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Some Features of Natural Gas Preparatıon for Transport in Extreme Condıtıons

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

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KEYWORDS
offshore development, gas, condensate, transport, separator, technological complications, gas drying, dew point.

INTRODUCTION

It is well 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 the Arctic and sub-Arctic regions of the world, deserts).

Remoteness of offshore installations, high humidity of the environment, limited area for fixed platforms, difficulties in mounting equipment are characteristic features of the gas transportation system of offshore fields.

During development stage of main technical solutions for preparation and transportation of gas from offshore fields there are many requirements for operation of subsea gas pipelines. In particular, it is necessary to have a justification of admissibility degree of the liquid phase presence in gas pipeline and the capability of its operation in two-phase transportation of gas and gas condensate. It should also consider for such a set of technological equipment and pipelines at which production could be uninterruptable during 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, carrying out part of them at onshore terminals for the acceptance of products.

The list and types of technological operations carried out offshore and onshore should be determined in each specific case taking into account the actual natural and climatic conditions, remoteness from the shore, depth of the sea, physical and chemical properties of the extracted products, reservoir pressures, the collection system, well production rate and other factors. The existing exploitation experience of the offshore fields in 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 Integrated Oil and Gas Treatment Unit (IOGTU), etc. Lastly, this has direct influence on the size of platform and total capital expenditures for the development of field deposits.

In offshore conditions pipelines which are designed for collection and transportation of hydrocarbons from wells are laid along the seabed for several kilometers, where due to natural throttling (the

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Joule-Thompson effect), the temperature of the gas decreases and a stratified-separate form of the gas-liquid flow is obtained. As a result, the gas pipeline operates in the plug and pulsation mode. This issue becomes particularly valid in cases where production of wells from several platforms is assembled into one platform for collection and treatment purposes. When descending (downflow) and lifting (upflow) of the pipeline at 90°, a considerable amount of liquid is collected in the elbows, which has adverse effects both on the wells production and the whole gas transmission system (Fig. 1).

