Generalization of Geological and Physical Characteristics of Fields Belonging to Oil-gas Production Department «Yamashneft» in order to Increase the Efficiency of Hydrodynamic Well Testing

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Abstract. Currently, the question of choosing the right approach for hydrodynamic testing and post-processing of the data is very important. The quality of the study and, respectively, data processing is influenced by various factors such as, lithological composition of rocks, their density, mechanical stress in the rock, hydrodynamic influence of rocks, filtration movement of fluids, pressure and temperature distribution in the formation. Fields of oil-gas production department "Yamashneft" are at the late stage of development, and the majority of wells are marginal. All these factors may affect the results of the pressure recovery curve processing, which often differ from the actual values of the state parameters of bottomhole formation zone, which means incorrect approach to research (recovery time of bottomhole pressure) and the choice of processing method.

Questions to obtain reliable information at a late stage of development are of particular importance, since on their basis significant technological and economic solutions are taken, such as shutdown of watered and marginal wells, technological measures to enhance the oil recovery factor are planned and implemented. During the well testing and interpretation of the data we must take into account the structure of the investigated layer, features of the pore space, geological and physical characteristics that will keep the correct calculation of reservoir properties.

To this end, the generalization of geological and physical data was made to divide fields into separate groups for the subsequent development of a methodology for each group, and select the optimum processing of results. Thus grouping of objects (lithological characteristics of reservoir, properties and composition of cement, type of porosity, permeability range, porosity range) causes a single, but a qualitative approach to conduct hydrodynamic well testing and the method of interpreting the results.

Keywords: hydrodynamic well testing, bottomhole formation zone, interpretation of hydrodynamic testing, geological and physical characteristics, porosity, permeability, change of filtration parameters, developed horizons.

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As a result of complex physical and chemical processes that occur in a long geological period, the producing formation acquires a certain structure. After its penetration by wells various processes occur and will occur in the bottomhole zone that violate or infringe the original equilibrium mechanical and physico-chemical state of the rock. These processes arise from the moment of the formation penetration, and as drilling extend deep into the bottomhole formation zone.

As a result, two zones are formed around the well: the 'skin' area, which is characterized by a radius r_s, permeability k_s, and distant part of the formation with the natural permeability k (Fig. 1).

There is a filtration of reservoir fluid through bottomhole formation zone in the well. If the same reservoir properties in the bottomhole zone change for some reason (improvement or deterioration) compared with the initial state of the formation, the well productivity also will be different compared to its natural value.

State of the bottomhole formation zone is determined by lithological composition of the rocks, their density; mechanical stresses in the rock; hydrodynamic influence of cracks; pollution of rocks and physico-chemical processes occurring in the reservoir; movement of filtration liquids, pressure and temperature distribution in the formation.

State of the bottomhole formation zone can be degraded in the primary and secondary drilling into the formation, well casing, jamming it in front of many repairs as well as during operation due to precipitation of asphalt-resin-paraffin deposits (heavy oil sediments) and inorganic salts in the pores of rocks, dirt by mechanical and other impurities.

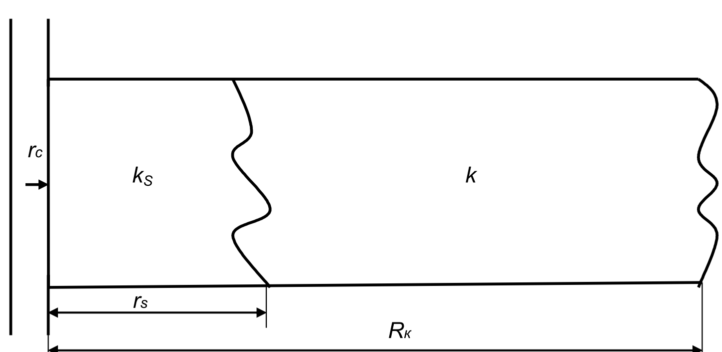

Fig. 1. Distribution scheme of two zones around the wells.

Changes in permeability around borehole space may reduce well productivity. This has a significant impact on the amount of fluid drag to oil flow when moving from the formation into the well.

