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MATERIAL BALANCE OF A GAS RESERVOIR OF SURMA BASIN BY FLOWING WELLHEAD PRESSURE APPROACH: A CASE STUDY

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Abstract- This *is a well known fact that the hydrocarbon demand increases by the day in the world as well as Bangladesh. Now, in order to meet this ever increasing demand it is essential for us to produce at the required rate over a specified period of time. The traditional material balance (P/Z) plot for gas pools requires fully built-up reservoir pressures, obtained by shutting in the wells. Due to critical production-demand situation, proper pressure survey cannot be conducted on a regular basis in the gas fields of Bangladesh. Shutting in the wells for pressure survey is also very expensive for the gas production companies. The material balance calculation could be done without shutting-in the well. The method is called "Flowing Material Balance". While this method has proven to be very good, it is limited to a constant flow rate, and fails when the flow rate varies. Flowing well method provides an opportunity for updating the reserves without interrupting the production. This procedure consists of a P/Z plot of the "flowing" pressure versus cumulative production. A straight line drawn through the flowing pressure data and then, a parallel line, drawn through the initial reservoir pressure (when flowing bottom hole pressure is used) and through the initial well head pressure (when flowing well head pressure is used) will give the original gas-in-place. Flowing well method of estimating the gas reserve is based on the assumptions that the wells have produced long enough to reach the pseudosteady state condition and the produced gas is relatively dry so that there is no liquid buildup in the well. In this study, actual flowing pressures of the twelve producing wells of the A Sand of Titas Gas Field have been analyzed using wellhead flowing pressures to find the reserve. Analytical justifications have been provided in support of this method. Limitations are also explained when applied to a particular gas reservoir. The results of this study have been compared with those of conventional material balance. The results have also been compared with those of other studies previously conducted on Titas Gas Field. These comparisons show that the gas in place values obtained from flowing well method compare well with those of other studies.*

Keywords: Material Balance, Flowing Wellhead Pressure, Gas Reserve A-Sand, Surma Basin.

1. INTRODUCTION

Reserves are those quantities of natural gas or oil that are estimated to be commercially recoverable in the future using commercial methods and government regulations. Reserves are estimates which are subject to revisions during the life of a field. In other words, reserve is the quantity of gas that we can extract from the gas initially in place (GIIP) in the gas field. GIIP refers to the total amount of gas present initially in the gas field underground [1]. In Surma (Bengal) basin of Bangladesh, Titas is the largest gas field in the nort-eastern part of Bangladesh. The reservoir sands in the field's area are composed of stacked sands which are divided into three groups A, B and C sands. Among them, A-group sand is largest thickness sand than the others [2] which is shown in Figure 1. The GIIP of Titas gas field was previously estimated by different organizations such as Interkomp

Kanata Management (IKM) 1991 [3], National Committee for Gas Demand & Reserve, 2002 [4], Petrobangla, 2009 [5], Miah, M. I. and Howlader, M F., 2013 (Volumetric method) [6]. The accuracy of reserve estimation of GIIP which depends on the availability of sufficient data to characterize the reservoir's areal extent, reservoir pressure, fluid mobility, and variations in net thickness.

Reserve estimation is a dynamic process so it needs to update the previous calculation with the new data. For best estimation it needs latest available all information of the gas field. The objective of this study is to separately re-estimate the GIIP of A group sand using Flowing Wellhead Pressure approach using Material Balance method.

