PERIÓDICO TCHÊ QUÍMICA
ARTIGO ORIGINAL

MATÉRIA-PRIMA BASE DE RESERVAS DE ÓLEO DE DIFÍCIL EXTRAÇÃO DA RÚSSIA

RAW MATERIAL BASE OF HARD-TO-EXTRACT OIL RESERVES OF RUSSIA

СЫРЬЕВАЯ БАЗА ТРУДНОИЗВЛЕКАЕМЫХ ЗАПАСОВ НЕФТИ РОССИИ

PRISCHEPA, Oleg M.[1*]; NEFEDOV, Yury V.[2]; KOCHNEVA, Olga E.[3];

[1,2,3]Saint-Petersburg Mining University, Oil and Gas Geology Department, Saint-Petersburg, Russia

** Correspondenceauthor*
e-mail: yurijnefedov@yandex.ru

Received 28 February 2020; received in revised form 15 March 2020; accepted 24 March 2020

RESUMO

A estimativa da parcela das reservas de petróleo difíceis de extrair nos depósitos da Rússia varia de acordo com diferentes fontes em uma faixa bastante ampla (de 30 a 70%). Devido à ausência de uma abordagem comum à sua definição, a variedade de parâmetros utilizados para estimar essa parcela e as condições fundamentalmente diferentes para o desenvolvimento dos grupos de reservas classificadas como difíceis de extrair tornam-se um desafio. Uma parcela significativa das reservas comprovadas de petróleo dos campos de petróleo russos - cerca de 34% (6,3 milhões de toneladas) - pertence a pesados (densidade de óleo superior a 0,871 g/cm^3) e superpesados (densidade de óleo superior a 0,895 g/cm^3). Em geral, a parcela de óleos de alta viscosidade e super alta viscosidade é de cerca de 13% (2,4 milhões de toneladas). A maior parcela refere-se aos depósitos de três distritos. Em coletores de baixa permeabilidade (permeabilidade inferior a 0,05 μm^2), enormes reservas estão concentradas - 8,2 milhões de toneladas ou 44,6% de todo o petróleo. A comparação da extração de petróleo e da estrutura de reservas indica uma boa correlação para a extração de óleo de coletores com baixa permeabilidade em 41,8% com o percentual de reservas em 44,6% assim como correlação relativamente boa em óleo super pesado em 13,4% com porcentagem de reservas em 18% e taxas baixas para óleo de viscosidade super alta em 1,7%, com porcentagem de reservas em 6%. Reservas comprovadas significativas de óleo de alta viscosidade na Rússia indicam a possibilidade de aumentar a produção com a introdução de tecnologias modernas, existentes e comprovadas, sob condições econômicas apropriadas. O envolvimento em larga escala no desenvolvimento apenas dos maiores depósitos de óleo de alta viscosidade permitiria à Federação Russa produzir pelo menos 25 a 30 milhões de toneladas no médio prazo.

Palavras-chave: *reservas de difícil extração, HTER, rochas de baixa permeabilidade, base de matérias-primas da Federação Russa.*

ABSTRACT

The estimation of the share of hard-to-extract oil reserves in the deposits of Russia varies by different sources, in a fairly wide range (from 30 to 70 %). Due to the absence of a common approach to their definition, the variety of parameters used to estimate this share and fundamentally different conditions for the development of the groups of reserves classified as hard-to-extract become challanging. A significant share of the proven oil reserves of Russian oil fields - about 34 % (6.3 million tons) - belongs to heavy (oil density more than 0.871 g/cm^3) and super-heavy (oil density more than 0.895 g/cm^3). In general, the share of high-viscosity and super-high-viscosity oils is about 13% (2.4 million tons). The largest share refers to the deposits of three districts. In low-permeable collectors (permeability less than 0.05 μm^2), huge reserves are concentrated – 8.2 million tons or 44.6 % of all oil. Comparison of oil extraction and reserves structure indicates a good correlation for oil extraction from low-permeable collectors in 41.8 % with reserves percentage in 44.6 % as well as a relatively good correlation in super-heavy oil in 13.4% with reserves percentage in 18 % and low rates for super-high-viscosity oil in 1.7% with reserves perecentage in 6 %. Significant proven reserves of high-viscosity oil in Russia indicate the possibility of increasing production with the introduction of modern, existing and proven, technologies under appropriate economic conditions. Full-scale involvement in the development of only the largest deposits of high-viscosity oil would allow the Russian Federation to produce at least 25-30 million tons in the medium term.

Keywords: *hard-to-extract reserves, HTER, low-permeable rocks, raw material base of the Russian Federation*.