As is known, the permeability changes in bottomhole formation zone are usually estimated by “skin-factor”. Its origin is due to the presence of altered permeability of the zone around the wellbore. Thus to overcome the arising resistance arising called ‘skin’, it is necessary to create higher pressures, thus limiting the energy capacity of the formation. As a result, the well productivity will decline (Andaeva, Sidorov, 2012).

Experience of oil and gas production department “Yamashneft” indicates a significant change in productivity of wells, and permeability during their operation (Fig. 2). In practice, the concept of oil and gas production, well productivity generally includes characteristic of production wells opportunities associated with both the reservoir properties of the productive horizons penetrated by the well, and its technical condition.

As seen from the graph, the productivity of the well No. 1276 of Shegurchinsky field decreased by 2 times in 10 years. During this period there have been no single event on the effects on the bottomhole formation zone.

Thus, the dependence is observed of the well productivity and dynamics of oil production in time (Fig. 3).

The specialist must have sufficient and accurate information about the formation, its energy capabilities, production opportunities for an adequate analysis of the development indicators and production prediction when implementing development projects. Most of this information can be obtained from the results of well studies in the unsteady modes.

Research on unsteady filtering modes (research by the pressure/level recovery, pressure drop, during the injection by method of level drop in the injection well and wells interference testing) is an integral part of petroleum engineering.

In practice, the possibility of a qualitative interpretation of well test results at unsteady conditions is often limited by:

1) lack of information;

2) lack of adapted techniques for the study of deposits with low-permeability reservoirs;

3) wrong choice and application of interpretation methods;

4) inability to properly organize the information, etc.

Most commercial engineers are faced with cases where for authentic interpretation accurate information is not enough on oil pressure and extraction of an earlier period, or the results of previous studies for comparison.

In general, a good rule is to conduct basic research on unsteady modes in production well soon after its completion and putting into operation after drilling. This facilitates early detection and prevention of many complications, of which only insufficient formation treatment is most apparent. Such studies also provide information about the reservoir parameters for mathematical modeling and baseline data for comparison in the event of complications in the formation and the well.

The presence of a significant fund of well with small and medium production rate, due to low water permeability of bed, leads to the fact that most of the level build-up curves are under-recovered. In addition to the short duration of withdrawal of such curves, significant drawback is usually in a small number of points on the level build-up curves. Under-recovery of curves affects the accuracy of determining the filtration parameters of the formation and the reservoir pressure.

As a result inaccuracy of the data complicates the ability to make a correct decision on conducting geological and technical measures aimed at restoring, improving or maintaining the existing level of filtration component in the bottomhole formation zone.

To determine the parameters of formation zone remote from the well, registration length of pressure recovery curve must be sufficient to eliminate the influence of ‘after-inflow’ (the continued inflow of fluid into the wellbore), and then an increase in pressure occurs only due to the liquid compression in the formation and its filtration from remote to the near formation zone (end portion of the pressure recovery curve).

The duration of the study of the production well by pressure recovery curves can range from a few tens of hours to a few weeks, so that the study range covers a large area

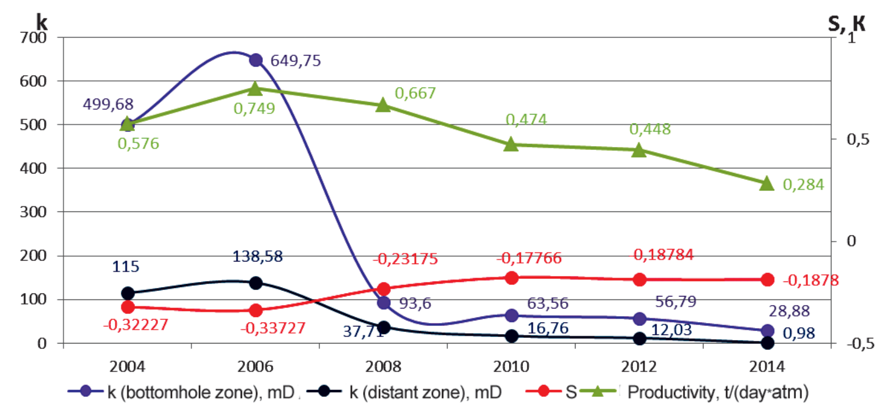

Fig. 2. Change dynamics of filtration parameters, characterizing conditions of the bottomhole formation zone of the well No. 1276 of Shegurchinsky field.

