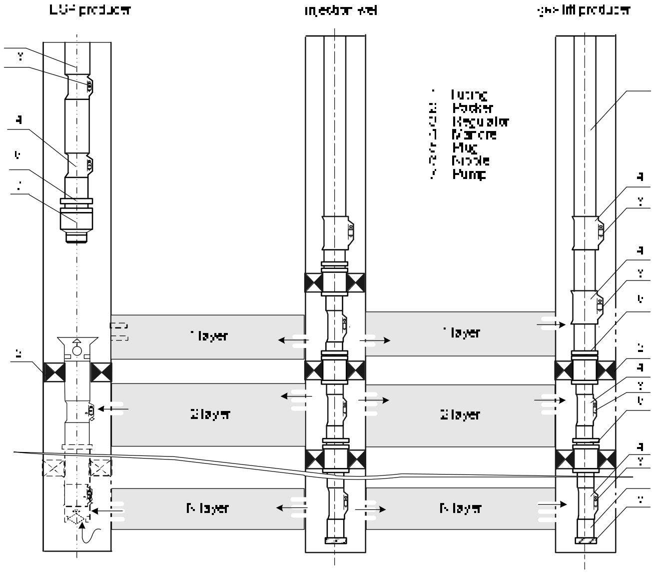
Since the reliable information for defining optimum effect by means of creation an appropriate reservoir pressure field, in practice is missing as a rule, that's why reservoir pressure change is made by means of adaptive way [6], defining necessary interlayer characteristics according to the individual reservoir interval data of the different interacting through reservoir wells.

This method is introduced in Van-Yogan oilfield in 7 gas-lift wells and in 12 injection wells. Fluid flow profile and injectivity profile optimization allows increasing not only current oil production by 15-25%, but oil recovery ratio no less than by 5%.

Technology *ОРРНЭО* allows to considerably expand the opportunities of hydrodynamical methods of influence on group of strata series with a single grid [12] which conditionally include a combination of several kinds of influence: repression optimization; depression optimization; forced withdrawal; change of filtration direction; non-stationary influence (flooding and withdrawal) on a reservoir. Thus modes of injection wells are changed by changing surface choke and bottomhole regulators, and change of product selection is performed on wells operated by natural pressure gaslift operatively adjusting their modes, changing the gas consumption and valves, using wireline operation.

Injection wells were selected for non-stationary flooding and were equipped with special assemblies for single-commingle or serial water injection (Picture 4). For non-stationary fluid selection similar assemblies for single-commingle reservoir exploration are used, but only on gaslift wells, since it is not possible to change a mode in a wide range with pumps, and the frequent well stops reduce their reliability. Since it is not possible to track fluid movement profile in the wells equipped with bore-hole pump, while in service, therefore for such wells before pump running it is possible to down installation with the open lift, and for maintenance of a planned mode at removal of a fluid movement profile (for multi permeable interlayer) it is possible to use installation with the jet pump or a gaslift installation.

These decisions have allowed to go from passive influence to all opened reservoirs of one production zone, to active individual influence on every reservoir and interlayer by demanded optimum depression [13, 14]. Thus the technology allows to trace the major geologic production reservoir characteristics, operatively generate fluid flows or injection of working agent that influences several intervals and sections of production zone with the necessary intensity. This establishes optimal depression for every reservoir (interlayer) individually.



Picture 4. Differential impact on interlayers with different permeability

During the introduction of single-commingle development of several reservoirs using the gaslift method, it is possible to optimally adjust processes of exploration for each reservoir due to operative change of their modes in a wide range.

Nowdays, a lot of oil fields in the late development stage are in need of large-scale fragmentation of production zone in order to increase the production rate. Let's consider the example of Samotlor oil field.

