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Features Of Gas Treatment İn Extreme Conditions Of Natural Gas Production

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ABSTRACT : *The main criterion is the requirement for the operation of subsea gas pipelines at developing the main technical solutions for the preparation and transportation of gas from offshore fields.In article it was shown the results of analyzes the operation mode of the preparation units and gas transportation systems in offshore conditions, and the causes of technological complications that have arisen in these processes and ways to eliminate them. In addition,It has been studied the operating mode of existing separators for primary gas treatment and has been noted their low efficiency in gas. Taking into account specific features of offshore conditions,it was developed and tested multifunctional device for for complex gas preparation. Positive test results are given.*

KEY WORDS: *offshore development, gas, condensate, transport, separator, technological complications, gas drying, dew point.*

I. INTRODUCTION

It is known that most of the natural gas production facilities are located in extreme conditions (offshore oil and gas condensate fields, gas and gas condensate fields of the Far North and desert conditions). Remoteness of marine crafts from the continent, high humidity of the environment, limited area of fixed platforms, difficulty in mounting equipment are characteristic features of the gas transportation system of offshore fields. As is known, during developing the main technical solutions for the preparation and transportation of gas from offshore fields, the main criterion is the requirement for the operation mode of subsea gas pipelines. In particular, it is necessary to have a justification of the degree of admissibility of the presence of the liquid phase in the gas pipeline and the possibility of its operation in two-phase transportation of gas and gas condensate. It should also provide for such a volume of a set of technological equipment and pipelines, at which production could be produced at all stages of field development. At the same time, it is necessary to strive to reduce the number of technological operations performed directly on platforms and to ensure, if possible, the carrying out of a part of them on shore terminals for the acceptance of products. The list and types of technological operations carried out on the sea and on the shore should be determined in each specific case taking into account the actual natural and climatic conditions, remoteness from the shore, the depth of the sea, the physical and chemical properties of the extracted products, reservoir pressures, the collection system, well rate and other factors. The experience of exploitation of the offshore fields of the Caspian Sea located far from the shore gives a wide opportunity for joint transportation of gas and condensate to the head structures located on the shore. The choice of the method for preparing gas and condensate for joint transportation, mode of operation and hardware design schemes, compactness and metal consumption should be simpler and less energy-consuming in comparison with IKPG, etc. Finally, this affects the size of the platform and the total capital expenditures for development of deposits.

In addition, in sea conditions, pipelines designed to collect and transport production of wells are laid along the seabed for several kilometers, where due to natural throttling (the Joule-Thompson effect), the temperature of the gas decreases and a stratified-separate form of the flow of the gas-liquid flow is obtained. As a result, the gas pipeline operates in the plug and pulsation mode. This issue is particularly acute in cases where production of wells from several platforms is assembled into one platform for collecting and preparing gas. When descending (downflow) and lifting (upflow) of the pipeline at 90 °, a considerable amount of liquid is collected in the bends, which adversely affects the operating modes and wells, and the gas transmission system (Fig. 1).

