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Hydrocarbon losses arising from phase transformations in field collection pipelines
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Abstract

In offshore fields, the quality indicators of the well product are subjected to change when it passes the initial preparation stage at the collection points and is transported to the shore. Researches show that most of the problems that arise in the collection points of fields operated in marine conditions are related to multi-component and multiphase flows. Contamination from the inner surface of the pipeline due to the internal phase transformations of the pipeline causes an increase in the operation and energy costs of the collection transport system. Blockages are formed in underwater pipelines when the liquid and mechanical particles in the transported gas are separated and settle inside the pipe.

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1. Introduction

The movement of gas and liquid phases that is a stratified flow form actually takes place in the gas pipeline. Separation of the liquid phase of hydrocarbon mixtures also causes certain errors in the measurement of the consumption of the transported gas. Thus, the existing international standards for measuring gas consumption are based on its monophase principles [1,2,3,4]. On the other hand, the presence of a liquid phase in gas flows causes pressure and consumption pulses. These harmful pulses cause pipelines to deform and fail prematurely [5,6].

2. Methodological part

A visual inspection of the inner surface of the pipes showed that sediments are mainly collected in the lower part and partly in the upper part. (Figure 1.)
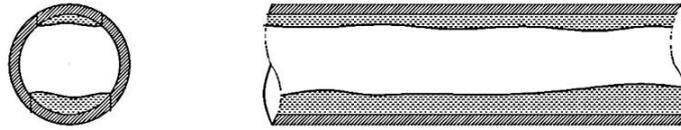
Figure 1. Accumulation of deposits in the gas pipeline

Operational experience shows that the occurrence of blockages in gas pipelines is mainly due to the following factors.

1. Incomplete drying of the gas

2. Occurrence of phase transformations with changes in thermodynamic conditions,

A visual inspection of the inner surface of the pipes showed that sediments are mainly collected in the lower part and partly in the upper part (Figure 1).

Water and heavy hydrocarbons contained in the gas condense during transportation and are adsorbed on the surface of mineral deposits in the inner part of the pipeline, forming layers of different strength on the inner surface of the pipelines.

Contamination of the inner surface of pipelines results in complications and costs. Thus, the throughput and productivity of the pipeline decreases. This results in losses of valuable raw materials [7,8,4,9,10].

Violation of the technological regime in the transportation process, non-compliance of the physico-chemical parameters of the gas with the current requirements, failure to timely remove the mechanical impurities of the liquid phase separated in the pipeline, cause hydrocarbon losses.

The operational experience of field technological pipelines of various purposes shows that even the deep separation implemented in transport systems cannot prevent the formation of a liquid phase in the gas pipeline. Although the free liquids (hydrocarbon condensate and water) contained in the gas are separated from the gas in primary processing units, water and hydrocarbon vapors in equilibrium enter the transportation system [13]. One of the reasons for the liquid phase to fall into the gas pipeline is related to the occurrence of phase transformations due to changes in the temperature and pressure of the transported gas. By performing the separation at sub-optimal temperatures and pressures below or above the maximum condensing pressure, the liquid in the separator is not falls apart and the remaining liquid subsequently sets apart in the pipeline at a lower temperature [11,12,13,14,10].

Thermobaric influences of the enviroment also cause thermodynamic parameters of the gas to change. As a result, hydrocarbon condensate and water vapors in its content condense and become liquid. Thus, the first reason for the drop of the liquid phase in the gas pipeline is the incorrect selection of the separation parameters. The second reason for the liquid to fall apart from the gas is related to the change of those parameters along the pipeline during transportation. Thus, at low temperatures, heavy hydrocarbons condense more intensively. The maximum drop in pressure in the gas pipeline due to condensation causes the gas to evaporate and pass into the gas phase due to an increase in moisture content. Gas drying ends up inside the pipeline. This process is called internal separation. But later, the gas phase is saturated with liquid, and with the next decrease in temperature, condensation of moisture occurs again. Therefore, in the high pressure zone, under certain conditions, "reverse condensation" or "reverse evaporation" processes occur. Since the

composition of the well product is constantly changing during the period of exploitation of the fields, the maximum condensation pressure determined for the initial stage of the field operation is not enough to separate the liquid phase from the gas in the separators at the later stages of development. At this time, as the temperature of the gas decreases, its composition becomes richer with water and heavy hydrocarbons [10,15,2,16,13,17,18].

