

Compressibility Factor and Formation Volume Factor of Liberated Natural Gas at Different Pressures by GC

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Abstract: The physical properties, compressibility factor (Z) and formation volume factor (FVF) and specific gravity of liberated natural gases from the studied western desert reservoir at different pressures and at ambient temperature were studied by gas chromatography GC. The gas compressibility factor and specific gravity are highly decrease with the increase of pressure from 0 to 2500 but above this pressure there is an increase with increase of gas specific gravity due to the increase of the heavier gases in the sample. It is required in connection with gas compression for the design of compressors and pressure vessels. F.V.F. of gas highly decreases with the increase of natural gas pressure till reaching a pressure of 2000 psi and showing slightly decrease up to 3500 psi this relation is very important for the observed volumes of gas production at the surface to that corresponding underground withdrawal.

Keywords: Physical properties, liberated natural gas, pressures, gas chromatography

Introduction

Natural gases play, nowadays, an important role in human life. A principal reason is the abundant supply of natural gases, as a clean source of energy and for the production of high value chemicals. Recently, natural gas supply chain was investigated using concepts related to natural gas industry [1, 2]. Natural gas replaced LPG, kerosene and gas oil in processing bakeries, recently it used in cars instead of gasoline to insure environment conservation, to save fuel costs and to increase petroleum exports rate [3]. Reservoir gas occurs underground in the free gaseous state or as gas dissolved in oil or water [3]. Associated gas occurs with oil as free gas, gas dissolved in oil or liquefied gas, non-associated gas occurs alone as free gas and as gas dissolved in water [3]. Gas is highly compressible compared with oil or water, gas also is very mobile in the subsurface. It is found more widely distributed vertically and laterally than oil because it migrates more easily. Also, it is generated from source rocks.

Those are more widely distributed than source rocks of oil. Both the hydrocarbons and non-hydrocarbons in natural gas have multiple sources. The major sources [4] of the hydrocarbon gases are (1) methanogenic bacteria, (2) all types of kerogens, (3) coal, and (4) oil in source and reservoir rocks. The major non-hydrocarbon gas CO₂, H₂S and N₂ are formed by both organic and inorganic processes. Natural gas will probably be the worlds major fossil

energy source during the next two centuries, for this importance, natural gas attracts our attention to study the effect of gas pressure on the physicochemical properties and the compositions of natural gas using gas chromatography. This study may serve in solving the problems of production, Transportation, uses, storage.....etc.

Experimental Sampling

The sampling is as important as the analysis itself, the greatest care must be exercised in obtaining a representative sample which must be taken by personnel trained in sampling techniques. The sample under study was subjected to eight different pressures. The crude oil under study was taken at pressure 3480 psig and the accompanied gas was collected by evacuated cylinder method according to API recommended practice or sampling petroleum reservoir fluids, API (1966) 44. Then the pressure of the studied crude oil was reduced to 2973 psig and also the liberated gas was collected and analyzed using gas chromatography. Also, other liberated gas samples were collected at pressure 2465 psig, 1958 psig, 1450 psig, 943 psig, 435 psig and atmospheric.

The specific gas gravity was calculated from the data obtained by using gas chromatography. Formation volume factor and compressibility factor were taken from P.V.T lab depending on the above analysis by gas chromatography.



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Gas chromatographic analysis

The analysis was performed using ATI unicom 610 gas chromatograph equipped with thermal conductivity detector (TCD) and flame ionization detector (FID) under the following conditions. The instrument is provided with three columns, the first is 13x molecular sieve [4] to separate O₂, N₂ and methane, the second is porapak [5] to separate CO₂ and light gases, the third is OV-101 capillary column [6] to separate the heavier hydrocarbons. The analysis was conducted under programmed temperature/ initial temperature 70 °C at 3.5 min initial time and final temperature 260 °C at 10 min as final time. The rate of increment was 10 °C min⁻¹. Hydrogen was used as carrier gas with flow rate 25 ml min⁻¹ [7]. The injector temperature was maintained at 220 °C however the detectors temperature was kept at 300 °C. The instrument was connected with the board data handling system for computing the peak area and mol percent. The quantitative analysis was accomplished by analyzing a standard reference sample of natural gas. The analysis done in accordance with ASTM method [8]

Results and discussion

Gas chromatographic analysis

Chromatography as an analytical technique is widely used in many industries to resolve and analyze gas and liquid samples into their constituents. Petroleum gas analysis is generally completed by using gas chromatography according to a documented specific American Society for Testing and Material (ASTM) standard method. This method is recognized standard with concomitant advantage that anyone can easily compare results from several laboratories on a common basis.

