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ESTIMATION OF GAS IN PLACE OF BANGLADESH USING FLOWING MATERIAL BALANCE METHOD

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Abstract Natural gas is the only significant commercial energy resource of the country and therefore, future development of the country largely depends on the judicial use of the valuable resource. Estimation of gas in place (GIP) and gas reserves are very crucial for the energy planning and natural gas utilization scheme. Estimation of gas in place and gas reserves are also very important for the sale of natural gas. In this study gas in place values of all the fields under Petrobangla have been estimated using flowing material balance method and volumetric method. The results have been compared with those of Petrobangla. The comparison shows that estimation of this study is significantly higher than those of Petrobangla study. This happened because in this study some new information revealed by some recently drilled development wells have been used. These recent development wells have showed that some of the reservoirs are much larger than previously thought. If all the gas fields are systematically developed, it is highly likely that the natural gas reserve of the country would increase significantly from the present value.

Keywords: Gas reserve, GIP estimation, material balance, and flowing material balance

NOMENCLATURE

A	reservoir area
B_{gi}	gas formation volume factor at initial reservoir pressure
G	initial reservoir gas volume
h_n	net reservoir height
h_g	gross reservoir height
h	reservoir height
p	reservoir pressure
p_i	initial reservoir pressure
p_{wf}	flowing wellhead pressure
S_{wi}	initial water saturation
T	temperature
z	gas compressibility factor
z_i	gas compressibility factor at initial reservoir pressure
ϕ	porosity

INTRODUCTION

Gas is the only significant natural energy resource of Bangladesh. It is the key factor in the development of national economy. Estimation of GIP has a consequential influence on national energy planning. Government and industry need to have a clear assessment of the quantities of gas available for production, and resource potential, which would become available within a practical time frame through additional field development, technological advances, or exploration. Gas in place estimation will be generally revised as additional data (engineering or geologic) becomes available.

According to the Society of Petroleum Engineers (SPE) and World Petroleum Congresses (WPC) (1987), reserves are those quantities of petroleum which are anticipated to be commercially recovered from known accumulations from a given date forward. All reserve estimates involve some degree of uncertainty. The uncertainty chiefly depends on the amount of reliable geologic and engineering data available at the time of the estimate and the interpretation of these data. Proved reserves are those quantities of petroleum which, by analysis of geological and engineering data, can be estimated with reasonable certainty to be commercially recoverable, from a given date forward, from known reservoirs and under current economic conditions, operating methods, and government regulations. Proved reserves can be categorized as developed or undeveloped. Probable reserves are those unproved reserves which analysis of geological and engineering data suggests are more likely than not to be recoverable. In this context, when probabilistic methods are used, there should be at least a 50% probability that the quantities actually recovered will equal or exceed the sum of estimated proved plus probable reserves. Possible reserves are those unproved reserves which analysis of geological and engineering data suggests are less likely to be recoverable than probable reserves. In this context, when probabilistic methods are used, there should be at least a 10% probability that the quantities actually recovered will equal or exceed the sum of estimated proved plus probable plus possible reserves. Gas in place (GIP) is defined as the total amount of hydrocarbons present in the pore volume.

Bangladesh Oil Gas and Mineral Corporation, popularly known as Petrobangla, which is under the ministry of Energy and Mineral Resources, primarily manage natural gas sector of Bangladesh. Petrobangla performs these activities with the help of its nine subsidiary companies. Apart from Petrobangla two International Oil Companies (IOC) are also involved in gas exploration and production under the Production Sharing Contracts (PSC). Out of the nine subsidiary companies of Petrobangla, three are in gas production. These are Bangladesh Gas Fields Company Ltd. (BGFCL), Sylhet Gas Field Limited (SGFL) and Bangladesh Exploration and Production Company Limited (BAPEX).

Bangladesh Gas Fields Company Ltd. (BGFCL) owns eight gas fields, namely, Titas, Habigonj, Bakhrabad, Narshingdi, Meghna, Begumganj, Kamta and Feni. Out of these eight fields, Titas and Habiganj are large fields. The production of Kamta and Feni Fields have been suspended. The pressure of Bakhrabad Gas Field is declining sharply and it is expected that this field will go out of production soon. The Begumganj field yet to be developed.

Sylhet Gas Field Limited (SGFL) owns six gas fields, namely, Haripur, Fenchugonj, Kailashtilla, Rashidpur, Beanibazar and Chhatak. Out of these fields, Kailashtilla and Rashidpur have substantial reserves. Production of Chattak gas field has been suspended. The Fenchugonj field has not been developed yet.

