<PILOT COALBED METHANE PRODUCTION IN THE KUZNETSK BASIN>

Main author

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ABSTRACT

Growing coalbed gas production in the world and on the other hand, forecasted immense methane resources estimated by $49 \times 10^{12} \text{ m}^3$ in Russian coal fields stipulate the urgency and practical orientation of experimental industrial tasks implemented by OAO "Gazprom" supported by the Kemerovo Region Administration in Kuznetsk coal basin (Kuzbass).

Expected coal bed methane resources in the main Russian coal fields estimated down to the depth of 1800 m equate $49 \times 10^{12} \text{ m}^3$. These resources correspond to 15% of the world coal bed methane resources and about 8% of Russian expected resources of natural gas. In the most researched and developed Russian coal fields- the Kuznetsk, the Petchora, the Donetsk, the Burein, the South Yakutia and the Zyiryansk regions- concentrated coal bed methane resources are estimated at $17 \times 10^{12} \text{ m}^3$.

Among Russian coal fields Kuzbass occupies a specific place being considered one of the largest coal bed methane source of immense real opportunities of methane production industry. The methane resources studied down to the depth of 1800 m are estimated at $13 \times 10^{12} \text{ m}^3$.

From the beginning of 2001 Gazprom under agreements with the Kemerovo Region Administration carried out works on preparation of geological-production and technological basement for CBM production in Kuzbass. Taking into consideration geological, geophysical and geological-production data in Kuzbass were chosen four first-priority structures for experimental production of CBM from coal seams. Total methane resources in these areas are estimated at $1,5 \times 10^{12} \text{ m}^3$ and characterized by the high concentration up to $3 \times 10^9 \text{ m}^3/\text{km}^2$.

Implementation of experimental works has two main goals:

− feasibility of creating in Russia a new branch of fuel-energy complex – methane production in main coal fields;
− preparation of first-priority areas in Kuzbass for industrial production of CBM in volume terms of $4-5 \times 10^9 \text{ m}^3/\text{yr}$.

Main tasks of the experiment are:

− experimental demonstration of possibility to commercially produce methane from coal seams with the help of boreholes drilled from the surface;
− estimation of methane resources industrial amounts and calculation of supply according to industrial categories on first-priority areas and experiment results;
− preparation of geological-production and technological basement for commercial project of CBM production;
− estimation of coal-bed methane production environmental impact.

In 2002-2004 were implemented managerial, prior and experimental works on CBM production from coal seams of Taldinskaya area in Kuzbass. Scientific ground with four experimental boreholes was created, where geophysical, core and gas-dynamic research was implemented. Intensification of methane inflow from coal seams by hydraulic fracturing method was done. Initial methane inflows with rates up to 3000 m$^3$ per day were received. Experimental boreholes now are at the stage of test production.
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1. PREAMBLE

In conditions of the Russian gas industry raw materials source deterioration, one of the most prospective direction of its development are hydrocarbon raw materials unconventional sources. Coalbed methane resources have a special place among them. Growing coalbed gas production in the world and on the other hand, forecasted immense methane resources estimated by 49 x 10^{12} m^3 in Russian coal fields stipulate the urgency and practical orientation of experimental industrial tasks implemented by Gazprom.

The key factor that pushed worldwide coalbed methane production is a large number of new technologies aiming production increase in the wells opening seams with relatively low permeability but high gas content.

The new technologies let effectively determine the coal seam areas with higher natural fracturing. Choice of well location on the coalbed methane fields is based on the results of the earth remote sensing including the fast response aeromagnetic exploration, 3D seismic survey, basin evolution and tectonic simulation, rock massive mode of deformation.

For hydrodynamic connection between wells with cleavage system and coal reservoir natural fracturing there are different technologies of highly permeable drainage channel creation depending on mining and geological conditions. (Table 1).