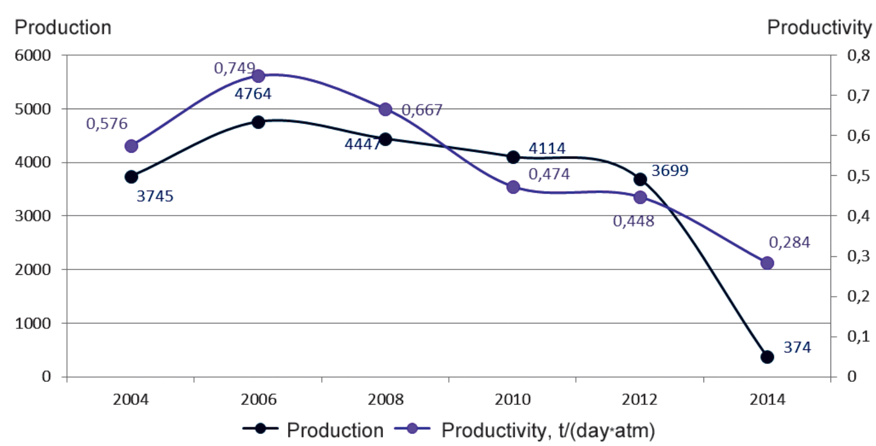

Fig. 3. Dependence dynamics of oil production from the productivity of well No. 1276 of Shegurchinsky field.

Lithological characteristics of the reservoir	Properties and composition of cement	Porosity Type	Range of k, 10^{-3} micron^2	Range of m, unit fraction	Field
1	2	3			4
Tulskian Horizon					
The reservoir consists of argillites dark gray, laminated, with interbedded sandstones and siltstones. In the middle of the horizon interlayer lies of limestone dark gray, finely crystalline, clayey. Sandstones are gray, dark brown, inequigranular, quartz, with oil saturated interlayers	The cement type (5-8%) is contact, cementing substance is secondary quartz and carbonate-clayey material	P	421…1272	0,187…0,25	Tyugeevsky, Sirenevsky, Berezovsky, Shegurchinsky, Ekaterinovsky
The reservoir is presented by unconsolidated sandy-siltstone rocks	The cement type is contact, partly porous	P	457…853	0,21…0,23	Ersubaykinsky, Arkhangelsky
The reservoir is presented by fine-grained sandstones, silty, partly clayey. Sandstones for 75-80% consist of quartz grains of intergranular pore space	Contact, interference	P	532,5	0,208	Krasnogorsky
Clastic rocks are argillites, siltstones and sandstones. Argillites are dark gray to black, irregularly silty; siltstone is dark gray, clayey, carbonaceous and calcareous. The sandstones are gray, brownish-gray to brown, calcareous. The layers of carbonate rocks are presented by dark gray argillaceous limestone	Cement is of calcite type, the type of filling is mainly incompletely porous, rarely crustified, and basal	P-C	473	0,197	Yamashinsky
Bobrikovian Horizon					
The reservoir is presented by quartz sandstone, fine-grained, interbedded with siltstone, mudstone, coals and carbonaceous shales, occurring mainly in ‘incision’ wells. Sandstones are dark brown, medium cemented, porous, heavily soaked with oil. Mudstones are brown to black, dense, with the remnants of charred plants. Shale is black, carbonaceous, with rare inclusions of pyrite	Cement is slightly developed, of quartz composition, distributed in the form of regeneration rims on detrital grains. Calcite and pyrite as a local cement are distributed quite widely, especially in formations of Tulskian age, but because of the local nature it has no appreciable effect on reservoir properties	P	81…938	0,2…0,32	Shegurchinsky, Yamashinsky, Tyugeevsky, Sirenevsky, Berezovsky
Bobrikovian reservoir is represented by quartz sandstones fine-grained, with silty interlayers. Reservoir is interbedded with low permeable, clayey, sometimes calcareous, siltstones, impermeable mudstones. Reservoir type is porous.	The cement type is contact, partly porous	P	220…1397	0,169…0,242	Ersubaykinsky, Arkhangelsky, Krasnogorsky
It is presented with interbedded sandstones, dark gray, oil-saturated and argillites dark gray, dense. Siltstones are dark gray, sandy, calcareous	The cement type is contact	P	1100	0,23	Ekaterinovsky
Vereiskian Horizon					
The reservoir is presented by carbonate and clastic (argillites, siltstones) rocks with a predominance of carbonate rocks (organic limestone interbedded with dolomite) in the lower part of the productive horizon	Cement of three generations: more crustified with a grain size of up to 0.03 mm, calcite or dolomite; late – unevenly cemented, small-medium-grained to 0.8 mm, calcite, porous or basal type		287…517	0,16…0,166	Yamashinsky