The government has recently extended BAPEX's activities to production in addition to its previous responsibility of exploration of oil and gas in the country. BAPEX has been given the ownership of Shahbazpur and Salda Nadi gas fields, of which the later is in production now. Shabazpur gas field has not been developed yet.

Under the Production Sharing Contracts (PSC) two International Oil Companies (IOC) are producing gas from two gas fields. Unocal Bangladesh Ltd. is producing from Jalalabad Gas Field in Sylhet region and Shell Bangladesh Exploration and Development B.V. is producing from the offshore Sangu Field in Chittagong region. Unocal has discovered two gas fields, namely, Bibyana and Moulovibazar gas fields, of which Bibyana is reported to have a substantial reserve. These fields are yet to be developed.

Using the production, pressure history, and the geologic data of the fields, gas in place of different fields have been estimated using the material balance method as well as the volumetric method. Detail reserve estimation of Rashidpur Gas Field has been presented in this paper as a sample calculation. In this study all the gas fields under Petrobangla have been considered. Gas fields under IOC have not been studied due to lack of data.

MATERIAL BALANCE ANALYSIS

Material balance methods provide a simple, but effective means for estimating not only original gas in place but also gas reserves at different stages of reservoir depletion. Material balance methods also provide a check for the gas in place estimates of the volumetric method.

Conventional material balance analysis for a gas reservoir relies on obtaining a straight line on *p/z* vs cumulative production (G_p) graph to estimate the reserves and initial gas in place (GIP). This method requires fully built-up reservoir pressures, obtained by shutting in the wells for a few days.

The accuracy of reserve calculations by the volumetric method is dependent upon the accuracy of data available, mainly on the quality of seismic and log data. On the other hand, the accuracy of reserves calculated from the material balance studies is dependent upon the accuracy of the production and pressure data of the wells. Unlike the volumetric method, the material balance accounts for reservoir heterogeneity and continuity variations, which occur within the reservoir. The accuracy of the material balance approach for estimating reserves increases with time as reservoir pressure declines as a result of additional production from the reservoir.

The general form of the material balance equation was first presented by Schilthuis in 1941. 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 general form of the material balance equation for volumetric gas reservoir is (Craft and Hawkins, 1991):

$$\frac{p}{z} = -\frac{p_i}{z_i G} G_p + \frac{p_i}{z_i} \qquad (1)$$

Since p_i/z_i , and G are constants for a given reservoir, plot of *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, then the corresponding G_p would equal to G, the initial gas in place. Deviations from this straight line can be caused by external recharge or offset drainage. In water drive reservoirs, the relation between Gp and p/z is not linear. Because of the water influx, the pressure drops less rapidly than that of a volumetric reservoir.

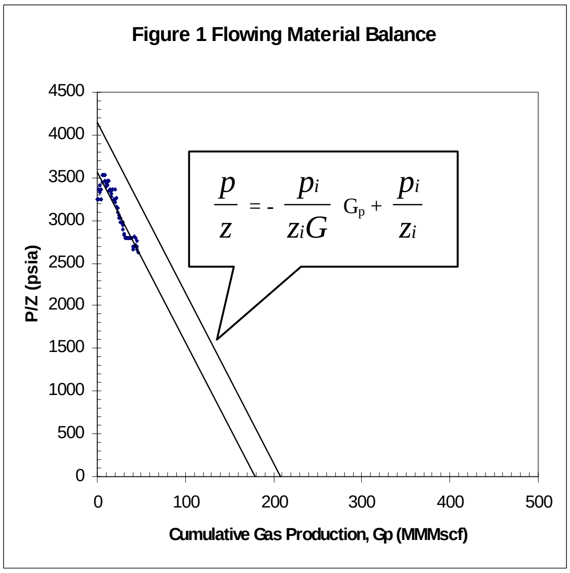
FLOWING MATERIAL BALANCE

One of the limitations of the conventional material balance method is that it requires fully built-up pressure obtained by shutting in the wells for a few days. 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 is drawn through the flowing sand face pressure data and then a parallel line from the initial reservoir pressure gives the original gas in place. Graphical presentation of this method is shown in Figure 1. This method of calculating the reserves of medium and high permeability reservoirs, using flowing pressure data has the potential of preventing loss of valuable production, without having to shut-in the well. The method is suitable for all gas fields in Bangladesh where routine pressure testing cannot be conducted due to critical demand-supply situation. To get accurate results, the production rate from the reservoir should be constant. pressure in parallel to the flowing wellhead pressure data gives the original gas in place. In this approach interference in pressure data due to production of other wells of the sand, will affect the accuracy of the results. Chowdhury and Gomes (2000) gave some more theoretical background on the flowing material balance method and applied the method on Bakhrabad Gas Field.