<table>
<thead>
<tr>
<th>Intensification methods</th>
<th>Applicability conditions</th>
<th>Usage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coal seam hydraulic fracturing</td>
<td>Applicable in various geological conditions</td>
<td>&gt;85%</td>
</tr>
<tr>
<td>Cavitation (air hydraulic impact)</td>
<td>Coal seams with total thickness &gt;20 m in the depth interval &lt; 100 m, permeability &gt;30 millidarcy (1 millidarcy=10^{-3} darcy). Seam pressure is visibly higher than hydrostatic</td>
<td>&lt;10%</td>
</tr>
<tr>
<td>Directional and horizontal drilling</td>
<td>Coal seams with low permeability, thickness &gt;2 m</td>
<td>&lt;1%</td>
</tr>
<tr>
<td>Open well bottom widening</td>
<td>Coal seams with high permeability from 100 millidarcy to 3 darcy and higher</td>
<td>&lt;5%</td>
</tr>
</tbody>
</table>

Table 1: Intensification methods of fluid inflow from coal seams

Implementation of methane inflow from coal seams intensification methods played the decisive role for development of these unconventional difficult to recover energy resources.

Scientific understanding of mechanism and process of sorbed in coal seams methane extraction was the last, and probably the most important among the scientific and technical achievements. Created on the base of coal seam filtration and capacity characteristics fundamental research results computer-based technologies, let to determine the mining and geological conditions influence on possibility to extract methane from coal seams and to choose technology for this energy resource production.

In order to determine and optimize the main technological parameters of coalbed methane fields development there are special hydrodynamic coal seam models, such as COMET 2, COALGAS, CBM (ECLIPSE by Schlumberger, Tempest-More by ROXAR) etc.

The fracture propagation in coal seam simulation using FRACPRO, FRACCADE, etc. and drainage zones creation during air hydraulic impact (cavitation) Cavity-PC model let to design purposefully the effective creation of drainage channels with high conducting capacity in order to provide the well connection with the coal reservoirs and to determine the main intensification methods technological parameters.
Despite the worldwide growing methane extraction from the coal seam volume, development of these unconventional ecologically clean raw materials resources in Russia is restrained by a number of reasons:

1. Immense hydrocarbon reserves in the traditional oil and natural gas fields let the oil and gas companies produce natural gas with lower costs, at least in the nearest future, until the main gas production centers transference to Yamal Peninsula and to north sea shelf.

2. Regulated by the government low internal natural gas price and absence of favorable economic conditions for methane production from coal seams.

3. Absence of experience and technological base for the difficult to recover coalbed methane reserves production.

4. Absence of the governmental support for development of unconventional hydrocarbon resources in coal seams, that was in the USA by giving the tax remissions to companies in order to stimulate unconventional hydrocarbon resources development and oil export dependence decrease.

Nevertheless, the Russian coal basins development with gas production in the nearest future will be implemented on the following criteria base:

1. The mining and geological conditions as well as technological base development, that stipulate possibility of stable commercial methane production rates in the wells drilled from the surface to the coal seams undischarged from rock pressure.

2. Economic and ecological conditions, considering, on the one hand, the consumer nearness and their benefits from transfer to technological and ecologically clean (in comparison to coal and mazut) fuel, and on the other hand, coalbed methane production and transportation cost efficiency and competitiveness on the regional market of energy resources.

2. COALBED METHANE RESOURCES IN RUSSIA

Expected coalbed methane resources in the main coal Russian coal fields are estimated down to the depth of 1800 m on the base of their gas content according to the mine field and geological exploration area tests, to the determined pattern of gas content change depending on depth and coal metamorphism extent. On their scale, the coal bed methane resources are comparable to the traditional natural gas fields and account to about $49 \times 10^{12} \text{ m}^3$. (Figure 1).

