CHAPTER III

STUDY CONCEPT AND METHODOLOGY

In order to investigate the applicability of the gas material balance or p/z plot method to a real gas reservoir, it is necessary to have all reservoir data and performance. These reservoir data and performance are generated in this study by using reservoir simulation. The reservoir simulation can provide GIIP, reserves, reservoir pressure, and other necessary data. These data are considered to be real data of a gas reservoir. The results from p/z plot can then be compared to these real data to investigate its applicability for evaluation of gas reservoir performance.

In this study, not only the applicability of the gas material balance equation or the p/z plot method but also the applicability of the pseudo-steady-state equation for gas reservoir is investigated. In addition, effects of various parameters on the methods to evaluate GIIP and reserves for single- and multi-layered gas reservoirs are investigated. The study will concentrate on single-layered, two-layered, and three-layered gas reservoirs.

3.1 Single-layered gas reservoir

For the single-layered gas reservoir case, the study is divided into four parts. Firstly, after the reservoir simulator is run and all required data are available, the gas pseudo-steady state equation will be used to calculate $\bar{p}$ at various time (or various

Gp). For simplicity, gas rate will be kept constant as long as possible so that the gas pseudo-steady-state equation can be used directly without the use of principle of superposition. If there is variation in rate, appropriate averaging technique will be used to estimate a constant average rate. Secondly, two p/z plots will be prepared for the cases that $\bar{p}$ is obtained by using the gas pseudo-steady-state equation and $\bar{p}$ is obtained from the reservoir simulation runs. GIIP obtained from the two plots will then be compared to the real GIIP obtained from the volumetric calculation by the reservoir simulator. Thirdly, the effect of various parameters including permeability, rate, porosity and thickness, gas specific gravity, impurities, and skin factor on the calculated GIIP obtained by using $\bar{p}$ from the gas pseudo-steady state equation and by using $\bar{p}$ from the simulator will be investigated in detail. Finally, a single-layered reservoir with two production wells will be investigated.

3.2 Two-layered gas reservoir

For a two-layered gas reservoir, the study may be divided into two main cases, two-layered reservoir with one production well and two-layered reservoir with two production wells. The study concept for the two-layered reservoir case may also be divided into two concepts, the separated-layer calculation concept and the combined-layer calculation concept. Application of these two concepts to the two-layered, one well and two wells cases will be investigated.

Using the separated-layer calculation concept, GIIP and reserves of each layer are calculated separately. Here, q_g and $\bar{p}$ for each layer are needed. The method to

obtain q_g for each layer will be thoroughly investigated and presented. After determining q_g for each layer, $\bar{p}$ for each layer can be calculated using the gas pseudo-steady state equation.

From q_g and $\bar{p}$, p/z and Gp can be obtained and the p/z plot can be prepared. Then, the calculated GIIP for each layer can be compared to the real values obtained from volumetric calculation using the reservoir simulator.

For the combined-layer calculation concept, the two-layered reservoir will be treated as a fictitious single-layered reservoir. The properties of the fictitious single-layered will be appropriate combined properties of the two-layered. The combined properties will be either additive properties, such as thickness, or average properties, such as porosity. The average properties must also be appropriately obtained. That is, it must be averaged based on suitable parameters, such as volume or others. After obtaining appropriate rock and fluid properties, $\bar{p}$ can be calculated using the gas pseudo-steady state equation. Preparation of p/z plot is now possible. The resulting GIIP can then be compared with the real GIIP (of both layers).

Both separated- and combined-layer calculation concepts can be applied to the case of two-layered reservoir with one production well. For the case of two-layered reservoir with two wells, it is separated into two cases. First, the case where each of the two wells penetrates and produces gas from the two layers. For this case, both layers have the same rock and fluid properties. Furthermore, both wells are located symmetrically to each other, and produce at the same rate. Therefore, for this case, both the separated-layer and combined-layer calculation concepts can be used. In addition, for this case, two other concepts concerning wells will be applied: separated-

well and combined-well calculation concepts. The results obtained from both layer calculation and well calculation concepts will be compared to real GIIP.

Second, the case where one of the two wells penetrates and produces gas only from one layer while the other well produces from both of the two layers. For this case, only the combined-layer calculation concept and the combined-well calculation concept will be used.

3.3 Three-layered gas reservoir

Only the case of a three-layered gas reservoir with one production well will be investigated. For simplicity, only the case where all three layers have the same rock and fluid properties will be considered. Therefore, both the separated-layer and combined-layer calculation concepts will be used. Again, resulting GIIP obtained from both calculation concepts will be compared to real GIIP.