**Proceedings of the
International Conference on Mechanical Engineering and Renewable Energy 2011
(ICMERE2011) 22- 24 December 2011, Chittagong, Bangladesh**

ICMERE2011-PI-181

MATERIAL BALANCE: A CASE STUDY FOR A GAS WELL PRODUCING FROM THE LOWER BOKABIL SAND IN SURMA BASIN

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ABSTRACT

The material balance is a very important tool used by reservoir engineers in the oil and gas industry. It can provide an estimate of initial hydrocarbon in place independent of geological interpretation, and can also serve the purpose of verifying volumetric estimates. The important requirement is to accurately estimate the average reservoir pressure at the required time intervals. The standard practice is to estimate the average reservoir pressure from pressure buildup test conducted on individual wells in a reservoir. Pressure buildup test require shutting off production for some time and it is not conducted on a regular interval due to the demand-supply situation prevailing in the country. Material Balance Method has been modified by different researchers to bypass the strict requirement of the average reservoir pressure as an input parameter. Instead, these techniques use static bottomhole pressure (SBHP) estimated from shut-in wellhead pressure, shut-in wellhead pressure (SWHP), flowing bottomhole pressure (FBHP) of the well and flowing wellhead pressure (FWHP). Current study has been conducted for a certain gas well producing from the Lower Bokabil Sand in Surma Basin. Due to the unavailability of required reservoir pressure data, this paper presents the results from applying the alternate methods mentioned above. Data for SBHP and SWHP methods were recorded during occasional shut-ins due to some production problems or any other reasons. Gas initially in place (GIIP) values estimated by using the static bottom hole pressure, shut-in wellhead pressure, flowing bottomhole pressure and flowing wellhead pressure approaches are 27 BCF, 28 BCF, 24 BCF and 21 BCF respectively. The conventional material balance estimated 26.95BCF with very limited reservoir pressure data.

Keywords: *Lower Bokabil Sand, Material Balance Analysis, Surma Basin, SBHP, FBHP, SWHP, FWHP, Initial Gas in Place, Recoverable reserves, Remaining reserves.*

1. INTRODUCTION

The determination of gas reserves is a fundamental calculation in reservoir engineering. Material balance is an important and generally accepted method for estimating original hydrocarbon in place and the evaluation of the reservoir driving mechanisms. This information is vital for the development of a production strategy, design of facilities, contracts and valuation of the reserves. Volumetrically determined reserves can be very imprecise, because the method depends upon detailed knowledge of many reservoir characteristics that are often unknown such as the areal extent of the pool. The material balance method uses actual reservoir performance data and therefore gives an idea of the hydrocarbon in place that will actually flow, thus a more reliable estimate of recoverable reserves can be made.

Once determined, the original gas-in-place can be used to reliably forecast the recoverable raw gas reserves under various operating scenarios[1].

The important requirement is to accurately estimate the average reservoir pressure at different time intervals. The correct method to estimate the average reservoir pressure is to conduct pressure buildup test on individual wells in a reservoir. Pressure buildup test require shutting off production for some time. Oil and gas companies are often reluctant to conduct pressure build up test on a regular basis because of the lost production. It is even more so in Bangladesh where the supply-demand scenarios are often quite restrictive. Material Balance

Method has been modified by different researchers to bypass the strict requirement of the average reservoir pressure as an input parameter. Instead, these techniques use static bottom hole pressure (SBHP) estimated from shut-in wellhead pressure, shut-in wellhead pressure (SWHP), flowing bottomhole pressure (FBHP) of the well and flowing wellhead pressure (FWHP).

In this paper effort has been made to study a certain gas well producing from the Lower Bokabil Sand in Surma Basin applying conventional material balance analysis as well as the other approaches mentioned above to estimate the initial gas in place and recoverable reserves.