![Figure 1: Coalbed methane resources in Russia](image)
These resources correspond to 15% of the world coal bed methane resources and about 8% of Russian expected resources of natural gas. In the most researched and developed Russian coal fields- the Kuznetsk, the Petchora, the Donetsk, the Burein, the South Yakutia and the Zyiryansky regions- concentrated coal bed methane resources are estimated at 17 x10^{12} m^3, 829 x 10^9 m^3 (5 % of total resources) are located within mine fields, 16625 x 10^9 m^3 (95%) are located within exploration and prospective for exploration parts and search-evaluation areas. On the considered coal basins upper floor – down to the depth of 1200 m – methane resources account to 9869 x 10^9 m^3 (61%), on the lower floor - 1200 to 1800 m - 6434 x 10^9 m^3 (39%).

The remaining in the coal seams and enclosing strata gases volume and relative fraction depend on mining and geological conditions of each basin and field. Unconventional hydrocarbon raw materials sources development may result in considerable growth of gas reserves in Russia.

Among the Russian coal fields Kuzbass occupies a specific place being considered one of the largest coal bed methane source of immense real opportunities of methane production industry. The expected methane resources there are estimated at 13 10^{12} m^3, their average density is 716 x 10^6 m^3/km^2. Within geologic-production areas the coalbed methane resources density varies in the limits from 0.35 x 10^6 m^3/km^2 to 2.5 x 10^6 m^3/km^2.

The main methane industrial production prospects in Kuzbass are related to methane sorbed in coal seams. But small part of resources is associated with the free gas accumulation in the main anticline structures. Total free gas resources are estimated in 98.6 x 10^9 m^3, that is less than 1% of sorbed methane resources. The average density of free gas resources is 24.3 x 10^6 m^3/km^2.

The free gas small accumulations are dispersed on the section and area and occupy position between dispersed gases and deposits. They are associated with the fine-pored fractured strata which filtration properties are stipulated by fracture permeability. The free gas accumulation in Kuzbass coal deposits within the one structure limits even of more than 5 x 10^9 m^3 scale may not be considered as small-scale gas fields, but only as an associated with a certain structure group of isolated, separated and dispersed free gas accumulation with total volume, comparable to the conventional small-scale field gas reserves.

High estimate of Kuzbass coal bed methane production prospect is based on its comparison with geological production characteristics of San-Juan in the USA, on the predicted technical and economic indexes and also on the occurrence of well-developed infrastructure and gas consumers at the distance of 15 – 150 km from the first-priority areas.

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Kuzbass</th>
<th>San-Juan</th>
</tr>
</thead>
<tbody>
<tr>
<td>Methane resources</td>
<td>Total 13.1 x 10^{12} m^3, including</td>
<td>Total 2.3 x 10^{12} m^3, including</td>
</tr>
<tr>
<td></td>
<td>prospective southern areas 3.0 x 10^{12} m^3</td>
<td>1.4 x 10^{12} m^3 in Fruitland formation, 0.9 x 10^{12} m^3 in Menephy formation</td>
</tr>
<tr>
<td>Methane resources density</td>
<td>500 to 3500 x 10^6 m^3/km^2</td>
<td>350 to 1000 x 10^6 m^3/km^2</td>
</tr>
<tr>
<td>Coal-bearing</td>
<td>Total coal seam thickness up to 120 m</td>
<td>Total coal seam thickness up to 30m</td>
</tr>
<tr>
<td></td>
<td>Separate coal seam thickness 10-18 m</td>
<td>Separate coal seam thickness 8-10 m</td>
</tr>
<tr>
<td>Depth</td>
<td>Down to 4000 m</td>
<td>Down to 1200 m (Fruitland formation)</td>
</tr>
<tr>
<td></td>
<td>During the methane estimation</td>
<td></td>
</tr>
<tr>
<td></td>
<td>were taken into consideration the</td>
<td></td>
</tr>
<tr>
<td></td>
<td>coal seams bedding higher than</td>
<td></td>
</tr>
<tr>
<td></td>
<td>1800 m</td>
<td></td>
</tr>
<tr>
<td>Productive groups quantity</td>
<td>6-8 groups in the intervals of 100 - 150 m in the section down to depth of 1800 m</td>
<td>1 group in the interval of 100 – 130m in the section down to 1200m</td>
</tr>
<tr>
<td>Gas-bearing of the coal</td>
<td>Up to 25-30 m^3/ton</td>
<td>Up to 15-20 m^3/ton</td>
</tr>
</tbody>
</table>
**Characteristics**