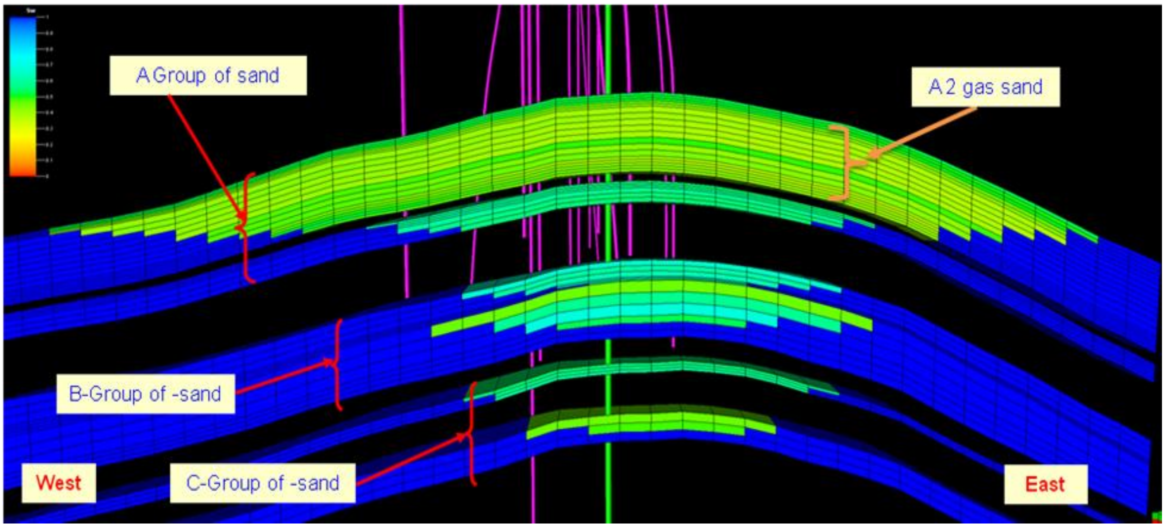

Figure-1: Structural Cross-Section through Titas Anticline and A group sand of Titas Field [6]

2. GEOLOGY OF SURMA BASIN

Most of the gas fields are available in Surma basin in Bangkadesh. Titas is the largest anticlinal closure so far discovered in the Bangladesh Folded Belt of this basin. This field was discovered by Pakistan Shell Well Company in 1962. The structure is an elongate north-south asymmetric anticline measuring about 19×10 square km with a vertical closure of 500m [1, 7]. This gas reservoir includes multiple Sandstone layers in the Buban and Bokabil Formation of Miocene-Pliocene age. The depth of the gas reservoirs are range from about 2616m to 3124m below the surface. There are more than ten distinct accumulations of hydrocarbons are encountered by the well drilled in the field, of which 5 are major with local extension across the gas field. The remaining gas zones are thinner and relatively restricted in areal extent. The qualities of the reservoir sandstones are generally very good with average porosity in range of 20% and average permeability in the range of 100-400 millidarcy. The sandstone reservoirs are medium to very fine grained, well stored and clean with little or no clay matrix [1].

3. METHODOLOGY

The information of reserve is crucial for the development of a production strategy, design of facilities, contracts and valuation of the reserves. Classically, reserves are estimated in three ways: Volumetric, Material Balance and Production decline. The volumetric and material balance methods estimate original gas-in-place where as production decline yields an estimate of recoverable gas. A material balance process is an exact accounting of the materials that enter, accumulate in or depleted from a defined volume in course of a given time interval of operation. The material balance is therefore an expression of the law of conservation of mass. The general form of the material balance equation was first presented by Schilthuis in 1936 [8]. The equation is derived as a volume balance, which equates the cumulative observed production, expressed as an underground withdrawal, to the expansion of the fluids in the reservoir resulting from a finite pressure drop. The volume balance can be evaluated in reservoir barrels (rb) as [9&10]: Underground withdrawal (rb) =
Expansion of oil and originally dissolved gas (rb) +
Expansion of gas cap gas (rb) +
Reduction in HCPV due to the connate water expansion and decrease in the pore volume (rb).

