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Effect of Dry Gases Injection into Egyptian Gas/Condensate Reservoirs on Condensate Recovery

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Abstract-- **Depletion of gas/condensate reservoirs initiates a decline in reservoir pressure below the dew point pressure of the retrograde gas. This leaves valuable amount of condensate in the reservoirs which is not only lost but results in a condensate blockage near the wellbore region and decrease in the productivity. Thus, it is of very essential and economical purposes to find applicable ways to increase the recovery of this lost condensate from the reservoirs. In this study, dry gases are injected into reservoir at initial conditions to delay the dew point pressure that in return enhanced the condensate recovery. This is relying on the fact that the production from gas condensate reservoirs is accompanied by declining in the reservoir pressure. The injection schemes that have been considered are: different injection rates and different reservoir conditions. The study investigated the effect of dry gases injection on 63 samples covers wide ranges of the main parameters of Egyptian gas/condensate reservoirs. Phase behavior, dew point pressure and maximum recovery are studied after and before injection. The study revealed that the dry gas injection into gas/condensate reservoirs minimized the dew point pressure by 18.4% to 23.55% and enhanced condensate recovery by 29.2% to 34.6%.**

Index Terms- **Enhanced Condensate Recovery, Gas/Condensate Reservoirs, Dry Gases and Dew Point Pressure**.

I. INTRODUCTION

Gas condensate production and reserves continue to rise however, regarding the total energy consumption, almost all of Egypt's 3.4 quadrillion British thermal units (Btu) of energy consumption in 2009 was met by oil (47%) and natural gas (48 %). The rapid growth of oil and gas consumption has been driven by increased industrial output, economic growth, energy-intensive gas and oil extraction projects, population growth, and fast-rising private and commercial vehicle sales. The productivity impairment problems have been reported in many field cases [1]. Increasing oil demand need for more research work regarding enhanced condensate recovery.

For gas/condensate reservoirs, the complete process of isothermal retrograde condensation resulted from the decrease of pressure at reservoir temperature included the sequence of states; single phase, dew point, increase in quantity of the liquid phase to a maximum followed by decrease in the volume to a second dew point, and finally the single phase sequence due to relatively low pressures are reached [2].

Dry Gas is primarily a mixture of methane and some intermediates. The hydrocarbon mixture is solely gas in reservoir and at normal surface separator conditions it falls outside the phase envelope; therefore no liquid is formed at the surface [3].

Gas injection is an process applied to minimize the condensate drop out in the reservoir. Accumulation of condensate in the reservoir causes a reduction in gas permeability and decreasing gas well productivity [4]. Gas recycling has been carried out in gas condensate reservoirs for many years, but due to developing new applications and the great value of natural gas, engineers worked to find an appropriate replacement for it in the injection process [5]. This study investigates the efficiency of injection different volume of dry gas for minimizing the dew point pressure and maximizing the condensate recovery from gas condensate reservoirs.

II. EXPERIMENTAL WORK

Constant Composition Expansion (CCE) is applied to gas/condensate samples to simulate the relation between pressure and volume of these hydrocarbon systems. The test is performed to determine the dew point pressure [6]. Constant volume depletion (CVD) is an experimental procedure used to study gas/condensate samples by being equilibrated in a PVT cell at reservoir temperature and pressure [7]. The test consisted of a series of pressure expansions and constant pressure displacements to return the sample to a constant volume, which was equal to the volume of sample at dew point pressure. This procedure was repeated down to the atmospheric pressure and at each pressure value the liquid drop out is measured by Interface Detection System.

The dry gases injection was applied on 63 gas condensates reservoirs from different regions in Egypt using the automated mercury free PVT cell figure (1). The recombined surface samples are charged into 500 cm3 volume PVT cell. The cell is fitted with glass windows, which permit observation of the hydrocarbon system inside the cell. The PVT cell is installed inside an air bath for temperature control. The volume of the cell can be controlled by injecting mineral oil with a piston located at the bottom of the PVT cell. Agitation of the sample to ensure equilibrium

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can be obtained by rocking the entire PVT cell. Before running any phase behavior measurement, integrity of the sample is checked to ensure against leakage.