Table 1. Generalization of geological and physical data for fields of oil-and-gas production department “Yamashneft”. F – fractured, P – porous, C – cavernous.

The lower pack is composed of limestone gray, brownish-gray, dark brown, organogenic-clastic, less crystalline granular, fractured, porous, interlayers of oil saturation (layers C2vr-5, C2vr-3 C2vr-2). Carbonate formations are separated by interbedded argillites dark gray, horizontally-layered, mica. Clastic pack is composed of interbedded mudstones, siltstones, among which there are rare interlayers of limestones	Cement type - contact, porous, crustified. Cement (10 - 40%) - micro–, fine- and small-grained calcite and clay material, its type - porous, crustified, rarely basal (sealed interlayers)	P	15…280	0,13… 0,15	Sirenevsky, Berezovsky, Arkhangelsky, Tyugeevsky
It is presented by organogenic-clastic limestone, slightly clayey, partly with thin interbedded mudstone. Top and bottom of layers is often clogged or sealed	Cement type is contact, presented with finely grained calcite	P	218…227	0,168… 0,27	Ersubaykinsky, Krasnogorsky
Lower - carbonate-clastic pack is represented by limestone light gray, fractured, with interbedded mudstones, oil saturation. Top - clastic pack is composed of mudstones greenish-gray with brownish tinge, dense, layered	The cement type is contact	P	156	0,148	Ekaterinovsky
It is presented by carbonate rocks. The lower part is composed of limestone gray, gray-brownish, organogenic-clastic, partly clay and dense with subordinate interbedded clays and silts.	The cement type is contact	P, F-P	134	0,164	Shegurchinsky
Bashkirian Horizon					
The reservoir is composed of limestone recrystallized, brecciated, cavernous, light-gray, brownish-gray, fine-grained, with smears of light green clay material on stylolite seams. Limestone is partly fractured, porous, interlayers or heavily soaked with oxidized oil. In some wells a significant portion of the Bashkirian top is eroded by Vereiskian ‘incision’	Limestone is cemented with micro and fine-grained calcite. Cement type is porous, crusitified, partly basal, of quantity - 10 - 35%	P	29,6…32	0,14… 0,16	Tyugeevsky, Sirenevsky
The reservoirs are presented mainly with organogenic limestone, rarely organogenic-detrital and fine-grained limestone. Dolomites are present is subordinate number, there are also brecciated rocks and interlayers of calcareous sandstone	The cement type is contact, porous	P, F-P	108	0.144	Shegurchinsky
The reservoirs are presented mainly with organogenic limestone, rarely organogenic-detrital and fine-grained limestone. Dolomites are present is subordinate number, there are also brecciated rocks and interlayers of calcareous sandstone	Cement is not heavy, sometimes basal	F-C-P	201	0.174	Yamashinsky
It is presented by limestone gray, organogenic-clastic, clay, with interlayers fractured and cavernous, partly oil saturated	Cement is made of unevenly grained calcite, which is 10-20% of rock volume; cement type – porous, contact, regeneration, less- basal	P,F-P	69	0,128	Berezovsky
It is presented with limestones recrystallized, fine-grained, fractured, poorly clayey, partly plastered with rare inclusions of anhydrite.	Cement type is mainly crusified, contact, partly porous	P, P-F	9,3…118	0,096… 0,148	Ersubaykinsky, Krasnogorsky, Ekaterinovsky
It is presented mainly by limestone yellowish-gray, interlayers of organogenic-clastic, porous, with numerous stylolite seams, with some interbedded limestones dark brown, porous, fractured, cavernous, soaked with oil. It lies on the eroded surface of the Serpukhovskian formations	Cement is contact, porous, less basal, consists from 5 to 25% of rock volume	F-P	193	0.13	Arkhangelsky

