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Method of in-seam gas drainage borehole testing

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Abstract. The paper describes the method of in-seam gas dynamic logging in long drill holes. The method uses a robotic tool based on the straddle packer assembly. The choice of a measurement scheme depends on the time planned for testing, required accuracy and quality of borehole walls. By the testing data, the intervals with low gas influx can be identified for further hydraulic fracturing to stimulate methane drainage, or it is possible to undertake prompt precautions in outburst-hazardous areas.

1. Introduction

Most published gas dynamic research findings are connected with drilling holes from surface down to coal seams. There is hardly any information on interval measurements of gas recovery in in-seam drainage boreholes. This is explained, firstly, by the generally accepted technology of gas drainage when a borehole is immediately connected to a gas drainage system and is not used for studying properties of rock mass, and, secondly, by high cost of work, among other things, due to inapplicability of traditional oil-and-gas technologies.

Filtration characteristics of a reservoir are most commonly determined using pressure–flow rate relationship, build-up and draw-down curves of gas pressure in a sealed interval of drainage boreholes. These methods are based on features of elastic behavior of oil or gas reservoir when cones of depression form around holes put in operation and expand at a certain rate in the reservoir [1, 2].

The method of gas dynamic logging described in this paper is based on profile measurement of gas influx rate in long drainage boreholes. Recently the mine industry in developed coal mining countries extensively uses directional drill rigs to make boreholes with a preset trajectory up to one kilometer long [3, 4]. It provides much larger gas drainage zone in a coal seam and much higher methane flow rate [5]. On the other hand, there seems to be no research into properties of coal seams using these holes toward optimization of methane recovery. The interval profile measurements of gas influx rate along drill holes at considerable distances from an excavation will reveal features of methane distribution and filtration in coal and rock mass, and will help select most favorable borehole intervals for hydraulic fracturing.

2. Schemes of in-seam gas dynamic drill hole logging

Based on the analysis of experience gained in borehole, including developed in-seam, testing and modern downhole tools, we put forward several approaches to in-seam measurements:

- For drainage boreholes with minor variable cross-section, e.g. in coal seam roof or in hard coal—robotic two-packer tool self-moving along a borehole without help of drill rig;



- For drainage boreholes with greatly variable cross-section due to sloughing and damage of walls, or strong deviation of the borehole diameter from the drill bit design size, which is most often observed in coal seams—single-packer tool pushed into the targeted interval of the hole using the string.

Let us discuss the gas dynamic logging using the robotic two-packer tool moved in hole using a special transport module. The tool has three independent lines of pressure feed, and it is well suited for research of standard and long gas drainage boreholes drilling in coals seam roof or in hard coal [6, 7]. The profile logging procedure is described below (Figure 1).

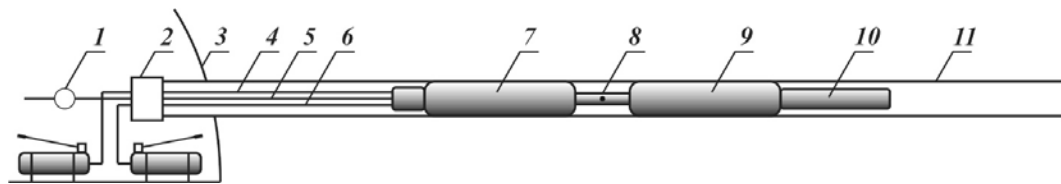


Figure 1. Scheme of gasdynamic logging using two-packer tool: 1—flow rate meter; 2—lubricator; 3—underground excavation; 4—pressure feed line to closer lying packer; 5—pressure feed line to farther lying packer; 6—line for pressure feed/degassing of interval between packers; 7—closer lying packer; 8—inter-packer interval; 9—father packer; 10—transport module; 11—hole.

