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LINEAR SWELLING TEST (LST) OF CLAY FORMATION UNDER THE INFLUENCE OF NEWLY DEVELOPED DRILLING FLUIDS WITH THE ADDITION OF CATIONIC POLYMERS***

1. INTRODUCTION

The swelling of clay formation under filtrate influence is a major issue during drilling with water dispersive drilling fluid. Formation swelling is a source of borehole's nominal diameter decrease and may cause complications while drilling, e.g. drill string seizure. Excessive water volume, which is separating out of the mud to formation, may severely affect the strength of a rock's bonding force. This may lead to borehole walls' pouring cavern forming. Therefore, it causes difficulties with borehole cleaning and cementing operations.

In order to validate the practical utility of developed drilling fluids for clay drilling, shale of Eocene age a swelling test was conducted. The test was performed in standard conditions [1] using a HPHT Linear Swell Meter.

2. THE TEST METHODOLOGY

A linear swelling test has been achieved with GRACE Instrument M4600 HPHT Linear Swell Meter (Fig. 1).

The apparatus is capable of high temperature (up to 500F) and high pressure (up to 2000psi) measurement of linear swelling of the formation (LST – Linear Swelling Test) in both static and dynamic conditions.

During the first phase of the research rock powder pellets were prepared with a M4600 Dual Core/Wafer Compator device (Fig. 2).

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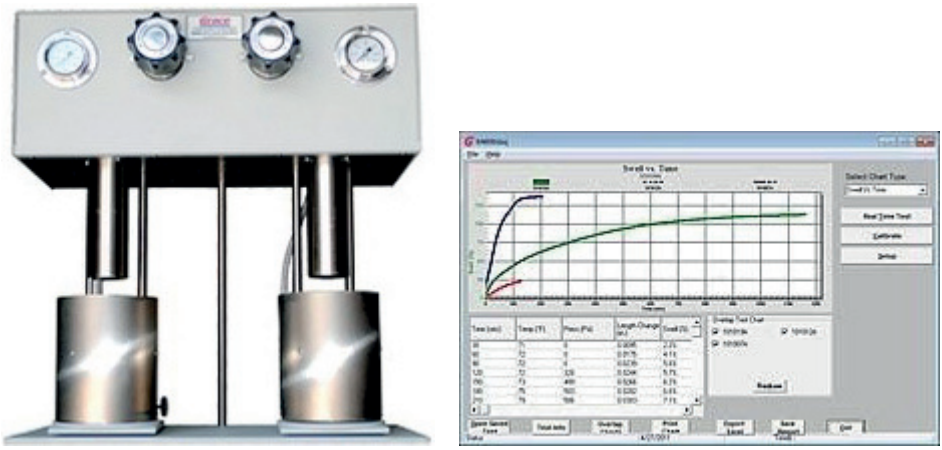

Fig. 1. GRACE Instrument M4600 HPHT Linear Swell Meter

Fig. 2. M4600 Dual Core/Wafer Compator

Samples of powdered rock, with mass ~11,5 gram, were inserted into cells of the M4600 Dual Core/Wafer Compator device and exposed to 2,500 psi pressure for 60 minutes. Pellets thus obtained were used in the further research.

In a subsequent phase, pellets made out of tested formation were inserted into the measuring cells of the M4600 HPHT Linear Swell Meter, and then saturated in the studied fluid. The swelling test was carried out under atmospheric pressure for 20 h at 30°C.

The dispersion of the clay shale formation test was performed at the Oil and Gas Institute. This test is a basic evaluation method of drilling fluid or inhibitors solution effectiveness

of inhibition, which establishes percentage recovery of the drill cuttings dispersed in solutions of inhibitors advised for the research.

Clay formation samples, dried at 105°C temperature and grinded in the mortar, need to be sifted through two sieves with a 5 and 1,5 mm round mesh. A dispersion test was performed with a fraction that was able to pass through the 5 mm sieve and left residues on 1.5 mm one. Sample received this way (in the quantity that enables carrying out few to over a dozen tests) need to be stored in desiccator for protection against moisture.