Applying some assumptions (i. e. a reservoir may be treated as a constant volume tank, pressure equilibrium exists throughout the reservoir, which implies that no large pressure gradients exist across the reservoir at any given time, laboratory pressure-volume –temperature (PVT) data apply to the reservoir gas at average pressure used, and reliable production & pressure measurements are available etc.), the above material balance equation can be written for a volumetric gas reservoir (when there is no initial oil, gas compressibility term is much greater than the formation and water compressibility, neither water encroachment into nor water production from a reservoir of interest, the reservoir is said to be volumetric) at isothermal process (i.e. reservoir temperature remains constant):

$$P/Z = (Pi/Zi)(1-Gp/G).$$

Since P_i (initial pressure), Z_i (compressibility factor at P_i), and G (GIIP) are constants for a given reservoir, plotting P/Z versus G_p (produced gas) 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, then the corresponding Gp equal to G [11, 12].

3.1 Flowing Well Head Pressure (FWHP) Approach:

In this approach monthly average flowing wellhead pressure data are used. The flowing wellhead pressure data are taken from monthly records of this field. Mattar and McNeil 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 buildup in the tubing [13]. While studying the plots for P/Z of FWHP vs. Cumulative production, it has been observed that the apparent gas in place is lower than that obtained from static bottom hole 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 (G). The summarized method is shown as below:

Step-1: Determination of the gas compressibility Factor, Z from gas composition of A group sand at reservoir pressure and temperature [14, 15 & 16].
Step-2: Calculate P/Z
Step-3: Plot the P/Z vs. Cumulative production, G_p at Cartesian plot.

4. RESULTS AND DISCUSIONS OF ANALYZED DATA

The Z factor is not a constant. It varies with changes in gas composition, temperature and pressure. Z factor as a function of Pseudo reduced pressure and Temperature [1, 15 & 17]. A relationship between pressure and Z factor is made using gas composition data [6] that is shown in Figure-2 including the correlation equation. For A sand of Titas gas field, initial pressure 3999.2 psia and reservoir temperature 187.8 ^{0}F are used for this study [2,3]. The monthly production data is used for 11 wells (T-1 to 7 & 11-16) individually for reserve estimation using P/Z method, show in figure-3 to 15. From data analysis, pressure is decreased with respect to production time increment. The GIIP (G) is varies with wells. Estimated GIIP ranges from 840 to 220 BCF (Billion cubic feet) by flowing wellhead approach.

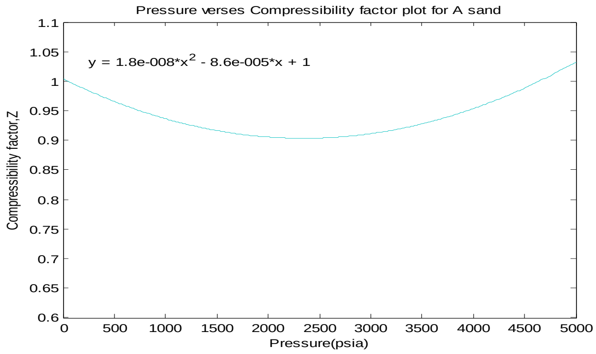

Figure 2: Z factor versus Pressure plot for A sand.

The reserves of the studied wells have been shown in Figure 3 to 15 (P/Z vs. G_p plot). The summarized result of each well is shown in Table-1.

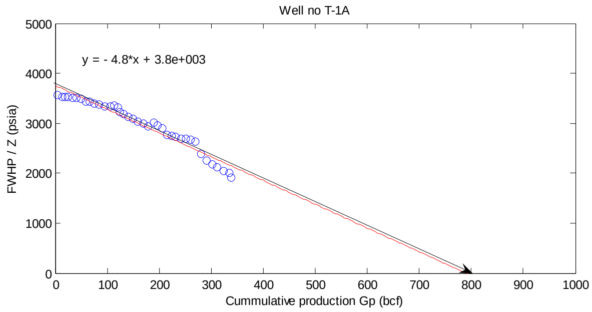

Figure 3: P/Z vs. Cumulative production of T-1.