DOI: 10.52571/PTQ.v17.n34.2020.939_P34_pgs_915_924.pdf

АННОТАЦИЯ

Оценка доли трудноизвлекаемых запасов нефти в месторождениях России варьирует по разным источникам, в довольно широком диапазоне (от 30 до 70 %). Это обусловлено отсутствием единого подхода к их определению, многообразием параметров, используемых для оценки этой доли и, что более существенно, принципиально разными условиями освоения групп запасов, относимых к трудноизвлекаемым. Существенная доля разведанных запасов нефти месторождений РФ - около 34 % (6,3 млрд т) относится к тяжелым (плотность более 0,871 г/см^3) и сверхтяжелым (плотность более 0,895 г/см^3). В целом доля высоковязких и сверхвысоковязких нефтей составляет около 13% (2,4 млрд.т.) Наибольшая их часть приурочена к месторождениям трех регионов. В низкопроницаемых коллекторах (с проницаемостью менее 0,05 мкм^2) сосредоточены огромные запасы – 8,2 млрд т или 44,6 % всех запасов нефти. Сравнение объемов добычи и структуры запасов свидетельствует о хорошей корреляции по добыче нефти из низкопроницаемых коллекторов 41,8 % при доле запасов в РФ 44,6 %, относительной хорошей корреляции по сверхтяжелой нефти 13,4 % при доле в запасах 18 %, и низких показателях по сверхвысоковязкой нефти - 1,7 % при доле в запасах 6 %. Значительные разведанные запасы высоковязкой нефти в России свидетельствуют о возможности наращивания объемов добычи при внедрении современных, уже имеющихся и апробированных технологий при соответствующих экономических условиях. По оценкам экспертов полномасштабное вовлечение в разработку только наиболее крупных залежей высоковязкой нефти позволило бы России дополнительно добывать не менее 25-30 млн.т. в среднесрочной перспективе.

Ключевые слова:*трудноизвлекаемые запасы, ТРИЗ, низкопроницаемые породы, сырьевая база РФ.*

1. INTRODUCTION:

The involvement in economic turnover of oil reserves belonging to various groups of hard-to-extract (HTER) has become possible due to advances in technology and changes in market conditions that allow the effective development of such reserves (Shpurov*et al*., 2006).

Assessment of the possibility of reserves development depends on the use and availability of extraction technologies, which in turn determine the economic characteristics of HTER projects (Prischepa *et al*., 2011; Shpurov *et al*., 2014; Zambrano *et al*., 2018;) makes it necessary to take a more careful approach to their differentiation.

The concept of "hard-to-extract reserves" is subject to significant revision over time (Shpurov *et al*., 2014). The classification of hard-to-extract reserves, developed by E. M. Halimov and N. N. Lisovsky (Lisovsky *et al*., 2009) proposed in 1994, established the basic criteria for such reserves require significant refinements with the introduction of tax incentives in 2012, but new technology has allowed cost-effectively develop a certain proportion of reserves that were previously considered ineffective (Shpurov *et al*., 2014). Accordingly, the criteria that characterize oil reserves as hard-to-extract have been rethought (Muslimov, 2011; Shelepov, 2013; Szydlowski, 2019; Shpurov *et al*., 2014; Prischepa, 2019; Prischepa, 2016;).

A typical example is given in a retrospective survey of 2014 year by Shpurov I. V. (Shpurov *et al*., 2014) on the change of the share of hard-to-extract oil reserves in West Siberia over the past 30 years, indicating that the reserves in the 80-90 years of the twentieth century belonged to hard-to-extract were involved in active production (Kontev *et al*., 2019). As a result of the use of the latest technologies that became widespread in the late XX - early XXI century, in particular the emergence of hydraulic fracturing technologies, horizontal drilling, and multidimensional digital reservoir models, oil extraction in West Siberia was about 300 million tons, i.e., in 2 times more than expected in accordance with development projects drawn up and approved before 1990.

When discussing the opportunities for the development of projects for the exploration of hard-to-extract oil reserves in recent years, the emphasis is mainly placed on two groups: deposits in low-permeable rocks and deposits of heavy and high-viscosity oil. The solution of the problem of stimulating the production of hard-to-extract reserves in modern conditions is complicated by the lack of a concept (definition) and a classifier for HTER of these two groups (Shpurov *et al*., 2014).

The most significant role in intensifying of exploration and development of hard-to-extract reserves had to play benefits for the tax on mineral extraction (TME), taking into account the permeability of the collectors (from reduced tax of 20% to completely “reset” for the extremely low permeability of bazhenovskaya, domanic, and hadumskaya formations) and benefits on extraction of heavy and high-viscosity oil. Meanwhile, criteria for hard-to-extract reserves

contained in low-permeability collectors, and reserves of high-viscosity oil with the progress of technology has substantially increased: permeability from 0.03 to 0.002 mm^2; by viscosity from 30 to 200 MPa·s. Accordingly, the volume of oil reserves that can be defined as hard-to-extract significantly decreased (from 10.8 billion to 4.7 billion tons, i.e., in 2 - 3 times when using such criteria). The objective of tightening the criteria is shown by the fact that about 60% of the reserves that were previously considered as hard-to-extract are already involved in the development. In 2014, only 4.8 billion of the 10 billion tons that previously belonged to this category remained uninvolved (Neizvestnaya *et al.,* 2018; Yemelyanov et al., 2019a,b, 2020; Voronkova *et al.,* 2019).

At the same time, the share of reserves involved in the development that are classified as hard-to-extract in accordance with the tax code is only 13% (with the exception of depleted reserves) (Shpurov *et al*., 2014; Lushpeev and Margarit, 2018; Lateef *et al*., 2019).

A separate category of projects for hard-to-extract reserves that have not yet been developed is projects for unusual HCM accumulations in extremely low-permeable collectors (oil from dense and shale collectors).

A push for development of such projects should have been the allocation of several specialized projects (including big companies - Gazpromneft (the project of The Bazhen technology center), Surgutneftegaz, Tatneft, Rosneft and LUKOIL) that allow testing approaches to technologies for the development of “dense” collectors and so-called “shale” formations, first of all, bazhenovskaya and domanic formations. These measures have played a role in the intensification of study, but in general, especially for the last group of commercially successful projects until now, including due to the uncertainty of the regulatory framework and the development of new methods for assessing reserves (Gutman *et al*., 2017; Kamenchukov *et al.,* 2019).

