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Original Contribution for Processing of Fluid Samples to Produce High-Quality Natural Gas and Hydrocarbon Liquids

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Abstract:* - Original contribution for processing of eighteen fluid samples at different stages of Egyptian gas-condensate Facilities were studied for detecting the efficiency of the all treatment units. The studied fluid includes gas and condensate samples and their hydrocarbon composition were determined via gas chromatography (GC) using capillary column packed with dimethyl poly siloxane as stationary phase. The treatment process includes measuring and purifying the hydrocarbons by removing water, acid gas and sulfur content from its produced gas and condensate. Our aim is study the technologies used for processing both associated and non associated gas to produce high-quality natural gas and hydrocarbon liquids for sales and exports.

***Key words:*-Fluid samples, Gas-condensate Facilities, gas chromatography, Dimethyl poly siloxane.**

I. INTRODUCTION

After extracting the natural gas from the underground reservoirs, additional processing is conducted in the field to prevent corrosion and other problems in downstream handling and processing equipment [1], thus, the gas as it leaves the reservoir, is normally saturated with water and, of course, it contains all the impurities normally associated with the gas [2]. Gas and liquids that enters the gas plant pass emergency shutdown valves, which isolate the plant from incoming streams and pig receivers, and then fed to an inlet separator that removes liquid water, heavy hydrocarbons, brine, and particulate matter from the incoming natural gas [3]. The gas is separated from liquids in a three-phase separation operation, in which gas, water, and liquid hydrocarbons are separated [2]. Condensed water, hydrocarbon liquids and solids are removed [3]. Water and solids are processed for disposal, and the hydrocarbon liquids go on to liquid processing. Natural gas is a combustible mixture of hydrocarbon gases “that provides one of the cleanest, safest, and most useful of all energy sources [4] and small quantities of various non-hydrocarbons existing in the gaseous phase or solution with oil in natural underground reservoirs at reservoir conditions [5]. Natural gas is a naturally occurring mixture of simple hydrocarbons and non hydrocarbons that exists as a gas at ordinary pressures and temperatures [6]. Natural gas and condensate compositions consist of paraffin’s, aromatic hydrocarbons and their side chains derivatives. These hydrocarbons are classified as:- (a) Organo paraffinic compounds which include saturated hydrocarbons either normal paraffin’s or iso-components, but without any ring structure [7]. The paraffinic content in natural gas varies from mixtures of methane (predominant component) and ethane with very few other constituents (dry gas) to mixtures containing all of the hydrocarbons from methane to pentane and even hexane and heptane (wet gas) [8]. The condensate contains higher paraffinic contents than that of the natural gas, thus it contains hydrocarbons up to C_{36}. The C_{6+} fractions of the condensate contain the normal paraffin’s, iso paraffin’s and cyclic paraffin’s. (b) The C_6+ fraction of natural gas may contain traces of aromatics called benzene, toluene, ethyl benzene, and xylenes (o, m, and p-xylene) [9, 10].

II. MATERRIAL AND METHODS

A. *The studied area*

The studied area was Obaiyed gas-condensate Facilities (OGCF) which lies in the North Western Desert of Egypt. OGCF are designed to produce a daily contract quantity (DCQ) of 360-420 MMSCFD of sales gas at an export pressure of 101 bars. The facilities consist of two gas processing trains, each train having a capacity of 210 MMSCFD. The collected gas and liquid are listed in Table 1.

B. *Sampling*

Stainless steel sample containers were used. These containers are of a type that ensures maximum safety and are resistant to corrosion by the product being sampled [12]. The sample container is fitted with an internal outage tube to permit release of 20% of the container capacity. The end of the container is fitted with outage tube.

