Parametric Analysis of the Hydrocarbon Mixture
Hydrodynamics in a Condensate Pipe

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Abstract. Thermobaric conditions of hydrocarbons flow in the pipe, as well as the component composition of the hydrocarbon system and the geometric shape of the pipeline, determine the stability of their operational complications. The power consumption for pumping a unit mass of a hydrocarbon mixture in the form of gas is 2+3 orders of magnitude higher than the power consumption for pumping a hydrocarbon mixture in the form of a liquid. The method for calculating the flow and heat and mass transfer of gas-liquid hydrocarbon media in the field and main pipelines during their design and operation is essential when solving energy conservation issues when transporting a hydrocarbon mixture. Over the past decade, research in the field of monitoring of technological processes in the pipelines of energy transportation systems has been conducted at Tyumen Industrial University at the Department of Hydrocarbon Resources Transport.

1. Introduction
This article shows the results of a parametric study of the hydrodynamics of a hydrocarbon mixture in a condensate pipeline based on the developed physical and mathematical model of the flow of an oil and gas condensate mixture in a pipeline. Based on the developed model, a calculation method was obtained with the help of which the hydrodynamic state is analyzed, and the component composition of the hydrocarbon mixture in each i-th section of the pipeline with changing thermobaric and hydraulic conditions. The developed method has been tested concerning the hydrocarbon mixture of deethanized condensate with oil transported from the northern gas condensate-oil fields via the main condensate pipeline to the refinery.

Gas condensate fields have many thermodynamic features that must be taken into account both in their field development and in the transportation and processing of gas condensate. The main feature is the complex phase behavior of the gas condensate system and the dependence, ceteris paribus, of the composition of the extracted raw materials on the phase state of the reservoir, therefore, the most critical task of designing and calculating condensate pipelines is to select the most appropriate methods for calculating the thermophysical properties and phase equilibria of the transported gas condensate.
2. Methods, results and discussion

In Tyumen industrial University, at the Department of Hydrocarbon Resources Transport, a physical and mathematical model of the flow of a hydrocarbon mixture in a condensate pipeline was developed, taking into account phase transitions and changes in the phase composition. A detailed description of the model is presented in [1–4].

The control volume method is applied to calculate the thermophysical properties of the gas-liquid mixture in the pipeline. The internal volume of the pipeline is divided into a finite number of instead small sections — control volumes V limited by the internal surface of the pipeline and cross sections S1 and S2 located at a distance Δz from each other (Fig. 1). The control volume, balance equations are applied: mass, momentum, and also the balance of the total energy. The first balance equations for the conservation of mass, momentum, and energy in a quasi-one-dimensional flow are written in the form proposed by Professor A. Shabarov.

![Figure 1](image1.png)

**Figure 1.** The balance of the i-th phase of masses, pulses, and energy of the i-th phase in the control volume V.

Based on the developed model, a calculation method was obtained using which the hydrodynamic state and the component composition of the hydrocarbon mixture in each i-th section of the pipeline are analyzed with changing thermobaric and hydraulic conditions. The developed method has been tested concerning a hydrocarbon mixture of deethanized condensate with oil transported from northern gas condensate-oil fields via a condensate line to a refinery. The results of a calculation and parametric study of the thermophysical parameters of the oil-condensate mixture in various sections of the product pipeline are shown (Fig. 2-5).

![Figure 2](image2.png)

**Figure 2.** Change in gas condensate temperature along the condensate line at various ambient temperatures.
A calculation and parametric study of the change in the temperature of the hydrocarbon mixture with a change in ambient temperature from −45 °C to 15 °C was carried out at an inlet pressure of 31 ata and a snow cover height of 0.6 m (Fig. 2). Analysis of the graphs leads to the conclusion that the ambient temperature significantly affects the thermobaric conditions in the condensate line.

![Figure 3](image1.png)

**Figure 3.** Mass fractions of the hydrocarbon mixture components (the original – by industrial data and changed towards a higher relative content of lighter components).

![Figure 4](image2.png)

**Figure 4.** Change in pressure and temperature along the path of the condensate pipeline with an increased mass content of light fractions of hydrocarbons.

The study provides a comparison of the mass fractions of the components of the initial hydrocarbon mixture, corresponding to the table. 1. and a modified hydrocarbon mixture (methane – 2.09%, ethane – 3.67%, propane – 15.98%, iso-butane – 13.63%, n-butane – 7.02%, iso-pentane – 7.33%, n-pentane – 8.9%, hexane + – 41.38%) (Fig. 3). From the data obtained, it follows that the hydrocarbon mixture of the above composition goes into a two-phase gas-liquid state at higher pressure with an increase in
the inlet pressure of the gas condensate to 33 atm. The two-phase flow zone increases and shifts by 60-70 km to the beginning of the condensate pipeline. In this case, the two-phase flow regime in the pipeline was determined to take into account the well-known algorithm [5, 6, 10].

A calculation and parametric study of changes in pressure and temperature of a gas-condensate mixture with the same component composition, but with a redistribution of the mass fractions of the components towards a relative increase in the mass of lighter hydrocarbons, led to the results presented in Fig. 4.

![Figure 5. Parameters of the hydrocarbon mixture along the condensate line.](image)

The results of calculations of the hydrocarbon mixture parameters along the pipeline route are presented in Fig. 5. Comparison of the calculated and actually observed pressure and temperature drops leads to the conclusion about the adequacy of the selected calculated physical and mathematical model of the condensate pipeline (the relative deviation of the calculated pressure drop from the actually observed is 4.6% and the deviation of the calculated temperature change from the experimental one was 1.5%).

3. Conclusions
Based on the results of the parametric analysis of the hydrodynamics of the hydrocarbon mixture in the condensate pipe, the following conclusions can be drawn [7-9]:

1) convergence of the results of calculating the changes in pressure and temperature based on the developed model with known field experimental data was confirmed;

2) influence of thermobaric conditions upon product inlet into the condensate pipeline on phase equilibrium and parameters in the outlet section of the pipeline is revealed;

3) conditions for pumping the product in liquid and gas-liquid modes are established, which significantly affects the thermohydraulic characteristics of the condensate line;

4) possibility of a calculation-theoretical determination of the permissible values of the mass concentration of light hydrocarbon fractions in the inlet section of the main condensate pipeline from the condition of ensuring a single-phase flow regime is substantiated;

5) results of a theoretical and theoretical study indicate that, with incomplete loading of the condensate pipeline in terms of power, sections with a two-phase flow take place in the pipeline.
Therefore, in order to reduce energy consumption for condensate transport, it is necessary to provide a single-phase flow regime along the entire length of the pipeline.

References

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