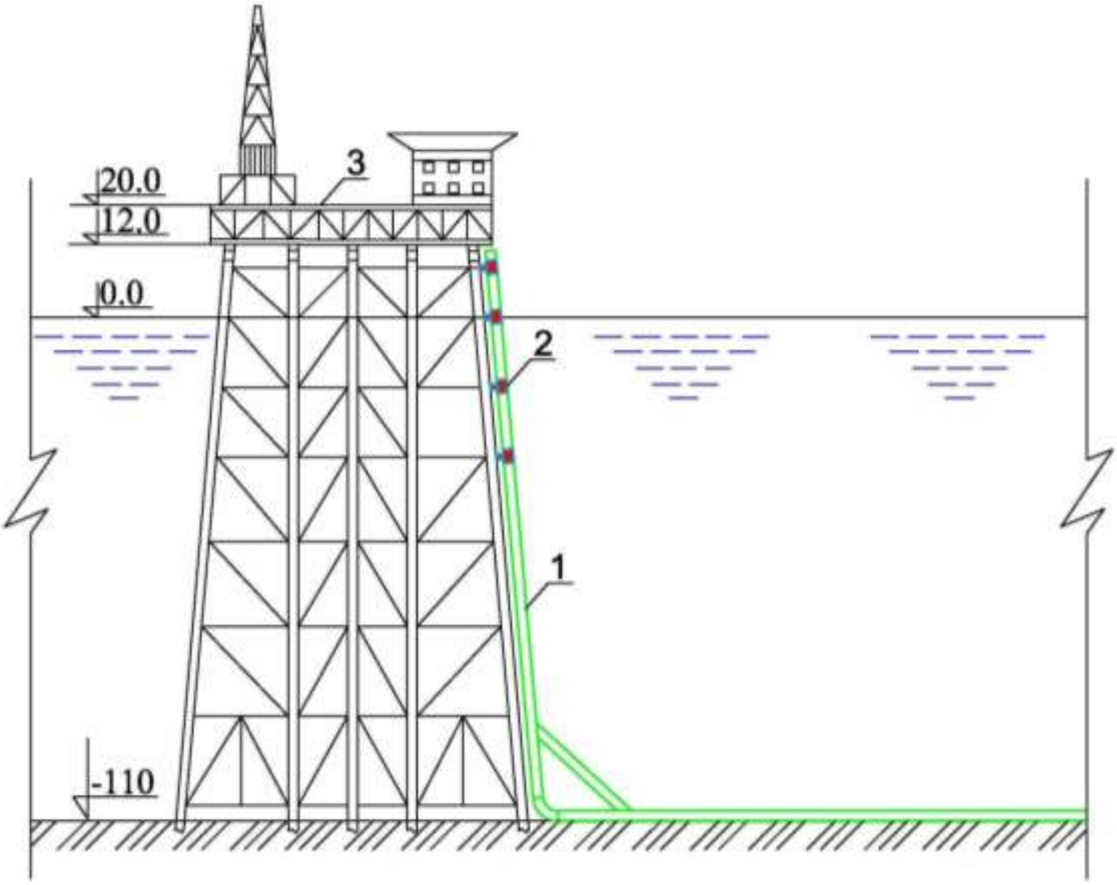

Fig.1 Installation diagram of vertical pipe according to the project 1- Vertical pipe, 2- Fixing element, 3- Platform

Among the main challenges of field development in extreme climatic conditions are harsh climate, lack of roads and lack developed infrastructure, limited technological scheme for collection and preparation of gas.

One of the features of the production, preparation and transportation of gas and gas condensate from arctic and sub-arctic regions is that the temperature of extracted products is significantly reduced while in production wellbore itself due to the cold of permafrost soils. As it continues to flow the produced gas-condensate mixture leaving the well enters the landfill trains transporting products with an ambient temperatures reaching -40 ° C and lower in winter. In this case wet gas is exposed to a sufficient degree of "cold processing" already in plume or collector due to the natural cold 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 reading of indicators obtained at modern low-temperature or sorption installations. In this case, the main task of gas treatment becomes timely removal of the liquid phase from the pipeline.

It should be noted that at present in the northern regions during winter period the gas is preheated from -50 ÷ −40° C to -20 ° C prior to entering gas treatment facilities. Carrying out this is necessary due to 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 expenditures.

Gravitational separation devices are widely used in the gas industry 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 of such factors as crushing and coagulation of liquid particles in the gas stream, presence of stagnant and vortex zones in devices, the existence of various structural forms of gas-liquid flow in the supply pipeline, separator, etc.

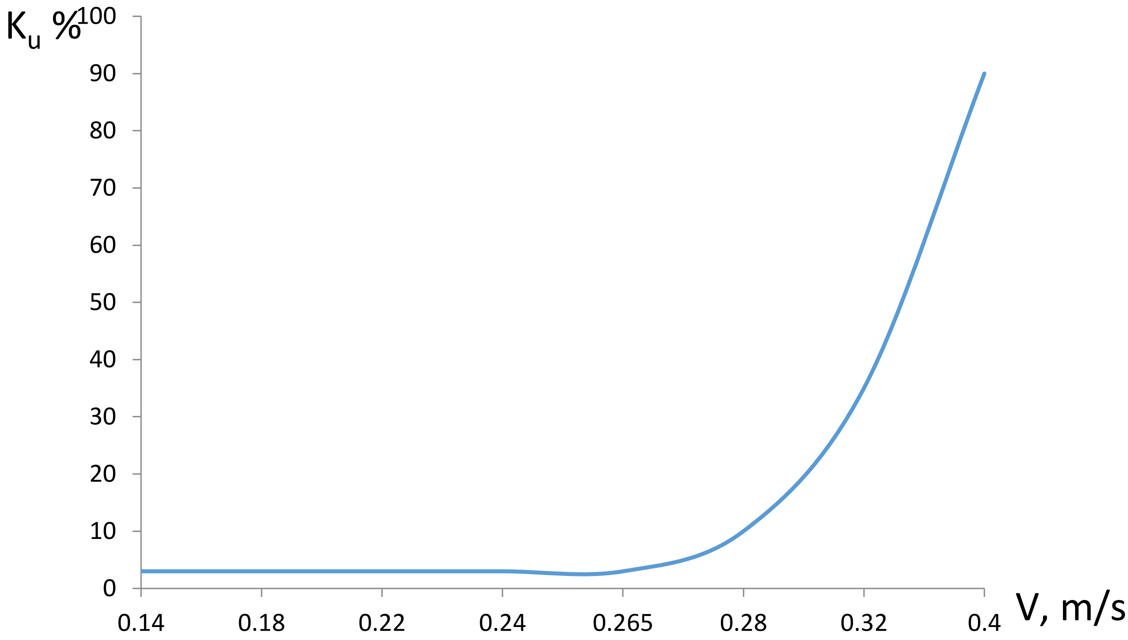

Fig. 2. Dependence of the 1st stage separator fluid entrainment coefficient K_u on the gas velocity.