Accordingly, in light of that, estimate of the share of hard-to-extract oil deposits in Russia varies in line to different sources, in a fairly wide range (from 30% to 70%) (Prischepa *et al*., 2011; Yakutseni *et al*., 2007; Lisovsky *et al*., 2009; Shpurov *et al*., 2014; Shelepov, 2013; Muslimov, 2011), due to the lack of a unified approach to their definition, many of the parameters used for the evaluation of this share and, more significantly, the fundamentally different conditions of development of groups of reserves classified as hard-to-extract. In “The strategy of development of mineral resources of the Russian Federation till 2030”, the mention of the 65% share of hard-to-extract reserves in Russia, with none of the classification parameters, indicating that classification of oil reserves with certain properties to be hard-to-extract (density and viscosity of oil, tar, sulfur, and paraffin content, etc.), such share in the structure of reserves is not mentioned.

Due to the fact that reserves can often be classified as hard-to-extract by several classification criteria (heavy and high-viscosity oils, high-tar and sulfur oils, etc.), a simple summation of the volume of reserves of such groups does not allow you to get an idea of the real share of hard-to-extract reserves and their structure (Prodanova et al., 2019).

This study aimed to analyze the share of hard-to-extract oil deposits in Russia, to establish a single approach to their definition, parameters used to estimate this share, and to see the different conditions of development of hard-to-extract reserves.

2. MATERIALS AND METHODS:

The most important parameters used to classify oil reserves as hard-to-extract are the quality characteristics of the fluids. Thus, according to the "Classification of oil and combustible gas reserves", there are oils with deteriorated (in terms of the possibility of development) physical and chemical properties, which include bituminous (density over 0.895 g/cm^3) and heavy (0.871-0.895 g/cm^3), super-high-viscosity (viscosity over 200 MPa•s) and high-viscosity (from 30.1 to 200 MPa•s), as well as oil with high (more than 500 m^3/t) or low (less than 200 m^3/t) gas saturation.

The next group of parameters is related to the collector properties of the hydrocarbon-containing strata. Here, the main classification parameters are both the collector capacity itself, which essentially determines the volume of reserves in the strata and such an important characteristic as permeability, which directly affects the development modes and extraction technologies.

In terms of permeability, productive layers are divided into low-permeable (up to 100 mD), medium-permeable (100-500 mD), and high-permeable (more than 500 mD).

There is a large group of parameters that also determines the complexity of development and the need to use special modes or technologies

– this is the occurrence of collectors at low depths and (or) in the permafrost zone, high or extremely low intra-layer temperatures, high water content of the extracted water-oil liquid, etc.

3. RESULTS AND DISCUSSION:

At the beginning of 2019, 3176, fields with deposits containing oil have been identified in the Russian Federation (Prischepa, 2019). Most of the oil reserves are accounted for in 2756 fields of the distributed subsoil fund (96.6% of all drilled developed reserves). Oil extraction in Russia as a whole for the 2018 year amounted to be about 3% of the current drilled developed reserves. In more than half of the multi-deposit oil fields (1720) in Russia, one or more deposits are characterized by properties that make it possible to classify oil reserves as hard-to-extract.

As of 01.01.2019, a significant share of oil reserves is characterized by properties that allow considering them as hard-to-extract. Thus, heavy (more than 0.871 g/cm^3) and super-heavy (more than 0.895 g/cm^3) oil fields in the Russian Federation amount to be about 34% (6.3 billion tons) of the current drilled industrial extractable reserves, which is significantly different from the estimates of international experts, who estimate 13.4 billion barrels (less than 2 billion m^3), probably due to accounting only super-heavy oil, which at the same time is high-viscosity and super-high-viscosity. The largest part of the reserves of heavy and super-heavy oil in absolute terms is concentrated in the deposits of the Urals Federal district (2.9 billion tons, or 45.9 % of all heavy oil reserves in Russia), including the Khanty-Mansi Autonomous region there are 1.7 billion tons (including 0.252 billion tons of super-heavy), the Yamalo-Nenets Autonomous region – 0.995 billion tons (0.958 billion tons of super-heavy); the Volga Federal district – 2.1 billion tons (33.2%); the North-West Federal district – 0.7 billion tons (11.1%) (figure 1). More than 90% of the reserves of heavy and super-heavy oil are concentrated in the fields of 3 specified Federal districts. Since the volumes of total current oil reserves recorded in the respective districts differ significantly, the share of reserves of heavy oil in them varies from 10.5% in the Urals Federal district, 26.8% in the Volga Federal district to 39.9% in the North-Western Federal district. In the Siberian Federal district, with relatively small amounts of recorded reserves, the share of heavy oil is 14.8%.

On a parameter of viscosity (when referring to a group of high-viscosity oil with a viscosity of more than 30 MPa•s and taking into account that for some fields, data on the quality of raw materials in the State balance are not given for 1092 million tons of extractable reserves or 6% of the oil reserves of the Russian Federation), the current structure of oil reserves in the Russian Federation differs slightly from the structure of distribution of reserves by oil density. So, in the whole of Russia, the share of high-viscosity (30.1-200 MPa•s) and super-high-viscosity (more than 200 MPa•s) oil is respectively 6.0 and 6.9% of extractable commercial reserves, or in the amount of 2378.6 million tons. Most of them are in the deposits of the Volga Federal district (940.9 million tons, or 39.6% of high-viscosity oil reserves of the Russian Federation), the Urals Federal district (902.5 million tons or 37.9%), almost all of them are in the Yamalo-Nenets Autonomous region (818.4 million tons) and the North-Western Federal district (426.3 million tons, 18.1%) (figure 2). In the structure of the reserves of these districts, the lowest share of high – viscosity oil (8.5%) falls on the Urals Federal district, and the largest (25.5 and 31.0%) - on the Volga and the North-Western Federal districts, respectively. It should also be noted that a significant share of Russian oil reserves belongs to the group of high-viscosity (10.1-30.0 MPa•s) - 1115.7 million tons, that most part (892 million tons) is also concentrated in the Volga Federal district.