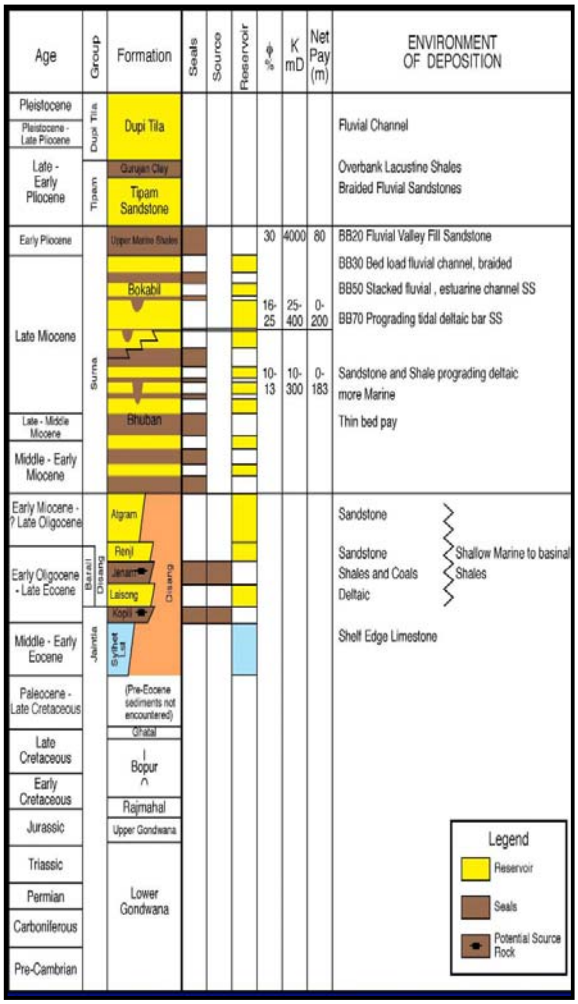

Figure 1: Stratigraphy of Surma Basin

2. PRODUCTION FROM LOWER BOKABIL SAND:

Current study conducted on only producing horizon of Lower Bokabil sand of a gas field under Surma Basin. After first work over, the well was producing from April 2005. The geology of Surma Basin[2] is given in the Figure -1. But in July 2008, production was suspended from the well z due to obstruction accumulation inside the tubing. The field again came in online after second work over in February 2010. Current analysis is conducted taking into consideration of production data[2, 3& 5] with more or less uninterrupted production from April 2005 to June 2010 (Figure 2).

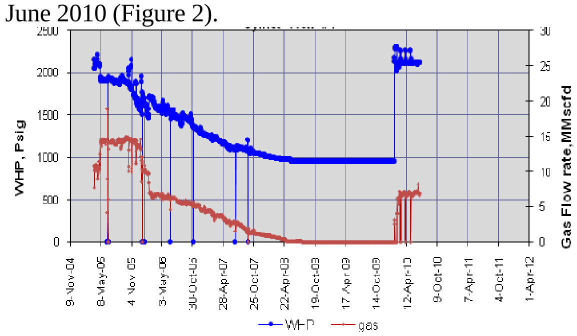

Figure 2: Production History[2]

3. MATERIAL BALANCE REVISIT

3.1 Traditional Material Balance

For a gas reservoir conventional material balance analysis relies on obtaining a straight line on P/z vs. cumulative production (G_p) plotted on Cartesian coordinate to estimate reserves and initial gas in place (GIIP). The accuracy is dependent upon the accuracy of the well's production and pressure data. Unlike the volumetric method, the material balance accounts for reservoir heterogeneity and continuity variations, which occur within the reservoir. This method, however, can be applied only after a certain amount of depletion of the reservoir, and when there is a noticeable trend in the pressure decline. Therefore it cannot be applied in newly discovered fields.

The general form of material balance equation was first presented by Schilthius in 1941[5]. The detailed derivation is not presented in this paper. The final form for a gas reservoir with closed boundaries, takes the form of equation (1).

$$P/z = -pi/(zi\ G)\ G_p + p/z \qquad (1)$$

Where, G_p is cumulative production, pi is initial reservoir pressure and z is the gas deviation factor. Since pi, zi, and G are constants for a given reservoir, plotting p/ z vs. G_p would yield a straight line. If p/z is set equal to zero, which would represent the production of all the gas from a reservoir, than the corresponding G_p is equal to G, the initial gas in place. Deviations from this straight line indicate external recharge or offset drainage. In water drive reservoirs, the relation between G_p and p/z is not linear, because of the water influx, the pressure drops less rapidly than under volumetric control.

