

# Research of the foaming agents' influence on the process of reservoir and condensate fluids recovery from Cenomanian gas wells on closing stage of development

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**Abstract:** Large gas and gas-condensate fields of Russia are getting depleted and gradually coming to the closing stage of development and that means that an increased number of “drowned” and “self-killed” gas wells appear. The urgency of this problem is approved by the gas-recovery ratio of such unique gas fields of Russia as Urengoyskoye, Medvezhye and Yamburgskoye. A significant share of gas is produced there and current gas recovery factor of the Cenomanian reservoir is about 80%. Insufficient flow velocity of the gas-liquid mixture in production casing and tubing is the reason of liquid accumulation. One of the most efficient methods of solving this problem is pumping foaming compositions downhole. Nowadays both liquid foaming solutions and solid foaming agents have been used to solve this problem. Many foaming compositions have been tested at unique West-Siberian gas fields. Before applying surfactants at production fields, laboratory research should be performed to assess their efficiency and influence on the processes of foam formation and liquid removal from the wellbore. This research is often performed under dynamic conditions using an installation simulating processes taking place in a gas well. The results of the laboratory research of different surfactants' influence on the processes of foam formation and liquid removal from Cenomanian gas wells are presented in this article and can be used by gas-producing companies.

## 1. Introduction

A lot of large gas and gas-condensate fields of Russia are getting depleted and gradually coming to the closing stage of development and that means that an increased number of “drowned” and “self-killed” gas wells appear. Accumulation of liquid inside gas and gas-condensate wells leads to their gradual killing by a liquid column, i.e. bottomhole pressure is getting balanced by hydrostatic pressure and gas discharge stops. [1]

High flow velocity of the gas-liquid mixture in production casing and tubing is necessary for well self-purification. So, insufficient flow velocity of the gas-liquid mixture is the reason of liquid accumulation. When the flow rate and water-gas-liquid ratio are both high, flow velocity can be sufficient (more than 3-5 m/s). Nevertheless, some problems may occur when:

- (a) liquid part (mainly reservoir water) from the recoverable fluid is increasing. The greater volume of the fluid phase heading to the bottomhole has no time to come out to the surface with the same gas flow velocity in the wellbore. In addition, the gas flow rate and gas flow velocity are decreasing, too due to the reduction in gas production (phase permeability of the



reservoir for gas is decreasing while the fluid part in the reservoir is increasing). This situation is commonly known as “gas well drowning”.

- (b) flow rates (flow velocities) are decreasing gradually due to the impossibility of subsequent reduction of bottomhole pressure after natural reservoir pressure decrease. The continuation of wellhead and bottomhole pressures reduction is impossible mainly due to the compressor equipment. Even though the liquid part in gas is low (for example, condensation water only) there is no liquid carryover so it gradually accumulates and this leads to flow rate reduction and well shut-off. This situation is known as “self-kill of gas well”.

Both reasons might take place separately or at the same time. If the (a) cause occurs it is possible to perform well service and water shut-off. The (b) case tends to be more urgent for gas-condensate wells. In both cases further well operation is possible using the following methods:

1. Re-equipment of a compressor equipment to obtain lower wellhead pressures.
2. Periodical blow-down of a well.
3. Replacement of tubing with a lower diameter one.
4. Blow-down of wells with high-pressure gas taken from “donor wells” without gas loss.
5. Application of concentric tubing.
6. Usage of bottomhole assemblies designed to pump out the liquid.
7. Application of plunger lift.
8. Pumping of foaming compositions downhole (surface active substances, surfactants). [2]

For many years “drowned” and “self-killed” wells have been the subject of study of such well-known scientists as James F. Lea, Henry V. Nickens, Mike R. Wells, A.S. Yepryntsev, P.S. Korotov, A.V. Nurmakin, A.N. Kiselev, A.A. Tochigin, G.E. Odishariya, N.V. Mikhaylov, V.L. Slivnev, L.S. Chugunov., A.V. Kusteshyv, K.I. Basniyev, L.F. Dementyev, S.N. Yermilov, Z.S. Aliyev, V.N. Shmyglya and others.

