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EVALUATION OF METHANE EXTRACTION FROM COAL FIELDS

Methane recovery from the coal fields (MRC) is the volume of the pure (100%) methane which is extracted from anything site and containing rocks of the seam. The conception "methane recovery" includes the economical aspect because the recovery of the fuel must be profitable. The specific methane extraction (SME) is the volume of extracted methane on the coal reserves unit. The unit is named as "removable unit".

MRC may be recovered from the coal fields both through boreholes and through mine workings. But the economical interest has the boreholes recovery only. MRC depends of flow rate through the borehole very much. Some specialists consider the economical methane flow rate must be as much as about 25 000–30 000 m^3 per day. If total number of the boreholes is known in the coal site the real MRC in the coal field will be found as the sum of the all flow rates of these boreholes.

The notion MRC is connected narrowly with the number of boreholes which need to drill in the conditions of limited reserves of the coal field for the methane recovery forecast. Meanings of coalbed methane reserves for the drainage area of several coal seams are shown in the Table 1.

Table 1

Potential reserves of coalbed methane (mln m^3) in the coal seams with methane content as 15 m^3/t

Total thickness of coal seams [m]	The area of the coal site [km^2]				
	3	5	7	9	11
8	486	810	1134	1458	1782
12	729	1215	1701	2187	2673
16	975	1620	2268	2916	3564
20	1215	2025	2835	3645	4455

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In the Table 1 we may see the flow rates through the boreholes are as more billion m^3 are begun in the area more 5 km^2 and extraction level as 3 year and flow rate 30 000 m^3/day.

The number of the methane boreholes for methane recovery and methane content as 15 m^3/t and the flow rate of individual borehole as 30 000 m^3/day and exploitation period 3 year are shown in the Table 2.

Table 2

Number of required methane boreholes for the determined coal area and flow rate through the single borehole as 30 000 m^3/day

Total thickness of coal seams [m]	The area of coal site [km^2]				
	3	5	7	9	11
4	157	262	367	472	577
8	314	524	734	943	1153
12	471	786	1101	1415	1430
16	628	1046	1468	1886	2307

Analysis of the Table 2 allows to make the next conclusion. The number of the active coalbed methane boreholes is changed from 157 to 2307 in dependence from the coal site and total thickness of the coal seams. Accordingly, MRC of the coal site is changed from 285 mln m^3 per year to 31.5 billion m^3 per year.

So as the natural coalbed methane return of the coal seams is very small (that is not more 2000–3000 m^3/day) and extraction effectiveness doesn't exceed the 25–40% the natural flow rate through the single borehole doesn't provide commercial effect of coalbed methane use. In consequence methods of artificial increase of the flow rate (intensive methods) must be used. There are practical using intensive methods of coalbed methane recovery: hydrofraturing, cavitation and physical and chemical treatment (PCT) of coal seams.

Table 3 contains the short experience data about the intensive methods use in the world-wide.

Table 3

Intensive method	Volume of liquid [m^3]	Flow rate of liquid [m^3/hour]	Effective radius of treatment [m]	Volume of liquid into opened fractures [m^3]	Area of MRC [m^2]
Hydrofracturing	3000–5000	290–325	150–180	72–180	7200–18000
Cavitation	4000–5000 400000*	15–30	15–30	29–72	1440–3600
PCT	2000–3000	100–215	100–120	145–360	5760–14400

* – injection of air

Analysis of Table 3 shows the general volume of treatment liquid is sent on the filtration process into the fractures walls of the coal massive. This concept was put in the base of the MRC parameters calculation for the coal site. The parameters for hydrofracturing process in a coal seam, created on the base of our concept, are shown further.

A volume of injected liquid into a coal seam V_{tot} may be determine as follow

$$V_{tot} = k_f \cdot \pi \cdot R_{ef}^2 \cdot h \cdot m_0 \tag{1}$$

where:

k_f – filtration coefficient of the liquid into the wall of the fracture;
k_f = 1.1–1.3;
R_{ef} – radius of hydraulic influence of the hydrofracturing borehole [m];
h – thickness of the coal seam [m];
m_0 – porosity of the coal seam.

The volume of the filtrated liquid into a single fracture wall V_f is determined as follow

$$V_f = 4.56 \frac{k \cdot h \cdot \Delta p}{\mu \cdot \sqrt{\pi \cdot \chi}} \sum_1^n R_{ef} \sqrt{T_{inj}} \quad [\mathrm{m}^3] \tag{2}$$

where:

k – permeability coefficient of the coal seam [m^2];
Δp = $p_d - p_g$;
p_d – pressure in the borehole bottom [Pa];
p_g – pressure of coalbed methane into the coal seam [Pa];
n – number of the hydrofracturing boreholes in the exploitation;
T_{inj} – time of the treatment of the coal seam [s];
μ – viscosity of the liquid [Pa·s];
χ – hydroconductivity of the coal seam [m^2/s].

The volume which make filling of the fracture V_{fr} is determined as follow

$$V_{fr} = V_{tot} - V_f \quad [\mathrm{m}^3] \tag{3}$$

The area of the fractures, created through hydrofracturing process, is determined as follow

$$S_{fr} = \frac{V_{fr}}{\delta_{fr}} \quad [\mathrm{m}^2] \tag{4}$$

where δ_{fr} – average width of all fractures of hydrofracturing process [m].

The experience of Russia allows to determine this parameter as = 0.001–0.01 m. Considering (1)–(4) we may to determine methane recovery from the coal fields (MRC) as

$$MRC = \alpha \sum_{1}^{n} Q_{bor}\, t_{ex} \quad [\mathrm{m}^3] \tag{5}$$

where:

- α – coefficient of flow rate of the borehole decrease for time tex, for example, for physical and chemical treatment $\alpha = 0.48 – 0.52$;
- Q_t – speed of way out of coalbed methane from the coal

$$Q_t = \varphi \cdot x\,[0.0004(V^{fl})^2 + 0.16] \quad [\mathrm{m}^3/\mathrm{m}^2 \cdot \mathrm{day}] \tag{6}$$

where: φ – coefficient dewatering of the coal seam after liquid treatment

$$\varphi = \frac{V_{dew}}{V_{tot}} \tag{7}$$

where:

- x – natural methane content of the coal seam [m^3/t];
- V_{dew} – volume of liquid which pumping from the coal seam after hydrofracturing process [m^3];
- V^{fl} – exit of fly matter from the coal [%];
- t_{ex} – time of boreholes exploitation during coalbed methane recovery [days].

CONCLUSIONS

1) Coalbed methane recovery from coal seams has determined difficult so as the coal have the low speed of gas exit from the ones.
2) For commercial coalbed methane use the active methods of artificial increase of it flow rate (intensive methods) must be used.
3) It is proposed method of calculation the parameters of hydrofracturing and chemical treatments of the coal seam.
4) The calculations of real the processes on mine fields (Pechora and Kuznetsk basins) of Russia have proved good consent with experience data.