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RESEARCH ARTICLE OPEN ACCESS

Reservoir Fluids Estimation and Modelling using MBAL for aCase Study of a Typical Limestone Formation

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ABSTRACT
The study is aimed at the estimation of the amount of hydrocarbons in a typical limestone formation. The material balance method is used in modelling for this estimation. The material balance method does not forecast production and hence, the use of a dynamic material balance modelling is applied for production performance forecast using a prediction profile subject to production schedules. Thisstudy applies the dynamic material balance modelling technique to forecast production in a typical limestone formation.The material balance modelling method was applied on a limestone reservoir, “W” field to determine the OOIP (Oil Originally in Place); presence and relative strength of an aquifer, relative driving mechanisms of the reservoir and simulate fluid production. Thedynamic material balance modelling was performed to estimate the reserve and forecast future production from the reservoir.Monte Carlo Analysiswas used to validate the OOIP obtained from the model using the 90^{th}, 50^{th} and 10^{th} percentile approach for economic analysis.“W” field was estimated to have an OOIP as 445.5 MMSTB with a predominant water drive having a moderate aquifer strength. 56.7% and 58.1% (+1.4%) of the reserve were recovered from primary drive and secondary drive (gas injection) at abandonment. It was predicted for the above cases, a recovery of 65.26% (15.1% of recovery factor at abandonment) with 3003 and 2961 psia at abandonment and end of predicted year respectively. The 50^{th} percent probability resulted in an OOIP of 468.58 MMSTB.
Key words: Material Balance**;**Dynamic Material BalanceSimulation; Reservoir Characterization, Production Performance Forecast; Monte Carlo Analysis.

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I. INTRODUCTION

Reservoir modelling or simulationentails building and executing a model in which the reservoir behavior of the model mirror’s to a minimum degree of reasonable doubt, the observedbehavior of the reservoir Ezekwe(2011)[1].

Carbonate reservoir is made up of limestone ($CaCO_3$) and dolomite ($CaMg(CO_3)_2$). The formation rocks are classified based on their origin of formation (Detrital and Chemical). The total porosity of a limestone reservoir is greater than its effective porosity and permeability range from 0.01 to 1000 millidarcy.

MBAL is a reservoir analysis software which applies the material balance equation to create a theoretical model for zero-dimensional reservoir modelling (tank model). Schilthuis (1936)[2] developed the “generalized material balance equation” which accounted for fluids entering, leaving and accumulating in the reservoir. The equation was transformed into a straight line formby Havlena and Odeh (1963)[3].Peculiar models were developed to account for aquifer effects such as Hurst Van Everdingen (1947)[4], Carter-Tracy (1960)[5]and Fetkovich (1971)[6] models. The Hurst Van Everdingen model was based on the principle of superposition and has becomethe most used model for aquifer influx because it represents the diffusivity equation which the other two models didn’t account for. Tracy (1995)[7] expressed the Material Balance Equation (MBE)in terms of three PVT functions. He formed an iterative technique for solving these equation by including instantaneous GOR equations with the convergence of GOR as the iterative watch.

The general material balance equation:

$$N = \frac{Np\,[Bo + Bg\,(Rp - Rs)] - [We - WpBw] - GinjBginj - WinjBw}{(Bo - Boi) + (Rsi - Rs)Bg + mBoi\left[\frac{Bg}{Bgi} - 1\right] + Boi\,(1+m)\left(\frac{Swicw + cf}{1 - Swi}\right)\Delta p} \quad (1)$$

N: Initial oil in place, STB; N_p: Cumulative oil produced, STB; B_o: Oil formation volume factor at reservoir pressure, bbl/STB; B_{oi}: Initial oil formation volume factor at initial reservoir pressure, bbl/STB; B_g: Gas formation volume factor at reservoir pressure, bbl/scf; B_{gi}: Initial gas formation volume factor at initial reservoir pressure, bbl/scf; R_p: Cumulative produced gas-oil ratio, scf/STB;R_s: Gas solubility factor, scf/STB;R_{si}: Initial gas solubility factor, scf/STB;m: ratio of initial gas-cap-gas reservoir volume to initial reservoir oil volume, bbl/bbl;W_e: Cumulative water influx, bbl; W_p: Cumulative water produced, STB; B_w: Water formation volume factor at reservoir pressure, bbl/STB, G_{inj}: Cumulative gas injected, scf; B_{ginj}: Injected gas formation volume factor, bbl/scf; W_{inj}: Cumulative water injected, scf;S_{wi}: Initial water saturation, fraction;c_w: Water compressibility, psi^{-1};c_f: formation compressibility, psi^{-1}.