Figure (1) : PVT Cell

CCE and CVD are conducted to 63 samples to determine dew point pressure and condensate recovery. A portion of the recombined reservoir fluid was charged to the automated mercury free PVT cell and subjected to the reservoir temperature and reservoir pressure. After stability a certain volume of dry gas (V_1) is injected into the PVT cell (10% from the Gas/Oil original Ratio). The effect of this volume on the original gas-condensate reservoir is studied by measuring the Compositional analysis of the system and routine laboratory tests (Constant Composition Expansion & Constant Volume Depletion). This process is repeated by injecting different volumes of dry gas (V_2, V_3, V_4, and V_5) into original gas/condensate reservoir and study the compositional analysis of the systems and CCE and CVD of the different systems.

It should be noted that all the collected data were used without excluding or eliminating any data. Table (1) lists the ranges of the main parameters for the 63 samples conducted in the study which cover the different nature of Egyptian gas/condensate reservoirs.

Table 1 : Ranges of Gas Condensate production and PVT Data

Property	Minimum	Mean	Maximum
Dew point pressure (Psia)	2029.7	4134.7	6239.7
Reservoir pressure (Psia)	2307.7	6161.2	10014.7
Reservoir temperature (°F)	165.2	240.6	316.0
Separator gas specific gravity	0.63951	0.74860	0.85768
Total Gas-oil ratio (SCF/STB)	5441.4	53816.4	102191.5
Stock tank oil API gravity	42.8	54.7	66.6
Well stream Heptanes plus Molecular weight	118.6	142.4	166.1

III. Results and Discussion

Different volumes of dry gases injection affected the original well stream composition for gas/condensate therefore most of physical properties of original gas condensate reservoirs changed such as; the phase behavior, the dew point pressure, the liquid drop out and the maximum condensate recovery.

Constant Composition Expansion test used to measure the phase behavior of the 63 samples at different temperatures include the reservoir temperature. The below mentioned results is for one sample as an example. Figure (2) explain how the dry gases injection strongly affects well stream gas composition and after several suctions of dry gas injection this effect is slightly encountered the dew point pressure. Figure (2) shows that among different volumes of dry gases injected into original gas reservoirs the dry gas injected volume (V3) obtained the best results as it gives the least dew point pressure by the least dry gases injected volume. The lower dry gases injected volumes (V1) and (V2) give higher dew point pressure and the higher dry gases injected volumes (V4) and (V5) give a slight different in dew point pressure with higher volumes of dry gases injected. The dry gas injected volume (V3) gives the Optimum Gas/Oil Ratio (OGOR) and the minimum dew point pressure. The Gas/Oil Ratio (GOR) before dry gases injections and at each volume of dry gases injected where GOR1 at V1, GOR2 at V2, GOR3 at V3, GOR4 at V4 and GOR5 at V5.

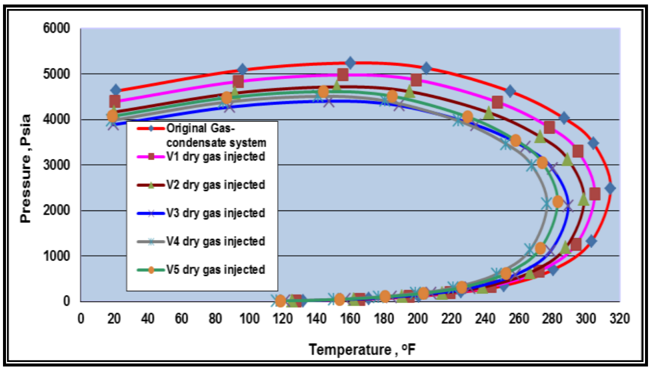

Figure (2) Phase behavior (Pressure - Temperature relation) before and after dry gas injection

Figure (3) show the optimum Gas/Oil ratio (GOR3) obtains the lowest dew point pressure. Original GOR of 14689.66 SCF/STB gives dew point pressure of 4808.7 Psia and after dry gas injected volume (V3), GOR3 of 37032.63 SCF/STB gives a dew point pressure of 3820.7 Psia. This revealed that the dew point pressure is decreased by 20.55%.