If gas extraction from a gas reservoir is about 80%, the amount of “self-killed” gas wells can reach one third of the total well stock. [3] The urgency of this problem is approved by the gas-recovery ratio of such unique gas fields of the Russian federation as Urengoykoye, Medvezhye and Yamburgskoye. A significant share of gas is produced there and current gas-recovery factor of the Cenomanian reservoir is about 80%. [4]

## 2. Research

One of the most efficient methods of solving this problem is pumping foaming compositions downhole. After injection of surfactants into the wellbore they are getting mixed with the wellbore fluid by an upward gas flow which creates foam. Density of the gas-liquid mixture and surface tension at the gas-water interface are both decreasing. These processes lead to a reduction in critical gas velocity (subsequent velocity of gas to carry liquid out of the well), gas-liquid mixture carryover and stable well performance.

Nowadays, both liquid foaming solutions and solid foaming agents have been experienced in application. Among the big amount of compositions tested at the Medvezhye field such samples as “FA-4275”, “Foamatron V-625” and “BT-Former” are worth noting. The results of application of various surfactants in different time periods are given in Table 1.

**Table 1.** Results of application of various surfactants at the Medvezhye field.

Surfactant	Experience of application	Results
“Morpen”	Medvezhye field – 2011	Increase in the flow rate is about 15 thousand m <sup>3</sup> /day. Increase in liquid carryover.
“BT-Former”	Medvezhye field – 2015	Increase in the flow rate is about 15 thousand m <sup>3</sup> /day. Increase in liquid carryover. Absence of negative influence on the processes of gas gathering and treatment.

“FA-4275”	Medvezhye field – 2013	Increase in the flow rate is about 30 thousand m <sup>3</sup> /day. Increase in carryover volume of liquid. Absence of negative influence on the processes of gas gathering and treatment.
“Foamatron V- 625”	Medvezhye field – 2015	Increase in the flow rate is about 27 thousand m <sup>3</sup> /day.

It is worth noting that it is important to take into account the composition of the wellbore fluid, gas flow velocity in production casing and tubing, bottomhole and wellbore temperatures while choosing a surfactant solution (its composition and concentration). Also the cost of the surfactant is a significant factor at determining its optimal concentration.

Before applying surfactants at production fields, laboratory research should be performed to assess their efficiency and influence on the processes of foam formation and liquid removal from the wellbore. This research is often performed under dynamic conditions using an installation simulating processes taking place in a gas well. A certain amount of wellbore fluid (or its simulated solution) is placed in a small-diameter tube and then gas or air is pumped through it with different velocities. The main measuring parameters are stability, foam expansion ratio and share of liquid carryover.

Since the issue of the Cenomanian gas wells drowning is urgent for the domestic industry, the decision was made to conduct laboratory research to determine the influence of surfactants on the process of foam formation and liquid carryover, which is simulated to be a liquid from Cenomanian gas wells. The results of the component composition analysis of reservoir and condensate fluids taken from the Urengoykoye field received during the systematic monitoring and hydrochemical analysis of well fluid samples were taken as a basis. [7]