If we consider the structure of heavy and high-viscosity oil reserves in the section of oil and gas provinces (OGP), most of them are in the Volga-Ural (Republic of Tatarstan, Samara region and Perm region), West Siberian (Yamalo-Nenets and Khanty-Mansi Autonomous regions) and the Timan-Pechora (the Republic of Komi) OGP. Also, a significant share of heavy oil is noted in the reserves of the Okhotsk province (Sakhalin island shelf) (Saitgaleev*et al*., 2019; Tannady *et al.,* 2019), but since it does not differ in high-viscosity, it is not hard-to-extract.

When comparing the structure of heavy (super-heavy) and high-viscosity (super-high-viscosity) oil, there are significant discrepancies (almost 2 times) in the recorded oil reserves in the Russian Federation as a whole. The volumes of heavy and super-heavy oil reserves of Russia are estimated at 6.3 billion tons, and high-viscosity and super-high-viscosity oil at 3.4 billion tons.

From the point of view of development conditions, super-heavy oils that do not have high-viscosity in layer conditions, in fact, not much differ from heavy and even medium-density oil. The limit of classification for hard-to-extract reserves by the value of oil density used in the previous classification (more than 0.92 g/cm^3) met the need

for special extraction technologies to a much greater extent than the recommended limit for super-heavy (bituminous) reserves - more than 0.895 g/cm^3 in the current classification. It is even less correct to classify heavy oil with a density of 0.87 - 0.895 g/cm^3 as hard-to-extract.

When comparing the ratio of super-heavy oil reserves in the Russian Federation (3.3 billion tons) and high-viscosity oil (3.4 billion tons), a good correlation is observed, which is confirmed by an additional comparison of these groups by Federal districts and subjects. Thus, in three Federal districts, the most important largest reserves of heavy and viscous oil, noted the following relationship: in the Urals Federal district - 1210 million tons of super-heavy oil and 939 million tons of high-viscosity and super-high-viscosity oil, in the Volga Federal district, respectively 1255 and 975 million tons, in the North-West Federal district – 541 and 436 million tons. For significant subjects of the Russian Federation, this ratio is as follows: in the Yamalo-Nenets Autonomous region - 958 and 854 million tons, in the Republic of Tatarstan - 689 and 569 million tons, in the Republic of Komi - 329 and 355 million tons, in the Samara region -135 and 128 million tons.

Thus, when the boundary of the classification of reserves as hard-to-extract changes in density increasing above 0.92 g/cm^3, the differences between the reserves of super-heavy and high-viscosity oil become even more insignificant. It is important to understand that despite significant reserves of high-density oil (more than 0.87 g/cm^3), for example, in the Khanty-Mansiysk Autonomous Region, the Nenets Autonomous Region, Krasnoyarsk region and Omsk region, such reserves should not be considered as hard-to-extract due to the fact that the oil is not viscous, and its extraction does not require significant additional costs compared to the extraction of lighter oil.

From the point of view of development conditions and, accordingly, the need to use technologies that significantly affect the economic performance of development projects (Prodanova *et al.,* 2019b), 3.3 - 3.4 billion tons of drilled explored reserves of the Russian Federation, which is about 18% of the total drilled reserves, are hard-to-extract in this way.

The largest deposits of heavy oil in Russia are the Russian, the Eastern-Messoyakhskoye and Severo-Komsomolskoye in the Yamalo-Nenets Autonomous region, respectively, 418, 201 and 147 million tons (extractable reserves of heavy oil); Yarega and Usinsk in the Komi Republic, respectively, 174 and 130 million tons. A separate issue when considering the development of hard-to-extract oil deposits is the issue of sulfur content. Oil extraction with high sulfur content requires the use of specialized equipment; such oil requires high additional costs during processing, and special transportation conditions, which affects the economy of projects and limits its extraction (Gennadyevich *et al.,* 2019).

The share of sulfurous oil (sulfur content 1.0-3.0%) in the explored drilled reserves of the Russian Federation is 27.9%, high-sulfur (more than 3.0%) - 6.0%, i.e., a third of all explored oil reserves of the Russian Federation belong to sulfur and high-sulfur. Almost 80% of the extractable reserves of high-sulfur oil from Russian fields (878.2 million tons) are concentrated in the Volga Federal district (including 511.3 million tons in the Republic of Tatarstan), and another 11.7% is in the Urals Federal district (129.3 million tons in the Khanty-Mansiysk Autonomous region). Taking into account the combination of sulfur and high-sulfur oil, in the Volga Federal district accounts for 3050 million tons (82% of all current registered reserves of the district, including the Republic of Tatarstan – 910.9 million tons and the Perm region – 443.9 million tons); the North-Western Federal district – 681 million tons (almost 50% of the district's reserves).