<table>
<thead>
<tr>
<th></th>
<th>Kuzbass</th>
<th>San-Juan</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>seams</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Coal metamorphism extent</strong> (vitrinite index of reflection)</td>
<td>0.6 to 2.0% (at the most prospective areas 0.75 to 1.2%)</td>
<td>0.7 to 1.5% (within productive level 0.78 to 1.2%)</td>
</tr>
<tr>
<td><strong>Coal seams permeability</strong></td>
<td>Up to 50 millidarcy and higher at the prospective areas according to the well tests</td>
<td>Up to 50 millidarcy</td>
</tr>
</tbody>
</table>

Table 2: Comparison of San-Juan and Kuzbass basins

Kuzbass coalbed methane resources are sufficiently larger than San-Juan resources - $13 \times 10^{12}$ m$^3$ against $2 \times 10^{12}$ m$^3$. Only in the most geologically examined south part of Kuzbass are concentrated about $3 \times 10^{12}$ m$^3$ of CBM resources. The density of resources on some areas reaches $3,5 \times 10^6$ m$^3$/km$^2$. According to this figure Kuzbass basin not only 2-3 times exceeds San-Juan, but can be compared to unique natural gas fields in the northern part of Tyumen region as well. Huge resources and high concentration of CBM is caused by high coal-bearing and methane-bearing capacities of Kuzbass coal seams. Total coal seams thickness at the depth down to 1200 m on separate areas reaches 120 m, and separate seams thickness is 10-18 m against 30 m and 8-10 m, accordingly, in San-Juan.

In Kuzbass region more than a half coal types belong to the groups of medium stage metamorphism. Usually they are characterized by the vitrinite index of reflection value $R^0$ which is changed (as in San-Juan) in the limits from 0.7 up to 1.5%. It gives us reason to suggest that the natural fracturing of coal seams is very high and, consequently, their permeability is high too.

### 3. GAZPROM SCIENTIFIC EXPERIMENTAL SITE FOR COALBED METHANE PRODUCTION IN KUZBASS

#### 3.1. First-priority structure selection

From the beginning of 2001 Gazprom under agreements with the Kemerovo Region Administration carried out works on preparation of geological-production and technological basement for CBM production in Kuzbass.

Taking into consideration geological, geophysical and geological-production data in Kuzbass were chosen four first-priority structures for experimental production of CBM from coal seams. Total methane resources on these structures are estimated at $1,5 \times 10^{12}$ m$^3$ and characterized by the high concentration up to $3 \times 10^6$ m$^3$/km$^2$. (Table 3).

<table>
<thead>
<tr>
<th>Structure</th>
<th>Area, km$^2$</th>
<th>Methane resources, $10^9$ m$^3$</th>
<th>Density of resources, $10^9$ m$^3$/km$^2$</th>
<th>Total thickness of coal seams, m</th>
</tr>
</thead>
<tbody>
<tr>
<td>Taldinskaya</td>
<td>31</td>
<td>95,3</td>
<td>3,0</td>
<td>140 - 150</td>
</tr>
<tr>
<td>Naryksko-Ostashkinskaya</td>
<td>330</td>
<td>918,0</td>
<td>2,78</td>
<td>от (30 - 35) до (130 - 150)</td>
</tr>
<tr>
<td>Tomskaya</td>
<td>45</td>
<td>121,1</td>
<td>2,69</td>
<td>62 - 65</td>
</tr>
<tr>
<td>Raspadskaya</td>
<td>134</td>
<td>357,2</td>
<td>2,83</td>
<td>70 - 75</td>
</tr>
<tr>
<td>Totally:</td>
<td>540</td>
<td>1 491,6</td>
<td>2,76</td>
<td></td>
</tr>
</tbody>
</table>

Table 3: First-priority structures in Kuzbass for coalbed methane resources development

Prior to industrial methane production from coal seams there were implemented experimental testing and adjustment of technology for CBM hole making and casing, fluid inflow intensification and
well development in on the scientific experimental site of Gazprom. In order to decrease financial risks experimental activities are carried out in two stages:

I stage – methane extraction from coal seams technologies adjustment, resources transfer into reserves of industrial categories at Taldinskaya area of Kuzbass.

