

# Natural gas drying technology

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**Abstract.** The article considers the issues of cleaning natural gas with water vapour. It was found that the increase in temperature in the process of gas drying will increase the moisture content in it to 0.5 g/m<sup>3</sup> and this will be an excess load on the adsorbent. The experimental tests of the compressed gas dryer showed that the technological scheme was chosen correctly and that it worked well and had the right parameters. The experimental device was tested at the N1 gas station in Samarkand. To study the effective operation of the device, 4 types of tests were conducted: the first was immediately connected to the device, and the second, third and fourth were conducted at 380, 800 and 1650 hours. During the test period, gas humidity was studied at the entrance and exit of the station, and the entrance and exit of the drying device, based on the obtained results, conclusions and suggestions were given. The purpose of the work is to select sorbents with high efficiency for natural gas drying and to create natural gas drying technology.

## 1 Introduction

With the growth of fuel and energy consumption in developed countries and the growth of economies and populations in developing countries, the world's energy demand is constantly increasing. In the modern world, the presence and high need for fuel and energy resources, their continuous supply to consumers and ensuring their effective use by consumers are becoming the main guidelines in the development of energy strategies in different countries of the world [1-2]. The presence of hydrogen sulphide in hydrocarbons causes several problems: the risk of corrosion destroys the development technique, pollutes the atmosphere as a result of burning, poses a great danger to living organisms and biosystems when burned in furnaces and torches, pollutes the environment, disrupts the energy balance of the earth, biological, biochemical breaks cycles [3-5]. In addition, if hydrocarbon raw materials are involved in chemical processes, hydrogen sulphide will disrupt the technological process, because it is very aggressive and combines with catalysts to form harmful compounds. Hydrogen sulphide, sulphur (IV) oxide not only poses a technological risk but also poses a great risk to living organisms and the environment

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during the extraction and exploitation process or transportation. Hydrogen sulfide ( $H_2S$ ) is a colourless gas with a characteristic odour. It is heavier than air, its density under normal conditions is  $1.5092\text{kg/m}^3$  (relative humidity in the air is 1.17), so it accumulates in low air circulation areas.  $H_2S$  is highly flammable (ignition temperature  $246\text{ }^\circ\text{C}$ ) and explosive when mixed with air. When mixed with air, the flammability limit (lower and upper limit) under normal conditions is 4.3-45.5% by weight. Therefore, hydrogen sulfide is prone to fire and explosion in the air, and if it is mixed with flammable gas, the explosion will be strong. The self-ignition temperature of hydrogen sulfide is  $290\text{ }^\circ\text{C}$ . The effect of hydrogen sulfide on the human body depends on its concentration in the environment [6-9]. It is known that in the environment, not hydrogen sulfide, but sulfur (IV) oxide, a product of its combustion, has a negative effect on living organisms. Sulfur (IV) oxide  $SO_2$  is colourless burnt sulfur with a strong odour. Sulfur (IV) oxide under normal conditions has a boiling temperature of minus  $10\text{ }^\circ\text{C}$ , a heat of vaporization of  $24.94\text{ kJ/kmol}$ , a melting temperature of  $-75.5\text{ }^\circ\text{C}$ , and a heat of fusion of  $7400\text{ kJ/kmol}$ . Currently, as a result of industrial development and human activities, the release of sulfur compounds into the atmosphere is several million tons, and when solid, liquid and gaseous fuels containing sulfur are burned, a lot of sulfur dioxide ( $SO_2$ ) is released into the atmosphere [10-12]. At this time, about two kilograms of sulfur dioxide are obtained from one kilogram of hydrogen sulfide. Sulfur dioxide is the most polluting substance of the environment, it falls back to the earth in the form of acid rain after a fire.  $SO_2$  has a settling speed of  $0.001\text{-}0.02\text{ m/s}$ , which means that it has fallen to the ground faster than other elements, such as nitrogen oxide, even small particles (in aerosols). Sulfur dioxide in the atmosphere has a bad effect on the body, plants, and living creatures, and also causes corrosion of metals. Land subsidence affects the composition of the soil, and vegetation, reduces productivity, adversely affects flora and fauna, dries up forests, and pollutes water. More sulfur gas is produced when coal, gas fuel, fuel oil and fuel containing sulfur are burned. The concentration of sulfur dioxide in waste gases is mainly proportional to the sulfur content of the fuel. Among the sulfur compounds, sulfuric anhydride is considered to be the main polluter of the environment, because it emits a large amount of poisonous gas into the atmosphere, which causes great damage to living organisms and the environment [13-16]. When hydrocarbons are ignited without first being cleaned, the environment is polluted with sulfur anhydride, which spreads to a radius of 8-12 km in that place. Therefore, because hydrogen sulfide and its compounds emit aggressive poisonous gas when burned, restrictions are placed on the amount of hydrogen sulfide in the air in all countries of the world [17-19]. In organic and petrochemical synthesis, obtaining ethylene series hydrocarbons from methane, synthesis gas and methanol and dimethyl ether based on it, vinyl acetate and acetone from acetylene, and creating sorbents and zeolite catalysts with high efficiency in these processes are of interest to world scientists [20-22]. The demand for the quality of hydrocarbon products is increasing in many countries, and this demand is increasingly being tightly controlled. Control over the quality of gas supplied to the population and gas supplied to the chemical industry (especially in hydrogen and gas synthesis) is becoming increasingly strong [23-25].