Consideration of the properties of the oil-containing strata indicates that the low-permeable collectors (less than 0.05 mm^2) contain huge reserves – 8.2 billion tons or 44.6% of all oil reserves of categories A+B1+C1, including the Volga Federal district – 1.1 billion tons (13.4%), the Urals – 6.0 billion tons (75%) and the Siberian – 0.76 billion tons (9.3%). Low-permeability collectors account for more than 56% of the current reserves of West Siberia, almost 30% of the reserves of the Volga-Ural OGP, and 17 % of the oil reserves of the Timan-Pechora province.

One thousand two hundred sixty-five million tons of oil, or 6.8% of the A+B1+C1 reserves, are concentrated in sub – gas deposits, including 650 million tons in the Urals region and 312 million tons in the Siberian Federal district.

Along with heavy and bituminous oil, bitumen is considered as a strategic reserve. The principal difference between super-heavy oil and bitumen is its mobility in the reservoir. Thus, the group of heavy and super-heavy oil includes, as a rule, oil with a viscosity of more than 100 MPa•s (Prischepa *et al*., 2011; Yakutseni*et al*., 2007;

Lisovsky *et al*., 2009), and bitumen has a viscosity exceeding 10000 sP. Many bitumens and super-heavy oil have a higher viscosity in the reservoir. There are many factors that affect the viscosity of hydrocarbons, which include the group composition, the presence of dissolved natural gas, and the temperature and pressure in the layer. In general, the viscosity of heavy oil or bitumen is approximated with the density.

The state balance of mineral reserves of the Russian Federation as of 01.01.2019 includes only three deposits of bitumen and asphaltites, one of which is associated with bituminous dolomites, and one with bituminous sands. Deposits with recorded reserves of bitumen and asphaltites are located only in two districts – Southern and Volga. The recorded reserves are not of industrial value due to their small size.

Huge accumulations of bitumen and heavy oil are known in Eastern Siberia (within three provinces). The main bituminous layers are found in the Vendian-Cambrian, Silurian, Carboniferous, and Permian formations. Clusters (deposits) are poorly studied due to their remoteness and lack of economic interest.

Numerous accumulations of heavy bitumen have been identified within the Volga-Ural province, most of which are shallow deposits of Permian age in the Central and Northern parts of the province. According to R. H. Muslimov and R. R. Ibatullin, the Republic of Tatarstan has the largest natural bitumen resources in Russia; there are 450 deposits in the upper Permian sandstones with reserves of 1.163 billion m^3 (7.3 billion barrels) (30-200 MPa•s). Heavy oil and bitumen in this province have high sulfur content (up to 4.5%) and contain metals (V, Ni, Mo).

Since the 80-ies of the last century, two fields of the Volga-Ural OGP - Mordovo-Karmalskoye and Ashalchinskoye fields - have been the testing ground for working out a good method for extracting natural bitumen. The following technologies have been designed and tested on them: core extraction in friable bituminous sandstones specially created by the coredigger; sampling of bituminous wells; initiating intra-layer thermal gas generator, high-frequency electromagnetic field, steam, electric heating installation UESK-100; thermocycler action on the bituminous-saturated layer by air, steam, and steam gas; area injection of air, steam, and steam gas; changes in the direction of filtration flows; extraction of NB by low-temperature oxidation (Muslimov, 2016).

Despite almost 40 years of research on the geology and extraction of NB from Permian deposits, the problem of starting their development has not been solved. It is concluded that the characteristics of heavy oil and natural bitumen deposits in the Republic of Tatarstan are worse than those in Canada, Venezuela, and the United States: much smaller thickness; lower collector properties; relatively low oil bituminous saturation; high water content; a significant share of hydrocarbons in complex, extremely heterogeneous layers, which does not allow automatic transfer of technologies developed in the West to the bitumen deposits of the Russian Federation. To solve the problem of involvement in economic turnover, of course, the most important is to solve theoretical issues, conduct research and experimental industrial work on the development of bitumen deposits, which is impossible without the participation of the state with direct co-financing on the terms of private-public partnership (Muslimov, 2016).

A significant negative indicator of large developed fields is the high depletion of their reserves, which in general is 56%, and for many large ones reaches 90%. The rest (unprocessed) part of oil reserves can be considered as hard-to-extract.

If we compare the structure of hard-to-extract oil reserves and the extraction of the considered groups, the largest degree of correlation is observed when comparing the volumes of oil in tight collectors – extraction was 214.5 million tons, or 41.8%, the proportion of reserves in such collectors of 44.6%; in sub-gas deposits, respectively 38.3 million tons (7.5%), with the share in reserves of 6.8%; for super-high-viscosity oil (with a viscosity greater than 200 MPa•s) – 8.7 million tons (1.7%) with the share in reserves of 6%, high-viscosity oil (viscosity more than 30 MPa•s) – 30.6 million tons (6%), with the share in the reserves of 12.8%; super-heavy oil with a density of more than 0.895 g/cm^3 – 68.8 million tons (13.4%) with a share in reserves of 18%, and taking into account heavy and super-heavy oil with a density of more than 0.87 g/cm^3 - 170 million tons (33.2% of extraction) with a share in reserves of 34%.

In the structure of oil extraction in the Russian Federation, due to the introduction of new efficient development technologies (hydraulic fracturing, horizontal drilling, thermal methods, etc.), the share of oil extracted from low-permeable collectors, sub-gas deposits, and heavy and super-heavy oil has increased significantly in recent years (Shelepov, 2013; Shpurov *et al*., 2014; Prischepa, 2019).

The main methods of development are thermal methods, which include: steam-thermal exposure, intra-layer combustion, hot water injection, steam-cyclic treatment of bottom-hole zones of producing wells, and a combination of these methods with other physical and chemical methods (combined methods).

