SEPARATION OF SOUR COMPONENTS FROM FLARE GASES IN ABSORPTION PURIFICATION OF GASES

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Abstract. This article presents the selection of reagents for cleaning flare gases containing carbon dioxide and hydrogen sulfide, including the study of chemisorption processes in the absorption of sour components in the gas, which is one of the urgent tasks of the "Mubarok Gas Processing" plant. The composition of flare gases, their physicochemical properties, and the results of experimental work on obtaining ammonium carbonate and ammonium sulfide solutions from sour components are presented.

Keywords: sour component, flare gas, utilization, CO_2, H_2S, chemisorption, sodium carbonate, sodium sulfide, absorber, ammonium carbonate, ammonium sulfide, gas, absorbent.

Аннотация. В данной статье представлен подбор реагентов для очистки факельных газов, содержащих углекислый газ и сероводород, включая изучение процессов хемосорбции при поглощении кислых компонентов в газе, что является одной из актуальных задач газоперерабатывающего завода "Мубарок". Представлены состав факельных газов, их физико-химические свойства, а также результаты экспериментальных работ по получению растворов карбоната и сульфида аммония из кислых компонентов.

Ключевые слова: высокосернистый компонент, факельный газ, утилизация, CO2, H2S, хемосорбция, карбонат натрия, сульфид натрия, поглотитель, карбонат аммония, сульфид аммония, газ, абсорбент.

Annotatsiya. Ushbu maqolada karbonat angidrid va vodorod sulfidini o'z ichiga olgan alangali gazlarni tozalash uchun reagentlarni tanlash, shu jumladan "muborak gazni qayta ishlash" zavodining dolzarb vazifalaridan biri bo'lgan gazdagi nordon komponentlarning so'rilishidagi kimyosorbsiya jarayonlarini o'rganish keltirilgan. Olovli gazlarning tarkibi, ularning fizik-kimyoviy xususiyatlari va nordon tarkibiy qismlardan ammoniy karbonat va ammoniy sulfid eritmalarini olish bo'yicha eksperimental ishlarning natijalari keltirilgan.

Kalit so'zlar: nordon komponent, olovli gaz, utilizatsiya, CO2, H2S, xemisorbsiya, natriy karbonat, natriy sulfid, absorber, ammoniy karbonat, ammoniy sulfid, gaz, changni yutish.

ISSN 3030-3907

Introduction

In the world, certain scientific and practical results are being achieved in the modernization of the gas processing industry, the creation of new reserves of absorbents, the development of technologies for the production of import-substituting products based on them, in particular, the development of competitive products and the use of gas processing industry flare gases containing sour components in the purification processes. In this regard, the search for opportunities to obtain ammonium carbonate, ammonium and sulfide sodium carbonate, sodium sulfide solutions as a result of the absorption of sour components (CO_2 and H_2S) in flare gases by absorbents is of great importance.

The annual amount of toxic gases released into the atmosphere during the flaring of gas from the Muborak Gas Processing Plant has been determined. According to calculations, if the flare gas is not utilized, more than 30 million m^3 of toxic gases are released into the atmosphere per year.

When examining the quantity and composition of products formed during the separation of CO_2 and H_2S from flare gases, flare gas containing 93.85% mol of sour components was separated from the "Muborak Gas Processing" plant in the presence of alkaline absorbents, and the composition of the purified gas was determined using a Kristallux gas chromatograph.

Table 1

Composition of flare gases purified at Unit 7 of the Mubarak Gas Processing Plant

№	Components	Amount, mole %
1	Methane	91,61
2	Ethan	4,02
3	Propane	1,64
4	*i-Bhutan*	0,17
5	*n-Butane*	0,15
6	CO_2	0,60
7	Nitrogen	1,80
Total:		**100**

The object was selected by examining the composition of flare gases at the “Mubarak Gas Processing” plant (Table 1). The properties of the reagents used in the research, their purity and preparation of solutions, qualitative and quantitative methods for determining the composition of products, methods for calculating the concentrations of flare gases released into the environment, methods for determining the composition and properties of flare gases using the “Gas Chromatography” method are presented. Two types of flare gas samples from units

ISSN 3030-3907

7 and 10 of the "Mubarak Gas Processing" plant, which are discharged into the flare system, are presented.

Table 2

Properties of flare gases from the Mubarak Gas Processing Plant

№	Indicators		Component composition, % mol												Molar weight of gas	Gas density, *kg/m³*
	P, *kgf/sm²*	T, °C	C_1	C_2	C_3	*i*-C_4	*n*-C_4	*i*-C_5	*n*-C_5	C_{6+V}	$\sum C_{5+V}$	CO_2	H_2S	N_2		
Block 7 of the Mubarak Gas Processing Plant	3,9	40	1,04	0	0	0	0	0	0	0	0	96,5	2,21	0,25	43,41	1,937
Block 10 of the Mubarak Gas Processing Plant	3,1	42	0,85	0	0	0	0	0	0	0	0	95,6	3,10	0,21	43,42	1,938

According to the results of the analysis in Table 2, flare gases from units 7 and 10 of the Muborak Gas Processing Plant were selected as the object because they contain the highest levels of CO_2 and H_2S.