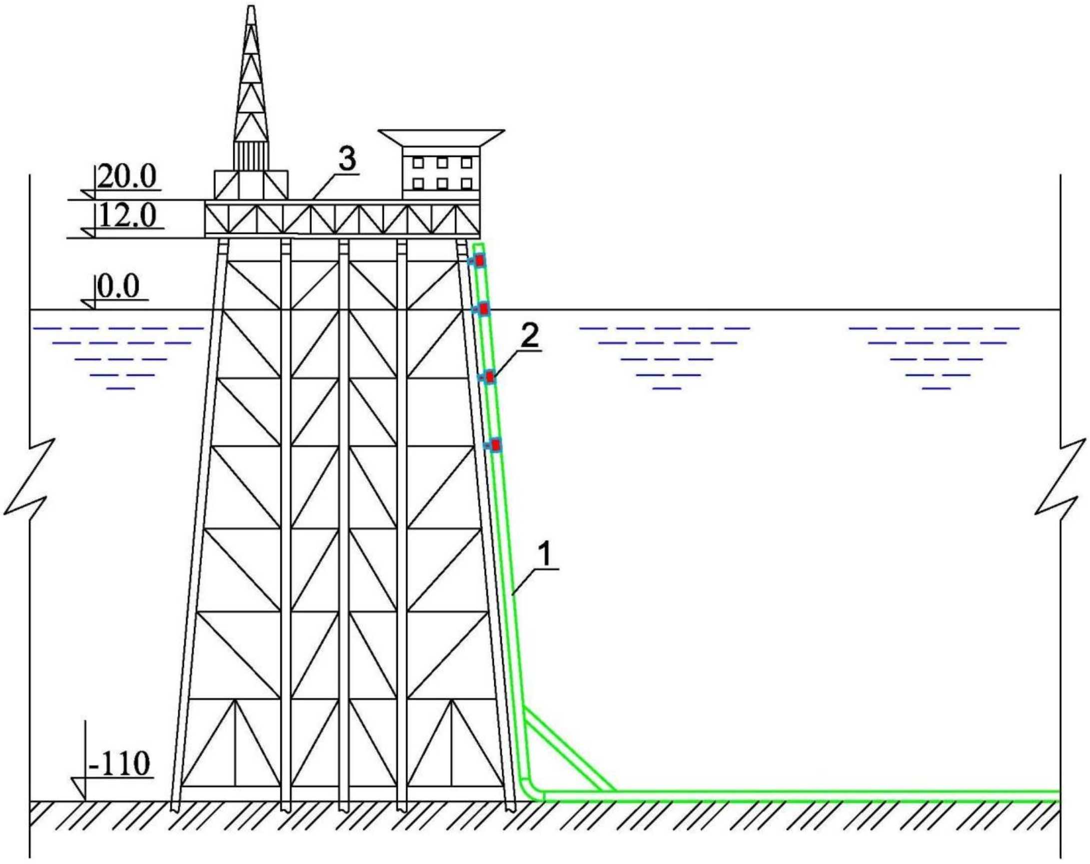

Fig.1 Condition scheme of vertical pipe according to the project
1- Vertical pipe, 2- Fixing cement, 3- Platform

The main difficulties in developing fields in extreme climatic conditions are a harsh climate, lack of roads, developed infrastructure, limited technological scheme for collecting and preparing gas. One of the features of the production, preparation and transportation of gas and gas condensate fields in the northern regions is that the temperature of the extracted products is significantly reduced already in the wellbore itself due to the cold of permafrost soils. Then, the produced gas-condensate mixture leaving the well enters the landfill trains transporting products with an ambient temperature that reaches to -40 ° C and lower in winter. In this case, the moist gas is, exposed to a sufficient degree of "cold processing" already in plume or collector due to the natural coldness of the environment. At the same time, the degree of dehydration of the gas phase, that is, the "dew point" for moisture and hydrocarbons, in the pipeline reaches lower values than indicators obtained at modern low-temperature or sorption installations. In this case, the main task of gas treatment is timely organize the removal of the liquid phase from the pipeline.

It should be noted that at present in the northern regions in the winter period before gas treatment facilities the gas is preheated from -50 ÷ $-40°$ C to -20 ° C temperature. Carrying this is necessary because of the limitations of frost-resistant process equipment. The implementation of measures for heating and heat insulation work in the transportation of large quantities of produced gas in the North requires significant additional capital and operating costs. In the gas industry, widely applied gravitational separation devices for removal of free liquids and solid impurities from the gas stream. The practice of their operation shows that they have a number of significant scarcities: low productivity and gas efficiency, high metal consumption, etc. It has been identified that the results of the actual operation of gravity separators significantly differ from the calculated parameters. This is because, a number of assumptions have been adopted in the existing method for calculating devices of this type: the constancy of the velocity of the fluid particles along the height (length) of the devices, the spherical shape of the particles, the proportionality of the gas flow velocity to the cross-sectional area of the supply pipeline and devices. Moreover, in this method is not taken into account the influence on the separation process such factors as crushing and coagulation of liquid particles in the gas stream, the presence of stagnant and vortex zones in the devices, the existence of various structural forms of gas-liquid flow in the supply pipeline, separator, etc.

