Formation of an algorithm for determining the criteria for the occurrence of critical events in gas condensate wells

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Abstract. This work is devoted to the construction of an algorithm to identify criteria for the occurrence of critical events for gas condensate wells. In the course of the work, a sufficient amount of data obtained from telemetric sensors with a time interval of two years was analyzed. Among the data presented, critical events were recorded that formed the basis for the formation of the algorithm and criteria for identifying critical events. The data on parameter changes during hydrate formation, self-injection of the formation with water, and unstable well operation are presented. As a result of the work, criteria were identified on the basis of which general rules (algorithm) were formulated to identify critical events.

1. Introduction
The gas field is now a complex system comprising various subsystems such as a comprehensive gas treatment plant, gas-gathering network, wells and gas-bearing formations themselves. One of the urgent tasks in operational management of the field is calculation of the planned technological mode of gas-condensate wells. The task of the planned well mode calculation, in fact, comes down to the selection of such parameters for wells, which on the one hand ensure the achievement of the planned production level for all wells as a whole, and on the other hand, stable operation of each well. One of the phenomena negatively affecting the planned and stable well operation mode is the emergence of critical events that occur in wells, negatively affecting both the production volume and the direct operation of the wells themselves. Prediction of such events and their timely elimination is an urgent and most important task of modern information on systems [1].

There is a physical explanation of events that occur in wells and lead to complications in its work, such as hydrate formation, fluid accumulation at the bottom, self-pressurization of the well, exit to an unstable mode [2]. However, all these explanations do not allow to predict the appearance of these events and take timely measures to prevent them.

That's why the development of information system for recognizing and displaying the precursors of events is relevant, which will allow taking timely measures to prevent them. The most important module of this information system should be a module implemented on an algorithm based on the identification of criteria for determining critical events.

The research is aimed at compiling algorithms for identifying signs of critical events for gas condensate wells based on data obtained from telemetric sensors.

2. Event search criteria identification

At present, due to the presence of many types of telemetry sensors, a sufficient number of measurements has been accumulated, which allows using various statistical and mathematical methods of analysis to build a mathematical (statistical) model based on the physical representation of the process and capable of predicting the appearance of events with a sufficient degree of accuracy [3].

In the course of the work, a sufficient amount of data obtained from telemetric sensors over a time interval of two years has been analyzed. Critical events were previously recorded among the data presented, which allowed to determine and check with sufficient accuracy the formulated criteria of critical events originating in gas condensate wells [4,5].

During the analysis of hydrate formation and fountain valves and loop gate valves, telemetric data were analyzed in terms of the emergence of the lower and upper boundary of the criterion for detecting hydrate formation in the well.

Table 1. Range of parameter changes during hydrate formation, %.

Pressure before surge tank		Pressure after surge tank		Temperature before surge tank		Consumption before surge tank	
l.r.l.	u.r.l.	l.r.l.	u.r.l.	l.r.l.	u.r.l.	l.r.l.	u.r.l.
4	25	-0.3	25	-54	-11	-57	-20

The values listed in Table 1 are the lower limit (l.r.l.) and the upper limit (u.r.l.) of the range detected.

Table 2. Self-pressurizing with formation water, %.

Pressure before surge tank		Pressure after surge tank		Temperature before surge tank		Consumption before surge tank	
l.r.l.	u.r.l.	l.r.l.	u.r.l.	l.r.l.	u.r.l.	l.r.l.	u.r.l.
-0.8	0.4	-1.11	-0.07	-5.0	-1.4	-31	-1

When analyzing the phenomenon of self-pressurization with formation water, it has been established that this phenomenon is characterized by monotonic decrease of all parameter's values. For Table 1-2, negative values reflect a decrease in parameter values; positive values reflect an increase in parameter values.

It is established that the change of parameters in this phenomenon can be detected 24 hours before the gas condensate well shutdown.

When analyzing data from telemetry sensors on the dynamics of parameter values change at the exit to the unstable operation mode of the well was additionally analyzed when combining unstable operation of the well with abundant fluid outflow.

Table 3. Process with removal of packs of water, %.

Pressure before surge tank		Pressure after surge tank		Temperature before surge tank		Consumption before surge tank	
l.r.l.	u.r.l.	l.r.l.	u.r.l.	l.r.l.	u.r.l.	l.r.l.	u.r.l.
-14	7.5	-0.4	0.4	-0.2	9	-14	7.7

Table 4. Process without removal of packs of water, %.

Pressure before surge tank	Pressure after surge tank	Temperature before surge tank	Consumption before surge tank

l.r.l.	u.r.l.	l.r.l.	u.r.l.	l.r.l.	u.r.l.	l.r.l.	u.r.l.
-0.05	0.09	-0.08	0.13	-0.07	0.02	-0.35	0.14

In unstable operating conditions with water in the trunk (e.g., removal of water packs), there is a direct close relationship between the dynamics of pressure changes before surge tank and consumption before surge tank (correlation coefficient 0.99) [4,5]. Negative values reflect decrease in parameter values, positive values reflect increase in parameter values.