## 2 Experimental part

Creation of natural gas drying technology at the gas station. The main purpose of summarizing the experiments of drying compressed gas using the device of the gas station is to check the correctness of using these methods, if it is incorrect, to think about the optimal technology in the gas station and to determine the dynamics of the activity of the adsorbent obtained from the experience. Device testing was carried out for 12 hours at 11% zeolite NaA mass at a production volume from the project, during which the dynamic

activity (before moisture from the dried gas). An increase in temperature during the drying process of gas leads to moisture in it up to  $0.5 \text{ g/m}^3$ , which is an excessive load on the adsorbent. Then the unit was operated in a variable production section (from 1 to 3 compressors), at this time, the adsorber worked for 24 hours in the construction stage (production was minimized) and the drying of compressed natural gas was well 4ppm, the drying quality was improved to dew point  $-67 \text{ }^\circ\text{C}$ . (0.1MPa) or  $-44 \text{ }^\circ\text{C}$  (at 2.5 MPa) where the absolute humidity of the dried gas is  $0.003\text{g/m}^3$ .

In the second adsorber, the sorbent regeneration time is 6 hours, the gas temperature at the entrance to the adsorber is  $245 \text{ }^\circ\text{C}$ , and the maximum temperature at the exit from the adsorber is  $184 \text{ }^\circ\text{C}$ . Regeneration gas consumption is  $165\text{-}175\text{m}^3/\text{h}$ . Thus, the experimental tests of the compressed gas dryer showed that the technological scheme was chosen correctly, and it has good performance and correct parameters.

### **3 Study of the effect of compressor oil on zeolite drying**

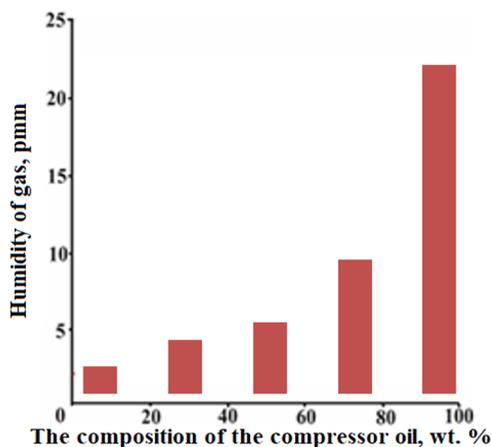
The gradual decrease in the adsorption capacity during the operation of sorbents is not well understood until now: several factors are known about it, which of these facts are related to the decrease in the adsorption capacity. Compressor oil is also known to reduce adsorption capacity. If there is no compressor oil, the water in the gas during the regeneration process will cause the adsorption capacity to decrease. In addition, in some cases, as a result of a sudden decrease in pressure in the compressor, the point velocity of the gas increases rapidly, as a result, a thinned layer is formed, and the adsorbent is removed with the gas flow. The adsorber inspection showed that the adsorption capacity decreases rapidly in the drying zone, this decrease is observed in the gas inlet (forehead). That part of the adsorbent is in contact with the wet gas entering the dryer. In addition, this is where the compressor oil is most abundant. During regeneration, all the moisture absorbed in the adsorption cycle leaves the front of the dryer.