Table 1 and Fig. 1. show the relation of gas formation volume factor (F.V.F.) against pressure, F.V.F. of gas highly decreases with the increase of natural gas pressure till reaching a pressure of 2000 psi and showing slightly decrease up to 3500 psi this relation is very important for the observed volumes of gas production at the surface to that corresponding underground withdrawal.

Compressibility factor of gas can be correlated with gas pressure Fig.1. It gives a parabola shape; the gas compressibility factor highly decreases with the increase of pressure from 0 to 2500 psi and increases gradually with the increase of pressure above 2500 psi. The use of reduced pressure-actual pressure divided by critical pressure and reduced temperature, actual temperature divided critical temperature (absolute), are used to determine compressibility factor. The compressibility data in Table 2 are required in connection with gas compression for the design of compressors and pressure vessels. The compressibility factor allow one to calculate gas density at pressures higher than atmospheric, its value varies with temperature.

Natural gas is the gaseous phase of petroleum, typically, a reservoir gas contains 60 to 100% methane, 1 to 10% ethane in addition to lower percentages of higher hydrocarbons through nonanes (C₉H₂₀) [3] Also, natural gas contains non-hydrocarbon constituents, such as carbon dioxide, nitrogen and hydrogen sulfide. The complete analysis of natural gas was achieved using gas chromatography connected with thermal conductivity and flame ionization detectors in presence of three columns of different polarities [8]. We calculate the specific gravity from the composition of natural gas under the studied pressures (Table 2) depending on the gas chromatographic analysis and correlate it against the gas pressure as shown in Fig. 1. The specific gravity of a gas decreases with the increase of gas pressures up to 2500 psig but above this pressure there is an increase of gas specific gravity. This is due to the increase of the heavier gases in the sample. It is usually expressed with reference to air, the latter being assigned the value of unity. Specific gravity affects the design and energy consumption of compressors, flow rates through pipes values and orifices, buoyancy and therefore shape of fames.

It is interesting to note that the point of both specific gas gravity and compressibility factor at which they change, their direction is the same point at which the mol percent of heavy paraffines are changed.

Table 1. Physical properties of liberated natural gases

Pressures (psig)	Calculated gas viscosity (CP)	Compressibility Factor (Z)	Gas F.V.F. (CP/SCF)	Gas gravity Air = 1.00
3480	0.02852	0.8548	0.00537	0.931
2973	0.02511	0.8202	0.00600	0.907
2465	0.02199	0.8044	0.00730	0.899
1958	0.01922	0.8065	0.00927	0.902
1450	0.01688	0.8265	0.01257	0.920
943	0.01495	0.8658	0.01988	0.961
435	0.01329	0.9272	0.04262	1.069
0	0.01148	1.0000	-	1.429

Table 2. Molecular Weight and Specific Gravity of studied natural gases at different pressures

Pressures (psig)	3482	2973	2465	1958	1450	943	435	0
Components								
Methane	60.92	62.97	62.42	62.39	60.73	55.84	44.58	19.44
Ethane Plus	39.08	37.03	37.58	37.61	39.27	44.16	55.42	80.56
Non hydrocarbons	9.60	9.15	9.06	8.74	8.94	8.96	9.07	5.89
Total	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Molecular Weight	26.969	26.269	26.029	26.138	26.463	27.843	30.951	35.701
Specific Gravity	0.9311	0.9069	0.8024	0.9198	0.9198	0.9612	1.0685	1.430