This situation significantly simplifies the aerogasdynamic conditions of the separation process and do not allow for reliable assessment of the role of these factors in each specific case.

The gas-liquid flow has very diverse forms of motion structures depending on the Froude number, the velocity, the specific content of the liquid, the physico-chemical properties of the gas-liquid mixture, the configurations of linear structures and many other factors. At the same time the decisive factors of flows should be considered the flow velocity and 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 considered that this form of the motion structure has the uppermost 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 due to a sudden change in its direction and the flow just before the separator becomes more pulsating. Passing through the separator, the flow expands very slightly, and continues the way to the exit despite 30÷40 times increase in the cross-section for passage. Calculated 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 device. As a metter of fact the flow moving inside 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 breaking of continuity of liquid phase in the flow and its spraying. Therefore the efficiency of the separation process remains low.

Unlike technological devices, the linear structures (plumes, manifolds, pipelines) have an extremely low frost resistance. That is why 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 refrain from measures for thermal insulation works in the harsh climatic conditions of the Arctic.

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 in the pipelines is for a longer time than in the separator. Therefore under appropriate conditions the thermodynamic equilibrium in pipelines is more stable than in a standard separation device. We have 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 gas with thin layer liquid is passing through existing separating devices of gravitational type as well as through devices equipped with stationary or non-stationary swirlers, the inverse process is observed, i.e. there is no separation of phases. Instead, liquid film formed in the pipelines with natural motion of the gas-liquid flow is sprayed.

We conducted an analysis of operation of the low temperature separation units (LTSU) operating in extreme harsh conditions in order to evaluate the I and II stages of traditional separators efficiency. The thermodynamic parameters of the LTSU are as follows: t = -22 ° C; P = 6.5 MPa. Having analyzed the work of the separator of the first stage it was established that at a gas velocity v> 0.265 m/s there is an intense release of liquid into the separator of the second stage (Fig. 2). This phenomenon is explained by foaming of the liquid inside device due to the presence of zones of increased turbulization. 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 of more than 158,000 m3 / h. through a separator.

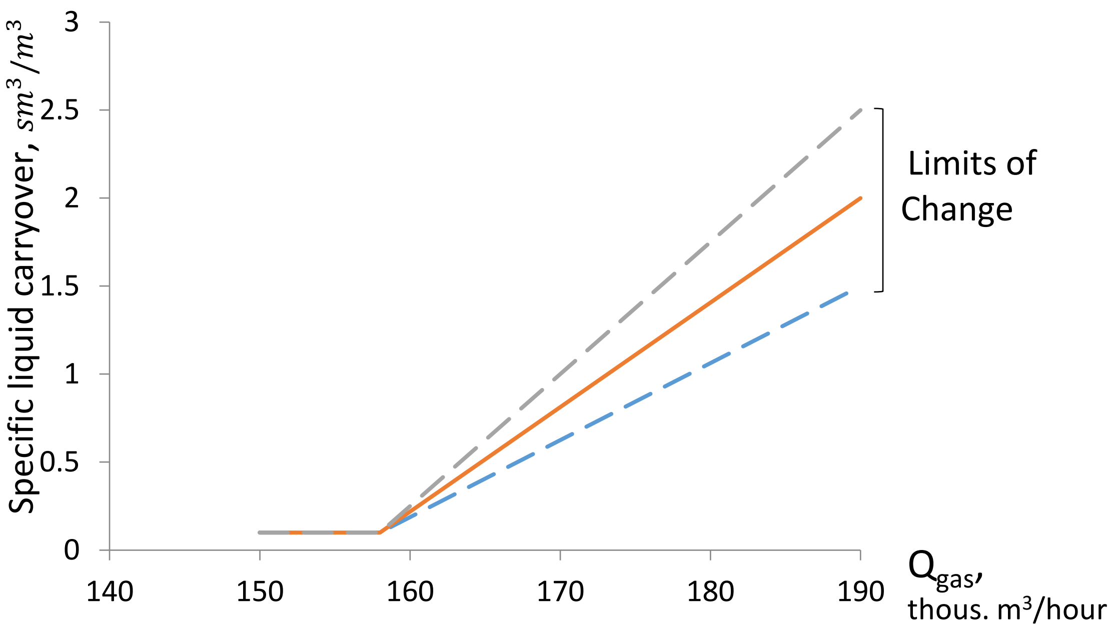

Fig 3. The diagram of the liquid mechanical entrainment from the second stage separator.

