Investigation of difficulties arising in the preparation of natural and indirect gases for transportation

Ijabika Sardarova, *Abdulaga* Gurbanov, and *Nazim* Huseynov*

Azerbaijan State Oil and Industry University, 27, Azadliq str., Baku, Az1010, Azerbaijan

Abstract. The causes of technological difficulties arising during the preparation and transportation of gases have been clarified and methods of their elimination have been determined. The operating mode of the existing gas preparation units was studied and the efficiency of certain equipment was determined. It has been established that the evaluation of the efficiency of the devices used in the gas industry, the deficiencies in the gas preparation devices are related to the correct selection of the constructive indicators of the devices. New innovative methods and technologies have been developed for the complex preparation of gases produced under difficult conditions for transportation. Application of tube-type devices made of such material has been determined to be useful in gas collection systems in cold climate conditions. Due to the nature of gas production and transportation systems in complex conditions, the temperature of the produced well products in the wellbore decreases sufficiently and the gas is subjected to cold processing. The construction of a multifunctional apparatus for simultaneous separation, installation and degasification of gases has been developed and applied on an industrial scale. The proposed device has been proven to be an effective device for preparing gas for transportation under extreme conditions.

1 Introduction

Natural gas production is recognized to occur mostly in harsh environments (sea oil, gas, and condensate reserves, extremely cold temperatures, etc.).

The characteristics of the operation of gas transportation systems of offshore fields include the placement of offshore mines far from the mainland, high humidity levels in the surrounding air, restrictions on the area of stationary foundations, and challenges associated with equipment installation.

The requirements for operating regimes of underwater gas pipelines are the primary criterion for preparing gas produced from offshore fields for transportation and for making technical decisions on transportation. Therefore, it is necessary to provide justification for both the allowable level of liquid phase in the gas pipeline and the pipeline's ability to operate in two phases [1-3]. Additionally, technology equipment should be chosen such that well-product production can continue during the entire field development process.

* Corresponding author: nazim.huseynov1@gmail.com

Simultaneously, efforts must be made to minimize the number of technological operations conducted in the wells, with some of these activities able to be completed at the coastal terminals for product receipt. Each unique situation should have its own set of technological procedures carried out on land and at sea. Climate, the deposit's distance from the coast, the sea's depth, the physico-chemical characteristics of the product produced, formation pressure, well productivity, and other variables should all be considered at the same time. Since the equipment is energy-intensive, metal, and in touch with the air, the technological scheme for gas preparation for transportation should be chosen with greater simplicity. Ultimately, these have an impact on the size of the foundations and the overall amount of capital needed to develop the field.

On the seabed are pipelines designed to collect and transfer well products in maritime environments. The natural throttles in these pipes (the Coul-Thomson effect) cause the gas temperature to drop and the gas-liquid flow to become stratified. [4-5]. The gas pipeline operates in a congested and pulsating manner as a result. the issue gets more acute when the well products are collected in a base. A significant amount of liquid builds up in the elbows during the pipeline's descending and rising flows at an angle of 90°, which has an adverse effect on well and gas transportation system performance.

2 Materials and methods

The main obstacles in developing fields located in complicated cold climates include harsh environment, absence of roads and developed infrastructure, restrictions in technology schemes for gathering and processing gas. The temperature of the produced product starts to drop in the wellbore during the collection, processing, and transportation of gas and gas condensate deposits situated in these kinds of environments. Through underground mining plumes, the gas-condensate mixture that is collected from the well is conveyed at room temperature. The average yearly temperature during the winter is minus 40°C, and occasionally it is considerably colder. Meanwhile, because of the natural weather, the wet gas is exposed to "cold processing" of the plume [6]. Coordinating the prompt extraction of the liquid phase from the pipelines is the primary concern in this instance.

It should be mentioned that the lack of frost-resistant technological equipment in the northern regions is the reason why gas must be heated before entering the current gas producing facilities in the winter. The implementation of heating and thermal insulation measures during the transportation of substantial gas quantities necessitates significant additional capital operational expenditures.

Besides, the operational experience of the separation devices used in the existing gas preparation facilities has shown that they have certain disadvantages such as low productivity and efficiency due to gas, large metal capacity, etc. It was also determined that the actual results of the work of those separators differ significantly from the results obtained by calculation. This is explained by the errors in the current methods of calculation, which assume that the liquid particle movement speed along the apparatus's height and (length) is constant and that the particles have a sphere-shaped shape. These methods also fail to account for the fact that liquid particles fragment and coagulate in gas flow, stagnation and vortex zones exist in the apparatus, and that different structural forms of gas-liquid flows exist in the devices' inlet pipes [7-8]. The aero-gasodynamic basis of the separation process is simplified in this scenario, and a thorough evaluation of the relative contributions of the various elements listed in the process is not possible.