Material balance study of Lower Bokabil sand was conducted using MBAL™ software. Because of unavailability, limited down hole data was used in this study. This study yielded a GIIP of 26.996 BCF (Figure 3). Using Hurst-Van-Everdingen-Modified aquifer model[5], current study observed (Figure 4) that there is no aquifer support in the lower Bokabil sand.

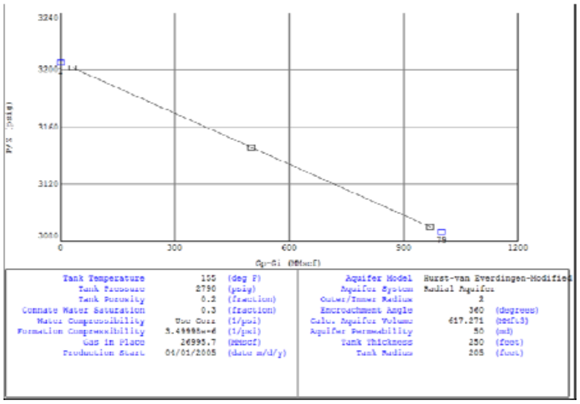

Figure 3: P/z vs. Cumulative Production Plots

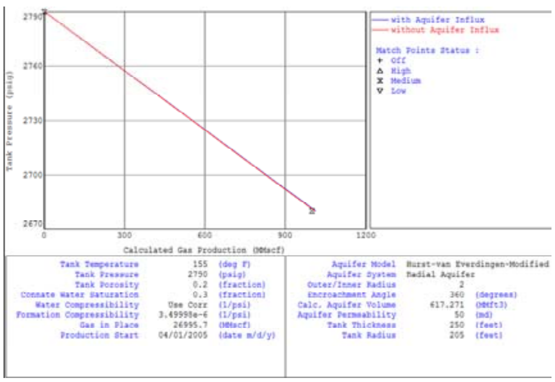

Figure 4: Model with Aquifer Influx

3.2 Alternative Methods of Material Balance:

Four different approaches were taken to study the subject field. These were: (a) static bottom hole pressure (SBHP) estimated from shut-in wellhead pressure (b) shut-in wellhead pressure (SWHP) (c) flowing bottom hole pressure (FBHP) of the well (d) flowing wellhead pressure (FWHP). Data for approach (a) and (b) were recorded during occasional shut-ins due to some production problems or any other reasons.

3.2.1 Static Bottomhole Pressure Estimated from Shut-in Wellhead Pressure:

Different wells of the field were shut-in from time to time because of production problems or any other reason and pressure build up data were recorded in these situations. The recorded shut-in wellhead pressure data was taken from monthly records of current Gas Field and corresponding bottomhole shut in pressure were calculated. The calculated static bottom hole pressure is, however, is not the same as the average reservoir pressure, which is used in the conventional material balance. Average reservoir pressure can only be obtained from a properly designed well test program.

3.2.2 Shut-in Wellhead Pressure:

In this approach field recorded shut-in wellhead pressure are used to make a p/z vs. cumulative production plot, where p is now the shut in wellhead pressure instead of the average reservoir pressure. The z factor is also evaluated at this pressure. The approach is based on the assumption that there is no liquid in the wellbore. For the material balance study, P/z term has been calculated by the means of calculating the z-factor using Hall and Yarborough[5] correlation. Since static gas gradient is very small, the plots set out for p/z using the shut-in wellhead pressure vs. cumulative production for Lower Bokabil sands of current Gas Field, should provide quite similar results. This method will yield erroneous results if there is a liquid build up in the tubing.