Thus, the adsorption capacity gradually decreases and finally, the adsorbent is replaced by a new one. To determine in advance when to replace the adsorbent with a new one, the effect of lubrication on NaA zeolite on the adsorption activity was investigated. The effect of the oiled state on the adsorbent was studied under static and dynamic conditions of laboratory adsorption activity at the dew point relative to water. After the activation of zeolite under static conditions, the maximum equilibrium state of compressor oil of adsorptive property was studied at a relative humidity of 100, 60, 40, and 20% of air by the desiccator method. The sample of adsorbent under study is placed in a closed glass bottle with a dry hard cap and weighed on an analytical balance. The bag is then placed in an open desiccator over sulfuric acid with a relative humidity of 20, 40 and 60% respectively.

### **4 Results and discussion**

100% relative humidity was achieved in the desiccator. Every day, the samples were weighed on an analytical scale, and the experiment was carried out for 30 days.

Wet gas enters the adsorber from top to bottom. During the experiment, constant: gas amount, gas temperature, humidity change and dried gas dew point are monitored. The results obtained from the experiment are presented in Figure 1.



**Fig. 1.** The relationship between the amount of compressor oil in zeolite and the amount of moisture in the gas.

Figure 1 shows that when zeolite contains more than 20% compressor oil, the dried gas contains moisture ( $0.009\text{g/m}^3$  or 12 ppm). To decrease the sorbent and extend its service life, the method of using solvents for oil extraction from zeolite is recommended. Benzene was used as a solvent. After the zeolite samples were washed from the oil, their adsorption activity against water was studied. Tests showed that the adsorptive moisture in samples washed with benzene increased by 1.5 times, which indicates that it is correct to use solvents to increase the service life of zeolite.

Experiments conducted in this way show that if the amount of compressor oil in the zeolite NaA adsorbent exceeds 20% by weight, the dried gas does not meet the requirements of GOST.

#### 4.1 Use of energy-saving technologies in gas drying at gas stations

In the case of regeneration of sorbents in natural compressed gases on an industrial basis, gas drying with the help of mesoporous sorbent synthesized by us at a pressure of 2 MPa, and regeneration of mesoporous sorbent synthesized by us at low (40-100 °C) temperature and 1.0-1.5 MPa pressure were studied. The main purpose of these inspections is to deeply introduce the proposed technologies into compressed gases and to evaluate the daily volume of natural gas drying in different modes. A mesoporous sorbent synthesized by us was used instead of NaA zeolite to dry gas using energy-saving technology for drying natural compressed gases.

The experimental device was tested at the N1 gas station in the city of Samarkand. To study the effective operation of the device, a 4-type test was conducted: the first one was immediately connected to the device, and the second, third, and fourth were conducted at 380, 800, and 1650 hours. During the test period, the moisture content of the gas was studied at the inlet and outlet of the station, at the inlet and outlet of the drying unit, and at the inlet and outlet of the drying unit. At the inlet of the fuel tank, the gas humidity was 770 to 900ppm or  $0.575\text{-}0.675\text{ g/m}^3$ , and the dew point pressure at 1-3 °C was 1MPa. Gas humidity at the entrance to the device (after the compressor) was  $0.3\text{-}0.45\text{g/m}^3$  depending on the cooling temperature from 400 to 600ppm, dew point 29.5-25.5 °C, pressure 0.1MPa or 2.5MPa at 30-38 °C. Thus, part of the moisture is reduced in the compressor to separate moisture and oil.

