# CHAPTER II

# LITERATURE REVIEW

This chapter discusses previous works that are related to gas injection and development of production from gas-condensate reservoirs study. Some works that applied simulation in their studies are also included.

## 2.1 Previous works on gas injection/production

While a gas-condensate reservoir is put on production, the reservoirs pressure continuously declines until reaching the dew point pressure. At a later time, gas starts to condense and drop out in the reservoirs. From this behavior, a condensate blockage problem will arise from a certain quantity of liquid in the reservoirs. So the well productivity intensely decreases as well as gas deliverability. Furthermore, some of the valuable condensate will be left in the reservoirs as residual oil. The pressure declining below the dew point pressure and the reduction in well productivity by condensate bank is predominantly a challenge to be avoided. One of the most effective methods of solving this problem is gas injection. The following literatures discuss some related works in maintaining the gas-condensate reservoirs pressure by gas injection.

Jamsutee [1] examined different strategies to maximize the economics of gas and condensate production using results obtained from a compositional simulator. He used reservoirs simulation to mimic the production profiles of a gas reservoir. The goal of this study is to analyze the economic results from different conditions. The setting strategy includes natural depletion, gas cycle production, and production with timely gas injection where the production and injection rates were varied.

The author found that the production with gas cycling and timely gas injection is the best approach in his research. Also, the hydrocarbon liquid can be recovered more productively from his result.

The applicability of one-time produced gas injection in removing the condensate bank around the wellbore and there by restoring well productivity was study by Marokane *et al.* [2]. Gas-condensate fluid samples with maximum liquid dropout of 6%, 10% and 21% were used. The benefit of the method was investigated using a full-field compositional reservoirs simulation model of gas condensate.

In the case of rich gases, injecting gas when the average reservoir pressure is above the maximum liquid dropout pressure the best result. The one-time injection does not only restore the well productivity and increase reservoir pressure but also increase the oil recovery factor.

The study of retrograde condensate recovery by revaporization was introduced by Smith and Yarborough [3]. The author performed an experiment by injecting dry gas into a 10.6-ft long core which contained consolidated sand pack at 100 F and 1500 psi. Methane was used to revaporize liquid from n-pentane-methane mixture. The impacts of injected gas volume and wettability were observed. The experiment results showed that the vapor-liquid equilibrium appears when a porous medium containing retrograde condensate has dry gas injected into it. This study also gives an indication of the necessary amount of dry gas to recover heavy components from a condensate that contains a large concentration of hydrogen sulfide.

Smith and Yarborough [3] summarized their study that "when dry gas is injected into a porous medium containing wet gas below the dew point, a part or all of the retrograde liquid is revaporized and the flowing fluid is the vapor in equilibrium with the liquid". After the first contact with the liquid, the dry injected gas becomes saturated within a short distance. The temperature, pressure conditions, the nature of the condensate fluid and sweep efficiency in the fluid injection process are other factors for the amount required in an actual reservoirs situation. The fluid arrangement in the pore space has no effect on the equilibrium revaporization of retrograde liquid at the flow rate employed, indicating that reservoirs wettability is not a factor in the revaporization recovery of retrograde liquids.

Lou *et al.* [4] investigated condensate recoveries in reservoirs that the dew point pressure is very high, under two development schemes (gas cycling above and below the dew point pressure). The attractive point from this research is lean gas and $C_{20+}$ components are effectively re-vaporized in the PVT cell. In addition, the author found that more condensate can be recovered if the gas cycling starts when the pressure is still above the dew point from an investigation on long core system. Thus, the investigator found the full pressure maintenance gives a higher recovery of condensate than partial pressure maintenance.

A detailed analysis of the development of miscibility during gas cycling in condensate displacements and the formation of condensate banks at the leading edge of the displacement front was studied by Jessen and Orr, Jr. [5]. The possible formation of condensate banks and fast screening of optimal injection gas composition was the strategy in their research.

Conclusively, the authors showed that multi-contact miscibility can develop at or below the dew point pressure of the reservoirs fluid mixture, depending on the compositions of the condensate and the injected gas.

A coherent thermodynamic analysis of the effects of lean gas injection in two Brazilian gas-condensate reservoirs through the determination of the phase behavior of injected/original gas mixtures was presented by Pires *et al.* [6]. During their investigation, the method of predictions with laboratory data was used to confirm the accuracy of their thermodynamic model. The result from this experiment showed that gas cycling process requires reliable information of thermodynamic properties and phase behavior of reservoirs fluid and mixtures generated during the cycling process.

Tompkins *et al.* [7] studied a sour gas condensate reservoirs simulation using a three dimensional block oil with extended PVT capability for history matching. The rich, retrograde condensate reservoir was simulated to assist with operation and development planning including the eventual blowdown.

The author summarized that the primary variables used for the matching process were permeability, and to a much lesser extent, porosity. The rapid breakthrough observed in the field was simulated at the level of high permeability streaks which is order of magnitude greater than the average zone permeability.

The complex mass transfer and composition changes for the Coyanosa Wolfcamp field, located in Pecos County, Texas were simulated by Kim [8]. In this simulation, the reservoirs is composed of poorly sorted, coarse-grained heterogeneous conglomerates with thinly interbedding shaly limestone. The dew point pressure is 6,179 psia at a reservoirs temperature of 175 F. The initial reservoirs pressure was 6,700 psia.

After matching the result with the past 23 years of production history, Kim [8] used his model to forecast future performance under various operating scenarios. He considered the sensitivity of liquid recovery to pressure, rate and degree of cycling as the sensitivity factors in his model. Moreover, the condensate reserve can be increased by the gas injection with selective zonal perforations.

Diamond and Randon [9] analyzed effects of gas injection into two gas condensate reservoirs in eastern Venezuela in order to establish optimum exploitation schemes. In this research, they investigated a reservoir which is subjected to a pressure maintenance process and another reservoir which is a dual gas condensate and black oil. They studied the accelerated natural depletion and pressure maintenance in which injection of lean gas took place. These simulation studies were performed utilizing a phase behavior simulation and a compositional simulation (COMSIM).

The results from this study show that simultaneous injection of gas through wells is the best exploitation scenario for the pressure maintenance process. On the other hand, the best option for future exploitation is the pressure maintenance scheme by gas injection, and the simultaneous production of wells from both gas condensate and black oil.

The literatures reviewed in this chapter are mainly concerned with "Optimal injection and production strategy for gas recycling in gas condensate reservoirs". Many subjects related to gas cycling process and concerned with maximizing condensate recovery are presented in this literatures review. For gas cycling, the optimal composition of injected gas, the determination of injected gas volume, the equilibrium of revaporization, the technical study of using different injected gases, and the optimum time of commencing gas injection, are reviewed as well. For other related theories, miscibility during gas cycling, studying of phase behavior, and the prediction of gas condensate recovery are also illustrated.