3 Results and discussion

In order to evaluate the efficiency of the traditional separators used in the gas industry, research work was carried out by us in the gas preparation unit working with the low-temperature separation method. The operating modes of I and II stage separators were studied. The analysis of the operation mode of the I-stage separator showed that when the gas flow speed b> 0.265 m/s, liquid is intensively thrown into the entrance of the II-stage separator (Figure 1).

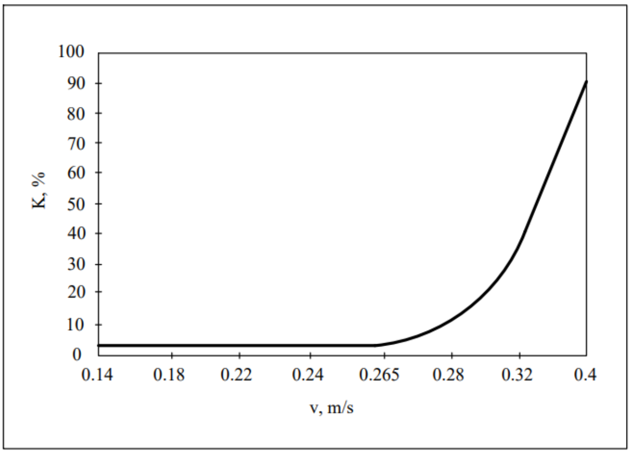

Fig. 1. Velocity dependence of the amount of liquid carried by the gas after the I-stage separator.

This is due to the presence of a highly turbulent zone inside the separator. The study of the working mode of the second-stage separator showed that when the gas consumption is above 160 000 m3/hour, the liquid phase is intensively thrown into the gas pipeline (Figure 2). These shortcomings are related to the incorrect calculation of the structural indicators of the devices.

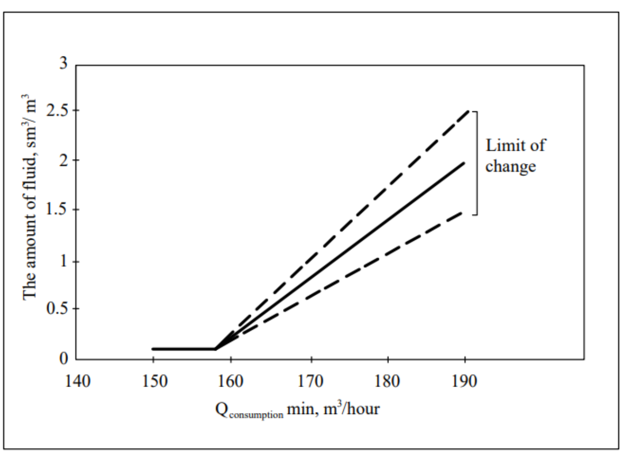

Fig. 2. The amount of liquid carried by the gas after the II-stage separator.

The following are the characteristic disadvantages of facilities for preliminary processing (separation, drying, purification, etc.) of gas in mining conditions:

- Low quality gas produced as a result of the next deposit development stage's failure to guarantee the separation mode in the low-temperature separators; low efficiency of the process due to the formation of intense foaming in the system upon contact of hydrocarbon condensate in the form of drops with liquid sorbents used in sorption processes of gas drying; impossibility of complex processing of gas in mining conditions.

Gas production equipment has a high energy consumption and a huge metal capacity. Because there are fewer spaces on platforms for placing equipment, this element is particularly crucial in maritime settings.

In light of these, it is necessary to create novel, cutting-edge techniques and technologies for the effective complicated preparation of gases created under harsh circumstances for transportation. In this arena, developing structures based on the linear devices' inherent ability to separate while accounting for the structural forms of gas-liquid flows is the most appropriate approach.

Numerous theoretical and experimental studies on the conditions of transition from one form to another, along with an examination of the various structural forms and modes of movement of gas-liquid flows, provide a wealth of opportunities for the development of tube-type devices for the implementation of the process of preparing gas for transport in the transport system [9]. Flutes, collectors, and pipelines are examples of linear devices that are more resistant to frost than technological equipment. In extremely cold areas, the use of tubular devices constructed of this material reduces the necessity for heating devices and heat insulation work in gas collection systems.