C. *Hydrocarbon compositional analysis*

a) *For gases*

Hydrocarbons from C1 to C9, carbon dioxide, and nitrogen were analyzed using Agilent model 6890 plus HP gas chromatograph equipped with thermal conductivity detector "TCD" and flame ionization detector "FID". The packed column Porapack-Q, 40 ft in length and 1/8 inch in internal diameter was used to analyze light hydrocarbons and capillary column 15 m in length and 0.53 inch in internal diameter and packed with molecular sieve was used for the analysis of nitrogen. DB-1 capillary column, 60 m in length and 0.32 mm in internal diameter were also used in attachment with TCD and FID respectively. Helium gas was used as carrier gas at flow rate of 4ml min-1. The elution of the studied gas mixture was achieved with temperature programming form 50 ºC to 200 ºC at a rate of 10 ºC min-1. The quantitative analysis of the gas mixture was achieved using a standard natural gas sample of known composition and according to the standard [ASTM: D 1945–03]. The injector and detector temperatures were 200 ºC and 250 ºC, respectively. The data was estimated by integration of the area under the resolved chromatographic profiles, using the HP computer of software chemstation.

b) For condensate

Hydrocarbons from C2 to C36+ were analyzed using Agilent 6890 plus HP gas chromatograph equipped with FID using fused silica capillary column HP–1 of 60m in length, 0.32 in internal diameter and 0.5 µm film thicknesses. The elution of the studied liquid was achieved with temperature programming from 40 ºC to 320 ºC at a rate of 5 ºC min-1. Nitrogen gas (Oxygen free) was used as carrier gas flowing at a rate of 1ml min-1. The injector and detector temperatures were 320 ºC and 350 ºC, respectively. The data was estimated by integration of the area under the resolved chromatographic profiles, using the HP computer of software chemstation.

III. RESULTS AND DISCUSSION

The processing of natural gas consists of the separation of some of the components present at the well exit, such as water, acid gases and heavy hydrocarbons, to adjust the gas to transport or commercials specifications (EIA 1996). The distribution of these operations between the field and the delivery point is dictated by economic considerations. It is usually preferable to conduct on the production site only operations that make the gas transportable. In simple terms, the gas processing industry gathers, conditions and refines raw natural gas from the earth into saleable, useful energy forms for use in a wide variety of applications. Eighteen gas and liquid samples are collected from Obaiyed gas plant and subjected for composition type analysis. The list of the selected gas and liquid samples was given in Table 1. This study was performed for the well stream sample which obtained from the combination of the compositions of flash gas and separator oil and the later was obtained from the combination of the condensate samples and its dissolved gas. The composition of the gas samples from outlet separators Tr-1 and Tr-2 are shown in Table 2. There is some change in the paraffinic compositions of natural gas in the separators Tr-1 and Tr-2 through the studied three periods. The fraction of hexane plus increase with the time. The inlet gas stream from outlet separators Tr-1 and Tr-2 contains high concentration of carbon dioxide. The high decrease in CO2 reflects the high efficiency of the Benfield absorption towards acid gas removal. The condensate samples (well stream) from outlet separators contain minor amounts of the carbon dioxide which present in the gases dissolved in such liquid condensate samples. The gas vented from Benfield regenerators is mainly composed of carbon dioxide in both separators Tr-1 and Tr-2. These results refer to the high efficiency of the Benfield regenerators.

IV. EVALUATION OF GAS AND LIQUID SAMPLES FROM OUTLET SEPARATORS

As the natural gas stream flows from the well it passes through two main separators Tr-1 and Tr-2 where gas, condensate and water streams are separated and subjected to processing.

Table (1): List of the gas and liquid samples collected from the studied Obaiyed gas

Sample No.	Location
1	The gas stream from the outlet separator Tr-1
2	The gas stream from the outlet separator Tr-2
3	The condensate stream from outlet separator Tr-1
4	The condensate stream from outlet separator Tr-2
5	Gas from outlet absorber (inlet glycol) Tr-1
6	Gas from outlet absorber (inlet glycol) Tr-2
7	Rich Benfield solution Tr-1
8	Rich Benfield solution Tr-2
9	Lean Benfield solution Tr-1
10	Lean Benfield solution Tr-2
11	Vent gas from Benfield regenerator Tr-1
12	Vent gas from Benfield regenerator Tr-2`
13	Gas from outlet glycol dehydration contactors Tr-1
14	Gas from outlet glycol dehydration contactors Tr-2
15	Gas dissolved in rich glycol Tr-1
16	Gas dissolved in rich glycol Tr-2
17	Gas dissolved in lean glycol Tr-1
18	Gas dissolved in lean glycol Tr-2