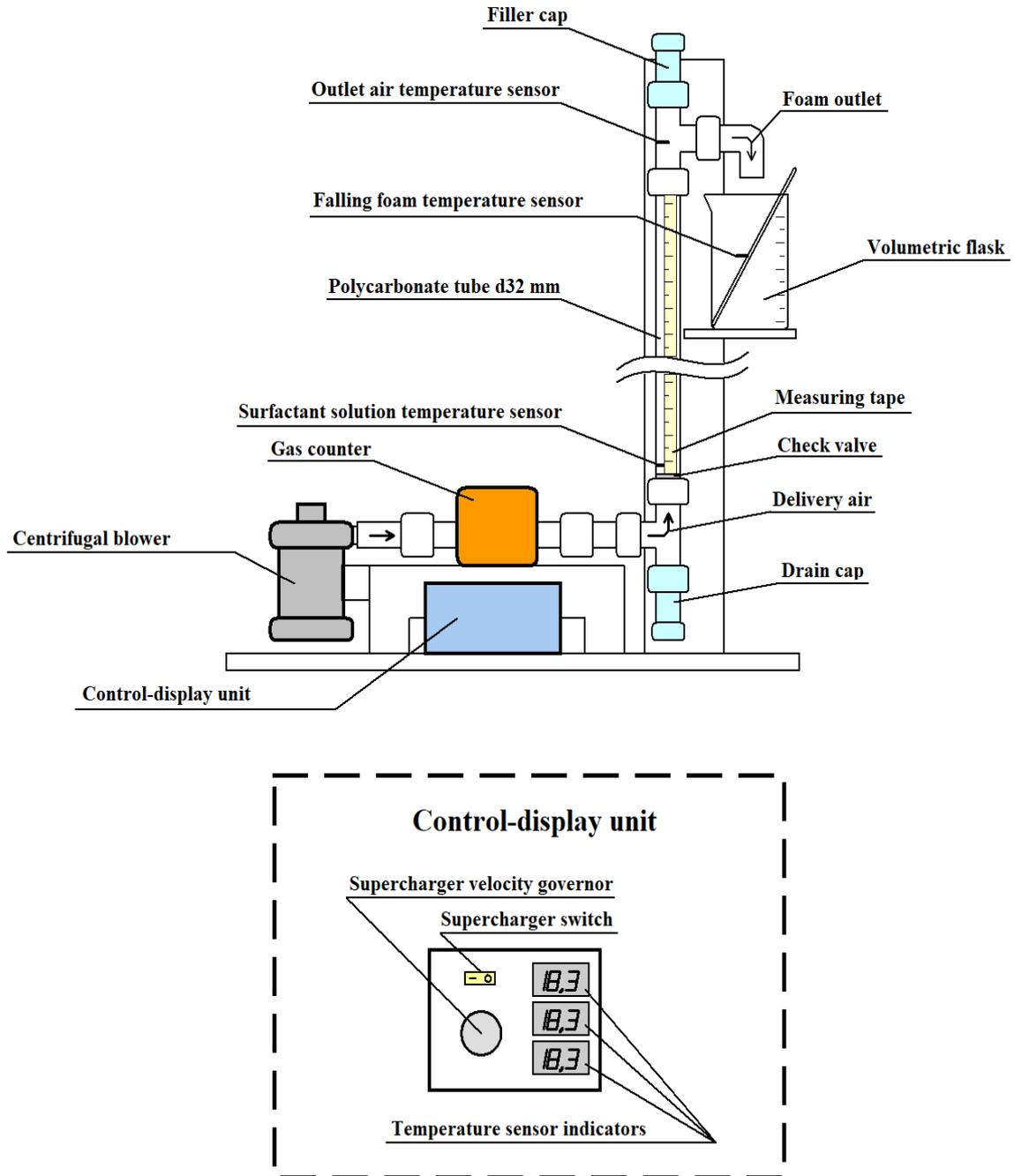
Compositions of the prepared simulated solutions are presented in Table 2.

**Table 2.** Chemical compositions of the simulated reservoir and condensate fluids from the Urengoykoye field.

Stage	Reservoir fluid	Condensate fluid
	Cenomanian	Cenomanian
Density, g/cm <sup>3</sup>	1.011	0.998
Chloride ion, mg/dm <sup>3</sup>	<u>9700–16462</u>	53–720
	10795	
Hydrocarbonate ion, mg/dm <sup>3</sup>	<u>164.7–356.2</u>	43–190
	242	
Sulfate ion, mg/dm <sup>3</sup>	<u>2.67–12.51</u>	1.85–6.48
	6.49	
Bromide ion, mg/dm <sup>3</sup>	<u>40.88–62.25</u>	0.47–2.45
	49.7	
Calcium, mg/dm <sup>3</sup>	<u>175–441</u>	3.17–72.82
	272	
Magnesium, mg/dm <sup>3</sup>	<u>84.6–137.1</u>	0.78–14.06
	99.69	
Sodium, mg/dm <sup>3</sup>	<u>6054–10507</u>	7.01–276.53
	6729	

The research was conducted using the installation simulating a section of a gas well wellbore, in the pipe with the inner diameter of 29 mm and height of 1.9 m. During the research, the simulated wellbore fluid with the volume of 50 ml was placed into the pipe with a certain volume of the surfactant and then air was pumped through the valve with a certain flow rate. The most important aims of this research were the conduction of tests with different values of the surfactant's

concentration, the ratio of reservoir/condensate fluids and the air flow velocities, as well as recording and measurement of the quantity of liquid carryover.