Realization of intensive system of development with wide-spaced well application, without the sufficient information about geological and physical structure of deposits and at restriction on capital investments was possible only due to association in one object of independent development from 15 (AB2-3) up to 24 (AB4-5) productive interlayers. With the purpose to increase oil production, year after year there was an integration of development objects, attaching more productive reservoirs to the production zones. This approach, stemming from the economic considerations and mismatching the physical concepts of oil replacement in the split and heterogenetic reservoirs, has played a negative role and has led to drowning and uncontrollable formation of water blockade of the separate not developed zones. Thus the negative influence of heterogenic reservoirs is increased, water invasion to bottomhole of producing well is stimulated, and, as a consequence, the volume of produced water and expense for its forcing increase.

In order to increase levels of oil production there is no other alternative, but further development of remaining recoverable reserves (nearby 1 billion t.) in Samotlor field; that is transforming them in a commercially exploitable reserves category. It is obvious, that for this purpose it is going to be necessary to have higher expenditures on fragmentation of the production zones in the future. When using traditional approaches and drilling backup wells for realization of a given program, there will be a requirement of more than 30 billion $

USA. The offered alternative decision - introduction of technology of the single-commingle development of several production zones (technology *ОРРНЭО*) will allow to reduce capital investments in 30-50 times!

It is necessary to note, that successful introduction of this technology at the current technology level is possible only in the wells that have open hole to reservoirs (i.e. injection or gaslift wells).

There are around 2,2 already opened (perforated) production zones for every operating well on Samotlor multiple zone oilfiled. This was put in effect in the late 80s to maintain the level of oil production during well construction capital investments restrictions.

Practice of joint field operation of several reservoirs has led (by estimations of experts) to loss of the following:

- recoverable oil reserves (300 million tons);
- cumulative oil production (80 million tons);
- current oil production (6 million tons);
- information about actual recovery and remaining reserves from each production zone.

Technology *ОРРНЭО* will allow to perform joint development of oil bank and gas cap and to prevent formation of gas and water cones.

An important advantage of the technology is the opportunity of reservoir development AV1-2 (“rjabchik”) on Samotlor oil field. Reserves AV1-2 (939 million tons) are considered hard to extract and consequently the choice of an effective technology for their development is very important. It is proposed to use the available well stock operating the underlying beds (AV13, AV 2-3,AV4-5, BV8, BV10) for the single-commingle operation with reservoir AV1-2. It will allow increasing profitability of operation for many highly drowned wells (including the ones presently inactive). It is necessary to note, that for achievement of design values, these wells have to be operated on forced operation conditions. The technology will allow to organize forced withdrawal with simultaneous large-scale restriction of water-inflow on gaslift wells.

When using gaslift, it is possible to supervise withdrawals from each object, and the most important factor – to adjust processes of development - to influence separate reservoirs according to operating changes of modes for each well reservoir in a wide range, that will allow increasing oil recovery factor.

Thus, on Samotlor oil field it is necessary to perform a large-scale fragmentation of production zones by industrial introduction of technology *ОРРНЭО* with the purpose of maintenance of the differentiated influence on various production zones (intervals and-or reservoir sections).

Another example can be Priobsk oilfield. There are three reservoirs being simultaneously developed on Priobsk field: AS10, AS11, AS12, and permeability of reservoir AS11 is much higher than the one on reservoirs AS10 and AS12. For effective development of reserves from low permeability reservoirs AS10 and AS12, there is other alternative, but introduction of technology ОРРНЭО on injection wells (as of today that is already implemented on than 15 injection wells).

At the present time, the technology ОРРНЭО is implemented on Tarasovskoe, Barsukovskoe, South-Tarasovskoe, Festivalnoe, East-Jagtinskoe, South-Kharampurskoe, Ust-Kharampurskoe, Komsomolskoe, Sporyshevskoe, Sredne-Iturskoe, Karamovskoe and other oil fields in Western Siberia.

The technology ОРРНЭО is implemented on the following well categories:

1.Injection wells -72 wells: 37 wells with three reservoirs and 35 wells with two reservoirs.

2.Wells operated by natural-pressure gaslift – 9 wells: 4 wells with three reservoirs and 5 wells with two reservoirs.

3.Wells operated by electric-centrifugal pump – 10 wells with ESP System: 7 wells with isolation of bore hole pump from inflow of extraneous water from leaking production casing; and 3 wells with two reservoirs.