This situation greatly simplifies the aerogasdynamic conditions of the separation process and do not allow reliably assess the role of these factors in each specific case. The gas-liquid flow, has very diverse forms of the structure of motion depending on the Froude number, velocity, the specific content of the liquid in it, the physicochemical properties of the gas-liquid mixture, the configurations of linear structures, and other factors. At the same time, the decisive factors of flows should be considered the flow velocity, charge gas saturation factor. At certain values of these parameters a stratified-separate form of the flow structure of the gas-liquid flow is formed in a horizontal pipeline of the appropriate diameter. It is this form of the structure of motion that is the best possibility of phase separation in the joint transport of a gas-liquid mixture in linear structures. When the gas flow approaches the separator the existing structure of motion is destroyed, because of a sudden change in its direction and the flow before the separator becomes more pulsating. Passing through the separator, the flow expands very slightly, and continues the way to the exit despite a 30-40-fold increase in the cross-section for passage. At the same time, Design flow rate in the cross section of the separator (0.1-0.2 m / s) does not reflect the actual situation of its movement in the devices. In fact, the flow moving in the separator slightly changes its cross-section and its velocity slightly differs from the flow velocity in the supply pipe. This situation is associated with the formation of large stagnant-vortex zones in the separator, where the velocity is low and the pressure is high. The pulsating flow of the gas-liquid mixture into the separator and the nonstationarity of its motion promotes break the continuity of the liquid phase in the flow and spray it. Therefore, the efficiency of the separation process remains low.

Linear structures (plumes, manifolds, pipelines), in contradistinction to technological devices, have an extremely low frost resistance. Therefore, the use of pipe-type separation devices made from the material of linear structures with an ultra-low frost-resistant capacity makes it possible to exclude boiler-heating installations from the gas collection system and to refuse measures for thermal insulation work in the harsh climatic conditions of the North. When linear structures are used for the gas separation process, the gas pipeline can be assimilated to a horizontal separator with an extended residence time of liquid droplets in the separation zone. It should be noted that the liquid phase is in the pipelines for a longer time than in the separator. Therefore, under appropriate conditions in pipelines, thermodynamic equilibrium is more stable than in a standard separation device. We have been established that in pipelines equipped with separation units, it is possible to perform gas separation at higher speeds than in existing louver and gravity separators.

The main disadvantage of existing separating devices is the following: when passing through a gas with thin layer liquid through existing separating devices of gravitational type, and also through devices equipped with stationary or non-stationary swirlers, the inverse problem, i.e., There is no separation of phases, but the spraying of the liquid film formed in the pipelines with the natural motion of the gas-liquid flow. We conducted an analysis of the operation of the NTS units operating in extreme harsh conditions for evaluation the efficiency of traditional separators of the I and II stages. The thermodynamic parameters of the NTS are as follows: t = -22 ° C; P = 6.5 MPa. Analyzing the work of the separator of the first stage, it was established that there is an intense release of liquid into the separator of the second stage at a gas velocity v> 0.265 m / s (Fig. 2). This phenomenon is explained by foaming of the liquid in the devices, in connection with the presence of zones of increased turbulence.

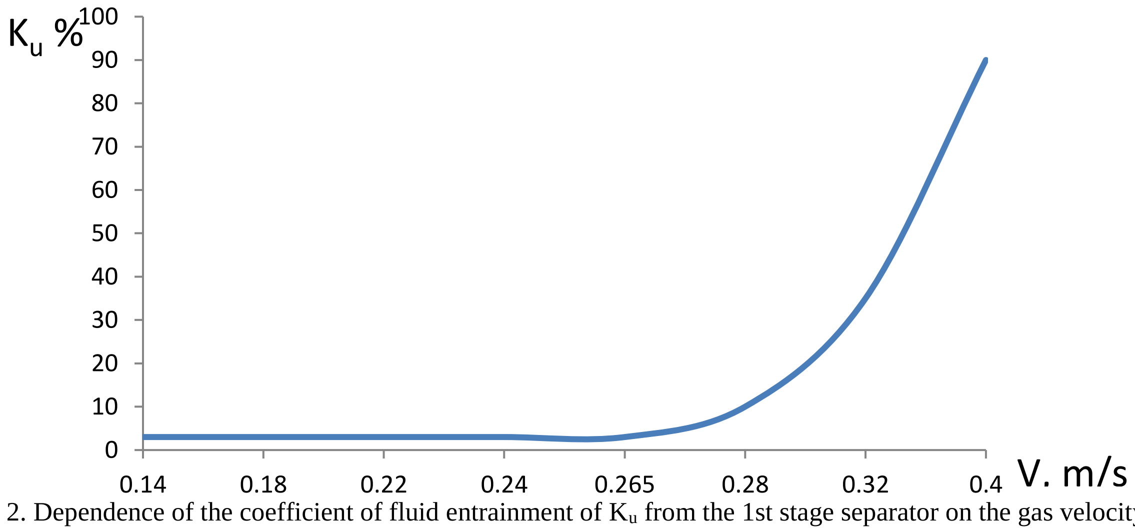

Fig. 2. Dependence of the coefficient of fluid entrainment of K_u from the 1st stage separator on the gas velocity.