Mattar and McNeil demonstrated 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 The straight line drawn from the initial wellhead

VOLUMETRIC ESTIMATION

Volumetric method of reserve estimation considers the reservoir pore volume (PV) occupied by hydrocarbons at initial conditions and at later conditions after some fluid production and associated pressure



reduction. The later conditions often are defined as the reservoir pressure at which production is no longer economical. Volumetric methods are used early in the life of a reservoir before significant development and production. These methods, however, can also be applied later in a reservoir's life and often are used to confirm estimates from material balance calculations. Beginning with the real gas law, the final form of volumetric equation is $G = \frac{Ah\phi(1-S_{wi})}{B_{gi}}$ (2)

where $B_{gi} = \frac{Z_i T P sc}{P_i T sc}$ (3)

The accuracy of volumetric estimates depends on the availability of sufficient data to characterize the reservoir's areal extent and variations in net thickness which are used to determine the gas - bearing reservoir PV. Obviously, early in the productive life of a reservoir when insufficient data are available to establish subsurface geologic control, volumetric estimates are least accurate. As more wells are drilled and more data become available, the accuracy of these estimates improves.

RESERVE ESTIMATION

In this section application of flowing material balance method to Rashidpur Gas Field is discussed detail. In flowing material balance of Rashidpur Gas Field, all flowing tubing head pressure data (from 1993 to January 2000) are used in p/z versus cumulative production plots. A straight line drawn through p_{wf}/z data and then a parallel line through the initial reservoir pressure gives the gas in place value. Six wells (RP#2 to RP#7), are producing gas from the lower sand and one well (RP#1) is producing gas from the upper sand. Adding up gas in place values of all seven wells gives the total GIP of the field. Table 1 shows the individual well values. p/z versus cumulative production curve giving GIP values of each well are shown through Figure 2 to Figure 8. Figure 2 shows the plot of p/z vs cumulative production of well 2 data of Rashidpur Gas

Field. A best fit straight line is drawn through the data. Then a parallel line to this straight line is drawn through the initial p/z data, intercept of which on the X-axis gives the initial gas in place value, in this case it is 208.19BCF. Similarly, Figures 2 to 8 show the plots for other wells.

The accuracy of the volumetric estimates depends on the quality of seismic and log data but is severely affected by well density. In calculating GIP, gross thickness maps are used, which are not revised after drilling new wells. Sand wise volumetric GIP and related parameters of Rashidpur Gas Field are shown in Table 2.

Table 1 Estimated GIP of Rashidpur Gas Field Using Flowing Material Balance Method

Sand	Well	Gas in Place (GIP) (BCF)	
Upper	RP # 1	1917.495	1917.495
Lower	RP # 2	208.19	1271.974
	RP # 3	364.524	
	RP # 4	527.11	
	RP # 5	106.77	
	RP # 6	8.59	
	RP # 7	66.01	
Total			3189.469

Figure 2 Flowing Material Balance of Rashidpur Gas Field (RP# 2)

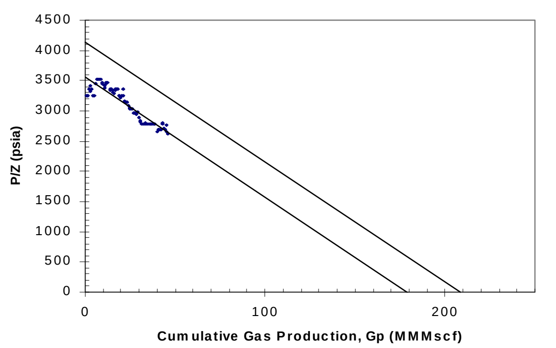


Figure 3 Flowing Material Balance of Rashidpur Gas Field (RP # 3)

