CHAPTER II

LITERATURE REVIEW

2.1 Wireline Formation Test (WFT)

Wireline Formation Tester (WFT) is used to obtain pressure profiles, formation fluid samples and permeability indicators information which are key parameters during exploration and development phase. WFT can be used to acquire various parameters such as fluid contact level, monitor reservoir depletion, detect supercharging effect and estimate reservoir permeability and thickness. Several analytical solutions, interpretation techniques of WFT, and the application of WFT for several situations have been presented in the literature.

Moran and Flinklea (1962) presented a theoretical analysis of pressure data from wireline formation test. This work is focused on interpretation techniques of data obtained from the wireline formation tester. Flow parameters and flow geometry data obtained from conventional well test are different from data obtained from wireline formation tester. The difference in flow geometry leads to a completely different equation for the analysis of the pressure response. Therefore, the interpretation needs to be modified. The authors assumed a homogeneous medium with single phase flow and developed the general equation for spherical flow in addition to van Everdingen and Hurst's equation (1949) 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 and also a case involving permeability anisotropy.

Culham (1974) illustrated a valid spherical flow equation of both conventional well test and wireline formation test. This work extended the previous work of Moran and Flinklea by showing 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. The author also derived the radius of investigation equation for spherical flow problem.

Stewart and Wittmann (1979) examine how permeability can be estimated from the Repeat Formation Tester (RFT) pretest pressure response, which is an extension of previous work by Moran and Finklea on the Formation Interval Tester (FIT). The authors illustrate the analytical solutions for spherical flow in both an infinite medium system and the case of a reservoir layer bounded above and below by impermeable barriers and also studied the effect of formation anisotropy and the depth of investigation. In addition, the authors 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 (1987) show an analysis solution to calculate horizontal and vertical permeability near the probe by using single probe formation tester during drawdown and buildup pressure response. The authors applied Darcy's equation to be an analysis solution with the assumption of the formation is homogeneous and anisotropic. As a result, it has been shown that the accuracy of the prediction of the horizontal permeability is better than that of vertical permeability.

Goode and Thambynayagam (1992) described 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) presented analytical solutions of wireline formation tester for both packer module and the observation probe. The authors revealed a new model for the behavior of the packer module and the observation probe and also illustrated a flow rate computation algorithm for the packer and probe combination tool. They developed an optimization scheme for estimation of the formation parameters such as reservoir pressure and vertical and horizontal permeabilities.

Kuchuk (1999) presented a new technique for determination of reservoir pressure from pressure buildup and impulse tests with short producing times. The new technique was compared with the well-known Horner method. Kuchuk concluded that the Horner method does not work well if the producing time is short or not known accurately whereas the new technique works better than the Horner method if the flow rate is unstable or the flow regimes are not fully developed.

Gringarten *et al.* (2000) demonstrated preliminary results of a systematic study of well tests in gas condensate reservoirs. The authors examined the conditions of existence of different mobility zones due to condensate blockage and velocity stripping. From the research, the main problem in analyzing the data is phase redistribution, but it may also create drawdown and build-up shapes that can be misinterpreted for reservoir behaviors.

Jackson *et al.* (2003) demonstrated an integrated approach of internal pressure transient test analysis using analytical and numerical methods. The approach includes simulation model generation, reservoir simulation, interactive sensitivity analysis and an automated history matching procedure for optimization. The reservoir parameters such as horizontal and vertical permeability can be estimated from analysis of MDT interval pressure transient tests, and the results can be validated by accurate numerical modeling and simulation together with a gradient based history matching techniques.

Whittle and Lee (2003) discussed the application and limitations of established methods of analysis used in well testing to the interpretation of pressure transients recorded during wireline formation tests taking into account differences in scale and geometry. The authors revealed that a well test can be replaced by a wireline formation test if the objectives of the well test can be met by the wireline formation test.

