CHAPTER II

LITERATURE REVIEW

This chapter discusses some of related works and development in well test in multilayer reservoirs and wireline formation test (WFT).

2.1 Well Test

Well test is used in the exploration and appraisal of hydrocarbon reservoir to obtain formation fluid samples, measure initial reservoir pressure, determine reservoir permeability, determine well productivity, identify reservoir limit or boundary, and examine near well bore condition such as skin .

Conventional well test provides estimation of average permeability and skin for a single layer system. In order to estimate the permeability and skin for each individual layer in a multilayer reservoir, multilayer test (MLT) is needed. The fundamental principle of the multilayer test is to measure the wellbore pressure, and the flowrate of each layer must be known. The multilayer test can be applied to the reservoirs with or without crossflow. Several techniques to estimate the permeability have been developed and presented.

Kuchuk *et al.* (1986) presented testing and analyzing techniques to obtain individual layer permeabilities and skin factors for layered reservoirs. They presented a test called "multilayer test". The test consists of a number of sequential flow tests, measuring the wellbore pressure and flow rate at the top of each layer. The reservoir model is commingled only through the wellbore. Two steps are needed in the analysis. The first step is logarithmic convolution which uses a single layer model with wellbore pressure and flow rate measurements to estimate the value of reservoir parameters. The second one is to run nonlinear least squares to improve the estimates obtained in the first step.

Bourdet (1985) presented an analytical solution for a layered reservoir with formation crossflow with consideration of wellbore storage and skin. The reservoir model is a two-layer formation with crossflow in double permeability. It exhibits three characteristic flow regimes, at early time, a two layer without crossflow behavior, then a transition behavior, and at late times, a homogenous behavior presenting the total system. He proposed type-curves of this model and compared them to those of homogenous reservoir, two layers reservoir without crossflow, and double porosity reservoir. This paper illustrated that this solution was more general for many reservoir models.

Ehlig-Economides and Joseph (1987) presented an interpretation technique for multilayer reservoirs consisting of n-layers with wellbore storage and skin effect. The reservoir may or may not have formation crossflow in any two adjacent layers. The solutions are provided for both infinite acting and bounded system. The key to find individual layer properties is the interpretation of the transient flowrate from each layer following a change of the total flowrate for the well. Pressure transients are also used in the analysis. This study demonstrates that the combination of wellbore pressure and layer flowrate provides sufficient information for determination of the complete layered reservoir description. The authors recommended the two-rate test, recorded flowrate and pressure versus time versus depth at initial flowrate and another one was the tare by one-half cut. They proposed two methods to estimate reservoir parameters. The first on is called pressure interpretation, yielding permeability thickness product. The second one is called flowrate interpretation, yielding each layer's permeability and skin.

Park and Horne (1989) worked on a model based on Ehlig-Economides and Joseph to present a method to analyze the well data and determine the reservoir parameters of each layer of a multilayer reservoir with crossflow. Generally, well test analysis is performed in two steps. The first step is to estimate the initial parameters and the second step is to perform a systematic regression to determine the reservoir parameters. If an initial estimation is poor, the interpretation result may not converge, no matter how good the regression algorithm is. Many works have been done to improve the regression algorithm and not emphasizing on the initial estimation. Thus, they presented two methods to determine the initial values of parameters. The first method works for a two isotropic layers crossflow system and requires history of wellbore pressure. The second method works for n-layers system and better when the reservoir is commingled but requires the entire history of wellbore pressure and layer production. By using equations and type curves, the estimations from those two method yield each layer's permeability and skin.

Cabrera *et al.* (1992) presented a computer program based on paper of Ehlig-Economides and Joseph to obtain parameters of multilayer reservoir. The estimation of layer parameters is done in three steps. In the first step, the program is used to estimate the approximate value of pressure and rate per layer. The second step defines the reservoir model and parameter estimates. In the third step, these parameters are refined by performing a history match on all sequential flow tests with the measures wellbore pressure.

Bidaux *et al.* (1992) presented a solution technique for the analysis of multilayer test. The technique is based on an analytical conversion of a single layer transient pressure response into a multilayer response. The model is multilayer formation with formation crossflow and variety of boundary conditions. The former analysis includes two steps. The first one is the diagnostic step which an appropriate model is selected and an initial estimate of parameters is made. Then, the validation step which is to check that the model matches the data and finds the best fit by adjust the parameters. The idea developed in this paper follows those two steps and added the sandface rate into account.

Jackson and Banerjee (2000) presented multilayer testing and analysis techniques to obtain each layer's permeability and skin factors using pressure and flowrate transient data from sequential flow tests acquired with production logging tool. They proposed a new integrated workflow and analysis technique which incorporates numerical well test analysis. The study also illustrated the potential for the application of automated history matching techniques in well test and multilayer test interpretation.

2.2 Wireline Formation Test (WFT)

Wireline formation test can be used as a common application to obtain formation pressure, examine fluid gradient, mornitor reservoir depletion, detect supercharging effect, and estimate reservoir permeability. Wireline formation test can provide the estimation of reservoir parameters. Several theoretical analysis, analytical solutions, and interpretation of WFT have been proposed.