This paper focuses on using the principle of dynamic material balance modelling to describe the behavior of a typical limestone formation using a fieldcase studyand analyze the effects of secondary drive mechanism (gas injection) on production performance. Monte Carlo analysis was used to enhance the modelestimation credibility of initial volume of oil using the 90^{th}, 50^{th} and 10^{th} percentile approach for economic analysis.

II. METHODOLOGY

The dynamic material balance modelling technique used to forecast production in a typical limestone formation is performed using the following sequential order:

2.1 Material Balance Modelling

This process entails the sequential performance of: Reservoir system selection, PVT data input, Tank data input, History matching using analytical and graphical methods, Energy plot and Fluid simulationusing production history.

2.2 Dynamic Material Balance Modelling

This process entails the sequential performance of: Prediction setup, Production constraints setup, Configuration of report schedules and Prediction runs to forecast production performance.

2.3 Monte Carlo Analysis

This process entails the sequential performance of: PVT data input, Probabilistic simulation, Calculations and Probabilistic result.

III. RESULTS ANALYSIS

3.1 Material Balance Modelling

PVT Correlation Selection

The PVT matching indicated Vazquez-Beggs and Petrosky et al were themost suitable for P_b, R_s and B_o correlations and oil viscosity respectively.

History Matching

a.) Analytical Method

The linear regression implementation was carried out twice (in the absence of aquifer) prior to the result shown in Figure 1. The OOIP from Figure1 was 445.5 MMSTB with an aquifer volume of 73752.3 MMRB.

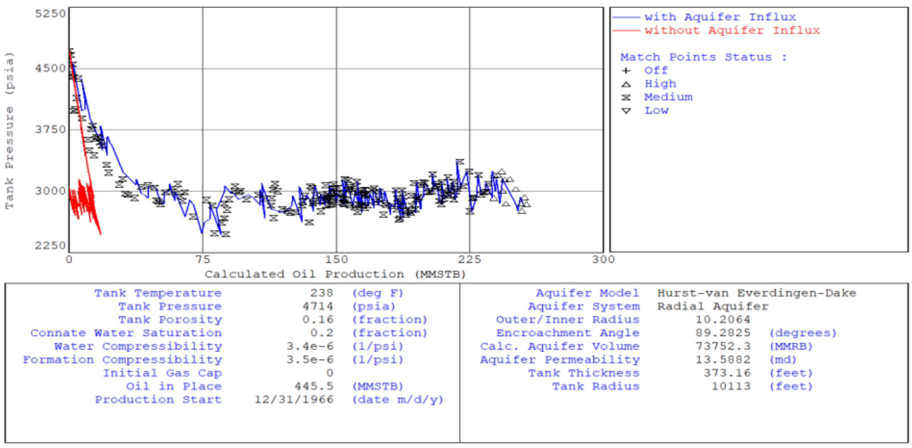

Figure 1
Analytical plot of history matched data

b.) Graphical Method

The graphical plot in Figure 2 was obtained using the (F – We)/Et versus F plot (Campbellmethod) withaquifer influx. The aquifer was in a pseudosteady state, depleting in accordance to the reservoir.The reservoir was experiencingan undersaturated production life with moderateaquifer strength.