Analysis of the operation of the liquid separator has shown that one of the reasons for undesirable separation of the water-methanol solution – condensate mixture is the imperfection of the device design. The liquid inlet is in the immediate vicinity of the condensate outlet.

In addition, the volume of the settling part of the device is very small. Separation and degassing of the methanol water-condensate mixture occurs under the action of gravitational forces. Since the difference in the density of the separating liquids is not great, 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 at a relatively long settling time (at least 30 minutes). At present, 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 poor 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] offer wide opportunities for the development of tube-type apparatus where it is possible to successfully combine transport and gas separation processes.

Separating capacity of linear structures mainly depends on the state of the interface, conditional 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 the gas-liquid mixture along the pipeline is mixed at high speeds, inserting a section of the pipe which would allow reaching the value Fr≤10, guarantees the presence of a stratified regime in this section i.e. complete phase separation.
It is possible to determine the maximum permissible velocity of the flow (υ_{per}) at which the separating ability of 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 the value of $\frac{\sqrt{m}}{s}$

D is the diameter of a linear structure, (pipeline), m.
The separation capacity of the pipeline deteriorates if this velocity is increased. With an increase in velocity above the critical value, the liquid film completely breaks down and breaks off from the walls of the pipeline [2].

$$V_{kp}=1500\sqrt{\frac{G}{\rho''}}\cdot\sqrt[3]{\mu}\cdot\sqrt{\frac{\rho'}{q\cdot D}} \qquad (2).$$

whereas:
v_{kp}-critical value of gas velocity, m/s;
G – gas-liquid intersurface tension kgf/m;
ρ'- gas density at üorking conditions kg/m^3;
ρ'' – liquid density, kg/m^3 ;
μ - liquid viscosity, kgf· s /m^2;
q- liquid content in gas flow, % ;

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 at which gas separation is carried out is within 3 ÷ 10 m/s.
Taking into account the above, we have developed a small-sized high-speed and high-performance gas separation devices made from a frost-resistant metal pipeline. The operation principle of these devices is based on the use of separating capacity of the 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 (at working pressure of 5.0 Mpa in both cases) 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 hydrocarbon 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 pipeline device testing.

Gas consumption K m^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 device effectively ensures the extraction of the liquid phase from the gas composition under extreme harsh conditions. Advantages of the proposed device in comparison with existing separation apparatus are:
rational use of the natural cold of environment; the pipeline combines transport, heat exchange and separation processes;

maximum use of environmental cold increases the depth of 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 perform insulation works under climatically harsh conditions;
capacity of the devices increases by 20-30% with full use of atmosphere cold due to a reduction in the compressibility factor of the gas in the operating conditions of the pipeline operated in the northern regions.
Unlike gas condensate fields exploited in arctic climatic conditions the issue of preparing gas produced in fields in extreme hot conditions (deserts) and offshore oil and gas condensate fields is somewhat different.
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 various high energy consumption metal-intensive installations are used. The cost of energy is growing much faster from year to year, so it is economical to use equipment that works with low energy consumption.
The typical shortcomings of this technology are:
low efficiency of gas separation in separators as a result of their structural imperfections;
deterioration of treated gas quality tied to the initial pressure drop which happens due to not providing of projected separation temperatures in low-temperature separator;
deterioration of the heat exchangers temperature regime as a result of liquid phase entrainment from the separator stages;
impossibility of complex processing of natural gas (simultaneous drying and purification) in field conditions;
enormous and high costy 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 the total integral value of the choke coefficient

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

The results of the tests are given in Table 2.