II stage – other intensive methane from coal seams extraction technologies testing (cavitation, directional well drilling); resources transfer into reserves at Naryksko-Ostashkinskaya, Tomskaya and Raspadskaya areas. Geological and geophysical basis preparation for industrial methane extraction from coal seams in volume of 4-5 x 10^6 m^3/year

![Figure 2: Gazprom scientific experimental site in Kuzbass](image)

3.2. Testing and adjustment of coalbed methane extraction using the surface to inseam wells technology

Two well clusters were constructed on Gazprom scientific experimental site in Kuzbass. Each cluster has two wells with depth of 640 to 980 m, each of the wells drains different groups of coal seams. The upper group of productive coal seams beds in the interval of 400 to 600 m, the lower – 600 to 880 m. Wells of each group open 5 to 7 coal seams with total thickness of up to 20 m per 1 well. Geophysical, core and hydrodynamic surveys carried out in the wells let to determine the main geological and productive parameters of the coal seams:
- thickness varies from 2 to 6 m,
- gas-bearing - from 14 to 21 m^3/ton,
- ash value – up to 12%,
- permeability - from 1 to 68 millidarcy.

Intensification of reservoir fluid inflow from coal seams by hydraulic fracturing method was implemented. There were created drainage channels of high conductivity and up to 80 m size, filled with propping agent (proppant). Hydraulic fracturing was made through oil-well tubing or through well casing. During the hydraulic fracturing the coal seam or several seams were isolated in the well by a simple packer and plugs or by straddle packer. As the hydraulic fracturing fluid was used linear or cross-linked gel, as propping agent – ceramic proppant 20 x 40 mesh size. The proppant concentration in the mixture was up to 600 kg per 1 m^3 of injected liquid. During the hydraulic fracturing up to 100 m^3 were injected into the well with working pressure from 10 to 23 MPa (1 MPa = 10^6 Pa) depending on seam bedding depth and hydraulic fracturing pressures. The injected into fractures proppant weight varied from 8000 to 40000 kg per one hydraulic fracturing. After the hydraulic fracturing the well development was carried out with the help of submersible screw pumps, providing water level decrease in the wells, pressure drawdown to the coal seams in the near-well space and methane desorption process. Initial water outputs in the wells varied from 30 to 120 m^3/day. Experimental wells are equipped with measuring separation unit for technological parameters control and gas-dynamic surveys. Initial methane outputs were up to 3 x 10^3 m^3/day per well on the pressure drawdown from 2 to 4 MPa. The experimental wells are in pilot operation now.
Worldwide CBM production experience analysis shows that in order to develop gas extraction in the Russian main coal basins it is necessary to meet the following key requirements.

In the first place, just same as for the traditional hydrocarbon raw material deposits, the main requirements are industrial methane inflow and high methane from the coal seams recovery ratio. Methane production is a highly technological branch of industry, and commercial CBM wells recovery rates may be achieved by meeting the following requirements:

− identification of prospective zones and segments within the coal basins on the base of geological and geophysical surveys prior to production wells construction;
− efficient well drilling and completion technologies implementation, well development using methods of fluid inflow from coal seam to well intensification;
− low well operation costs.

Corresponding to mining and geological conditions and production technologies the CBM well outputs can vary more than hundred times: from less than 2 to more than 200 000 m$^3$/day. The main geological and technologic tasks are identification of highly productive zones within the coal basins and technical decisions for well construction, completion and development, to secure the largest gas production rates.