Daungkaew (2004) illustrated the information that can be obtained from WFT data using an advanced well test analysis technique to analyze the WFT pressure response. The authors revealed that the pressure transient analysis technique (PTA) can be applied to WFT. PTA technique can provide spherical permeability, vertical to horizontal permeability ratio, tool compressibility and storage, formation skin factor and the radius of investigation of the WFT data. In addition, the wireline formation tests can then be used to identify valid tests or quality control.

Xian *et al.* (2004) presented an applicable approach for interpretation of interval pressure transient testing (IPTT). IPTT with an advanced formation tester MDT has been widely used to measure permeability and permeability anisotropy. IPTT also has been applied to perform sweep efficiency monitoring of gas injection, formation characterization in retrograde gas fields, and characterization of fractures and faults. An analytical model with non-linear regression (history matching) technique was used to analyze IPTT incorporated with a reservoir model with initial parameter.

2.2 Mud Invasion Effect

When an oil/gas well is drilled, some of the borehole fluid (mud filtrate) can leak into the formation, displacing the native formation fluid creating an invaded zone around the wellbore. A number of literatures here presented interpretation techniques of WFT in reservoir formation including invaded zone.

Goode and Thambynayagam (1996) presented a model that includes an invaded zone together with an analysis of its effect at each of the probes of a multiple probe formation tester. This work examined a variety of the effects, for instance, the invasion radius, mobility ratio, and compressibility ratio on each probe of multiprobe tester which are horizontal probe, vertical probe, and sink probe. Using a multiprobe tool, the properties of the uninvaded region can be determined.

Sarkar and Lee (2000) investigated the effects of mudcake quality on fluid sampling and supercharging when oil-based muds are used. The sensitivity analysis technique was used in this paper to study the effects of mud quality to the pressure drawdown and the pumpout concentration fraction. The results indicate that both the mudcake permeability and the mudcake-to-formation permeability ratio must be low to achieve high-quality samples.

Wu and Torres-Verdin (2002) introduced a new inversion technique to estimate the formation petrophysical properties from the time record of all measured quantities during the sample pumpout process. The inversion process makes use of a reservoir simulator to generate the acquired measurements such as flowrate and pressure vs. time, and then an artificial neural network is used to determine the formation properties. The authors also presented the mud filtrate invasion process and pumpout process of both water-based mud and oil-based mud with a new combined miscible and immiscible multiphase wireline formation tests sampling model.

Proett *et al.* (2002) presented the results of analyses based on the first wellbore invasion simulator that models both WBM and OBM invaded reservoirs. The invasion process is a complex multi-phase problem particularly when mixed miscible and immiscible fluids are present. Differential equations for miscible and immiscible fluids, with fluid compressibility, rock anisotropy, and gravity were developed. The authors created the new model which is used to accurately predict the complete set of transient data recorded during the sampling process.

Gok *et al.* (2003) examined the effect of invaded zone on pressure transient data from multi-probe and packer probe wireline formation testers in single and multilayer (crossflow) systems. They found that multi-probe tests in vertical wells, sink and horizontal probe pressure data show significant sensitivity to invaded zone properties, while vertical probe pressure data are controlled mainly by the uninvaded zone properties. They also discovered that packer-probe tests in vertical wells, the pressure data are more sensitive to invaded zone properties at early times, but at late-time the pressure response is mainly controlled by the uninvaded zone properties.

Malik *et al.* (2006) generated a new compositional code for the numerical simulation of oil-based mud invasion and formation tester measurements with no restricting assumptions to the degree of miscibility between oil-based mud and native oil by using a time-marching implicit pressure explicit concentration (IMPEC) scheme for solving the time-space evolution of component concentration. The authors found out that time required to retrieve clean fluid samples of formation oil is governed by the petrophysical and properties of the tested formation as well as by the flow rates imposed during fluid pumpout. In addition, they showed that in reservoirs that are not at irreducible water saturation the water fractional flow can be influenced by relative permeability and capillary pressure.