**Figure 1.** Laboratory installation scheme.



**Figure 2.** Photo of the laboratory installation.

The most common and available surfactants, such as anion-active surfactant sulphanoles and non-ionic surfactant “OP-10”, were chosen as foaming agents. Based on the previous field experience of surfactant application, the surfactant’s concentration was changed from 0.5 g/l to 5 g/l. [7] Time of air delivery was 20 min, temperatures at the “bottomhole” and in the “wellbore” of the installation as well as the ambient temperature were changed from 18 to 27 °C.

### 3. Results and discussion

The research results are summarized in Table 3.

**Table 3.** Results of the research

Composition of simulated fluid	Quantitative content of components, g/l		Air velocity, m/s	Liquid carryover, ml
	Sulphanoles	“OP-10”		
Cenomanian reservoir fluid	-	0.5	0.5	0
	-	2.5		26
	-	5.0		27.9
	0.5	-	1.3	0.8
	2.5	-		19.9
	5.0	-		26.5
	-	0.5		0

	-	2.5		26
	-	5.0		27.9
	0.5	-		0
	2.5	-		19.7
	5.0	-		26.8
	-	0.5	3	0
	-	2.5		4.1
	-	5.0		26.4
	0.5	-		0
	2.5	-		3.4
	5.0	-		19.3
Cenomanian condensate fluid	-	0.5	0.5	1.3
	-	2.5		23.8
	-	5.0		28.1
	0.5	-		1.6
	2.5	-		15.8
	5.0	-		22.1
	-	0.5	1.3	1.3
	-	2.5		23.8
	-	5.0		28.1
	0.5	-		0
	2.5	-		16.5
	5.0	-		24.3
	-	0.5	3	0
	-	2.5		6.3
	-	5.0		17
	0.5	-		0
	2.5	-		4.8
	5.0	-		13.2
50% Cenomanian reservoir fluid - 50% Cenomanian condensate fluid mixture	-	0.5	0.5	0
	-	2.5		9.1
	-	5.0		15
	0.5	-		0
	2.5	-		13.9
	5.0	-		20.8
	-	0.5	1.3	0
	-	2.5		10.2
	-	5.0		15
	0.5	-		0
	2.5	-		9.2
	5.0	-		12.4
	-	0.5	3	0
	-	2.5		9.1
	-	5.0		22.8
	0.5	-		0
	2.5	-		7.5
	5.0	-		17.6

The analysis of the research shows that the best carryover is observed with lower air flow velocities and higher surfactant's concentration. When the concentration of a surfactant was 0.5 g/l there was

practically no liquid carryover. The reason is that if surfactant's concentration is low there is absence of such surface effects as surface tension reduction, resiliency of a bubble film, restoration of destroyed bubbles. [7] When the air flow velocity is increasing the degree of air usage (a ratio of foam flow rate to air flow rate) is decreasing due to partial air slippage and the reason is that the part of gas has no time to disperse and foaming agent disrupts. The lower the surfactant's concentration, the sooner the foaming agent will disrupt. So, the higher the surfactant's concentration the bigger the share of liquid carryover is. It is worth noting that the non-ionic surfactant "OP-10" proved to be more efficient during the research. In general, non-ionic surfactants are practically not exposed to the chemical effect from mineralized reservoir water that is why these surfactants are recommended to use when mineralization of the well is unknown.

#### 4. Conclusion

The research results were compared to the results of the research conducted by SevCavNIPIgaz Research Institute. [5] Their research results showed higher share of liquid carryover and the reason might be the difference between test conditions: time of air delivery was 30 min and liquid volume was 250 ml. Under such conditions, the foam quantity in the installation's "wellbore" many times exceeds the foam quantity obtained during our research and that allows the foam to come out of the wellbore to the surface in a solid column without gaps. Time spent on the experiment also increases the amount of liquid carryover to the surface. Moreover, SevCavNIPIgaz used liquids of other compositions.

There was no research conducted using the mentioned surfactants under the conditions of the closing stage of development of Cenomanian gas reservoirs at the West Siberian fields. The results obtained can be taken into account by gas producing enterprises when choosing surfactants to solve the problem of liquid accumulation in gas wells under corresponding conditions.

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