4.Flowing wells – 2 wells

5.Gas producing – 2 wells

6.Producing oil from oil bank (without gas cone formation) – 2 wells

7.Operating injection well, used for oil production and agent injection-1well

8.A well used for injection and water utilization – 1 well

9.A well used for water and gas influence by gas crossover from the lower bed and surface water injection.

At the present time there is subsurface equipment available for the following sizes of production casing: 178 mm, 168 mm and 146 mm.

There are only two companies “New Oil Technologies” and “Neftegastechnica” that legally implement (licensed and registered) this *ОРРНЭО* technology.

The prior experience shows that the results and effectiveness largely depend on engineering maintenance.

The central Commission on hydrocarbonic raw material deposits development recommends the licensed technology ОРРНЭО to the following:

- subsoil users for wide use when developing oil, oil and gas fields;
- to the design organizations for obligatory consideration when designing field development.

1 Donkov P.V., Leonov V.A., Kirilov S.I., Savchenko S.I. (2003). Identification of hydro-dynamical model of non-uniform reservoirs. The Intensification of oil & gas recovery. Works of International technological symposium.

2 Leonov V.A., Sharifov M.Z. The patent of the Russian Federation 2211311 Method of dual pumping development of several operating objects and well installation for its realization. (2003).

3 Leonov V.A. Subdivision of development zones as a mean of hydrodynamic model. Technological forum SIS GeoQuest. Sochi – 2002.

4 Leonov V.A. Optimization of producing wells group operation modes interacting through the reservoir. Technological forum SIS GeoQuest. Paris – 2000

5 Leonov V.A. Method of formation pressure adaptive optimization. Scientific-practical conference “Latest methods of oil recovery enhancement – theory and practices of implemetation”. Kazan-2001

6 Leonov, V.A., Donkov, P.V., Sabanchin, I.V., Savchenko, S.I. Reservoir oil recovery increase by subdividing development objects of the depleted oilfields. Poster session on 12-th European symposium dedicated to increase of reservoir oil recovery. Materials of exhibition « Oil & gas. Petrochemistry 2003 », Kazan.

7 Leonov V.A., Donkov P.V., Ahtjamova E.N.(2003). High viscosity oil development on Van – Yogan oilfield. 12-th European symposium « Increase of reservoir oil recovery». Kazan.

8 Leonov V.A., Donkov P.V., Akhtjamova E.N. (2001).Well operation method influence on reservoir oil recovery. Theses of scientific - practical conference report «Ways of Khanty-Mansiysk oil-and-gas potential realization».

9 Osadchij V.M., Leonov V.A., Pereginets V.A., Polygalov V.F., Sharifov Makhir Zafar ogly, Musaverov R.Kh., Garipov O.M., Sineva Ju.N., Mokryj M.V. The patent of the Russian Federation 2249108 Device for Measuring inner well parameters (2003)

10 Sharifov M.Z. , Leonov V.A. The patent of the Russian Federation 2253009. Method for concurrent-separate operation of several beds via one force well in turns. 2003

11 Garipov O.M., Leonov V.A.. THE USAGE OF MULTI PACKER ARRANGEMENT IN INTELLIGENT WELLS FOR SIMULTANEOUSSEPARATE OR ALTERNATE OPERATION ON MULTIHORIZON OIL FIELDS. 6th International Petroleum Conference and Exhibition. Value from Hydrocarbons. Advance in Science & Technology. New Delhi, India. January 2005. p.38

12 Leonov V.A., Donkov P.V., Vojtov O.V., Sorokin A.V. (2003). Influence on strata series using single grid when developing new objects. Poster session on 12-th European symposium dedicated to increase of reservoir oil recovery. Materials of exhibition « Oil & gas. Petrochemistry 2003 », Kazan.

13 Apasov T.K., Kanzafarov F.J., Leonov V.A. The patent of the Russian Federation 2270913 Method for well botton zone treatment. 2004

14 Kanzafarov F.Ja., Leonov V.A. The patent of the Russian Federation 2244111. Method of treating botton zone of low-permeable oil reservoirs. 2003