The two-packer tool with the transport module 10 is moved along the hole 11 to its bottom and pulls the pressure feed lines 4–6 meant for pumping the packers 7 and 9, as well as pressure feeding/degassing of the inter-packer interval 8. The hole is equipped with the lubricator 2 preventing gas outflow from the hole to the excavation 3 during the tests. As the tool is set at the hole bottom, pressure is fed to the packers to seal the inter-packer interval which is the testing interval in this case. Gas released from coal to the test interval is fed using the line 5 and the flow rate meter 1 to the mine drainage system. The air-and-methane flow rate is recorded. Then, the packers are blown off, the tool is moved to a certain distance, and the packers are inflated again. The measurements are taken. In this manner, by moving the tool from the mouth to the bottom of the hole and taking measurements, the gas influx–hole length curve is plotted.

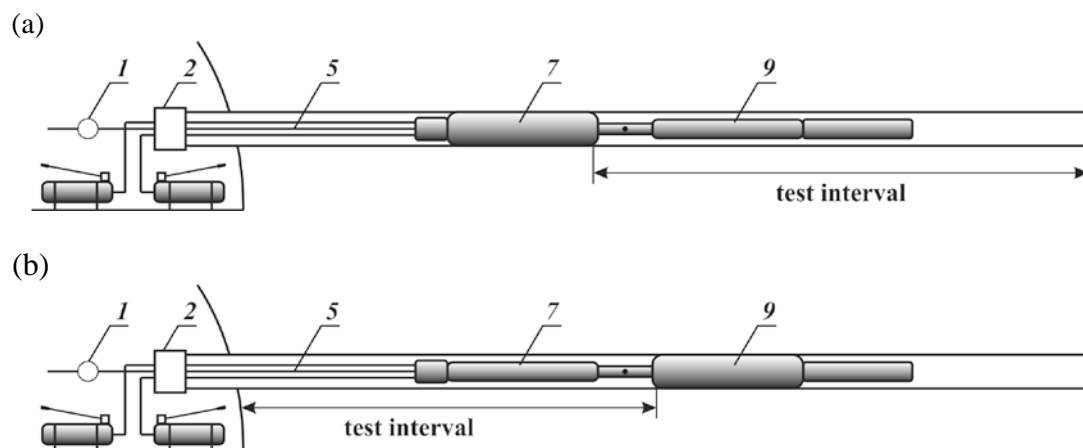


Figure 2. Scheme of fast gasdynamic logging with two-packer tool: (a) measurement interval is between the packer and hole bottom; (b) measurement interval is between the packer and hole mouth; 1—flow rate meter; 2—lubricator; 5—pressure feed line to father lying packer; 7—closer lying packer; 9—farther lying packer.

The second gas logging scheme is used when rapid estimate of gas release along the hole is required and featured shorter operating time (Figure 2). In this case, the testing interval is longer due to independent operation of inflated packers within the tool structure; the number of measurement points can be reduced without significant loss of the test information content.

Figure 2a depicts the tool in the hole, the measurement interval is between the closer lying packer 7 and the hole bottom. Gas discharge in the interval is measured by the flow rate meter *I* and recorded. Then, the packer 7 is blown off and the packer 9 is inflated. In this case, the measurement interval is between the packer 9 and the hole mouth (Figure 2b). Gas discharge in this interval is also measured and recorded. Thus, gas influx is measured in two different intervals at the same position of the tool. After the tool is moved closer to the hole bottom, measurements are repeated. The number of measurement points is governed by the wanted precision and time limit of work. This scheme is a quick method to reveal zones of different gas influx along drainage boreholes. Even with two measurements at the same point at the middle of a hole, it is possible to roughly assess which half of the hole has higher gas recovery, and, if necessary, to plan and perform more comprehensive testing.

Figure 3 shows some theoretical curves obtained in modeling gas influx in a 150 m long hole. Measurements are taken each 10 m; at each measurement point two values of gas recovery are recorded for the intervals: closer packer–bottom (Figure 2a), mouth–farther packer (Figure 2b).