- The liquid phase separator remains in the pipeline for a considerable amount of time, so this needs to be considered. Thermodynamic equilibrium is more stable in pipelines than it is in conventional separators under the right circumstances. We have found that compared to current devices, gas separation can occur faster in pipelines that have separation nodes installed.
- The separation capacity of linear devices depends to a large extent on the state of the phase separation surface. The state of phase separation is determined mainly by the roughness coefficient β and the Froud number (Fr). P1 characterizes the ratio of inertia forces to gravity in the flow. It was determined that the most favorable conditions for phase separation in the pipeline are obtained at the value of the Froude number $Fr \leq 10$. If the gas-liquid flow through the pipeline moves at a high speed, it is possible to create a stratified flow regime in this area, or rather to ensure complete separation of phases, by installing a pipe section that ensures the fulfillment of the condition $Fr \leq 10$ for its certain ratio.

Taking into account that $Fr = \eta^2 / gD$, it is possible to determine the permissible speed of flow Vy, at which the separation capability of linear devices is preserved.

$$V_y = 9.9045D,$$

where D is the diameter of the pipeline, m.

When this speed is exceeded, the separation ability of the pipeline deteriorates. When the speed increases above the critical value, the liquid layer begins to completely disintegrate. It was determined that linear devices of different diameters have different values of permissible speed due to separation properties. For example, for mining plumes with a diameter of D_f = 150 mm, the permissible gas separation speed is 3.83 m/s. When the pipe diameter increases to 200 mm, the value of this speed increases to 4.4 m/s. In pipes with a diameter of 400-1000 mm, the permissible flow speed for gas separation is in the range of 3-10 m/s.

It should be noted that in the existing separators, the permissible speed limit of the gas flow according to the project is up to 0.3 m/s.

In actuality, though, the separators' gas velocity is many times greater than the allowable limit. Particularly in fields that are nearing the end of their useful lives, this scenario is particularly dire. As a result, the gas preparation units' inlet pressure drops sufficiently, the gas-liquid flow rate rises, and the separators' efficacy declines as a result of the wells' potential energy being used up. As a result, the gas quality indicators satisfy normative document standards.

When such gas is transported, the thermodynamic circumstances change, causing heavy hydrocarbons and water in both its vapor and equilibrium states to settle inside the pipeline. This leads to problems with technology in the transportation network. In light of the aforementioned, we constructed a multipurpose small-diameter tube-type device for the simultaneous separation, drying, and regulating of gas, and the Republic of Azerbaijan has awarded it a patent. The components of the apparatus are as follows:

- liquid extracted in the form of droplets from the gas;
- mass exchanger for gas drying;
- degasification of gas.

An industrial test sample of the proposed device was developed and tested in a gas-condensate field in the final stage of development.

Test works were carried out primarily for the gas drying process. Diethylene glycol (DEQ) was used as absorbent. The gas pressure at the entrance of the apparatus was 3-4 MPa, the temperature was 25-30°C, consumption was 12-60 thousand m^3/h, the volume of DEG was 7.0 kg/1000 m^3, the gas consumption in the apparatus was 3-13 m/s (Table 1).

As a result of these works, it was determined that the amount of liquid contained in the apparatus is 20-24 sm/m3, the density of DEQ before processing is 85, and after processing is 70-74 volume %, the dew point of the produced gas is 3-12°C.

In the following phase, experiments were conducted on the gas degasification process. Stable condensate was employed as absorbent. The absorbent's fraction composition is listed below:

- Boiling start, °C - 74
- 10% - 85
- 20% - 96
- 30% - 105
- 40% - 115
- 50% - 125
- 60% - 137
- 70% - 151
- 80% - 170
- 90% - 196
- After boiling, °C – 247

Table 1. The results of the tests carried out in the process of gas drying in gas condensate mines.

Gas scarf, min m^3/hour	Pressure, MPa	Temperature, °C	Gas velocity, m/s	The amount of liquid separated in the apparatus sm^3/m^3	Consumption of DEQ. kq/1000m^3	Layer of DEQ, volume %		Processed gas dew point, °C
						Before processing	After processing	
12	3.0	20	3	16.6	7	83	68	-3
21	3.5	20	6	20.0	7	83	70	-6
43	3.5	22	8	23.0	7	83	72	-9
50	4.0	23	10	22.4	7	83	72	-12
62	3.5	22	13	24.5	7	83	71	-12
62	4.0	20	11	21	7	83	71	-10

The thermodynamic parameters and gas consumption of the unit during the test work are the same as in the first experiment.