3.2.3 Flowing Bottomhole Pressure of the Well:

Theoretically it has been understood for many years that original gas in place can be estimated using measured gas volumes and flowing pressures. This method is based on the pseudo steady state pressure behavior, which requires that the rate of change of pressure at every location of the reservoir is constant. It can also be assumed that after the attainment of the pseudo steady state the rate of change of the average reservoir pressure is also constant as production continues. Mattar and McNeil (1998) illustrated that original gas in place can be determined from the flowing data (pressure and production). These authors have opined that it is possible to determine original gas in place with reasonable certainty when shut-in pressures are not available. This procedure requires the flowing sand face pressure at the wellbore to be measured for plotting p_{wf}/z vs. cumulative production. A straight line drawn through the flowing sand face pressure data and then a parallel line from the initial reservoir pressure gives the original gas in place. The method of calculating the reserves of medium and high permeability reservoirs, from flowing pressure data have the potential of preventing loss of valuable production, without having to shut-in the well. The method is especially suitable for current gas field as well as for other gas fields of Bangladesh where routine pressure testing cannot be conducted due to critical demand-supply situation.

The flowing bottomhole pressure is calculated from the monthly representative flowing wellhead pressure and the monthly average gas flow rate of different wells, using the PROSPER software.

3.2.4 Flowing Wellhead Pressure:

In this approach daily average flowing wellhead pressure data are used. The z-factor for the p/z term is calculated using the same methodology as in the shut-in wellhead pressure. The flowing wellhead pressure data was taken from daily records of current well. Mattar and McNeil[1] demonstrated in the "flowing" material balance method that the wellhead pressure also has a similar trend of decline as the sand-face pressure. This is true when single phase gas flows through the well and there is no liquid build up in the tubing. While studying the plots for p/z of FWHP vs. cumulative production, it has been observed that the apparent gas in place figure of the producing sand of Current Gas Field are lower than that of obtained from static bottomhole pressure and shut-in wellhead pressure methods. This makes sense because flowing wellhead pressure decreases from the shut-in wellhead pressure because of frictional losses. The straight line drawn from the initial wellhead pressure in parallel to the flowing wellhead pressure data gives the original gas in place.

The *p/z* vs. cumulative production graphs of well for static bottom-hole pressure, shut-in wellhead pressure, flowing wellhead pressure and flowing bottomhole pressure appears in Figure 5, Figure 6, Figure 7 and Figure 8 respectively.

Gas in place values estimated from the plots of p/z vs. cumulative production using the static bottomhole pressure, shut-in wellhead pressure, flowing bottomhole pressure and flowing wellhead pressure approaches are 27 BCF, 28 BCF, 24 BCF and 21 BCF respectively.

As of July 2008, the cumulative production from well was 7.087 BCF. Assuming the gas in place value for the well as 24 BCF (using flowing bottomhole pressure approach), reserve at the abandonment p/z of 1000 psia is 16 BCF. Remaining reserve for this location is 8.0 BCF. The recovery factor of this sand till July 2008 is 66.67%.