Based on the data obtained, the criteria presented in Tables 5-6 have been identified.

The tables show the mutual change of parameters (increase or decrease), necessary for the occurrence of a particular critical situation.

As you can see from the table, there can be events with the same set of criteria (by the growth (↑) or decrease (↓) of parameters, or no changes (-)). Schemes have been created based on the table data (Figures 1-2) showing the dependencies between critical events.

Table 5. Event search criteria for hydrate formation.

Event	Experiment type	Pipe pressure	Pipe temperature	Annulus pressure	Well output
Hydrate in tubing	«Pipe»	↓	↓	↑	↓
Hydrate in the annulus	«Pipe»	-	↓	-	↓
Hydrate in the valve	«Pipe»	↑	↓	↑	↓
Hydrate in the annulus	«Pipe +annulus»	-	↓	-	↓
Hydrate in the valve	«Pipe +annulus»	↑	↓	↑	↓

Table 6. Event search criteria.

Event	Experiment type	Pipe pressure	Pipe temperature	Annulus pressure	Well output
Problem	«Pipe»	-	↓	-	↓
Problem	«Pipe +annulus»	-	↓	-	↓
Decreased productivity	«Pipe»	-	↓	↑	↓
Decreased productivity	«Pipe +annulus»	-	↓	-	↓

Liquid accumulation at the bottom	«Pipe»	-	↓	↑	↓
Liquid accumulation at the bottom	«Pipe +annulus»	-	↓	-	↓
Tubing break	«Pipe»	=Annulus pressure	↓	=Pipe pressure	↓
Tubing break	«Pipe +annulus»	-	↓	-	↓

The tables 5, 6 provide data for the main critical events that occur in gas condensate wells: hydrate formation, decreased productivity, fluid accumulation at the bottom, tubing breakage.

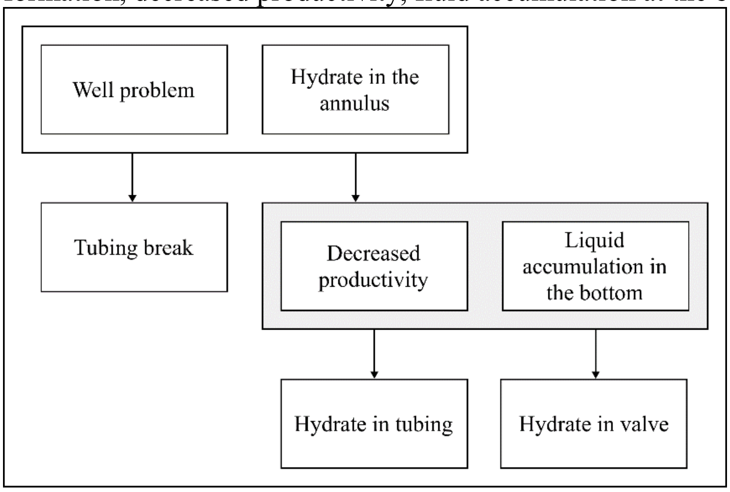

Figure 1. Scheme of the dependence of events (type of experiment in the pipe)

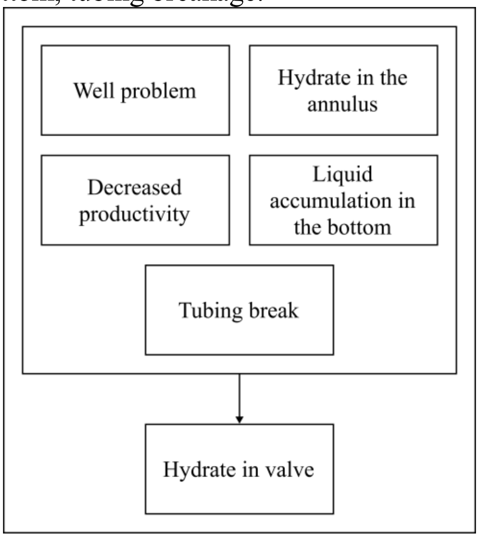

Figure 2. Scheme of the dependence of events (type of experiment in a pipe and an annulus)

On the basis of these schemes there was developed a heuristic algorithm of clarifying issues, for example, "well problem", "productivity decrease", "hydrate formation in tubing" for the case of well with the method of operation "Pipe". At the same time, as it can be seen from Figure 1, each following event clarifies the previous one: there is a "well problem" - which one? "Decrease in productivity", why? - Because of the "hydrate formation in the tubing".

3. Results and Discussion

Figures 3-4 below show the experimental data from telemetry sensors on the dependence of pressure changes before surge tank and temperature in the pipeline before surge tank.