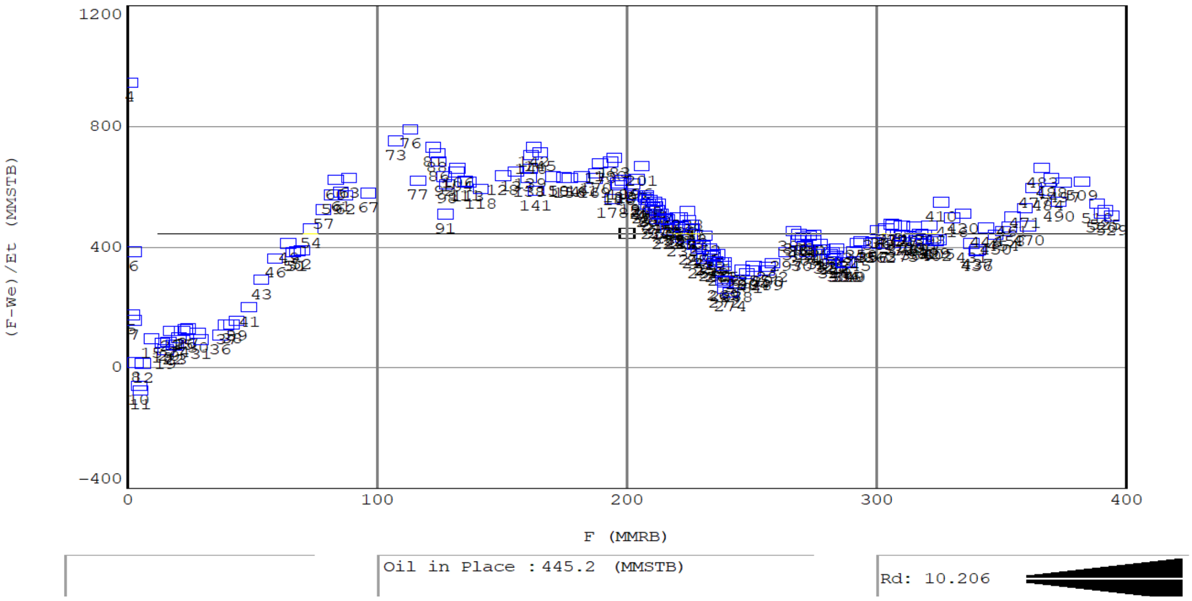

Figure 2
Campbell graphical plot of history matched data

Energy Plot

From Energy plot of Figure 3, the reservoir was operating with fluid expansion, pore volume compressibility and water drive mechanisms. At the start of production, the energy contribution were 47.76%. 24.48% and 27.76% for fluid expansion, pore volume compressibility and water drive respectively.Throughout the production life of the reservoir, the predominant drive was water with a contribution of 95.22% at abandonment.

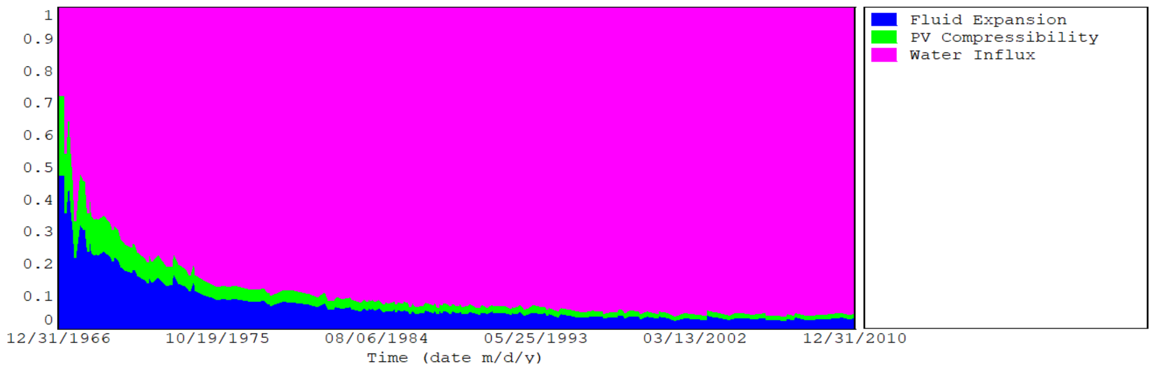

Figure 3
Energy plot of history matched data

Simulation

As in Figure 4, the reservoir experienced a rapid pressure decline at the early years of production and a relative stable decline from middle to abandonment stage.