Gas drying technology based on the regeneration of mesoporous sorbent synthesized by us was tested on an industrial basis at a gas station in Samarkand under a pressure of 2.5 MPa.

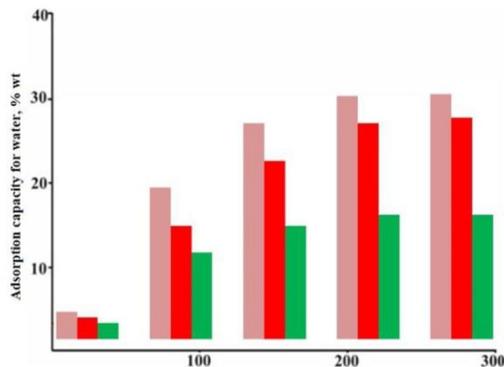
#### 4.2 Analysis of gas drying plant operation using mesoporous sorbent synthesized by us

Taking into account the positive results of the sample construction of the use of the mesoporous sorbent synthesized by us as an adsorbent in gas drying, and to reduce energy consumption in the regeneration processes of the mesoporous sorbent synthesized by us, the production of gas drying blocks consisting of the mesoporous sorbent synthesized by us as a gas station dryer has been started.

#### 4.3 Studying the effect of compressor oil on drying using a mesoporous sorbent synthesized by us

Three samples taken from different layers of gas dried using a mesoporous sorbent synthesized by us were studied at the gas station of Samarkand City. The layer was in mud 1.5 months ago, and after the device worked for 8 hours, the second sample was taken from the layer 1/3 and 1/2 height.

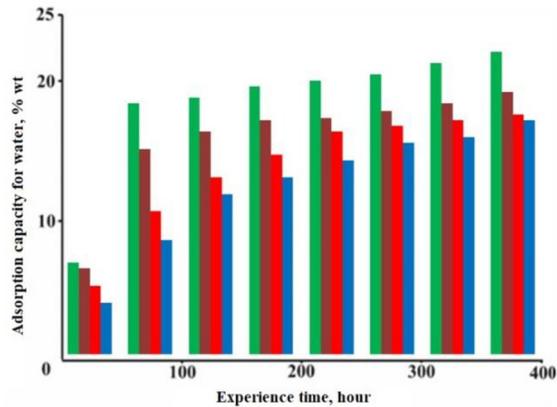
The mesoporous sorbent and compressor oil synthesized by us using the desiccator method under static conditions were studied at 100, 60, 40, and 20% relative humidity. Figure 2 shows the kinetic curve of samples taken from a 1.5-month layer at a gas station in the city of Samarkand at a relative humidity of 100%.



*The amount of oil, wt.%. 1-21.5; 2-4.0; 3-0.8*

**Fig. 2.** The adsorption capacity of the mesoporous sorbent synthesized by us with respect to water

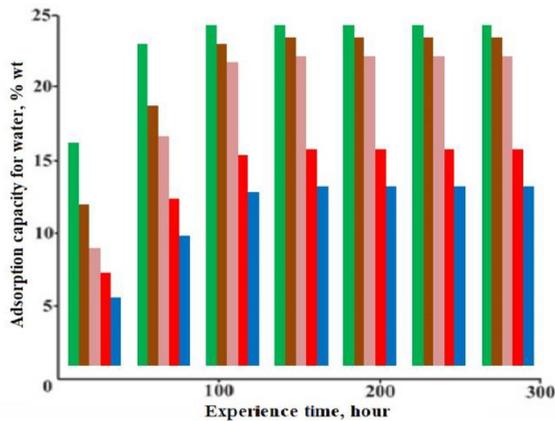
The samples were dried at 150-160 °C. The curve shows that the sample is 21% by weight (curve 1), and the maximum value of the adsorption property is 16% by weight. Figure 3 shows the adsorption kinetic curve of a sample processed for 8 months in an industrial plant at a relative humidity of 100%.