The work of the second stage separators was also investigated. The results of the studies are shown in Fig 3. As shown in the graph, a progressive loss of liquid from the separator to the gas pipeline begins at a gas flow rate through a separator of more than 158 thousand m3 / h.

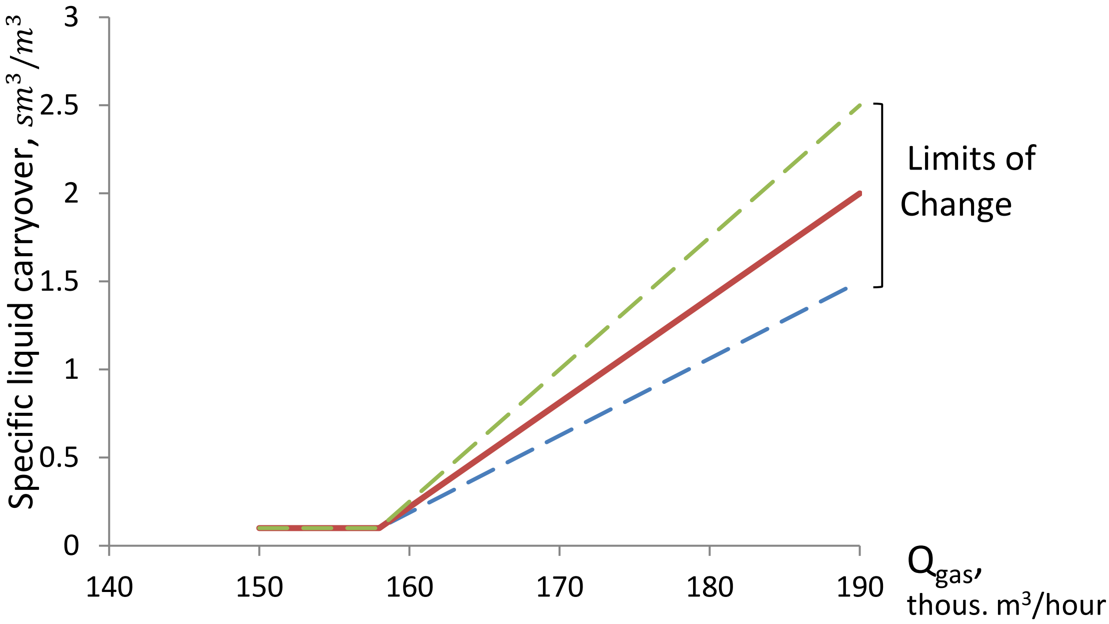

Fig 3. The diagram of the mechanical entrainment of liquid from the

separator of the second stage. Analysis of the operation of the liquid separator showed that one of the reasons for the unsatisfactory separation of the mixture of water-methanol solution-condensate is the imperfection of the devices design. The liquid inlet is in the immediate vicinity of the condensate outlet. In addition, the volume of the settling part of the devices is very small. Separation and degassing of the methanol water-condensate mixture occurs under the action of gravitational forces. Seeing the difference in the density of the separating liquids is small, the gravity of the phase with a higher density is close to the strength of the medium's resistance. Therefore, gravity separation of the mixture under such conditions is possible only with a relatively long settling (at least 30 minutes). Currently, condensate sludge in the devices occurs within 18-22 minutes. Thus, the volume of the condensate part is small. The mechanical fluid carryover is 0.06kg / 1000m3, due to the unsuccessful design of the settling part of the low-temperature separator.