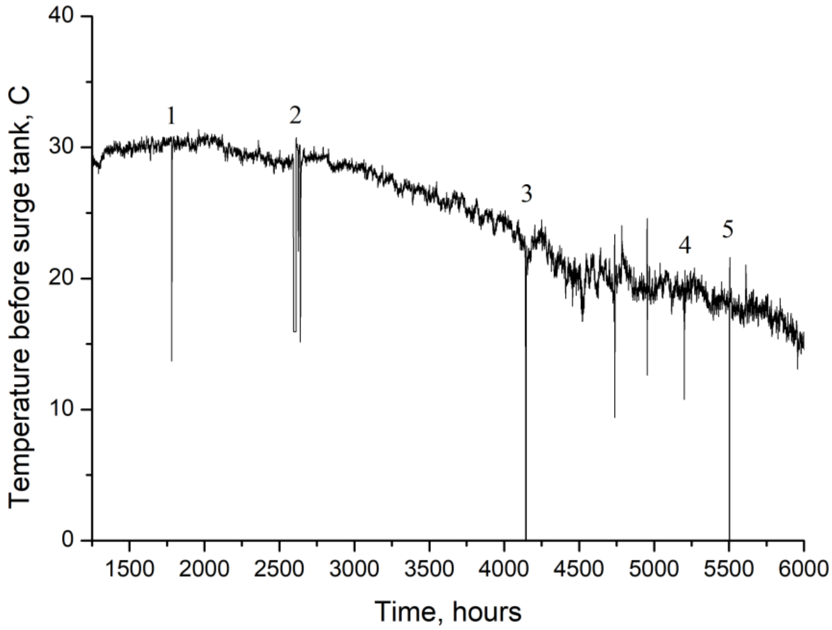

Figure 3. Diagram of temperature dependence of the pipeline to surge tank on time

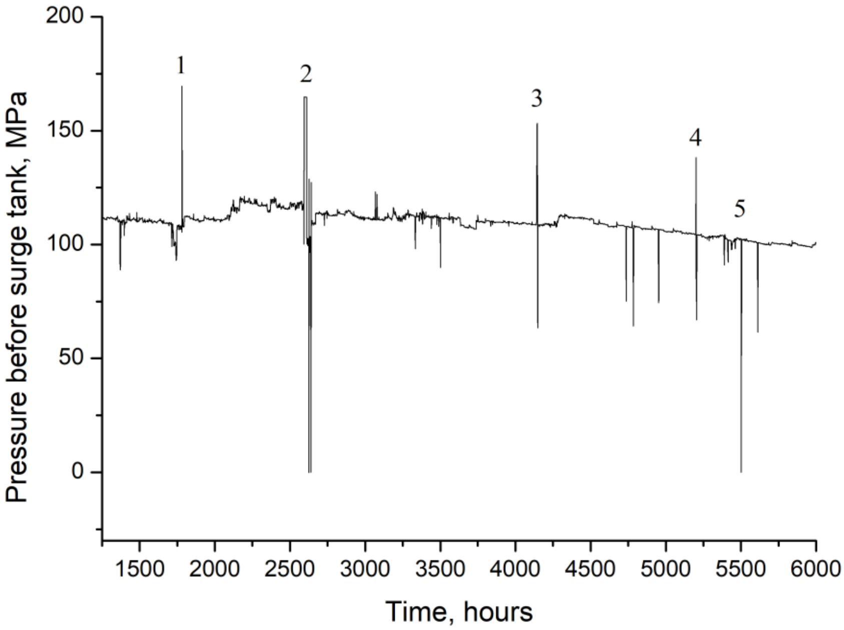

Figure 4. Diagram of pressure dependence to surge tank on time

The number 1 in Figures 3-4 indicates the sign of hydrate occurrence in the valve, the numbers 2,3 and 4 indicate the signs of hydrate occurrence in the tubing, the number 5 indicates the sign of hydrate occurrence in the annulus.

The presented graphs reflect well the previously revealed criteria of mutual change of various parameters, in particular, temperature and pressure. The graphs clearly show the signs of critical events simultaneously for different parameters.

These criteria will be used in the construction of a mathematical model for the identification of critical events. This model is necessary for use in the module of the implemented information system, which is responsible for data analysis and processing.

4. Conclusion

In the course of the work, preliminary criteria were developed for identifying critical events according to the data received from telemetric sensors (temperature, pressure), in particular for the case of hydrate formation, accumulation of liquid and self-pressuring with water. The obtained data will be used in the formation of the algorithm and its subsequent implementation in the development of the information system.

At further investigation, it will be necessary to answer the following questions:

- Is this interpretation of events correct?
- If yes, can this interpretation be extended to any chain of events (see Figure 1), where each next event has a wider set of criteria, in which in addition to the criteria of the previous event there are new ones, clarifying?
- If so, should the user be notified of each event in that chain or only of the end event?

References

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