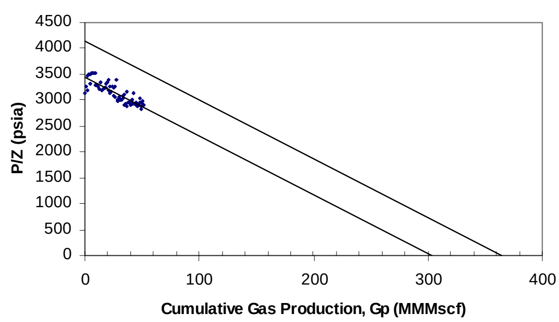


Figure 4 Flowing Material Balance of Rashidpur Gas Field (RP # 4)

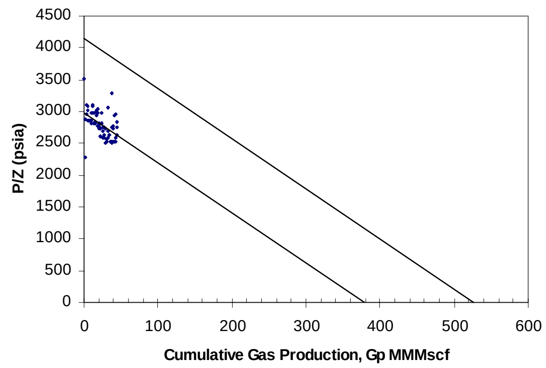


Figure 5 Flowing Material Balance of Rashidpur Gas Field (RP # 5)

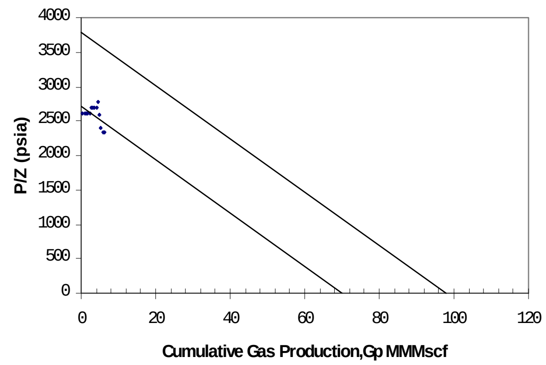


Figure 6 Flowing Material Balance of Rashidpur Gas Field (RP # 6)

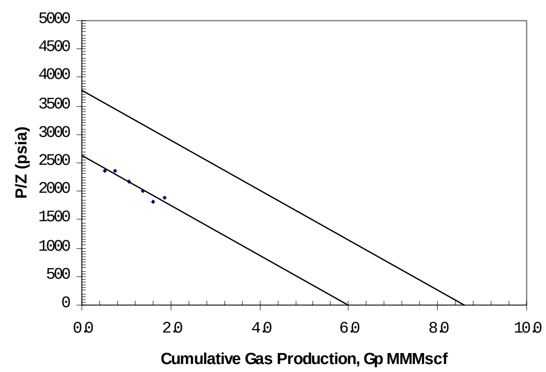


Table 2 Estimated GIP of Rashidpur Gas Field Using Volumetric Method

Sand	Area (A) (acres)	h avg (ft)	hn/hg	Porosity	Sgi = 1 – Swi	Bgi (rcf/scf)	GIP* (BCF)	
							Prov.	Prob.
Upper	1841	255.5	0.687	0.22	0.67	0.00666	311.6	
	762	328.6	0.699	0.22	0.67	0.00666	168.7	
	2899	183.6	0.689	0.22	0.67	0.00666		353.6
Lower	3249	280.4	0.573	0.17	0.73	0.00445	634.1	
	3971	280.4	0.573	0.17	0.73	0.00445		775.0
Total							**2243**	

COMPARISON OF RESULTS

Gas in place of different gas fields have been estimated using the flowing material balance as well as volumetric method. Results of these two methods and that of Petrobangla are shown in Table 3. IKM Reservoir Engineering Report (1990) concluded that the recovery from the upper gas sand in the Habiganj Gas Field would be controlled by the water drive mechanism. The report also mentioned the size of the aquifer to be ten times greater than the reservoir. Large difference between the gas in place values from the material balance method and volumetric method is due to aquifer support in the upper sand. In this case material balance method overestimates the GIP. Production was suspended in the gas fields Fani and Kamta for some unknown reasons. Contour maps of those fields were not updated. For this reason gas in place values based on volumetric method are different than those of material balance method.

DISCUSSION

Material balance study has been conducted to estimate the GIP of the producing fields and the results are compared with the volumetric estimates. In most of the instances these results are comparable except for Titas and for the fields where water drive is suspected. GIP is over-estimated by the material balance in presence of water drive. However, the presence of water drives is not certain in any reservoir yet and the suspected water drive reservoirs may ultimately turn out to be huge gas reservoirs.