The effect of various factors on the chemisorption process with solutions of CO_2 and H_2S contained in flare gas was studied, and a laboratory device for the separation of CO_2 and H_2S from flare gases and its material balance were constructed.

ISSN 3030-3907

This laboratory device performs the two-stage chemisorption process of flare gas.

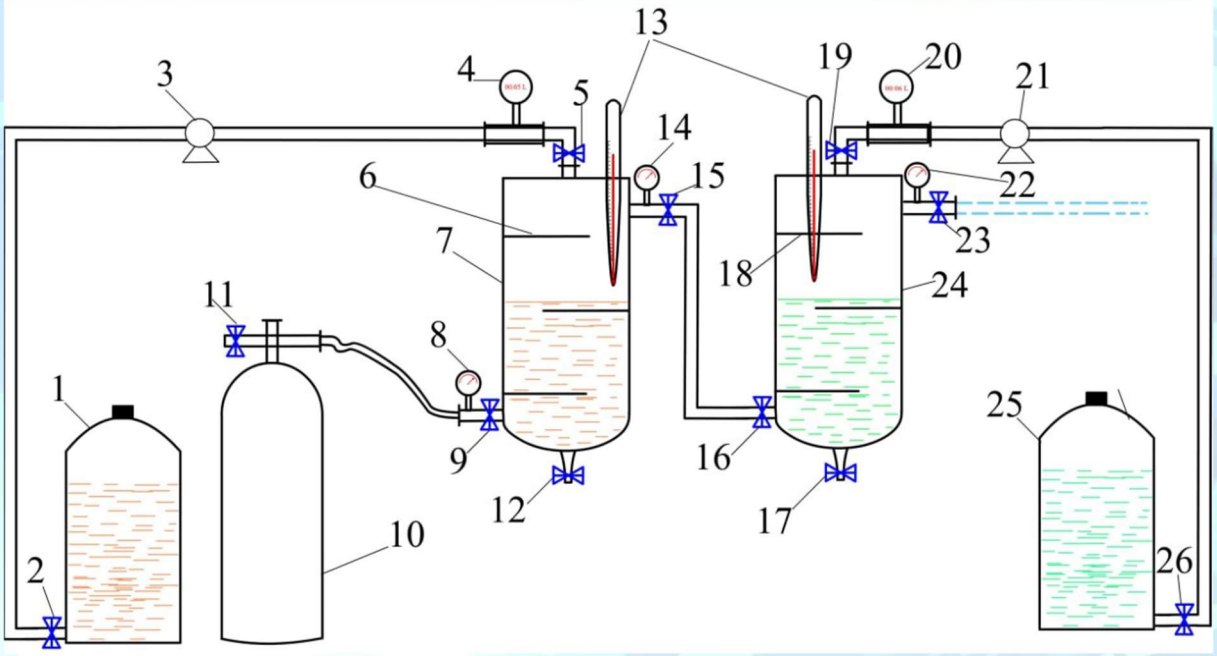


Figure 1. Laboratory device for separating acidic components from flare gases and obtaining sulfide and carbonate salt solutions

1-capacity for storing an aqueous solution of ammonium hydroxide; 3,21 - pump; 4,20 - flow meter; 2,5,9,11,12,15,16,17,19,23, 26 - crane; 6,18 - barrier; 7,24 - absorber; 8,14,22 - monometer; 10 - capacity for torch gas; 13 - thermometer; 25 - capacity for storing an aqueous solution of sodium hydroxide.

Research method. In this, the CO_2 and H_2S components in the flare gas were separated to obtain an ammonium carbonate and ammonium sulfide solution. According to the chromatographic analysis of the obtained solution, the CO_2 content was reduced from 68.60% to 32.4% and the H_2S content from 24.24% to 21.36% using a 20-25% NH_4OH solution, and its composition is presented in Table 3.

Table 3

Gas composition obtained from the cleaning of flare gases with NH4OH

№	Components	Torch gas		Gas purified with NH_4OH solution	
		% mol	% mass.	% mol	% mass
1	Methane	5,73	2,30	43,83	23,95
2	Ethan	0,19	0,14	1,45	1,48
3	Propane	0,10	0,11	0,76	1,14
4	*i*-buthan	0,01	0,015	0,08	0,16
5	*n*-butane	0,01	0,015	0,08	0,16
6	CO_2	68,60	76,7	32,4	47,48

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7	H_2S	21,25	20,64	21,36	24,8
8	Nitrogen	0,11	0,08	0,84	0,83
Molecular mass, *kg/kmol*		39,95		29,27	
Density, *kg/m³*		1,783		1,307	

The maximum value of the absorption level of CO_2 and H_2S components contained in the flare gas into an aqueous solution of NH_4OH with a concentration of 20-30% was achieved.