The amount of oil, wt.%: 1 and 3 - 7.8; 2 and 4 - 10.3.  
Regeneration temperature, °C: 1 and 2 -160; 3 and 4 -100

**Fig. 3.** The adsorption capacity of the mesoporous sorbent synthesized by us after 8 months of use

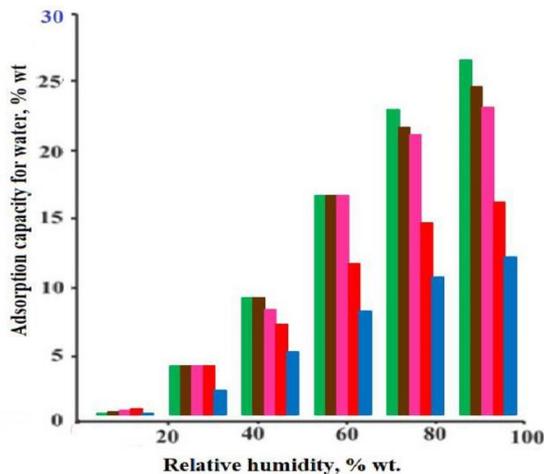
Samples were pre-dried at 100 and 160. Sample No1 has 10.5% oil content, sample No2 has 7.8% oil content. If the temperature is lowered from 160 °C to 100 °C, the adsorption activity decreases by 14÷16%. In addition, to study the effect of oil on the properties of the adsorbent of the mesoporous sorbent synthesized by us, samples were created by rubbing 2.0, 4, 4, 11 and 20% oil on the mesoporous sorbent synthesized by us. The samples were preheated to 100 °C and activated. Then, the adsorption capacity at different relative humidity levels was studied using the desiccator method. Figure 4 shows the kinetics of water adsorption at maximum humidity, 100% relative humidity.



The amount of compressor oil, % wt. 1-0; 2-2.0; 3-4.4; 5-20.0

**Fig. 4.** Kinetic curves of water saturation of the synthesized samples of mesoporous sorbents lubricated by us

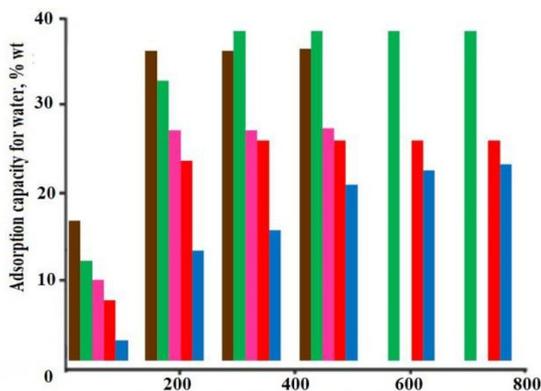
It can be seen from Figure 4 that when the oil content is 2.0%, the adsorptive property decreases, while at 4%, and 4.4% oil, water adsorption decreases by 8%. 2.0 above in Figure 5; 4.4; 11 and 20% respectively. Examples of water adsorption isotherms are given.



The amount of compressor oil, % wt. 1-0; 2-2.0; 3-4.4; 5-20.0

**Fig. 5.** Water adsorption isotherms on the mesoporous sorbent synthesized by us

It can be seen from Figure 5 that at a high relative humidity of 11%, the adsorption capacity of the mesoporous sorbent synthesized by us decreases to 35%, when the relative humidity decreases, that is, below 50%, the adsorption isotherm of the sample (curve 4) approaches the isotherm of the pure mesoporous sorbent synthesized by us. In the mesoporous sorbent synthesized by us, which contains 20% compressor oil, the adsorption activity is reduced by two times. Various solvents were used to clean the sorbents from oil and thereby extend their useful life. Pentane and benzene were used as solvents. After removing oil from the samples of mesoporous sorbent synthesized by us, the adsorption activity of mesoporous sorbent synthesized by us was studied by the desiccator method. The results of the experiment are presented in Figure 6.