Numerous theoretical and experimental studies devoted to the study of regimes and various structural forms of motion of the gas-liquid flow and the conditions for the transition of one form to another [1] give us wide opportunities for the development of tube-type apparatuses where it is possible to successfully combine transport and gas separation processes. Separating capacity of linear structures depends on the state of the interface, due mainly to such parameters as the consumption gas content (β) and the Froude criterion (Fr) characterizing the ratio of inertia and gravity forces in the flow [1-3]. It has been established that the most favorable condition for phase separation in the pipeline is reached at Fr≤10. If in the pipeline the gas-liquid mixture is mixed at a high speed, inserting a section of the pipe into it, allowing to reach the value Fr≤10, guarantees the presence of a stratified regime on this section, and complete phase separation.

It is possible to determine the maximum permissible velocity of the flow (υ_{per}), when the separating ability of the linear structure still exists,taking into account that Fr=$\frac{v^2}{gD}$, i.e.

$\upsilon_{per} = 9{,}9045\sqrt{D}$ (1).

Here, 9,9045 has dimensions$\frac{\sqrt{m}}{s}$

D is the diameter of a linear structure, (pipeline), m.

The separation capacity of the pipeline deteriorates if this speed is exceeded. With an increase in velocity above the critical value, the liquid film completely breaks down and breaks it off from the walls of the pipeline [2].

It is established that linear structures of different diameters have different values of the permissible velocity for the separation capacity of the pipeline. At d = 150 mm, the value of the permissible separation gas velocity is 3.83 m / s. If we increase the diameter of the pipeline to 200 mm, the value of this velocity reaches 4.4 m / s. In pipes with diameters of 400-1000 mm, the permissible flow rate is within 3 ÷ 10 m / s. At this speed gas separation is carried out. Taking into account the above, we have developed a small-sized high-speed and high-performance devices made from a frost-resistant metal pipeline for separating gas. The principle of operation of these devices is based on the use of the separating capacity of linear structures. These devices are intended for use in technological schemes for the collection and preparation of gas. They combine the work of separators and combs for collecting and separating gas and can be used in plumes, common collectors, export gas pipelines. The maximum use of environmental cold during the gas separation process increased the efficiency of the low-temperature process, and also significantly reduced the irreversible losses of methanol in the gas and condensate phase.

Comparison of the two thermodynamic conditions of the gas phase with a temperature of - 20 ° C and - 40 ° C (with working pressure of 5.0 MPa) shows that in the first case the amount of methanol dissolved in the gas is 4.6 times more than in the second case. Consequently, irreversible losses of methanol in the gas phase are reduced with a decrease in the separation temperature. The same low temperature improves the operation of the gas separating capacity of the liquid and reduces the amount of methanol dissolved in the condensate. This position increases the concentration of methanol in the captured formation water. The developed device is made and tested in extreme conditions. The separation temperature was reduced from -12 to -22 ° C. The results of the tests are shown in Table. 1.

Table. 1 The results of testing the tube devices.

Gas consumption thous..м^3/hour	Pressure, MPa	Temperature, ^{0}C	Specific yield of hydrocarbon condensate sm^3 / m^3	Total specific yield of liquid, sm^3 / m^3
56	6,5	-12	38	90
55	6,45	-14	40	92
55	6,5	-18,5	48	120
56	6,5	-21,5	60	130
55	6,45	-22	68	139
55,5	6,5	-22	70	142

As can be seen from Table 1, the developed tube devices effectively ensures the extraction of the liquid phase from the gas composition under extreme harsh conditions. Advantages of the proposed devices in comparison with existing separation apparatus are:

Rational use of the natural cold of environment, the pipeline combines transport, heat transfer and separation processes;

- maximum use of environmental cold increases the depth of the gas stripping, methanol losses in the gas phase and condensate are sharply reduced:
- there is no need to carry out expensive measures to preheat gas and heat insulation work under climatically harsh conditions;
- the capacity of the devices increase about 20-30% with full use of atmosphere cold by due to a reduction in the compressibility factor of the gas in the operating conditions of the pipeline operated in the northern regions.
- The issue of preparing gas produced in fields in hot extreme conditions (desert) and offshore oil and gas condensate fields is quite different in contradistinction to gas condensate fields, exploited in severe climatic conditions.
- Currently, at such gas and gas-condensate fields classical technological schemes of gathering and processing are applied for gas preparation.
- For drying and cleaning of gas in the fields are used, various metal-intensive plants that work with high energy costs. In recent years, the cost of energy is growing much faster, so it is economical to use equipment that works with low energy costs.
- The characteristic shortcomings of this technology are:

- Low efficiency of gas separation in separators as a result of their structural imperfections;
- -decrease in the quality of the gas being prepared with a reduction in the initial pressure of natural gas;
- deterioration of the temperature regime of the heat exchangers as a result of the entrainment of the liquid phase from the separator stages;
- impossibility of complex processing of natural gas (simultaneous drying and purification) in field conditions;
- enormous and high cost of the equipment used for gas treatment. This factor is particularly important in offshore environments, where platforms have a limited area for equipment installation.
- According to the technological regime of low-temperature separation installations, the main indicators are:
  -input temperature t_{in} = 55-60 ° C
  -input separation pressure P_{in} = 9,9-10,0 MPa
  - temperature of separation t_{sep} = (-10) - (-12) ° C
  -pressure of separation P_{sep} = 5.5-5.7 MPa

According to these main indicators, it is possible to estimate preliminary the total integral value of the choke coefficient

$$\beta = \frac{t_{in}-t_{sep}}{P_{in}-P_{sep}} = \frac{60-(-10)}{100-55} = 1.55\ °\ C\ /\ atm$$

This value is the largest for the overall value of the integral coefficient of the choke effect at using a low-temperature separator installation in natural cold conditions.
In this case, the maximum value of the coefficient of the differential choke effect of the throttle itself is;

$$\delta = \frac{0-(-10)}{99-56} = 0.23\ °\ C\ /\ atm$$

In the future, with a decrease in the value of the inlet pressure at a constant capacity of the low-temperature separation unit, the velocity of the gas-liquid flow increases and, accordingly, the efficiency of the separators worsens, as a result of which the temperature regime does not provide the required amount of gas to be treated. Therefore, qualitative indicators of gas do not meet the requirements of regulatory documents due to low reservoir pressure and high separation temperature.

When such gases are transported by export gas pipelines due to changes in thermodynamic conditions, there is a loss from the composition heavy hydrocarbons and reservoir waters in a vaporous, equilibrium condition and mechanical impurities enter the gas pipeline. All these processes create technological complications. Such phenomena, cause losses of expensive hydrocarbon condensate, and also, pollute the environment. Taking into account the above, we have developed a horizontal multifunctional devices for simultaneous separation, drying and purification of gases. The device includes the following sections:

- separation section for removing liquid droplets from the gas;
- Injection unit for absorbent;
- Absorption section for gas drying and purification.

Various absorbents are used for the separation, its depends on the task. Glycols are used to dehydrate the gas, for the separation of heavy fractions of hydrocarbons, and for purification - amine compounds. An experimental-industrial sample of a horizontal tube device was manufactured and tested at one of the gas-condensate field at a late stage of development. The device was installed in front of the separator of the second stage of the gas preparation unit on the bypass line. Such an arrangement of the device allowed testing without intervention in the operation of the existing technology. First, tests were conducted to dry the gas. As an absorbent was used diethyleneglycol. The inlet pressure of the device was 3.0-4.0 MPa, the temperature 25-30 ° C, the gas flow rate through the apparatus during the test period varied within the limits of 12-1400 m3 / h.
The specific consumption of DEG was 7 kg / 1000 m^3, the gas velocity in the device varied from 3.0 to 13.0 m / s.

The results of the tests are given in table. 2.

Table. 2. Results of experimental-industrial tests of a multifunctional device for gas drying

Consumption of gas, thous m^3/h	Pressure MPa	Temperature, °C	Speed m/s	Amount fluids settled in device, sm^3/nm^3	Consumption of DEG, kg/ thous m^3	Concentration of DEG,%		Dew Point of Treated Gas, °C
						Fresh	After Treatments	
12,0	3,0	20	3,0	16.6	7,0	85,0	70,0	-3,0
20.0	3.5	20	6.0	20.0	7.0	85,0	72.0	-6.0
45,0	3,5	22	8,0	23,0	7,0	85,0	74,0	-9,0
60,0	4,0	23	10,0	22,4	7,0	85,0	74,0	-12,0
74,0	3,5	22	13,0	24,5	7,0	85,0	73,0	-12,0
74,0	4,0	20	11,0	21,0	7,0	85,0	72,0	-10,0