Heavy oil is extracted in three main oil provinces: the Volga-Ural, the Timan-Pechora, and West Siberia. In all regions, the extraction of heavy and super-heavy oil is growing due to the improvement and application of modern extraction technologies.

In the Volga-Ural province, Ashalchinsky and Mordovo-Karmalsky fields are being developed, which are the oldest developed heavy oil fields. The Yareg and Usinsk super-heavy oil fields are being developed in the Timan-Pechora OGP (the Komi Republic). The Yareg high-viscosity oil field contains about 130 million m^3 of heavy oil confined to the Devonian sandstones located at a depth of 180-200 m.

The peculiarity of the development at present is the transition from the long-used mining methods (thermoshaft method, thermocyclic impact) for more than 70 years to purely surface ones. According to LUKOIL, this will lead to a significant increase in the extraction of super-heavy oil at the field – up to 2 million tons per year or more. In conjunction with the second Usinsky field that being developed in the Timan-Pechora OGP, where the proven reserves of high-viscosity oil in the Permian-coal reservoir amount to more than 170 million tons, oil extraction is close to 5 million tons. The total accumulated extraction of high-viscosity oil on the territory of the Komi Republic as of 01.01.2018 exceeded 100 million tons.

4. CONCLUSIONS:

Progress in extraction technologies, combined with benefits for extracting high-viscosity, super-heavy oil, and oil from low-permeable collectors, has led to a significant increase in its extraction (achieving a share in extraction comparable to the structure of current proven reserves) and the possibility of extending this invaluable experience to other projects in Russia, which will significantly support current production in the long term.

Significant proven reserves of heavy and high-viscosity oil in Russia indicate the possibility of increasing extraction volumes with the introduction of modern, existing, and proven technologies under appropriate economic conditions. This is evidenced by such achievements as a significant increase in the share of heavy oil in the production structure, a sharp increase in the volume of oil extraction from low-permeable collectors in the Russian Federation. At the same time, the rate of extraction of high-viscosity oil, despite the growth, is significantly behind the share of the corresponding structure of oil reserves due to the need to use high-cost technologies (thermal methods, etc.) in the development.

One of the most important measures recommended by the specialists of SRC (Shpurov *et al*., 2014) and supported by the specialists of the regions with huge volumes of hard-to-extract oil reserves is the creation of a classifier of hard-to-extract reserves, as well as developing a scientifically sound definition of hard-to-extract reserves and its application, including the criteria for the appointment and cancellation of tax incentives for different types of these reserves.

According to experts, full-scale involvement in the development of only the largest deposits of high-viscosity oil would allow Russia to extract at least 25-30 million tons in the medium term (Prishchepa *et al*., 2011; Muslimov, 2016).

5. REFERENCES:

1. Gutman, I. S., Potemkin, G. N., Postnikov, A.V., Postnikova, O. V.,Kozlova, E. V., Alekseev, A.D., Karpov, I. A. *Methodological approaches to reserves calculation and resources evaluation of bazhenovskaya formation,* Oil industry*,* **2017**, (03), 28-32.
2. Gennadyevich, Y. S., Pakhomova, E. G., & Olegovna, D. K. (**2019)**. Reliability of RC frame-braced systems in dangerous geological conditions. Journal of Applied Engineering Science, 17(2), 245-250.
3. Kamenchukov, A., Pugachev, I., Yarmolinsky, A., Vasilyev, A., & Kulikov, Y. (**2019**). Improving the criteria for determining dates of repair of highways. Journal of Applied Engineering Science, 17(1), 8186.
4. Kontev, A., Konteva, O., Kremneva, A., Voronkova, O., Kiseleva, N., & Zhuravlev, P. (**2019**). Economic and ecological fundamentals for the establishment of the metallurgical complex in siberia in the 18th century. *Journal of Environmental Management and Tourism, 10*(7), 1628-1636. doi:10.14505/jemt.v10.7(39).20

5. Lateef, A. O., Bin, M. S. H., & Ademola, F. J. (**2019**). Performance assessment based on Intelligent power management for standalone PV system in remote area of Ibadan, Nigeria. Journal of Applied Engineering Science, 17(1), 52-60.

6. Lisovsky, N. N., Halimov, E. M. *On the classification of hard-to-extract reserves*, Bulletin of the Central Committee of Rosnedra, **2009**, (6), 33-35.

7. Lushpeev, V., & Margarit, A. (2018). Optimization of oil field development process based on existing forecast model. Journal of Applied Engineering Science, 16(3), 391-397.

8. Muslimov, R. H. *Experience of development of resources of super-high-viscosity oils and natural bitumens of the Volga-Ural oil and gas province*, Oil economy, **2011**, (11), 42-47.

9. Muslimov, R.H. *New strategy of oil fields in modern Russia – optimization of production and maximization of EOR*, Oil. Gas. Novations, **2016**, (4), 8-17.

10. Neizvestnaya D.V., Kozlova N.N., Prodanova N.A. (**2018**). Application of CVP-Analysis at the Water Transport Organizations. Helix. 2018. Vol. 8(1). Pages 2811-2815. https://doi.org/10.29042/2018-2811-2815

11. Prischepa, O.M., Halimov, E.M.*Hard-to-extract oil: potential, state and opportunities for development*, Oil and gas vertical, **2011**, (5), 24-29.

12. Prodanova, N., Plaskova, N., Popova, L., Maslova, I., Dmitrieva, I., Sitnikova, V., & Kharakoz, J. (**2019a**). The role of IT tools when introducing integrated reporting in corporate communication. Journal of Advanced Research in Dynamical and Control Systems, 11(8 Special Issue), 411-415.