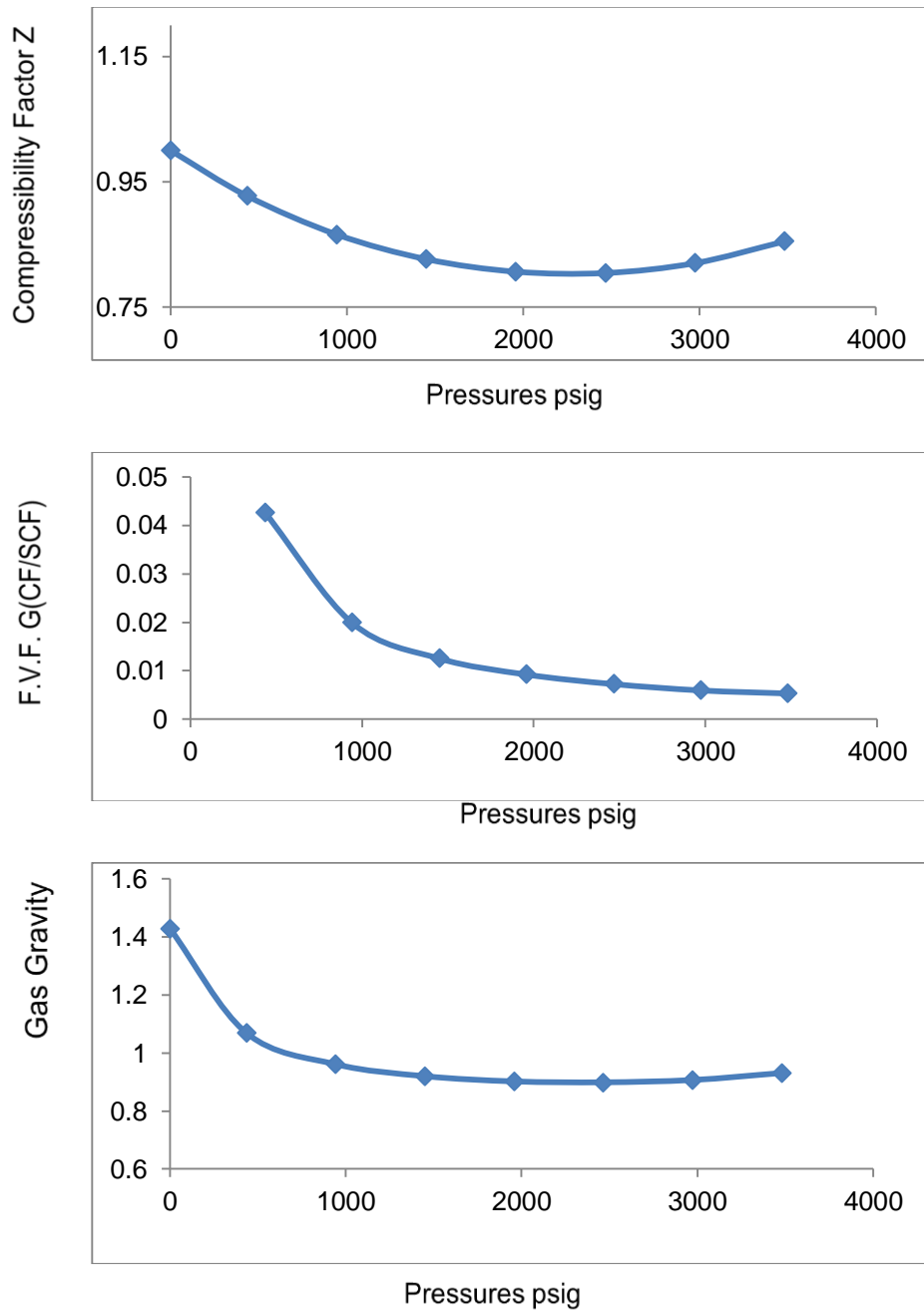


Figure 1: correlation between the studied physical properties and gas pressures

Conclusion

- The compressibility factor is required in connection with gas compression for the design of compressors and pressure vessels. Also, it allows calculating gas density at pressures higher than atmospheric.
- The relation between formation volume factor and gas pressures is very important for observing volumes of gas production at the surface to the corresponding underground withdrawal.
- Specific gas density affects the design and energy consumption of compressors and flow rates through pipes.
- This study may help the petroleum engineering in solving the problems of production, transportation, uses and storage.

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