In the second place, the CBM wells construction and operation costs should be low in order to secure profitable production when the outputs are rather small, that is usual for coal basin mining and geologic conditions. Reasonable and acceptable methane production costs per unit for may be achieved due to small depths of well construction – less than 1200m.

In the third place, an important requirement for commercial methane production from coal basin is a solvent market presence in immediate proximity. Coalbed methane production costs per unit are higher than those for natural gas. CBM is competitive to natural gas when the distance from the wellhead to consumer decreases and when the transportation costs sharply decrease.

The large scale CBM production projects are more effective. Production volumes and production well quantity should reach the critical level providing cost-efficiency. The minimal methane production scale depends on many factors such as gas price, distance to consumers, infrastructure presence etc. For the new distanced coal basins in the USA commercial threshold is considered as 2 x 10$^9$ m$^3$/annual production volume and 400 production wells.

Regarding the above-mentioned, CBM resources development in prospects Russia for the period until 2020 are related most of all to Kuznetsk and Pechora coal basins.

Methane resources potential in Kuzbass, economic-efficiency of its production and transportation as well as prospective gas demand in the neighboring southern regions of Western let to forecast the production volume growth up to 20 x 10$^9$ m$^3$/year in 2020. After 2020 the further production increase may be economically sound by the export gas supply to the Asian-Pacific region countries.

In Pechora coal basin the most prospective for commercial CBM production is Vorkutinsky region. Expected coalbed methane resources in Vorkutinsky region coal seams (excluding Seidinskoye field) are 589 x 10$^9$ m$^3$. Currently methane is extracted as associated mineral wealth by degassing units of Vorkutinsky region in total volume of 200-300 x 10$^6$ m$^3$/year. Only 120-150 x 10$^6$ m$^3$/year of this volume are used for mine heater units and processing plants. Resource basis of Pechora basin and prospective gas demand for Vorkuta-city electricity supply let to produce 1.5 x 10$^9$ m$^3$/year.

Prospect for gas production in the Apsatsky coal basin are related to energy supply of the nearest Charo-Udokansky territorial-industrial complex. Expected coalbed methane resources there are estimated in 55 1.5 x 10$^9$ m$^3$ and concentrated mainly in thick (4-6 m) and extra-thick (up to 20 m)
coal seams within the area of about 10 km² and stipulate the annual production volume up to 1.5 x 10⁹ m³/year for energy supply of ore mining and processing enterprise and gas supply for the city with 100 000 people population.

5. CONCLUSIONS

Today Gazprom implements the first in Russia experimental project of coalbed methane production in Kuznetsk coal basin. The main task is to create geological, geophysical and technological base for coalbed methane deposits development. The first results of the experiment show high prospect of these tremendous unconventional hydrocarbon resources development, that will give to Gazprom the following opportunities:

− to expand considerably the raw materials base of gas industry in the populated regions with developed infrastructure, sufficient both for gas supply of extensive adjoining territories on the south of Western Siberia and for strengthening of the Russian gas fuel export base;

− to release considerable natural gas volume transported from the fields of the Tyumen region northern parts and direct it to the central Russia and to export due to the natural gas substitution by the coalbed methane.

Production rate of the first-priority coal basins development by gas fields depends mostly of economic conditions and competitiveness of coalbed methane on the regional fuel market. To involve this tremendous potential into the country’s economy President Vladimir Putin commissioned the Government both to ensure international cooperation with the purpose to organize the industrial coalbed methane production in Kemerovo region and to work over the proposals of governmental support. To accomplish the commission a taskforce attached to the President Administration was created. The taskforce will provide managerial, economic and legal base for the coalbed methane production project implementation, including:

− Government rate and tax conditions regulation for coalbed methane production.

− Coalbed methane entry into industry classificatory as an independent mineral wealth.

− Customs regulation for import of foreign coalbed methane production technologies and equipment that do not have domestically produced analogues.
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