A. Gas streams from outlet separators Tr-1 and Tr-2

For each gas sample, there are some amounts of condensate and water, so it is important to calculate the weight percent of well stream composition from the combination of the compositions of flash gas and separator oil and the latter was obtained from the combination of the condensate samples and its dissolved gas. The efficiency of measuring the chloride content in gas samples depends mainly on the water extraction method from gas sample, because there is no standard method for measuring the chloride contents in gases. The results of the compositional analysis of gas samples from outlet separators Tr-1 and Tr-2 are shown in Table 2. Although the separators technique is based on the principles of gravity segregation, reaction force from the separator wall and mist eliminator that can remove up to 99.9% of the entrained liquids from the gas stream [13], it has been found that the gas samples from outlet separators Tr-1 and Tr-2 contain some condensate and some water as given in Table 3. The lower contents in case of Tr-2 reveal that its efficiency is slightly higher than that of Tr-1. From the compositional analyses of these gas streams it was found that the compositions of the two outlet gas streams from separators Tr-1 and Tr-2 are nearly the same. Consequently, the all calculated physical properties are nearly the same as given in Table 3.

B. Condensate streams from outlet separators Tr-1 and Tr-2

The gas chromatographic analysis of the condensate samples in all studied trips was performed up to C36. The well stream compositions of the condensate sample is shown in Table (2). The compositions of the condensate streams is nearly the same for both Tr-1 and Tr-2. Also the molecular weights are nearly the same. These condensate streams contain up to 14.9 wt % of middle hydrocarbon fraction C2-C5 and 65.89 wt % of C6+.

From the compositional analysis of studied well stream of condensate sample, the well stream of condensate samples in the two studied separators have the nearly the same hydrocarbon compositions of both paraffin's and light aromatics

C. Evaluation of Benfield Absorber Efficiency

As the gas streams exit the outlet separators, the saturated feed gas, passes from the filter and enters the bottom of the absorber and passes through a Benfield solution, which is used in more than 600 plants worldwide. The Benfield process is a chemical absorption of the H2S, CO2 and to some extent COS. The Benfield process is based on an aqueous solution of potassium carbonate and bicarbonate, with potassium vanadate as an anodic inhibitor and with an amine as an accelerant (Obaiyed Training Manual) The potassium carbonate solution enters the absorber at the top. As the solution flows down the column contacting the up-flowing acid gases (CO2 & H2S), the absorption reactions proceed, and the liberated heat of absorption increases the temperature of the solution. When the upward flowing raw natural gas containing CO2 and H2S contacts the down flowing potassium carbonate solution in a counter current flow, the potassium carbonate absorbs CO2 and H2S.

D. Gas streams from outlet Benfield absorption process

Table (2) shows the compositional analysis of the gas samples from outlet absorber Tr-1 and Tr-2. The compositions of the gas samples from outlet absorbers Tr-1 and Tr-2 are nearly the same. These gas samples contain up to 3 mol % of carbon dioxide which agree with the pipeline specification limits. Compared to the percent of carbon dioxide in the gas from outlet separators, it is clear that the Benfield solution removes up to 60 % of the original CO2. The molecular weight of the gas samples from outlet absorbers are lower than that of inlet absorber indicating that beside the absorption of the acid gas components (H2S and CO2) the Benfield solution absorbs to some extent high molecular weight hydrocarbons from the feed gas. Accordingly, both the molecular weights and specific gravities decreased. On the other hand, the lower molecular weight hydrocarbons concentrations increased. Also, an advantage of the Benfield solution is that there is minimum co-absorption of hydrocarbons resulting in slight change in the paraffinic composition [14]. Other reason of the slight paraffinic change comes from the distribution of the absorbed amount of CO2 on all paraffinic compositions in order to keep the total weight percent of the gas sample.