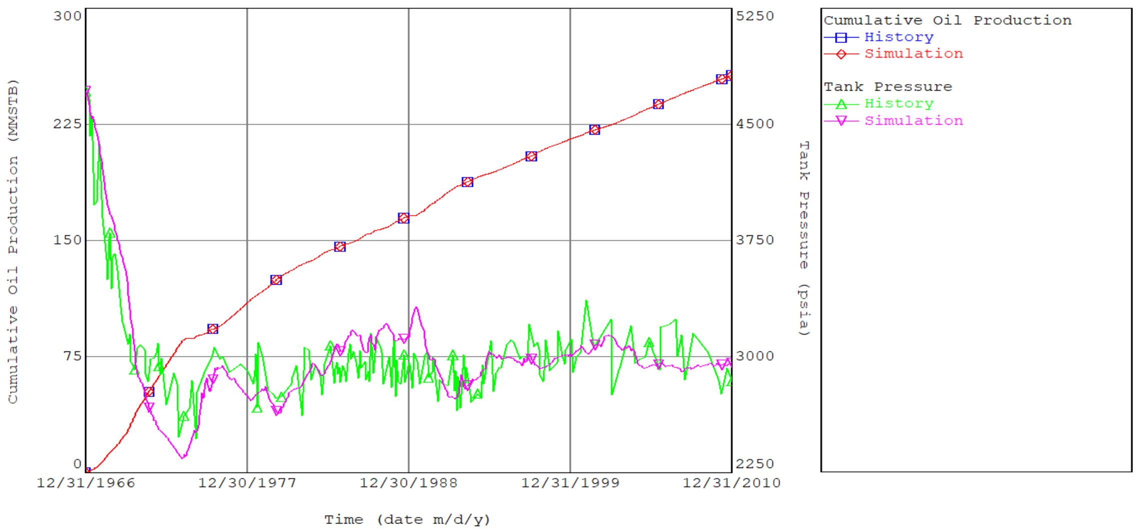

Figure 4
Cumulative oil produced, Tank pressure against time for history and simulation data

3.2 Dynamic Material Balance Modelling
Case 1: Production prediction without injection

Production prediction was carried out using the prediction type of no-wells with no injection. The start date was the start of production (12/31/1966) and the end date, 12/31/2020.From Figure 5, the cumulative oil produced at the end of the production history was 252.56 MMSTB and the cumulative oil produced at the end of the predicted year was 290.724 MMTB. The oil recovery factor were 56.7% at abandonment and predicted to be 65.26%.