The amount of hydrocarbons passing from the gas phase to the liquid phase as a result of phase transformations can be determined by the following expression:

$$x_i = \frac{z_i}{L + k_i V} \quad (1)$$

Here: Z_i and x_i - mole density of component i in the liquid phase in the mixture, respectively; and L. and V are the mole fractions of the components in the liquid and gas phase, respectively. K_i was the equilibrium coefficient:

$$K_i = \frac{y_i}{x_i} = = \frac{(P\,d)_i}{P} \quad (2)$$

Here: Pd is the saturation pressure of the i-th component; P-is the pressure in the system.

From expression (2), the following expression can be written for the equilibrium state of the system:

$$y_i \cdot P = x_i \cdot (P_d)_i$$

If $= \sum x_i = 1$ is obtained as a result of solving the expression (1) by the method of gradual approximation, then the problem has been considered to be solved correctly.

Depending on the seasons of the year, an imbalance occurs between the volumes of gas transported to the shore as a result of phase transformations in underwater pipelines.

Calculations on phase transformations were performed on the basis of Pedlix-Kwong and Peng-Robinson equations of state:

$$P = \frac{RT}{V-b} = \frac{a}{T^{0.5} V(V+b)} \quad (3)$$

$$P = \frac{RT}{V-b} = \frac{a(T)}{V(V+b) + b(V-b)} \quad (4)$$

Here: P, T, V and R are the pressure, temperature, volume and universal constant of the gas, respectively, and a and b are coefficients.

Calculations are performed with two equations at the same time due to the fact that the Pedlich-Kwong equation gives more accurate results for relatively "dry" gases, while the Peng-Robinson equation of state gives more accurate results for "oily" gases.

3. Results and discussion

In order to investigate the thermodynamic reasons for the separation of the liquid phase in the gas pipeline, experiments and calculations were carried out using available literature sources data. The studies were conducted on the basis of the following primary data.

     1. Temperature -10 °C.

     2. Pressure P=2.0; 4.0; 6.0; 8.0; 10.0 and 12.0 MPa.

Amount of liquid phase precipitated per 100 moles of gas mixture (Mol/100 Mol)

(C_3H_8, C_4H_{10}, C_5H_{12}, C_6H_{14}, C_7H_{18}, C_8H_{18}) are assigned.

Figure 2 shows the dependence of the precipitated liquid phase on the presssure
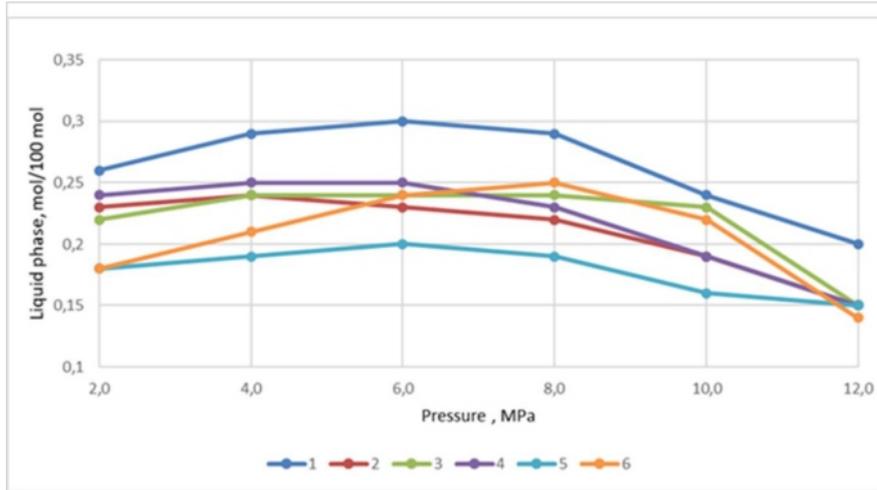
Figure 2. Amount of liquid phase precipitated at different pressures.