E. Compositional analysis of the dissolved gases in rich carbonates solutions

The compositional analysis of the dissolved gases in both rich and lean carbonate solutions are given in Table 4. The results show that there are wide variations in the compositions of dissolved gases through the studied three trips, which may be due to the absorption efficiency in each trip. The dissolved gases are characterized by the presence of high concentrations of carbon dioxide ranging from 59.3 to 71.4 mol %. From the results of CO2 concentrations, it may be shown that higher absorbing efficiency was observed in the second trip B for both Tr-1 and Tr-2.

Table (2): The compositional analysis (Mol %) of gas stream and condensates from outlet Separators and outlet Benfield absorbers Tr-1 and Tr-2

Samples	Gas stream from outlet separators		Condensate stream from outlet separators		Gas samples from outlet Benfield	
Component	**Tr-1**	**Tr-2**	**Tr-1**	**Tr-2**	**Tr-1**	**Tr-2**
Nitrogen	0.717	0.565	0.181	0.173	0.942	0.933
Methane	77.837	78.136	17.949	17.928	80.351	80.518
Carbon Dioxide	8.357	8.443	3.275	3.241	3.194	3.060
Ethane	7.533	7.604	5.446	5.457	8.762	8.804
Propane	2.824	2.867	4.844	4.791	4.014	4.072
i-Butane	0.388	0.384	1.476	1.461	0.724	0.720
n-Butane	0.852	0.843	3.484	3.5	1.174	1.128
i-Pentane	0.375	0.363	2.239	2.271	0.278	0.266
n-Pentane	0.194	0.175	2.747	2.749	0.242	0.225
Hexane Plus	0.923	0.620	58.359	58.429	0.319	0.274
Total	100.000	100.000	100.000	100.000	100.000	100.000

Table (3): the calculated physical properties of gas stream samples Tr-1 and Tr-2

Analytical parameter	Results	
	Tr-1	Tr-2
Gas wt%	91.450	95.700
Condensate wt %	3.130	2.270
Water wt %	5.420	2.030
Mol Wt	21.970	21.697
Specific gravity	0.759	0.749
Equivalent liquid density	0.337	0.334

F. A compositional analysis of the dissolved gases in lean carbonate solutions

The compositional analysis of the dissolved gases in the carbonate solutions are given in Table 4. As observed in gases dissolved in rich samples, there are wide variations in the composition. it was found that the gases dissolved in lean samples from Tr-1 and Tr-2 contain high percentages of CO_2 respectively. the gases were found to be wetted with the heavy hydrocarbons especially in case of Tr-1 which explain the higher molecular weight of such gases. Also, these gases are characterized by the high percentages of BTEX especially benzene and toluene fractions since they contain.

G. Vent gases from Benfield Regenerators

In the regenerator, CO2 is driven out of the carbonate solution because of its lower partial pressure in the acid gas relative to the corresponding equilibrium pressure of the carbonate solution. The regenerator column runs at near atmospheric pressure and is heated to 112ºC using hot oil. The sudden reduction in pressure experienced in the regenerator flashes a large amount of the acid gases on the regenerator's tray. The steam from the reboiler passes up the packed column and strips the CO2 and H2S from the solution.

H. Compositional analysis of Vent gases from Benfield regenerators

The compositional analysis of Vent gases from Benfield regenerators is given in Table 4. It was found that the gas samples are composed mainly of carbon dioxide ranging from 82 to 95.8 wt %, in addition to some middle hydrocarbon fractions and BTEX components. The results of the molecular weights of the gas samples indicate that they are characterized by their high molecular weights. These gases being vented to the atmosphere, some safety considerations should be taken into considerations.