According to the results of the study, it was found that the amount of discarded liquid on the device is 20-24 cm3 / m^3, the concentration of fresh DEG is 85%, and the concentration of DEG after treatment is -70-74%, the "dew-point" of the prepared gas (-3) - (-12). Further studies were carried out to determine the degree of recovery of C_{5+} hydrocarbons after the first stage of gas separation. Stable condensate was used as an absorbent. The fractional composition of the absorbent is given below:

The beginning of the boil, °C 74

Distillation at temperature, °C

10%	85
20%	96
30%	105
40%	115
50%	125
60%	137
70%	151
80%	170
90%	196

The end of the boil, °C 247

Table. 3. Test results of multifunctional device

Consumption of gas, thous m^3/h	Pressure MPa	Pressure MPa	The content of hydrocarbon condensate in the source gas, gr/ $м^3$	The content of hydrocarbon condensate in the gas after treatment, gr/ $м^3$	Specific consumption of absorbent gr/ $м^3$	Condensate recovery from gas, %
12,0	3,0	20	2,1	0,61	11,2	71,0
20,0	3,5	20	1,9	0,55	12,7	71,1
20,0	3,5	22	1,7	0,42	12,1	75,3
45,0	4,0	23	2,2	0,60	13,1	72,7
45,0	4,0	22	2,0	0,61	12,9	74,0
60,0	3,5	21	1,6	0,37	12,4	76,9
60,0	4,0	20	1,7	0,36	13,9	78,8

As can be seen from table 3, when the absorbent is consumed within the range of 11.2 - 14.0 g / m3, the degree of hydrocarbon condensate recovery from gas is 71.0 - 79.0%. The experimental-industrial tests showed that the multifunctional device developed by us is an effective technical tool for the preparation of gas extracted from gas and gas condensate fields located in extremely hot climatic (desert) conditions, as well as deposits at a late stage of development.

In addition, the compactness of the device makes it possible to widely use it on offshore platforms, where there is a limited area for mounting technological equipment. In marine conditions, this installation can be mounted on horizontal and vertical sections of the platform using the cold of deep water. Advantages of the device in comparison with existing gas treatment equipment are:

- The process of separation and drying of gas at high speeds (3.0 - 13.0 m / s), but in traditionally existing separation and absorption devices, the gas treatment process is carried out at speeds 0,3 м/с.
- multifunctionality of the device allowing to carry out the process of separation, drying and cleaning simultaneously in one device;
- compactness and small size;
- Insignificantness of drop pressure at 0.1 - 0.15 MPa;
- the possibility of carrying out the process of gas preparation both in commercial and transport conditions.

II. CONCLUSİON

1. The main difficulties in the development of deposits located in extreme climatic conditions is considered a harsh climate, lack of roads, developed infrastructure, limited technological scheme for collecting and preparing gas.
2. Distance of marine crafts from the mainland, high humidity of the environment, limited area of fixed platforms, difficulty in mounting equipment are characteristic features of the gas transportation system of offshore fields. In addition, pipelines designed to collect and transport production of wells are laid along the seabed, where due to natural throttling, the gas temperature decreases and a layered-separate form of the gas-liquid flow is formed, as a result of which the gas pipeline works in the plug and pulsation regime.
3. Features of gas preparation and transportation in severe northern regions is that the temperature of the extracted products is significantly reduced already in the wellbore itself due to the cold of permafrost soils, then they are transported with ambient temperature (minus 40 ° C and below). In this case, the wet gas is, as it were, sufficiently "cold-worked" already in the plume, the manifold, the pipeline due to the natural cold of the atmosphere.
4. An analysis of the operating mode of existing separators for primary gas treatment has been conducted. It is established that they have a number of significant drawbacks: low productivity and gas efficiency, high metal consumption, etc. This is explained by the fact that a number of assumptions have been made in the existing methodology for calculating apparatus of this type.
5. It was developed and tested a small-sized, high-speed devices for gas separation in severe northern conditions. It has also been developed and tested a horizontal multifunctional device for simultaneous separation, drying and purification of gas in offshore fields and in hot extreme conditions.
6. The conducted experimental-industrial tests of both devices have shown that they are effective technical means for gas preparation both in extremely severe and in offshore conditions.

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