The studied polymer solution or drilling fluid (350 ml each) is poured into autoclave of 500 ml volume along with the prepared clay formation sample (50 g). Tightly closed autoclaves have to be put in Rolen-Oven for approximately 16 h. After this time, the content (of the disassembled autoclave) is separated on a 0.5 mm mesh sieve. In order to remove drilling fluid's or polymer solution's remains, it is slightly washed with water. Next, it is dried and weighted to an accuracy of 0.01 g. Sample thus prepared is again poured into an autoclave and flooded with 350 ml of sloppy water. The autoclave is placed in a rotary kiln for 2h and after taking out the content is separated on a 0.5 mm mesh sieve. Residues are dried until a constant mass is obtained and weighted to an accuracy of 0.01 g.

The result of the dispersion test is the percentage ratio of the sample leftover mass on a sieve (after 16h of dispersion in drilling fluid or a polymer solution) to the sample total mass used in the test, marked as "P1".

P1 value is given by the equation:

$$P_1 = \frac{m_p \cdot 100}{m} \ [\%] \tag{1}$$

where:

P_1 – the percentage ratio of the sample leftover mass (after dispersion in the mud) to the output sample mass (sample recovery after dispersion in the mud),

m – mass of the output sample used in the test [g],

m_p – mass of the sample remaining on the sieve after dispersion in the mud and dried [g].

Tests of drilling fluids technological parameters were performed according to API specification standard [2].

3. POLYMERS – SYNTHESIS

Synthesis of cationic polymers and cationic-anionic polymers with low steric hindrance were prepared for the sake of the project.

The BG-007 polymer is a low molecular weight cationic polymer – polyvinylamine. Vinylamine does not exist as a stable monomer, thus a synthesis of the polymer was obtained by N-vinylformamide (NVF) free radical polymerization. Created polymer, polyvinyl formamide, was hydrolysed with a alkaline hydrolysis method (with KOH). In result polyvinylamine containing 75% of ion groups is received.

The BG-009 polymer is a low molecular weight polymer – polyvinylamine hydrochloride. This polymer was obtained by N-vinylformamide (NVF) free radical polymerization,

likewise BG-007 polymer. However, hydrolysis was obtained with the acid hydrolysis method (with HCl). In that case polymer with 50% iconicity is obtained.

The BG-010 polymer is a copolymer of vinylamine and N-vinyl sulfonic acid. Copolymerization by radical polymerization was performed. Received polymer was hydrolysed with the alkaline hydrolysis method (with KOH).

4. DRILLING FLUIDS' FORMULAS

The research consists of formula development of the drilling fluid with triple-inhibition mechanism glycol-potassium-polymer. As a comparison mud without addition of polymers was used. Drilling fluids' formulas are presented in Table 1.

Table 1

Drilling fluids' formulas

Formula	Mud-00 [%]	Mud-07 [%]	Mud-07a [%]	Mud-07b [%]	Mud-07c [%]	Mud-09a [%]	Mud-10a [%]
Bentonite	3	3	3	3	3	3	3
CMC LV	2	2	2	2	2	2	2
XCD	0.03	0.03	0.03	0.03	0.03	0.03	0.03
KCl	5	5	5	5	5	5	5
Glycol	1	1	1	1	1	1	1
BG-007	–	0.5	1	1.5	1.25	–	–
BG-009	–	–	–	–	–	1	–
BG-010	–	–	–	–	–	–	1
Blok M-25	7	7	7	7	7	7	7
Biocide	0.5	0.5	0.5	0.5	0.5	0.5	0.5

5. TECHNOLOGICAL PARAMETERS

Developed drilling fluids were tested for rheological properties, filtrate loss and lubricity coefficient. The results are summarized in graphs – Figure 3.

The findings indicate that the introduction of polymers into drilling fluid's formula does not change technological parameters in comparison to the output mud (Mud-00). Furthermore, a significant decrease of lubricity coefficient value have been observed.