1 - Original sample, oil content 21.5% by weight. 2, 3 - sample activation temperature 100 °C; 4, 5 - sample activation temperature 160 °C; 2, 3 - sample treatment with pentane; 4, 5 - sample treatment with benzene

**Fig. 6.** Effect of solvent treatment of oily silica gel on its water activity

It can be seen from Figure 6 that the adsorption capacity of the samples saturated with water (after 20 hours) increases significantly: in the pentane-treated sample, the capacity is 3 times from 2.5 wt.% to 7.5 wt.%, the benzene-treated sample is 4 times the capacity 2, From 5% to 10%. (samples regeneration temperature 100 °C). Adsorption capacity balance

increases by 2-2.3 times in washed samples. In this way, the mesoporous sorbent synthesized by us, cleaned of oil, significantly increases the time of its use.

The adsorption capacity of lubricated adsorbent under static conditions was studied. The depth of natural gas drying was studied under dynamic conditions based on the mesoporous sorbent synthesized by us. Adsorption drying of compressed natural gas using a mesoporous sorbent synthesized by us was studied in a pilot plant. In the pilot plant, a device consisting of two adsorbers was used, one of which operated in the drying cycle. The diameter of the adsorber is 100 mm, the thickness of the adsorber layer is 550 mm, and the mass is 3100 grams. Compressed gas temperature was used for sorbent regeneration. The hot compressed gas falls on the adsorber after two compressors. The gas passes through a mesoporous sorbent layer synthesized by us, moisture is separated from it, and then it is cooled in a water cooler.

The moisture adsorbed in the separator is separated and the gas enters the second adsorber dryer. The volume of gas production is 35m<sup>3</sup>/h, regeneration and drying pressure is 20MPa, and regeneration temperature is 100-150 °C. After increasing the regeneration cycle to 130-150 °C, the gas drying depth was better.

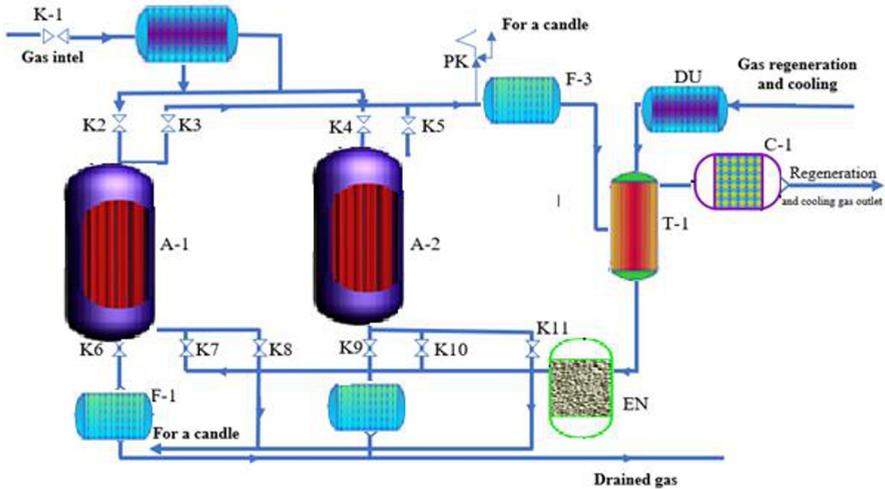
The dynamic capacity of the mesoporous sorbent synthesized by us was studied on a clean and lubricated sorbent, which resulted in the loss of moisture in the dried gas. The moisture content of the dried gas was determined using the "Baikal-3" moisture meter. 1353m<sup>3</sup> of gas was dried until the moisture was removed in the new mesoporous sorbent synthesized by us, the moisture content was 0.18g/m<sup>3</sup>. During the adsorption process, the drying depth was 0.004g/m<sup>3</sup>, and the dynamic activity of the mesoporous sorbent synthesized by us was 7.7% by weight. When the mesoporous sorbent synthesized by us contained 5 wt.% oil, 1211 m<sup>3</sup> of gas was dried, while the dynamic activity was 6.8 wt.%, and the drying depth was 0.004-0.005 g/m<sup>3</sup>. The composition of the mesoporous sorbent synthesized by us was 16% by weight, if it was compressor oil, the drying depth was 0.008g/m<sup>3</sup>, and the dynamic activity was 3.8% by weight.