13. Prodanova, N., Savina, N., Kevorkova, Z., Korshunova, L., & Bochkareva, N. (**2019b**). Organizational and methodological support of corporate self-assessment procedure as a basis for sustainable business development. Entrepreneurship and Sustainability Issues, 7(2), 1136-1148. doi:10.9770/jesi.2019.7.2(24)

14. Prischepa, O. M. *State of the raw material base and extraction of hard-to-extract oil reserves in Russia*, Mineral resources of Russia, Economics and management,**2019**, (5,168),14-20.

15. Prischepa, O. M. *Problems of reproduction of hydrocarbon reserves: the Arctic shelf and (or) hard-to-extract reserves*, Mineral resources of Russia, Economics and management, **2016**, (1, 2), 18-34.

16. Saitgaleev, M., Senchina, N., Sokolova, J. *Application of the method of ion-selective electrodes in exploration work on the sea shelf*, Marine Technologies, Gelendzhik, **2019**, DOI: 10.3997/2214-4609.201901811

17. Shelepov, V. V. *The work of the Central Commission on development at the present stage (to the 50th anniversary of its formation)*, Oil and gas industry, Oil industry, **2013**, (4), 4.

18. Szydlowski A.. (**2019**). "ORGANON OF DEMOCRACY". *Baltic Humanitarian Journal* Vol. 8 Iss. 4 p. 407 - 411 ISSN: 2311-0066.

19. Shpurov, I. V., Rastrogin, A. E., Bratkova, V. G. *On the problem of developing hard-to-extract oil reserves in West Siberia*, Oil economy, **2014**, (12), 95-97.

20. Tannady, H., Gunawan, E., Nurprihatin, F., & Wilujeng, F. R. (**2019**). Process improvement to reduce waste in the biggest instant noodle manufacturing company in South East Asia. Journal of Applied Engineering Science, 17(2), 203-212.

21. Yakutseni, V. P., Petrova, Yu. E., Sukhanov, A. A. *Dynamics of the share of the relative content of hard-to-extract oil reserves in the general balance*, Oil and gas Geology, Theory and practice, **2007**, (2),http://www.ngtp.ru/rub/9/023.pdf

22. Yemelyanov, V., A. Nedelkin, and N. Yemelyanova. (**2020)**. Expert System Software for Assessing the Technical Condition of Critical Lined Equipment. Advances in Intelligent Systems and Computing. Vol. 1115 AISC. doi:10.1007/978-3-030-37916-2_92.

23. Yemelyanov, V. A., Nedelkin, A. A., & Olenev, L. A. (**2019a**). An object-oriented design of expert system software for evaluating the maintenance of lined equipment. Paper presented at the 2019 International Multi-Conference on

Industrial Engineering and Modern Technologies, FarEastCon 2019, doi:10.1109/FarEastCon.2019.8934414

24. Yemelyanov, V. A., Yemelyanova, N. Y., Nedelkin, A. A., Glebov, N. B., & Tyapkin, D. A. (**2019b**). Information system to determine the transported liquid iron weight. Paper presented at the Proceedings of the 2019 IEEE Conference of Russian Young Researchers in Electrical and Electronic Engineering, ElConRus 2019, 377-380. doi:10.1109/EIConRus.2019.8656693

25. U.S. Energy Information Administration, **2016**, *Petroleum and other liquids*,http://www.eia.gov/dnav/pet/PET_CRD_CRPDN_ADC_MBBL_A.htm

26. U.S. Energy Information Administration, **2019**, *Venezuelan crude oil production falls to lowest level since January 2003*,https://www.eia.gov/todayinenergy/detail.php?id=39532#

27. Voronkova, O. Y., Iakimova, L. A., Frolova, I. I., Shafranskaya, C. I., Kamolov, S. G., & Prodanova, N. A. (**2019**). Sustainable development of territories based on the integrated use of industry, resource and environmental potential. International Journal of Economics and Business Administration, 7(2), 151-163.

28. Zambrano, C. J. R., Kovshov, S., & Lyubin, E. (**2018**). Assessment of anthropogenic factor of accident risk on the main oil pipeline Pascuales - Cuenca in Ecuador. Journal of Applied Engineering Science, 16(3), 307-312.