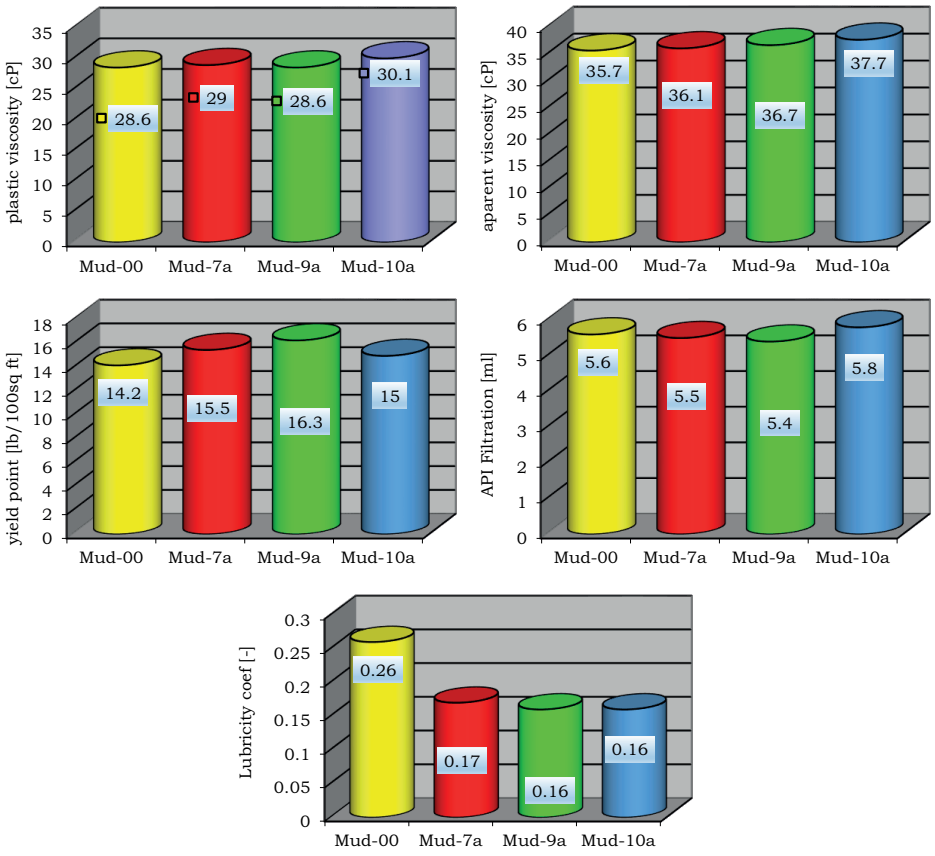

Fig. 3. Technological parameters of developed drilling fluids

6. TEST OF EOCENE AGE SHALE LINEAR SWELLING

In order to validate the practical utility of the developed drilling fluids for clay drilling, shale of Eocene age swelling test was carried out. The test was conducted with HPHT Linear Swell Meter apparatus in standard conditions, according to the methodology described in the second paragraph. The results are presented in Figure 4.

Test results show that introduction of output mud (of the synthesized polymers) into formula contributes to significant decrease of the Eocene shale swelling value. Twenty hours test indicates that the best properties of hydration inhibition are exhibited by drilling fluid marked as Mud-07, in which the concentration of the BG-007 polymer is equal to 1%.

Therefore, a test of the BG-007 polymer concentration's influence on Eocene age shale swelling has been conducted. The outcome is presented in Figure 5.

Based on the results, it can be concluded that an increase of BG-007 polymer concentration in the mud causes reduction of the swelling process of the Eocene age shale.

Figure 5 summarizes the results of the linear swelling test of Eocene shale for every studied drilling fluid.