This value is the largest for the overall value of the integral coefficient of the choke effect 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:

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

Eventually with decrease in the inlet pressure at a constant capacity of the low-temperature separation unit, the velocity of the gas-liquid flow increases and therefore the efficiency of the separators drops 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 pipelines there is a loss of heavy hydrocarbons, mechanical impurities and vaporous reservoir waters from the composition due to changes in thermodynamic conditions. All these reside inside pipelines and create technological complications.
Taking into account the above we have developed a horizontal multifunctional device for simultaneous separation, drying and purification of gases. The device includes following sections:
- separation section for removing liquid droplets from the gas;
- absorbent injection point;
- absorption section for gas drying and purification.
Depending on the given task various absorbents like glycols and amine compounds are used for the separation.
An experimental-industrial sample of a horizontal tube device was manufactured and tested at one of the gas-condensate fields which was at late stage of development. The device was installed prior to second stage separator of the gas treatment unit on the bypass line. Such an arrangement of the device allowed for testing without intervention in the operation of the existing technology.
Firstly 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 12k-14k m3 / h.
The specific consumption of diethyleneglycol was 7 kgs/ 1000 m^3, the gas velocity in the device varied between 3.0÷13.0 m / s.

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

Gas consumption, K m^3/h	Pressure, MPa	Temperature, ºC	Speed m/s	Fluids captured in device, sm^3/nm^3	Consumption of DEG, kg/ K m^3	Concentration of DEG,%		Dew point of treated gas, ºC
						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 established that the amount of discarded liquid in 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 C_{5+} hydrocarbons recovery after the first stage of gas separation. Stable condensate was used as an absorbent. The fractional composition of the absorbent is given below:

Start of boiling	°C	74
Distillation at temperature,	°C	
	10%	85
	20%	96
	30%	105
	40%	115
	50%	125
	60%	137
	70%	151
	80%	170
	90%	196
End of boiling	°C	247

Thermodynamical parameters of device and gas consumption were the same as in first experiment. The results of experiment are shown below in Table 3.

Table 3: Test results of multifunctional device

Consumption of gas, K m^3/h	Pressure, MPa	Temperature, °C	Hydrocarbon condensate content in source gas, gr/ м³	Hydrocarbon condensate content in gas after treatment, gr/ м³	Specific consumption of absorbent gr/ м³	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 has shown that developed multifunctional device 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 the area for mounting technological equipment is often limited.

In marine conditions, this installation can be mounted on horizontal and vertical sections of the platform using the cold of deep waters.

Advantages of the device in comparison with existing gas treatment equipment are:

process of gas separation and drying is performed at high speeds (3.0 - 13.0 m/s) as opposed to 0.3 m/s in traditionally existing separation and absorption devices.

multifunctionality of the device allowing to carry out the process of separation, drying and cleaning simultaneously;

compactness and small size;

insignificant pressure variations at 0.1÷0.15 MPa;

possibility of carrying out gas preparation process in field as well as in transport conditions.

CONCLUSION

The main difficulties in the development of deposits located in extreme climatic conditions are considered harsh climate, lack of roads and developed infrastructure, limited technological scheme for collecting and preparing gas.

Remoteness of offshore installations, high humidity of the environment, limited area for fixed platforms, difficulties in mounting equipment are characteristic features of the gas transportation system of offshore fields. Pipelines which are designed for collection and transportation of hydrocarbons from wells are laid along the seabed for several kilometers, where due to natural throttling, the temperature of the gas decreases and a stratified-separate form of the gas-liquid flow is formed. As a result, the gas pipeline operates in the plug and pulsation mode.

One of the features of the production, preparation and transportation of gas and gas condensate in severe northern regions is that the temperature of extracted products is significantly reduced while in production wellbore itself due to the cold of permafrost soils. As it continues to flow the produced gas-condensate mixture leaving the well enters the landfill trains transporting products with an ambient temperatures reaching -40 ° C and lower in winter. In this case wet gas is exposed to a sufficient degree of "cold processing" already in plume or collector due to the natural cold of the environment.

Analysis of the existing separators operation for primary gas treatment has been conducted. It was established that they have a number of significant drawbacks: low productivity and gas efficiency, high metal consumption, etc. This could be explained by the fact that a number of assumptions have been made in the existing methodology for calculating apparatus of this type.

A high-speed and small-sized device for gas separation in severe northern conditions was developed and tested. Additionally, horizontal multifunctional device for simultaneous separation, drying and purification of gas in offshore fields and in hot extreme conditions has also been developed and tested.

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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