Research was conducted based on the dependence of the pressure and temperature indicators in the absorber on the flare gas emitted from the Muborak Gas Processing Plant when taking each sample of ammonium carbonate and ammonium sulfide solution ($(NH_4)_2CO_2$ and $(NH_4)_2S$).

Table 4

The rate of absorption of CO_2 in flare gas by NH_4OH

The pressure in the absorber device, *kgf/sm²*	Temperature in the absorber device, °C	CO_2 absorption rate by the absorbent, %				
		$(NH_4)_2CO_3$-1 (CO_2:NH_4OH) 1:1.5-1.7	$(NH_4)_2CO_3$-2 (CO_2:NH_4OH) 2.0:2.5	$(NH_4)_2CO_3$-3 (CO_2:NH_4OH) 1:2,5-2,8	$(NH_4)_2CO_3$-4 (CO_2:NH_4OH) 3:3,5	$(NH_4)_2CO_3$-5 (CO_2:NH_4OH) 1:3.5-3.8
4,7	28	24,6	28,7	32,7	31,8	30,3
5,2	30	25,8	29,6	33,6	32,8	31,1
5,7	33	27,5	30,4	35,2	33,5	32,3
6,2	36	30,2	33,5	37,9	35,7	34,1
6,5	39	29,3	30,1	36,2	33,8	32,5

The maximum value of the CO_2 absorption degree of the flare gas by the absorbent was 38.01% of CO_2 as a result of chemisorption of a sample with a molar ratio of $(NH_4)2CO3$-3 (CO2:NH4OH) 1:(2.4-2.45) at a pressure of 6.2 *kgf/cm²* and a temperature of 36 °C. We can see in Table 4 that 37.9% of the CO2 in the flare gas was absorbed by a solution with a molar ratio of 2.5-2.8 NH_4OH as a result of chemisorption at a pressure of 6.2 *kgf/cm²* and a temperature of 36 °C.

As a result of chemisorption of the sample of $(NH_4)_2CO_3$ and $(NH_4)_2S$-3(H_2S:NH_4OH) in a molar ratio of 1:2.3-2.6 in Table 5 at a pressure of 5.5 *kgf/cm²* and a temperature of 35 °C, the maximum value of the absorption level of H_2S in the flare gas by the absorbent was 2.90 % H_2S.

Table 5

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The degree of absorption of H_2S in flare gas into NH_4OH

Working pressure in the absorber *kgf/sm²*	Working temperature in the absorber °C	The degree of absorption of H2S by the absorbent, %				
		$(NH_4)_2S$-1 (H_2S:NH_4OH) 1:1.5-1.7	$(NH_4)_2S$-2 (H_2S:NH_4OH) 1:2-2.3	$(NH_4)_2S$-3 (H_2S:NH_4OH) 1:2,3-2,6	$(NH_4)_2S$-4 (H_2S:NH_4OH) 1:2.7-2.9	$(NH_4)_2S$-5 (H_2S:NH_4OH) 1:3-3.5
5	27	1,58	1,66	1,67	1,64	1,63
5,5	30	2,44	2,38	2,71	2,72	2,55
5,0	33	2,65	2,56	2,83	2,76	2,75
5,5	35	2,75	2,76	2,90	2,84	2,81
6,0	38	2,84	2,85	2,84	2,81	2,70

Based on the absorption rates of CO_2 and H_2S components in the flare gas, it can be concluded that when the molar ratio of CO_2 and H_2S and NH_3 in the flare gas with a concentration of 20-25% is (CO_2 and H_2S:NH_3H_2O=1:2.5-2.6), and when the chemisorption process is carried out in the absorber under a pressure of 5.5 *kgf/cm²*, the absorption rate of CO_2 and H_2S in the flare gas with an absorbent was 37.90% CO_2 and 2.90% H_2S, which gave the highest rate.

Using the laboratory device shown in Figure 1, research was conducted to obtain a solution of sodium carbonate and sodium sulfide with the aim of maximum absorption of CO_2 and H_2S components in the flare gas, as a result. According to Table 6, the content of CO_2 in the initial purified flare gas in chromatographic analyses was reduced from 32.14% to 0.57%, and complete absorption of H_2S was achieved using a 10-12% solution of NaOH.