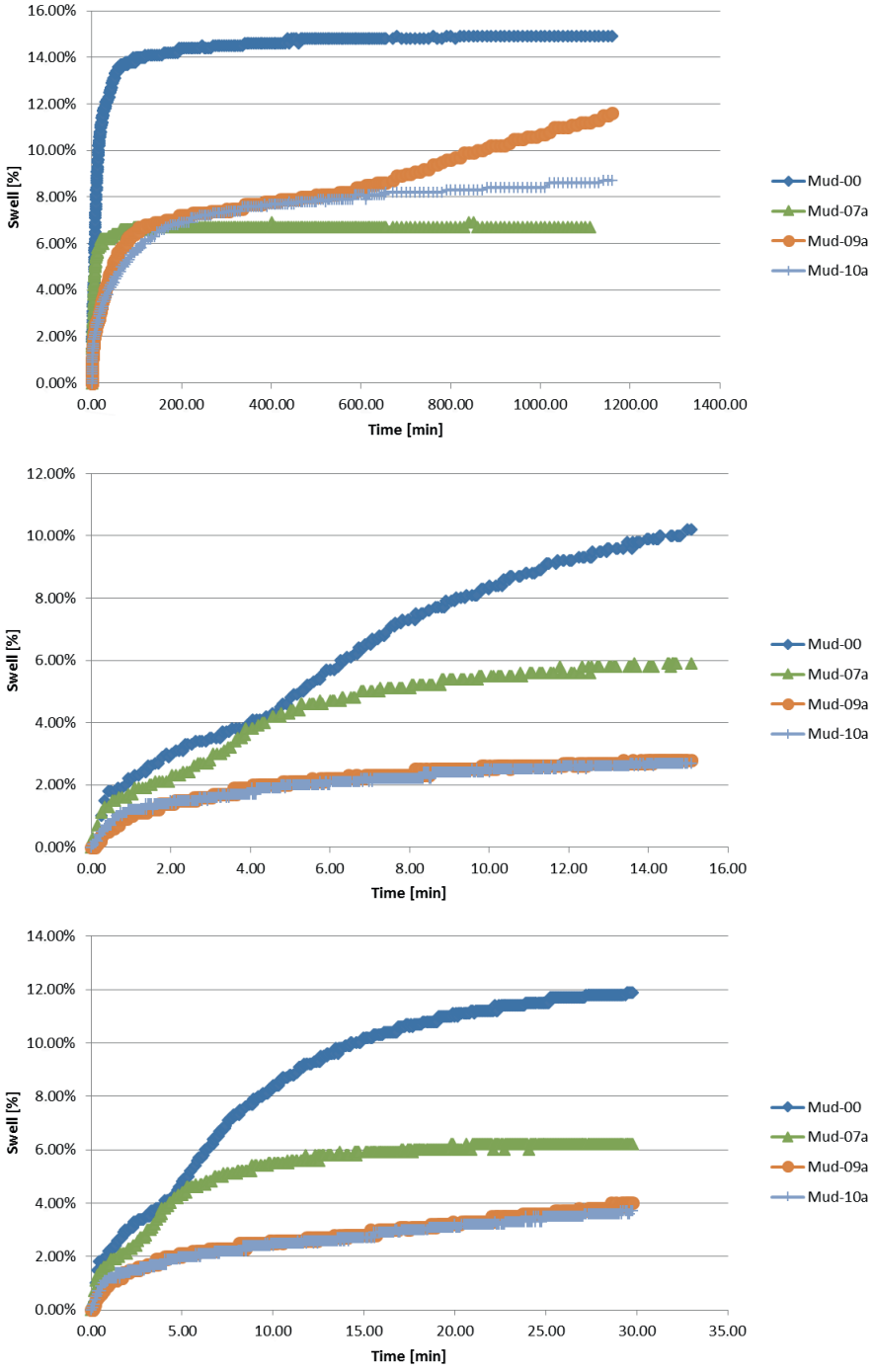

Fig. 4. Results of the test of Eocene age shale linear swelling under the influence of the developed muds