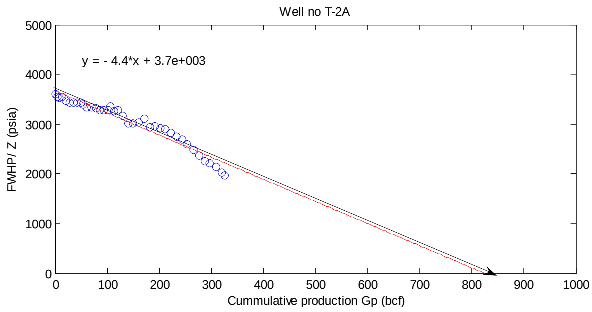

Figure 4: P/Z vs. Cumulative production of T-2.

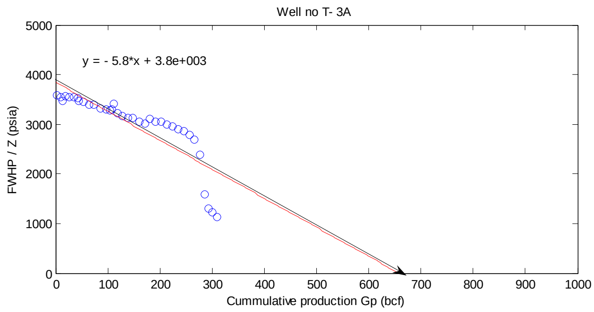

Figure 5: P/Z vs. Cumulative production of T-3

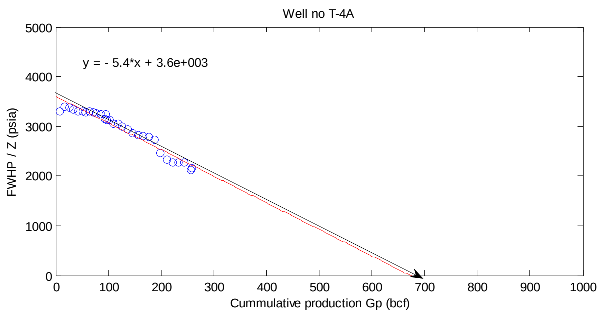

Figure 6: P/Z vs. Cumulative production of T-4

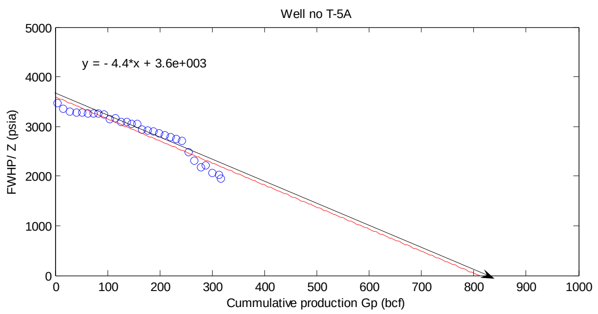

Figure 7: P/Z vs. Cumulative production of T-5

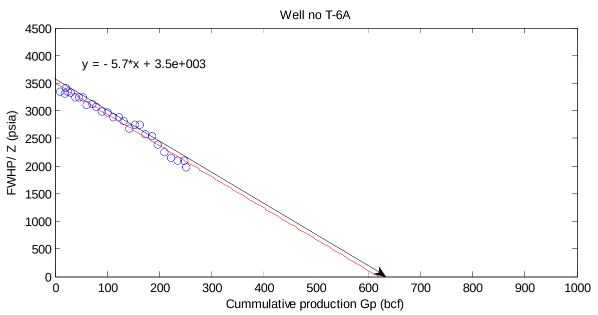

Figure 8: P/Z vs. Cumulative production of T-6

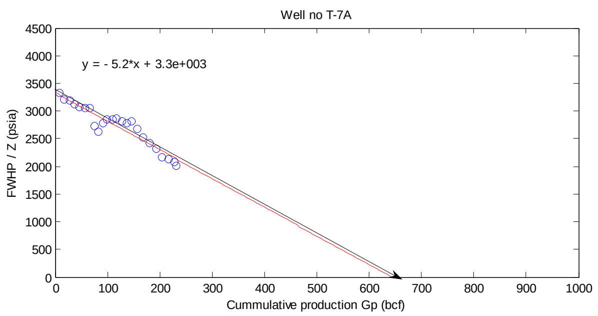

Figure 9: P/Z vs. Cumulative production of T-7

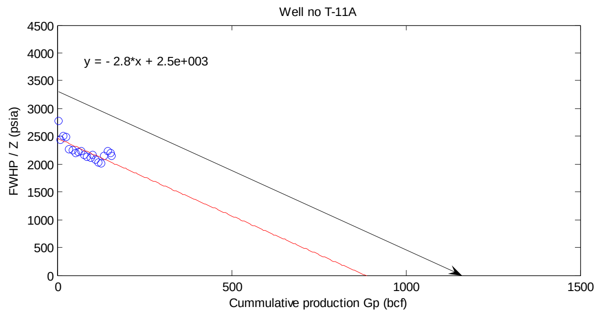

Figure 10: P/Z vs. Cumulative production of T-11

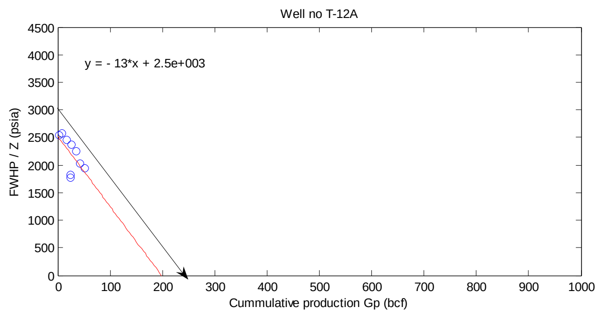

Figure 11: P/Z vs. Cumulative production of T-12

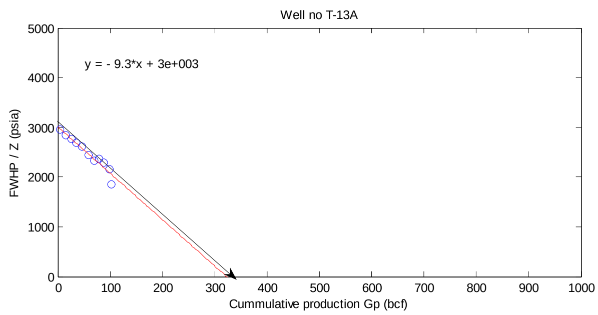

Figure 12: P/Z vs. Cumulative production of T-13

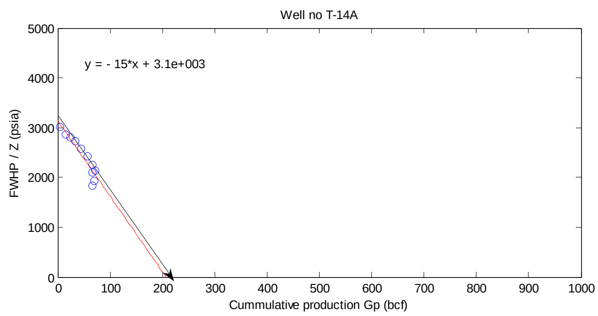

Figure 13: P/Z vs. Cumulative production of T-14

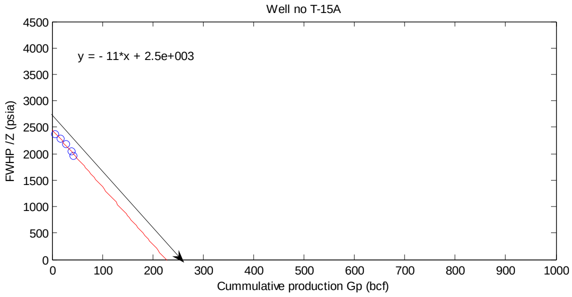

Figure 14: P/Z vs. Cumulative production of T-15

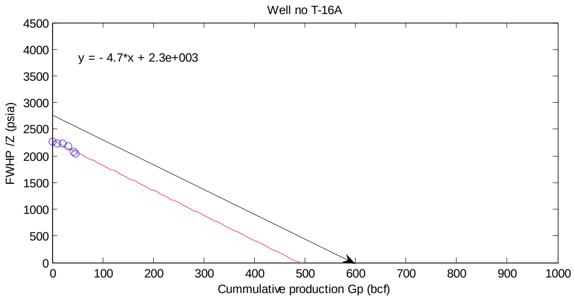

Figure 15: P/Z vs. Cumulative production of T-16

Table-1: Estimated GIIP of each well of A sand reservoir of the studied field by FWHP approach.

Well no.	**GIIP (BCF)**	**Well no.**	**GIIP (BCF)**
T-1	800	T-11	1150
T-2	840	T-12	240
T-3	660	T-13	340
T-4	690	T-14	220
T-5	825	T-15	260
T-6	630	T-16	600
T-7	665	**Total**	**7,920**