Moran and Flinklea (1962) presented a theoretical analysis of pressure data from wireline formation test. The main purpose is to extend the pressure build up technique which is a method of determining permeability from conventional well test to the interpretation of data obtained from wireline formation tester. Because of the differences between the operations of the conventional well test and the wireline formation test, flow parameters and flow geometry are different. The different in flow geometry leads to a completely different equation for the analysis of the pressure response. So, the interpretation needs to be modified. The authors assumed homogenous medium with single phase flow and developed the general equation for spherical flow in addition to van Everdingen and Hurst's equation for linear flow and Horner's equation (1951) for radial flow. There was also a discussion on the depth of investigation which was shown to be large comparing to the size of spherical sink (perforation) and also a case involving permeability anisotropy.

Culham (1974) presented a spherical flow equation that is valid for both wireline and conventional formation tests. He performed an extension of the previous work of Moran and Flinklea by demonstrating that the assumption of spherical flow is not only valid for a single perforation but also the conventional wellbore geometry or, on the other hand, any limited entry perforation. In addition, equations for calculating formation permeability and skin factors were presented. He also derived the radius of investigation equation for spherical flow problem.

Stewart and Wittman (1979) extended the work of Moran and Flinklea to examine the permeability from RFT pretest pressure response. The purpose was to determine the anisotropy where radial flow is observable. They gave an analytical solution for spherical flow in an infinite homogenous medium. They also studied the effect of formation anisotropy and radius of influence in drawdown and buildup test. They also discussed the upper limit of measurable permeability from buildup by presenting the relationship between the maximum detectable permeability and gauge resolution for different fluid properties.

Dussan and Sharma (1987) performed an analysis solution to obtain horizontal and vertical permeability using a single probe formation test data during drawdown. The assumption is that the formation is homogenous and anisotropic so that the dynamics of the formation fluids can be adequately described by the Darcy equation.

Yildiz and Langlinais (1989) presented a 3D analytical model to improve the analysis of transient pressure response of a reservoir to wireline formation testing. The mathematical model was used to evaluate the validity of available interpretation techniques and to investigate the sensitivity of transient pressure behavior to wellbore parameters.

Goode and Thambynayagam (1992) presented an analytical model to interpret pressure transients measured by a multiprobe formation tester. It consists of three probes, one sink probe and two observation probes. The sink probe generates a pressure pulse by withdrawing fluid from the formation while the resulting pressure response is measured at the sink probe and at each of two observation probes. The authors presented an analytical equation to model the tool response in both vertically bounded and unbounded reservoirs. It was demonstrated that a multiprobe formation tester can provide data to determine the horizontal and vertical permeabilities and the formation storativity.

Kuchuk *et al.* (1994) described basic features of the packer module and the observation probe tool combination of the multiprobe wireline formation tester. They presented an analytical solution for the formation behavior with the packer and probe geometry using a modified dimensionless function and provided estimation of the formation parameters.

Proett *et al.* (1994) introduced a technique to estimate compressibility of the fluid in the flow line, pressure, and permeability in tight zone reservoir. Since wireline formation tester draws fluid in a short period of time and small volume, the data may be distorted by flow line storage effect when the test is conducted in a tight zone. The authors introduced a special plot to interpret real time data obtained during initial drawdown and buildup.

Ayan and Kuchuk (1995) introduced a new interpretation technique for determining horizontal and vertical permeability and storativity using multiprobe wireline formation tester in layered formation. The interpretation technique is based on formulation called pressure-pressure convolution which eliminates flow rate measurement from the formulation. The method uses the pressure recorded by the horizontal and vertical observation probe.

Kuchuk *et al.* (1996) presented an interpretation of multiprobe wireline formation test in multilayer reservoirs. The main purpose is to estimate vertical and horizontal permeabilities in the tight layered formation.

Parke *et al.* (1998) discussed the problems of wireline formation testing in tight reservoirs, presented developed solutions to these problems and showed example of where those solution have been applied.

Whittle *et al.* (2003) discussed the greatly improved quality of pressure and rate transients measured during wireline formation test. The transients can theoretically be interpreted in the same way as well test. The paper focused on the information that can be obtained from the pressure transient recorded during a wireline formation test and compares with the data recorded during a well test. The authors discussed the application and limitations of established method of analysis used in well testing to the interpretation of pressure transient recorded during wireline formation tests. Field examples were also given.

Daungkaew *et al.* (2004) illustrated that a wide range of information can be obtained from wireline formation test data using an advanced well test analysis technique to analyze the pressure response measured from WFT. Numerical simulation using a single well model for a wireline formation test with a single probe was used to verify the pressure transient analysis results.

In summary, formerly, well test has been used to obtain reservoir parameters such as permeability and/or skin factor. Later, there were many developments for the estimation of parameters in multilayer reservoir to obtain each layer's property individually. Several techniques, concepts, and equations have been proposed to meet the task. In 1950's, wireline formation test was break-through in formation evaluation. At first, WFT had their limitation and could provide reservoir parameter in a small scale of information, only the near-wellbore property. Similar to well test, many works in WFT presented analytical solutions and interpretation techniques to obtair reservoir parameters. WFT tools now have improved quality in data measuremen while well test has higher cost, less safety, and more environmental impact Consequently, WFT can be an alternative method to acquire reservoir parameters.