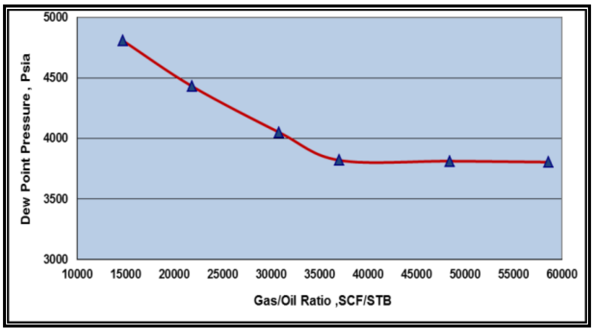

Figure (3) Gas/Oil Ratio – Dew Point Pressure relation before and after dry gas injection

Constant Volume Depletion test is used to measure the liquid drop out and the maximum condensate recovery. Figure (4) explains that the optimum volume of dry gases injection (V3) achieves the maximum condensate recovery and as the volume of dry gases injection decreases or increases the condensate recovery decreases. Figure (4) shows that after injection of different volumes of the dry gases volume (V3) obtained the highest liquid drop out. The lower dry gases injection volumes (V1, V2) and the higher dry gases injection volumes (V4, V5) give lower liquid drop out.

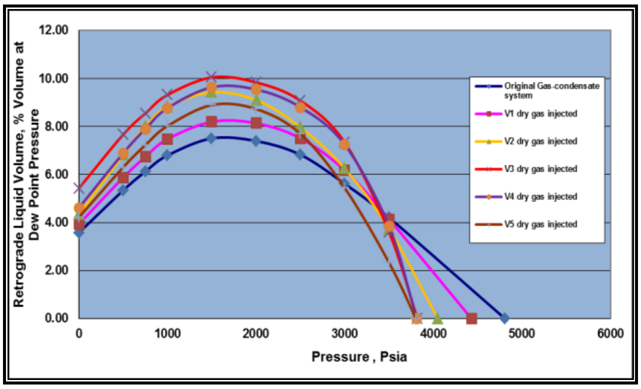

Figure (4) Pressure – Retrograde Liquid Volume, % relation before and after dry gas injection

Figure (5) show that the optimum Gas/Oil ratio (GOR3) obtains the maximum condensate recovery. Original GOR of 14689.66 SCF/STB gives condensate recovery volume of 7.51 % and after dry gases injected volume (V3), GOR3 of 37032.63 SCF/STB gives a condensate recovery volume of 10.05 %.This revealed that the condensate recovery is increased by 33.82%.

IV. Conclusions

Based on the obtained results, dry gases injection can be considered as a very effective way to increase the condensate

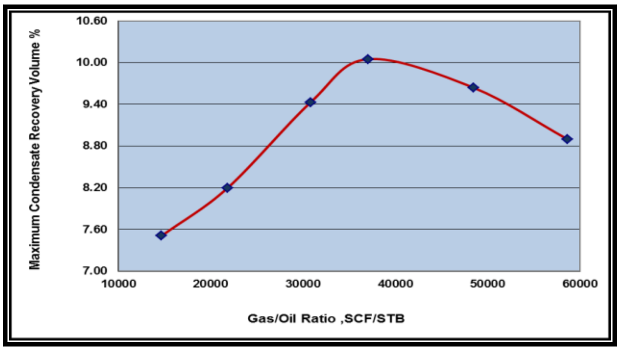

Fig. 5 : Gas/Oil Ratio – Maximum Recovery % relation before and after dry gas injection

recovery. Dry gases recycling affects the original well stream composition which leads to reduction in dew point pressure between 18.4 % to 23.55 %. Dry gases injection increases the maximum condensate recovery than the original gas condensate reservoir between 29.2 % to 34.6 %..

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