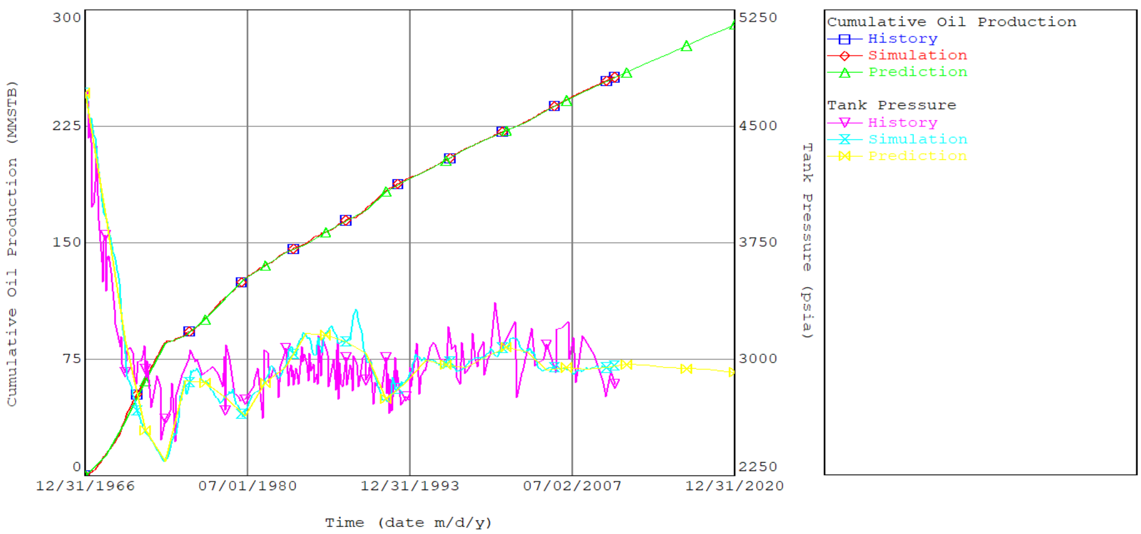

Figure 5
Production Prediction (no gas injection) showing Cumulative oil produced, Tank pressure against time

Case 2: Production prediction with constant gas injection of 500,000 scf/day

From Figure 6, the oil recovery factor and pressure at abandonment were 58.1% and 3003psia while 65.26% and 2961psia were their values at the end of the predicted year.

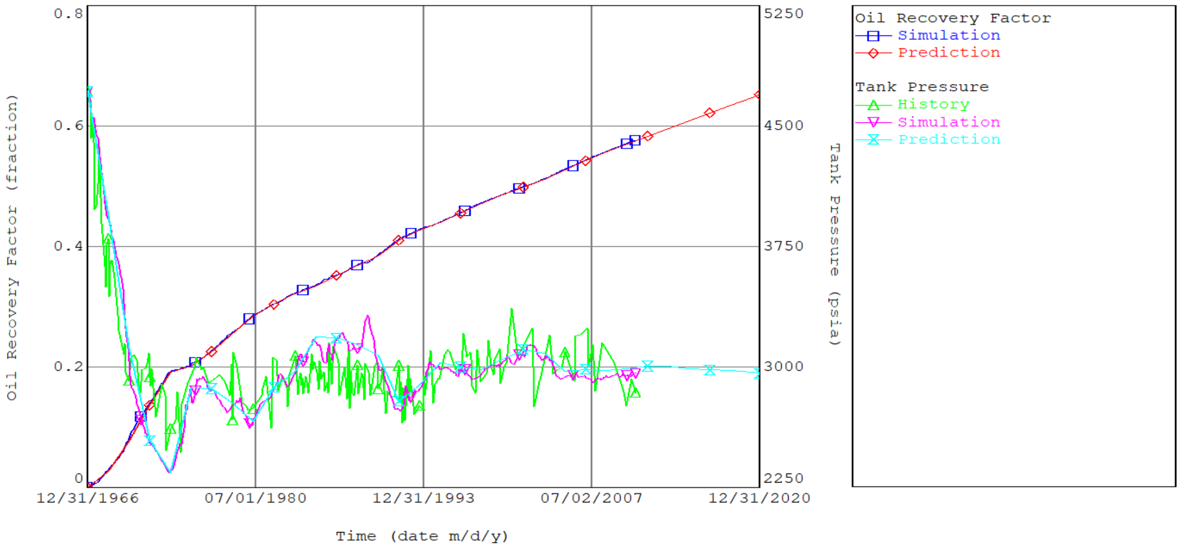

Figure 6
Production Prediction of 500,000 scf/day gas injection showing Oil recovery factor, Tank pressure against time

3.3 Monte Carlo Analysis

The reservoir model was validated using the Monte Carlo tool. The 50thpercent probability, 468.581 MMSTB is +5.18% of the estimated OOIP from material balance method as obtained in the analytical method.

IV. CONCLUSION

A ten year period predicted the reservoir pressure would build-up by 72.98 psia thus allowing 8.56% increase in recovery factor. The case scenarios shows a significantly low increase of 1.4% in oil recovery factor by constant gas injection at abandonment. Though gas injection caused an increase in reservoir pressure, there was a negligible difference in recovery factor between natural depletion and secondary drive by gas injection. The likely cause would be the presence of a fault in the formation. "W" field would require a development plan based on production economic viability. The economic viability would not solely depend on oil recovered but, among other factors, the potential and problem analysis in accordance to regulatory policies.

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