Total GIIP of 11 wells is 7.92 TCF (Trillion cubic feet) where 7.293 and 4.138 TCF is estimated by National Committee for Gas Demand & Reserves, 2002 [4] and IKM, 1991 [3]. Current studied is higher than the previous estimation causes for updating the pressure-production data and sub-surface geological information. On the other hand, GIIP is 9.45 of A gas sand reservoir by conventional material balance method [12]. The gas recovery efficiencies depend on number of factors including porosity-permeability of the reservoir, fluid properties, reservoir drive mechanism, abandonment pressure etc. Generally, recovery of gas from the GIIP in typical gas fields range from a low of 50% to a high 0f 90% [7,11]. From production data analysis, the recovery factor is 62% at 1000 psia (abandonment pressure). Uncertainties concerned 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 reasonable certainty where periodic bottom hole pressure survey normally is not conducted. Some points are mentioned as below for gas material balance reserve estimation by flowing wellhead pressure method.

1. The traditional material balance (p/z) plot for gas pools requires fully built-up reservoir pressures, obtained by shutting in the wells. The procedure described in this paper does not require shut-in of wells. Instead, it utilizes information normally obtained but not usually used by reservoir engineers to quantify the original gas-in-place—the daily gas production rates and flowing pressures.

2. Flowing well method, if properly applied, is a very useful tool to update the gas in place and reserve estimates of gas reservoirs without interrupting the production.