The results of the conducted tests are given in Table 2.

Table 2. Change of parametrs in the study of gas degasification process.

Gas scarf, min m^3/hour	Pres sure, MPa	Temperature, °C	Amount of hydrocarbon condensate in the processed gas, q/m^3	Theamount of hydrocarbon condensate in the gas after processing, q/m^3	Specific consumption of absorbent, q/m^3	Gas condensate output rate, %
12	3.0	20	2.1	6.1	11.3	71.0
21	3.5	20	1.9	5.5	12.7	71.1
21	3.5	22	1.7	4.2	12.1	75.3
43	4.0	23	2.2	6.0	13.1	72.7
45	4.0	22	2.0	6.1	12.9	74.0
62	3.0	21	1.6	3.7	12.1	76.9
62	4.0	20	1.7	3.6	13.9	78.8

As can be seen from the table, the extraction rate of hydrocarbon condensate from the gas content is 71-79% at the absorbent consumption values of 11.2-14.0 g/m^3.

The multifunctional apparatus that we designed is an efficient technological tool for the preparation of gas produced from fields in the latter stages of development under harsh conditions, as demonstrated by the results of tests conducted on an experimental and industrial scale. The device's tiny size and compact design make it suitable for widespread use in areas where there are few places where technological equipment can be installed on seabeds. The following are the benefits of the suggested apparatus over the current gas preparation machinery:

- carrying out the initial gas processing under mining conditions quickly (3–13 m/s) because the apparatus is multifunctional, it can handle the simultaneous operations of gas separation, drying, and degasification;
- being compact and small-sized;
- low pressure drop (0.1-0.15MPa);
- the possibility of conducting the process of gas preparation for transportation both in mining and in transportation conditions.

4 Conclusion

The primary challenges in field development under complicated climate circumstances are thought to be the following: severe weather, inadequate infrastructure (roads and buildings), and constraints in gas collection and processing systems. One of the defining characteristics of gas transportation systems in offshore fields is the location of offshore mines distant from the mainland, the high humidity of the surrounding air, the restricted regions on permanent foundations, and the difficulty of equipment installation operations. The temperature of the generated well products drops as soon as they enter the wellbore, and the gas goes through "cold processing" in the plumes, which is a defining property of how gas production and transportation systems operate in extremely cold regions.

The operating modes of separators in gas production facilities that are now in use were examined, and certain deficiencies (such as high metal capacity and low productivity) were discovered.

On an industrial scale, the development and testing of a multifunctional device for the simultaneous separation, installation, and degasification of gases under complicated conditions has been completed. The test results demonstrated that the suggested gadget is a useful technological instrument for preparing gas for transportation in harsh environments.

We thank SOCAR management and the oil and gas administration, as well as the engineering and operational staff who, with their work and advice, made a significant contribution to our research. With their help, experiments were carried out and the results of our research were successfully applied.

References

1. V.M. Mamayev, F.E. Odishariya, *Movement of Gas-Liquid Mixtures in Pipes* (Hedra, Moscow, Russia, 2017).
2. E.Y. Aliyev, E.A. Abdullayev, N.N. Sultanov, *Gas Separation in Pipelines* (Nafta press, Baku, Azerbaijan, 2006).
3. A.M. Qasımov, *Field Processing of Gas and Condensate in the Conditions of the Orenburg Gas Condensate Field* (VNİEQazprom, Moscow, Russia, 2018).
4. V.M Abbasov, M. Hany Abd El-Lateef, L.T. Aliyeva, E.E. Qasimov, I.T. Ismayilov, M. Mai Khalaf, Egyptian Journal of Petroleum **1**, 12 (2013).
5. A.S. Malikov, U.F. Gasanov, *Application of Flow Measuring Devices in the Gas Industry* (Nafta-Press Publishing House, Baku, Azerbaijan, 2007).
6. G.K. Seyfullaev, On diagnosing the internal condition of gas pipelines, in *Proceedings of the XIX Republican Scientific Conf. of Doctoral Students and Young Researchers* **1** (Baku, Azerbaijan), pp. 100-101 (2015).
7. A.N. Gurbanov, I.Z. Sardarova, J. Damirova, EUREKA: Physics and Engineering **6(37)**, 48-56 (2021).
8. R.Q. Nurmamedova, F.B. İsmayılova, Journal Pipeline Transport. Theory and Practice **2(48)**, 22-27 (2015).
9. D.A. Mirzoev, *Fundamentals of Offshore Oil and Gas Production* (Moscow, 2009).