Table 1. (Continued). Generalization of geological and physical data for fields of oil-and-gas production department “Yamashneft”. F – fractured, P – porous, C – cavernous.

of the formation. However, during long-duration studies end portions of the pressure recovery curve may be distorted by the influence of neighboring wells on the pressure distribution in the remote zone of the formation.

Level build-up curves method is used, including, for wells with low reservoir pressure (with low static level), i.e. non-gushing (without overflow at the wellhead) or unstably gushing.

Duration of registration of level build-up curves or pressure recovery curve depends on the well productivity as a whole, fluid density, and hydrodynamic connection between the bottomhole formation zone and remote formation zone.

The processing results of pressure recovery curves often differ from the actual values of the bottomhole zone state parameters, indicating on the wrong approach to research (recovery time of bottomhole pressure) and choice of treatment method. A large part of the pressure recovery curves obtained in the study of fields of oil-and-gas production department “Yamashneft” does not meet the requirements under which their unique treatment can be carried out. Questions to obtain reliable information at a late stage of development are of particular importance, since based on them such important technological and economic decisions are taken, like shutting of watered and low-yield wells, technological measures to enhance the oil recovery factor are planned and implemented (Guidance document ... 2015; Karnaukhov, Pyankova 2010; Chodry, 2011).

Thus, to determine the application conditions of reliable pressure recovery curve processing methods is an urgent task.

To this end, the generalization of the geological and physical data was conducted, which allows combining fields into separate groups for the subsequent development of recommendations for selecting the type of data processing at the hydrodynamic studies of wells (Table 1).

The main horizons developed on fields of oil-and-gas production department “Yamashneft” were considered. The group is made separately for each reservoir with respect to the type of porosity, properties and composition of cement and lithological characteristics of the reservoir. Ranges of porosity and permeability values are also specified, affecting the quality of the interpretation of the level build-up curves.

Clastic reservoirs and deposits of Bobrikovian and Tulskian horizons of the Lower Carboniferous are of high capacity and highly permeable. All over the productive section the reservoir type is porous. Average permeability range – 220...850x10^{-3} mm2. Cement type is mostly contact, less porous. Cement is slightly developed, of quartz composition, distributed in the form of regeneration rims on detrital grains.

Group of fields from Tulskian-Bobrikovian are presented with three types of rocks: sandstones, mudstones, siltstones.

Productive formations are mainly characterized by the unevenness of the section and heterogeneity.

Carbonate rocks of Bashkirian age are represented mainly by organogenic limestone interbedded with lime dolomite, rarely chemogenic (fine-medium-grained) limestone. In addition to limestone Bashkirian section is marked with inequigranular dolomites often fractured. The cracks are of up to 20 microns.

Reservoirs of Vereiskian horizon are represented mainly by limestone organogenic-clastic interbedded with mudstone silty, micaceous, with thin layers of sandstones grained, calcareous. The middle part of the horizon is composed of carbonate-clastic rocks. Organogenic limestones Tare widely developed in the section of Vereiskian layers.

From Table 1 it is clear that Tyuteevsky, Sirenevsky, Berezovsky, Shegurchinsky, Ekaterinovsky fields have the general geological and physical properties in clastic reservoirs, while their similarity is much less in the carbonate section.

During the hydrodynamic studies and interpretation of the data we must take into account the structure of the investigated formation, especially the pore space, geological and physical characteristics that will keep the correct calculation of reservoir properties.

The present compilation of deposits was held with the aim of developing methodologies for research for each group and selecting the optimal method of results processing. Thus, the grouping of objects by the parameters represented in the table (lithological reservoir characterization, properties and composition of cement, type of porosity, permeability range, porosity range) causes a single, but a qualitative approach to how to conduct well testing and interpreting of the results.

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