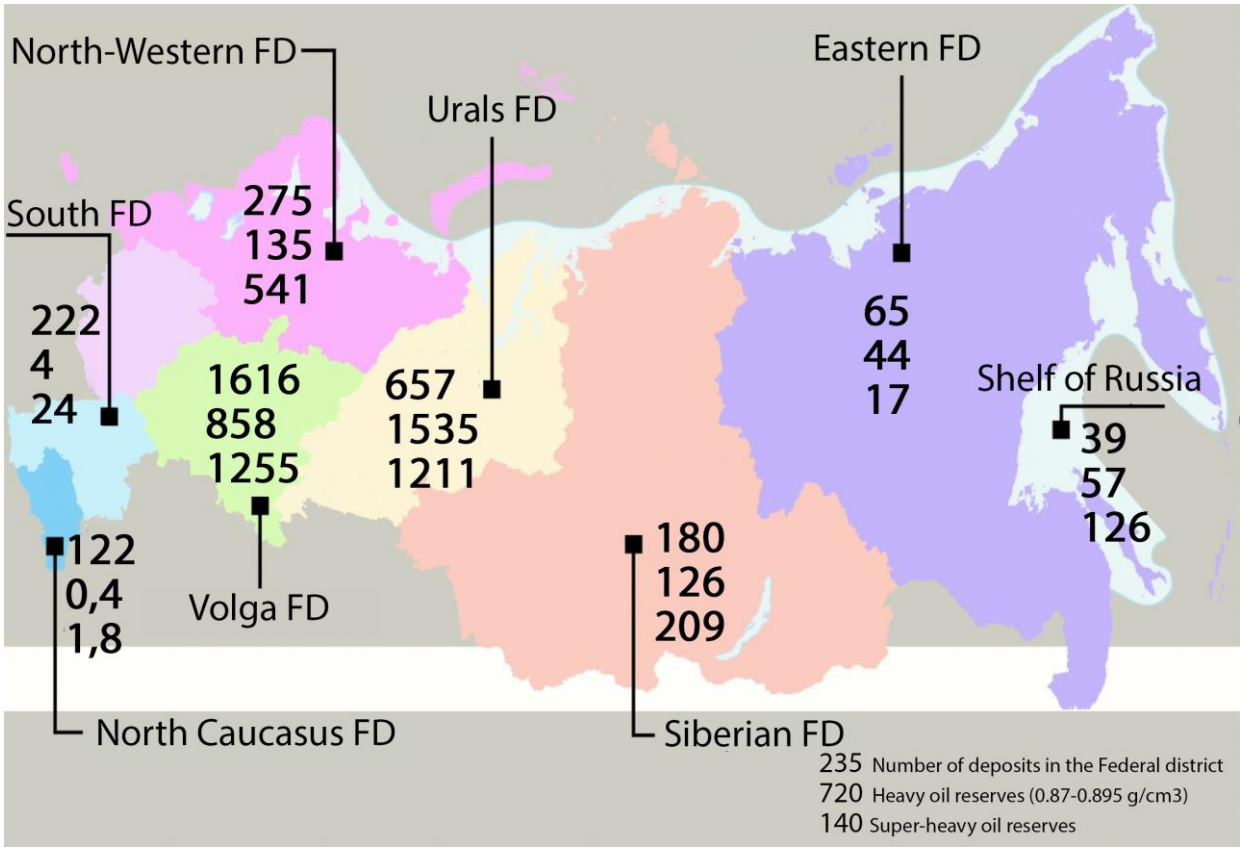

Figure 1. *Distribution of heavy and bituminous oil reserves by Federal districts in the Russian Federation*

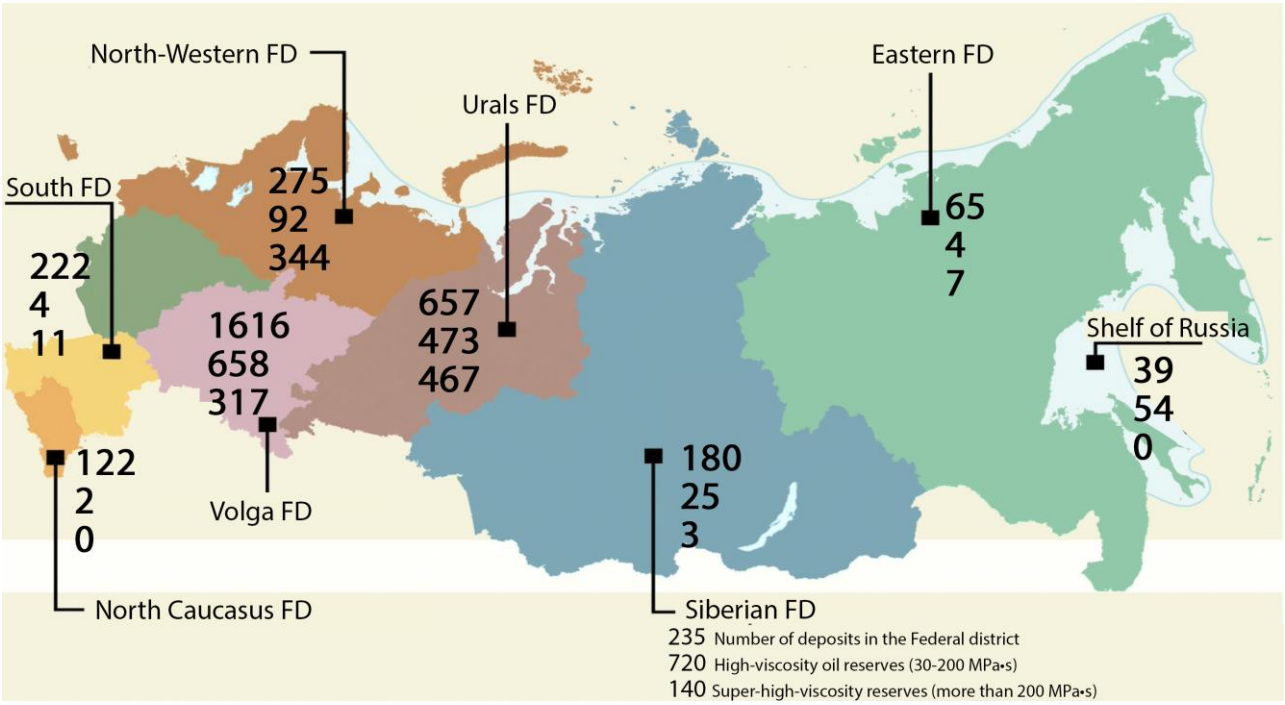

Figure 2. *Distribution of high - and super-high-viscosity oil reserves by Federal districts in the Russian Federation*