Table 6

Composition of the initial purified gas before and after purification with NaOH

№	Components	Initial purified gas		Gas purified with NaOH solution	
		% mol	% mass.	% mol	% mass.
1	Methane	42,81	24,95	91,63	84,18
2	Ethan	1,48	1,98	3,07	6,3
3	Propane	0,73	1,64	2,61	4,10
4	*i-butane*	0,07	0,14	0,14	0,54
5	*n-butane*	0,07	0,14	0,14	0,54

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6	CO_2	32,14	45,48	0,57	1,69
7	H_2S	21,30	24,8	0	0
8	Nitrogen	0,84	0,83	1,80	2,66
Molecular mass, *kg/kmol*		30,25		17,3	
Density, *kg/m³*		1,277		0,781	

To determine the maximum value of the absorption rate of CO_2 and H_2S contained in flare gas into a 10-12% aqueous solution of NaOH, research was conducted on the dependence of the amount of absorbent selected, the operating pressure and temperature in the absorber.

As a result of chemisorption of Na_2CO_2 and Na_2S - 3 samples at a pressure of 5 *kgf/cm²* and a temperature of 35 °C in a molar ratio of 10-12% concentration of CO_2 and H_2S components of the flare gas at a temperature of 35 °C, it can be seen that the maximum value of the absorption level of CO_2 and H_2S in the initially purified flare gas by the absorbent was from 32.3% to 0.57% of CO_2 and the complete absorption level of H_2S.

Table 7

The rate of CO_2 absorption in the flare gas using NaOH

Working pressure in the absorber, *kgf/sm²*	The working temperature in the absorber, °C	CO_2 absorption rate by the absorbent, %				
		Na_2CO_3 - 1 (CO_2:NaOH) 1:1,7-1,9	Na_2CO_3 - 2 (CO_2:NaOH) 1:2-2,5	Na_2CO_3 - 3 (CO_2:NaOH) 1:2,3-2,7	Na_2CO_3 - 4 (CO_2:NaOH) 1:2,6-2,9	Na_2CO_3 - 5 (CO_2:NaOH) 1:2,8-3
3,4	27	25,67	26,04	26,42	26,31	26,76
3,9	29	26,44	27,11	27,11	27,94	27,87
4,2	33	27,27	28,07	27,39	28,34	28,02
4,9	35	28,45	29,39	32,3	30,93	28,57
5,4	38	29,7	30,41	31,12	29,56	29,02

The dependence of the degree of absorption of H_2S in the flare gas on the absorbent on the working pressure in the absorber, temperature, and the amount of absorbent in the sodium carbonate and sodium sulfide solution samples is presented in Table 8.

Table 8

The rate of H_2S absorption in flare gas using NaOH

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Working pressure in the absorber *kgf/sm²*	Working temperature in the absorbert °C	The degree of absorption of H2S by the absorbent, %				
		Na_2S - 1 (H_2S:NaOH) 1:1.6-1.9	Na_2S - 2 (H_2S:NaOH) 1:1.7-1)	Na_2S - 3 (H_2S:NaOH) 1:2,2-2,5)	Na_2S - 4 (H_2S:NaOH 1:2.0-3.0)	Na_2S - 5 (H_2S:NaOH) 1:2.5-3.0
3,7	27	16,1	15,1	16,2	16,1	15,2
4,1	29	17,2	16,9	17,2	16,8	16,4
4,6	32	18,6	17,5	18,6	17,4	17,5
5,1	35	19,7	19,4	20,4	19,9	19,7
5,6	39	19,3	18,9	19,9	18,8	19,1

In this Table 8, the chemisorption of the Na_2S - 3 sample at a pressure of 5.1 *kgf/cm²* and a temperature of 35 °C resulted in complete absorption of the H_2S contained in the initial purified flare gas onto the absorbent.

Based on the indicators of the absorption rate of CO_2 and H_2S in the flare gas by the absorbent, it can be concluded that when the CO_2 and H_2S components in the flare gas are in a molar ratio of 10-12% concentrated aqueous solution of NaOH (Na_2CO_3 and Na_2S:NaOH=1:2.3-2.7), and when the chemisorption process is carried out in the absorber at a pressure of 5.1 *kgf/cm²* and a temperature of 35 °C, when taking a sample of Na_2CO_3 and Na_2S-3, the absorption rate of CO_2 and H_2S in the flare gas by the absorbent is 32.3% of CO_2 and H_2S are completely absorbed. According to the results of the study, it was determined that by separating CO_2 and H_2S from 30 million *m³* of flare gas per year, 10,202.7 *m³* of clean gas can be obtained per year.

Conclusion. It was found that flare gas from power units 7 and 10 of the Mubarek Gas Processing Plant emits more than 30 million m3 of toxic gases into the atmosphere per year. It was revealed that in flare gas containing 91% acid gases purified using alkaline solutions by chemisorption, their content in pure gas decreased to 0.57%.l

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