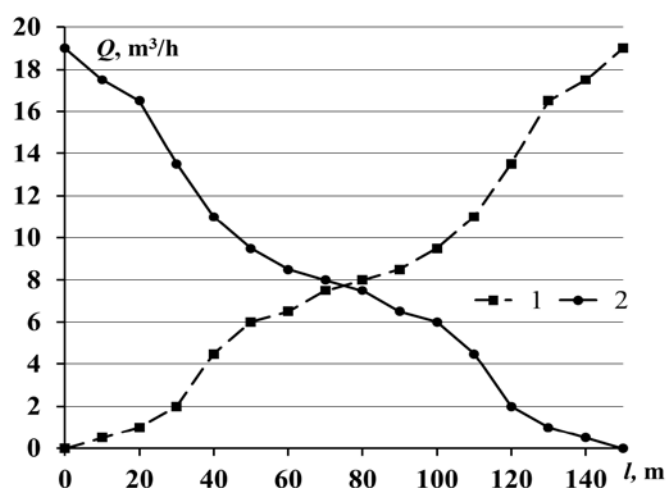


Figure 3. Theoretical curves of modeling gas influx in hole for different measurement intervals: 1—mouth–farther packer; 2—closer packer–bottom.

Analysis of the curves allows us to distinguish sections with different gas release, and the curves slope between two measurement points yields gas influx in this section. Plotting two curves creates the opportunity to improve the measurement accuracy by means of averaging test results in long drainage boreholes.

When it is impossible to operate the robotic equipment due to bad condition of the hole walls, the scheme with one elongated packer can be used (Figure 4).

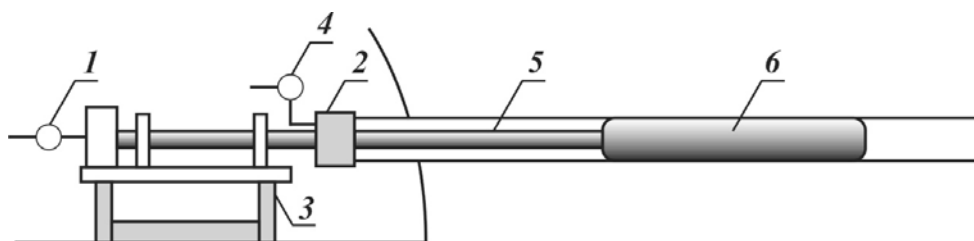


Figure 4. Scheme of gasdynamic logging with single-packer tool: 1, 4—flow rate meter; 2—lubricator; 3—drilling equipment; 5—drilling string; 6—packer.

Using the drilling rig 3 or a special system to advance the pipe 5 in the hole, the packer 6 is pushed to the bottom and inflated. An additional rigid tube is placed in each drill pipe and set in special holders at both ends of the pipe. It provides two independent channels for packer inflation and gas extraction. The packer has a through channel for gas flow to the flow rate meter 1. The flow rate meter 1 records gas influx from the measurement interval between the packer and hole bottom. The flow rate meter 4 mounted on the lubricator 2 shows gas influx from the measurement interval between the packer and hole mouth. Similarly to the express-logging scheme with the two-packer tool two values of gas influx are obtained at one measurement point, which improves the method reliability. After the measurements are taken, the packer is moved toward the mouth, and the process is repeated. The test curves are similar to the curves in Figure 3.

Thus, the efficient gas dynamic logging algorithm is as follows. Firstly, condition of the gas drainage borehole walls is estimated, its real diameter compliance with the standard size drill bit is checked, and gaging is performed. If free displacement of the string is obstructed, the hole is washed and cleaned using auxiliary downhole equipment, e.g. air hammer. Underground mining experience shows that such preparation can be required in holes drilled in soft coal or in seams under high stresses and high jointing. In such cases, the gas dynamic logging is to be carried out using the scheme with the elongated packer mounted on the drill string. In a hole drilled in the roof or in hard coal, it is possible to use robotic system to transport the logging tool in the present hole interval without assistance of the drill rig and to perform full-package profile measurements.

3. Conclusions

The schemes of in-seam gas dynamic logging in long drainage boreholes have been developed. The choice of a scheme is governed by the limited time of work and required accuracy of measurements, as well as by the hole quality. In holes drilled in the coal seam roof or in hard coal, it is suggested using the two-packer tool, which provides the opportunity to take longer measurement intervals and shorter time of testing. For logging in weak rocks in holes with damaged walls the scheme with the elongated packer is proposed, which provides the high quality sealing of the measurement interval. In all schemes it is necessary to use a lubricator for higher accuracy of the results.

Acknowledgements

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