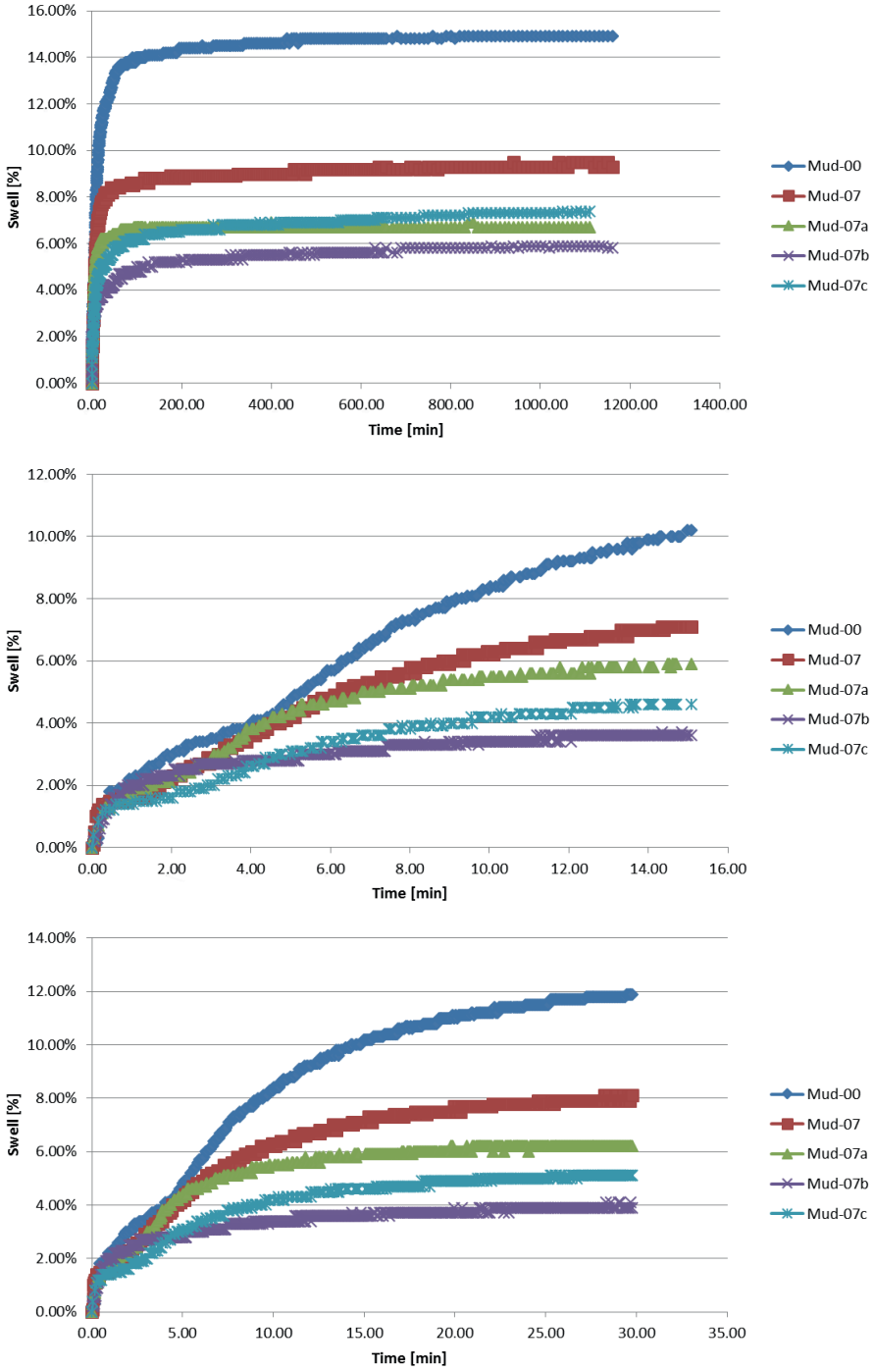

Fig. 5. Test of Eocene age shale swelling depending on concentration of BG-007 polymer