1- C_3H_8, 2- C_4H_{10}, 3-C_5H_{12}, 4- C_6H_{14}, 5-C_7H_{18}, 6- C_8H_{18}

As it can be seen from Figure 2, the maximum precipitation of the liquid phase due to condensation corresponds to the pressure value of 6.0 MPa (maximum condensation pressure). It is clear from Figure 2 that the amount of precipitated liquid is greater at higher values of pressure. This is due to the fact that gases such as methane, ethane, nitrogen and carbon in the gas change from higher pressures to the liquid phase. Thus, studies show that as a result of the imperfection of the separation process, water and gas vapors enter the gas pipeline and condense and cause various complications. Such complications caused by phase transformations lead to the need to remove the liquid phase accumulated in separate parts of the transport systems from the pipeline. In the oil and gas industry, various methods and devices are used for this purpose.

The values of gas "losses" due to liquid deposition in the pipeline varies depending on both pressure and temperature. In order to evaluate gas losses depending on pressure and temperature changes, the amount of condensed hydrocarbons was determined at selected points (for the samples taken) based on laboratory experiments. Figure 3 provides a 3D dependence showing the dynamics of changes in the calculated values of gas losses (in 1kg/1000m³) for samples under transport conditions, i.e. along the length of the gas pipeline.
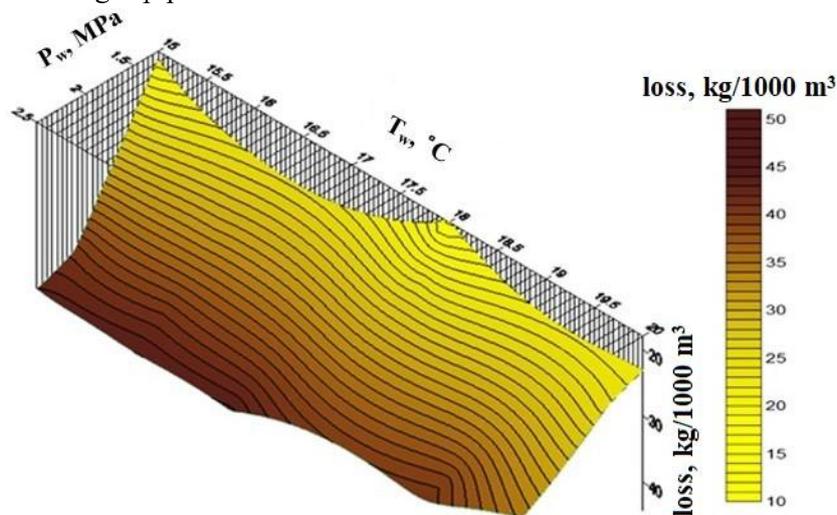
Figure 3 Changes in gas loss values depending on temperature and pressure in transport conditions

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As it can be seen from Figure 3 gas losses per 1000 m³ of gas volume have different values with temperature and pressure changes. So, the dynamics of changes in dependence shows that, the amount of gas losses along the pipeline decreases with a drop in pressure. For example, in examples 1 and 8, a slight change in temperature (1 °C) is accompanied by a 2-fold decrease in pressure (from 2.5 to 1.3 MPa), so the loss of hydrocarbons per 1000 m³ of gas decrease from 44 to 18.0 kg. That is, pressure changes have a sharper effect on the dynamics of changes in gas losses compared to temperature.

4. Conclusion

Researches have shown that as a result of the imperfection of the separation process, water and heavy hydrocarbon vapors entering the gas pipeline condense in the pipeline and cause phase transformations. As a result, hydrocarbon losses occur. The conducted reports have shown that these losses are related to the condensation process caused by pressure changes along the pipeline, and it is possible to significantly reduce the losses caused by phase transformations by correctly setting the maximum condensation parameters at each stage of operation.

Conflict of interest

The authors declare that they have no conflict of interest in relation to this research.

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Technology of reverse-osmosis sweetening of seawater with permeate softening

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Abstract

In energy production systems, the allowable concentration of hardness in feed water is 1-10 µg/l to ensure smooth operation of medium and high pressure (3.9-13.4 MPa) steam drum boilers. Calculations show that during reverse osmosis (RO) processing of Caspian Sea water, the hardness of sweetened water (permeate) is higher than required: depending on the prcentage of permeate (50-80%) and the selection of the membrane (99-99.8%), it varies between 0.23 mg/l and 2.1 mg/l. Therefore, softening of the permeate is required. Usually, the Na-cationization method is used for this purpose, and cationite regeneration is carried out with a 3-8% solution of external NaCl salt.

The article shows that in the softening of the permeate, the waste concentrate which is rich in NaCl and Na_2SO_4 salts of the RO process can be used instead of external NaCl salt for the