Table (4): Compositional analysis of gases dissolved in rich and lean Benfield samples and vent gas from Benfield regenerators of Tr-1 and T-2

Separator	Gas dissolved in rich Benfield		Gas dissolved in lean Benfield		Vent gas from Benfield regenerators	
Component	**Tr-1**	**Tr-2**	**Tr-1**	**Tr-2**	**Tr-1**	**Tr-2**
	Mol %	**Mol %**	**Mol %**	**Mol %**	**Mol %**	**Mol %**
Nitrogen	0.662	0.673	0.680	0.613	0.000	0.000
Methane	11.082	12.161	4.866	5.077	1.250	1.620
Carbon Dioxide	71.427	70.218	78.681	78.123	96.420	94.98
Ethane	9.506	9.763	7.246	7.404	0.100	0.120
Propane	1.978	1.822	4.007	4.119	0.030	0.060
i-Butane	1.075	1.053	0.712	0.732	0.010	0.010
n-Butane	1.162	1.101	1.251	1.210	0.010	0.020
i-Pentane	0.642	0.718	0.548	0.510	0.010	0.010
n-Pentane	0.645	0.717	0.545	0.551	0.010	0.010
Hexane Plus	1.821	1.774	1.644	1.661	2.160	3.17
Total	100.000	100.000	100.000	100.000	100.000	100.000

V. GAS STREAM FROM OUTLET GLYCOL DEHYDRATION CONTACTOR

A. Compositional analysis

The gas from outlet glycol contactor was collected in only the first trip A. The compositional analysis of the gas samples from Tr-1 and Tr-2 are shown in Table (5). It was clear from the compositional analyses that both gas samples have more or less similar composition. Samples from outlet Benfield absorbers and outlet glycol contactor were found to have nearly similar hydrocarbon composition. This indicates that there is no recognized co-absorption of the hydrocarbons during the dehydration process.

B. Rich glycol samples

Table (5) shows the compositional analysis of gas dissolved in rich glycol samples. From the compositional analysis of the dissolved gases in rich glycol samples for both Tr-1 and Tr-2 through trips A and B, it was found that these gases are characterized by the presence of significant values of CO2 ranging from 7.6 to 18.5 mole %. Also these gases are concentrated with middle hydrocarbon fraction (C2-C5). These gases contain very low percentages of BTEX components. The gas chromatographic analysis of rich glycol samples are given in Table (5). Also, there are significant proportions of the

BTEX components (5 wt %) which may be due to the higher solubility of aromatics in TEG [15].

Table (5): The compositional analysis (Mol %) of gas samples from outlet glycol dehydration contactors from gas dissolved in rich and lean glycol samples of separators Tr-1 and Tr-2

Samples	Gas from outlet glycol dehydration contactors		Gas dissolved in rich glycol		Gas dissolved in lean glycol	
Component	**Tr-1**	**Tr-2**	**Tr-1**	**Tr-2**	**Tr-1**	**Tr-2**
Nitrogen	1.03	1.025	0.740	0.810	0.74	0.93
Methane	78.516	79.013	35.090	46.620	66.10	77.24
Carbon Dioxide	3.265	3.059	18.520	12.870	4.99	1.81
Ethane	8.989	8.859	15.500	14.150	6.00	5.64
Propane	4.796	4.578	14.380	11.950	4.58	2.96
i-Butane	0.955	0.934	3.260	2.690	1.43	0.78
n-Butane	1.563	1.552	7.220	5.690	4.07	1.92
i-Pentane	0.308	0.38	1.750	1.600	1.89	1.00
n-Pentane	0.262	0.331	1.670	1.560	2.20	1.26
Hexane Plus						
Total	100.000	100.000	100.000	100.000	100.000	100.000

VI. CONCLUSION

- This study is an Original contribution for studying the performance of the Egyptian gas-condensate Facilities through the evaluation of hydrocarbons in each treatment unite.
- The gas chromatographic analysis of the condensate samples was performed up to C_{36}. The compositional analysis of the gas samples from Tr-1 and Tr-2 from outlet Benfield absorbers and outlet glycol contactor have similar hydrocarbon composition. This indicates that there is no recognized co-absorption of the hydrocarbons during the dehydration process.
- The composition of the vented gases were found contain significant proportions of carbon dioxide ranged reflecting the high efficiency of the Benfield solution.
- The technologies used for processing both associated and non associated gas aimed to produce high-quality natural gas and hydrocarbon liquids for sales and exports.

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