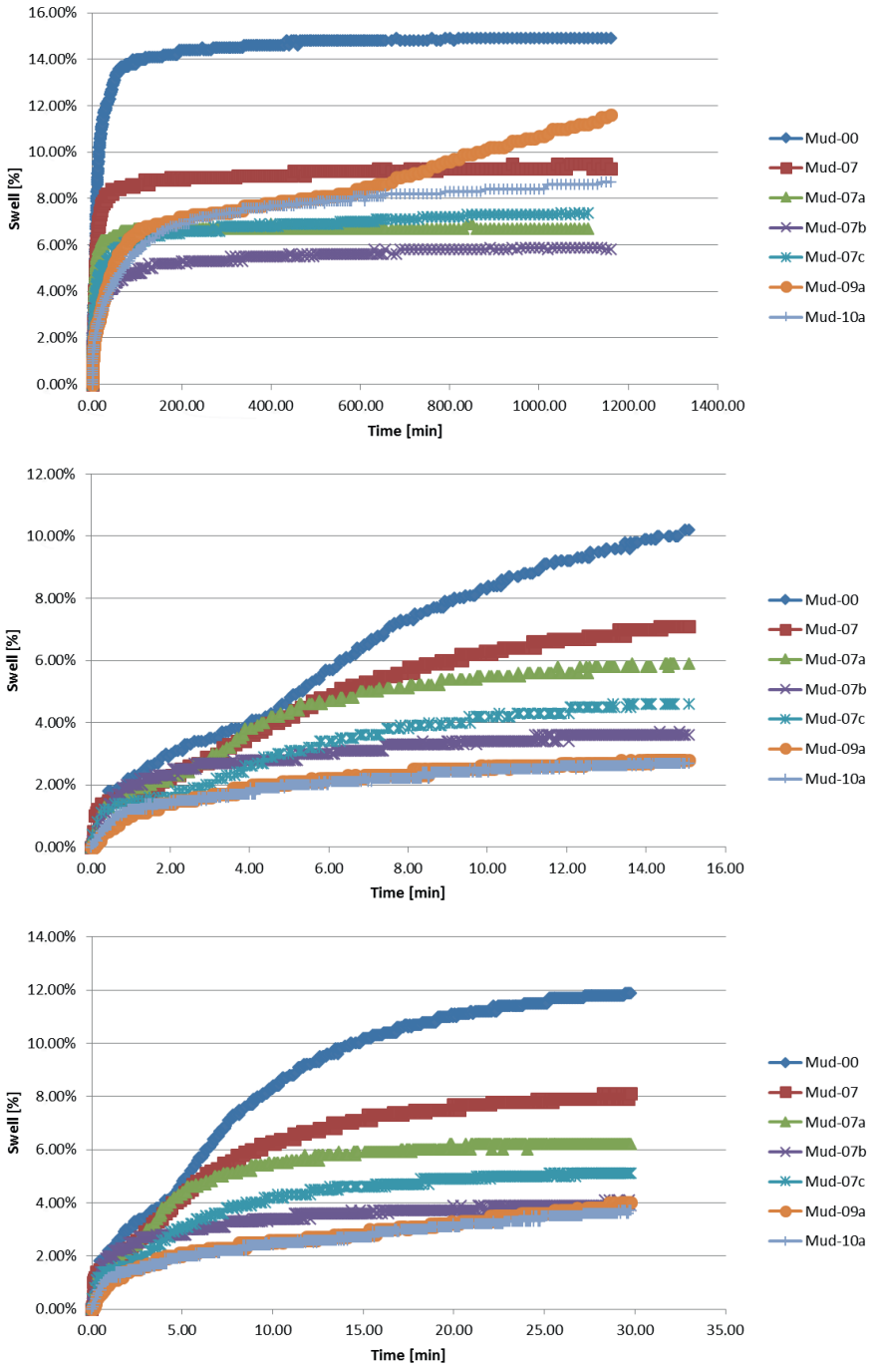

Fig. 6. Results summary of the Eocene age shale linear swelling test depending on developed muds influence

On the basis of the above results, it has been found that the lowest hydration of clay formation is caused by drilling fluid marked as Mud-7b. It consists of BG-007 polymer in 1.5% concentration, working as an inhibitor.

7. DISINTEGRATION TEST OF EOCENE AGE SHALE

Developed drilling fluids were tested for disintegration of shale of Eocene age. A test was conducted according to the methodology described in first paragraph. The results are presented in graphs – Figure 7.

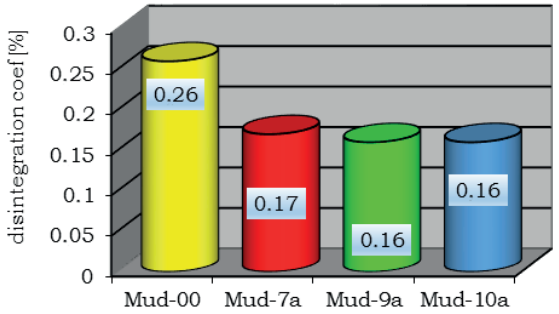

Fig. 7. Results of the disintegration test of Eocene age shale

The outcome shows that developed muds efficiently protect the clay formation from disintegration.

8. CONCLUSIONS

The research findings indicate that synthesized polymers as well as developed on its base drilling fluids effectively inhibit hydration and prevent the disintegration of the clay formation. Synthesized polymers do not affect the rheological properties of the studied muds (compared to the output mud). Nonetheless, it is beneficial for diminishing the lubricity coefficient value of developed drilling fluids. Thus, good rheological behaviour and low value of filtrate loss can be observed for developed drilling fluids.

REFERENCES

[1] Bielewicz D.: *Płyny wiertnicze*. Wydawnictwa AGH, Kraków 2009.
[2] API Specification 13B-2, Fifth Edition, April 2014.