#### **4.4 Implementation of gas drying technologies at small gas stations**

Drying is done after compression in a gas compressor. Zeolite was used as an adsorbent. The connection of the adsorber drying cycle to the regeneration was connected after 15 hours when the inlet humidity was maximum. During the regeneration process, the adsorbent was heated using electricity. Three options for drying technology were considered.

1. Option-regeneration adsorbent in zeolite partially dried gas under a pressure of 14.8-24.6 MPa.
2. Option-adsorbent regeneration gas drying under a pressure of 2.5-4.0 MPa.

All the proposed options allow deep gas injection. The technological scheme of both options mentioned above is presented in Fig. 7.



*A-1,2 - adsorbery; F-1,2,3 - filter; T-1 - heat exchanger; S-1,2 - separator; EN - electromagnet; DU - throttle; K1-K11 - electric armature*

**Fig. 7.** The principle technological scheme of the block of cooling natural gas

The compressed gas is directed to the S-1 separator to separate the liquid from the droplet form. Then the gas falls into the A-1 adsorber from top to bottom, the adsorbent is separated into zeolite layers, then the adsorbent is cleaned of dust in the F-1 filter and directed to the accumulator. After the end of the adsorption process, A-2 for drying and A-1 for regeneration start working automatically. The gas is dried in the part taken from the regeneration battery. This condition provides an opportunity to perform high-quality adsorbent regeneration and subsequently obtain high-quality deep-dried gas. In addition, the gas obtained from the accumulator batteries allows the regeneration process to be carried out even when the compressor stops. Gas throttled and passed through the EP-1 heater goes to the A-2 adsorber for regeneration. After the gas from the adsorber is cleaned of sorbent dust using the F-3 filter, it is cooled in the T-1 heat exchanger, and after passing through the S-2 separator, it passes to the suction compressor to separate moisture condensation. The adsorber is cooled using dried gas. Some of this gas passes through a switched-off electric heater to the adsorber. NaA zeolite is recommended as an adsorbent because it has a very low dew point and a high adsorption activity in the water, which leads to a decrease in the size of the adsorber. In addition, zeolite is stronger than other used adsorbents and withstands rapid changes in pressure and temperature.

## 5 Conclusion

The experimental device was tested at the N1 gas station in the city of Samarkand. To study the effective operation of the device, a 4-type test was conducted: the first one was immediately connected to the device, and the second, third, and fourth were conducted at 380, 800, and 1650 hours. During the test period, the moisture content of the gas was studied at the inlet and outlet of the station, at the inlet and outlet of the drying unit, and at the inlet and outlet of the drying unit. At the inlet of the fuel tank, the gas humidity was 770 to 900ppm or 0.575-0.675 g/m<sup>3</sup>, and the dew point pressure at 1-3 °C was 1MPa. Gas humidity at the entrance to the device (after the compressor) was 0.3-0.45g/m<sup>3</sup> depending on the cooling temperature from 400 to 600ppm, dew point 29.5-25.5 °C, pressure 0.1MPa or 2.5MPa at 30-38 °C. Thus, part of the moisture is reduced in the compressor to separate moisture and oil. In the pilot plant, a device consisting of two adsorbers was used, one of

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