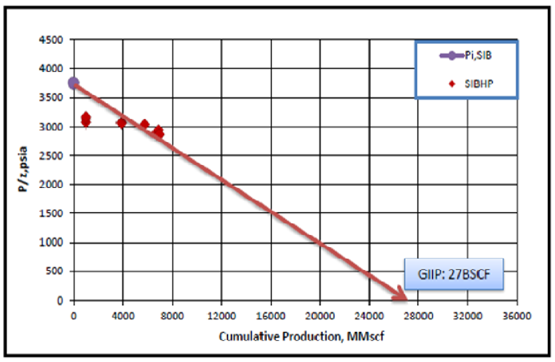

Figure 5: P/z SIBHP vs. Cumulative Production

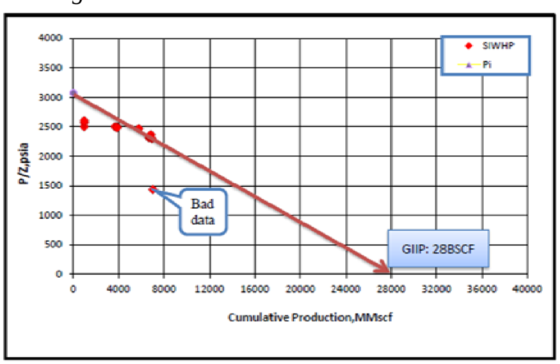

Figure 6: P/z SIWHP vs. Cumulative Production

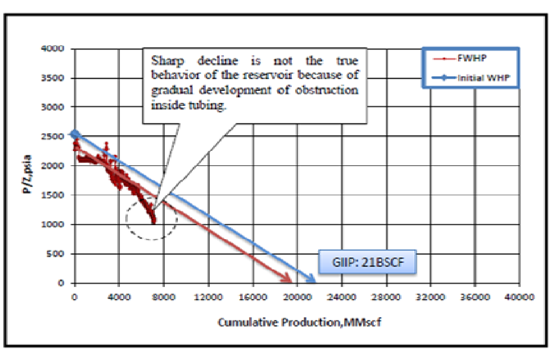

Figure 7: P/z FWHP vs. Cumulative Production

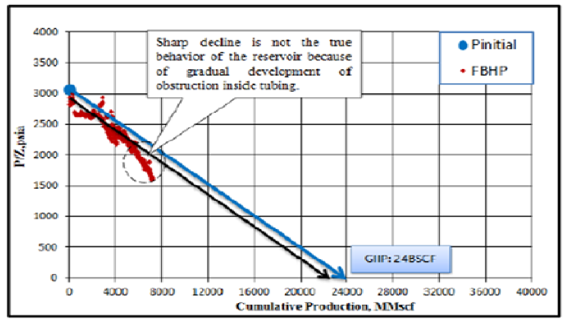

Figure 8: P/z FBHP vs. Cumulative Production

4. SUMMARY AND CONCLUSION

Several methods are presented for estimating the original gas-in-place. The calculated values for this particular case are summarized in Table 1:

Table1: Summary of Material Balance Result

Sand	GIIP, BCF Using Different Approaches of Material Balance				Conv. MBAL, BCF
	SBHP	SWHP	FBHP	FWHP	
LBB	27	28	24	21	26.995

The cumulative production from thw well is 7.087 BCF. Assuming the GIIP using FBHP approach as 24 BCF, reserve at the abandonment p/z of 1000 psia is 16 BCF. Remaining reserve for this sand is 8.913 BCF. The recovery factor is 66.67%.

The results obtained from different methods are not very different. However, the FBHP method can be considered most reliable, because in this method maximum data were availbale, and it consideres Pseudo-steady flow regime prevailing in the reservior. On the other hand, conventional material balance had the least amount of data points, therefore results are less reliable. Other two static pressure methods, although may have more data, do not conform to the requirement of the average reservoir pressure. These could be close approximations in case no other alternatives are available.

5. RECOMMENDATION

- The procedure presented in this paper provides a very practical tool for estimating gas-in-place using data generally available in normal production operations. In addition, production losses can be minimized by not having to shut-in wells. It is possible to determine original gas-in-place with reasonable certainty when shut-in pressures are not available.
- Uncertainties involved in reservoir pressure and draw down will be reduced by conducting periodic bottom hole pressure survey and that will help to accurately model the reservoir and analysis.Alternative methods of material can be applied with resonable certainty where periodic bottom hole pressure survey normally is not conducted.

6. ACKOWLEDGEMENT

I am extremely grateful to the entire Petroleum Engineering department, BUET for their significant contribution to my overall academic and research facilities. Special thanks also go to Chevron Bangladesh for supporting my research efforts using their commercial soft wares.

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8. NOMENCLATURE

Symbol	Meaning	Unit
BSCF	Billion Standard Cubic Feet	-
P	Pressure	(psi)
Z	Gas deviation Factor	-
SWHP	Shut in Well Head Pressure	(psi)
SBHP	Shut in Well Head Pressure	(psi)
FWHP	Shut in Well Head Pressure	(psi)
FBHP	Shut in Well Head Pressure	(psi)
GIIP	Gas Initially In Place	(BCF)
G_p	Cumulative Gas Production	(BCF)
HCPV	Hydrocarbon Pore Volume	(BCF)
Pi	Initial reservoir Pressure	(psi)
Zi	Initial Gas Deviation Factor	-
Rb	Reservoir Barrel	(bbl)
LBB	Lower Bokabil	-