3. Gas in place estimates of this study based on flowing well method seems realistic and is consistent with the simulation results. The gas in place estimates also compare very well with those of the conventional material balance method utilizing the occasional shut-in data.
4. The flowing well method is especially suitable for the gas fields of Bangladesh, where pressure surveys cannot be conducted regularly due to critical supply-demand situations.

5. UNCERTAINTY OF RESULTS

Data quality is an important issue in material balance calculation. Uncertainty due to data errors can be found in gas field production data, average reservoir pressure-temperature, and measured gas composition and specific gravity etc [9,18].

6. CONCLUSIONS AND RECOMMENDATIONS

Material balance is simple and one of the most important reservoir engineering tools. GIIP is 7.92 TCF by flowing wellhead pressure approach method of material balance method. Advanced and Dynamic gas material balance methods [19,20] can be used for estimation of GIIP of the studied field.

7. ACKNOWLEDGEMENT

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9. NOMENCLATURE

Symbol	**Meaning**
BCF	Billion Cubic Feet
BAPEX	Bangladesh Petroleum Exploration and Production Company Ltd.
G	GIIP
Gp	Cummulative gas production
GIIP	Gas Initail In Place
N	. Initial Oil In Place
Np	. Produced Oil
T	Titas Gas Field
TCF	Trillion Cubic Feet
RDMD	. Reservoir and Data Management Division
SPE	Society of Petroleum Engineers