Intercomp-Kanata Management LTD (IKM) undertook last comprehensive reserve estimate in 1990. According to IKM original gas in place (GIP) was 2.62 TCF based on volumetric estimation, and 10.53 TCF based on material balance study. Recently drilled development wells have revealed surprising new information. These new wells have shown that the reservoir boundary extends beyond the previous one. With the new data and information, revised reserve estimation has been conducted. At the same time, the revised sub surface maps of Titas Gas Field have been constructed for volumetric estimation. Both volumetric and material balance results suggest that GIP of Titas Gas Field is much higher than previously assumed value.

In 1999 wells RP # 5, RP # 6 and RP # 7 were completed in the lower gas sand of Rashidpur Gas Field. Both upper and lower sand contains a very dry gas consisting mainly methane. The mechanism of recovery is considered to be volumetric depletion. No evidence of aquifer support exists at this time. Maps have not been updated using the information of the new wells.

Table 3 Estimated GIP of Different Gas Fields

Field	No. of sand	No of well	Estimated GIIP[a] (TCF)		GIP Petrobangla ,1998 (TCF)
			MB	Vol.	
Producing					
Titas	13	14	10.24	9.050	4.132
Habiganj	12	7	8.022[b]	3.669	3.669
Bakhrabad	5	8	1.120	1.332	1.432
Narshingdi	2	1	0.402	0.194	0.194
Meghna	1	1	0.095	0.160	0.159
Saldanadi	2	2	0.227	0.351	0.200
Sylhet	2	2	0.84	0.444	0.444
Rashidpur	2	7	3.189	2.243	2.242
Kailastila	3	4	3.588	3.656	3.657
Beanibazar	2	2	0.108	0.243	0.243
Non Producing					
Shahbazpur	1	1		0.514	0.514
Fenchuganj	3	2		0.404	0.350
Production Suspended					
Chhatak	1	1	0.406	1.900	1.900
Kamta	1	1	0.137	0.109	0.325
Fani	2	2	0.117	0.132	0.132
Total (TCF)			28.49	24.401	19.593

[a] Proven GIP only
[b] May be overestimated due to water drive

CONCLUSIONS

1. If the periodic production test data are not available, Flowing Material Balance Method can be applied to the gas reservoirs provided the reservoirs are volumetric. This method seems to be applicable to most of the gas reservoirs of Bangladesh.
2. Although most of the major gas fields in Bangladesh have been discovered in the sixties, these fields have not been properly developed or evaluated yet. If properly evaluated, there are strong possibilities that the reserves or the GIP may increase significantly in some of the major gas fields. This has been proved in

Titas gas field in which some development wells have been drilled recently.

REFERENCES

1. Choudhury, Z. and Gomes, E.: "Material Balance Study of Gas Reservoirs by Flowing Well Method: A Case Study of Bakhrabad Gas Field" paper SPE 64456 presented at the 2000 SPE Asia Pacific Oil & Gas Conference and Exhibition, Brisbane, Australia, October 16-18, 2000.

2. Craft, B.C. and Hawkins, M.F., Jr. (1991): Applied Petroleum Reservoir Engineering, 2nd Edition, Prentice Hall PTR, Englewood Cliffs, NJ.

3. Hall, K.R. and Yarborough, L. (1973): "A New Equation of State for Z-Factor Calculations", Oil & Gas J. (June 18) 82-92.

4. Intercomp-Kanata Management Ltd. (IKM) (1990): "Gas Field Appraisal Project, Geological, Geophysical and Petrophysical Report, Rashidpur Gas Field, Bangladesh", Canadian International Development Agency (CIDA) & Bangladesh Oil, Gas and Minerals Corporation (BOGMC) report, September 1990.

5. Intercomp-Kanata Management Ltd. (IKM) (1990): "Gas Field Appraisal Project, Reservoir Engineering report, Rashidpur Gas Field, Bangladesh", Canadian International Development Agency (CIDA) & Bangladesh Oil, Gas and Minerals Corporation (BOGMC) report.

6. Intercomp- Kanata Management Ltd. (IKM) (1990): "Gas Field Appraisal Project, Facilities Engineering report, Rashidpur Gas Field, Bangladesh", Canadian International Development Agency (CIDA) & Bangladesh Oil, Gas and Minerals Corporation (BOGMC) report.

7. Kumar, Sanjay (1987): Gas Production Engineering, Volume 4, © Gulf Publishing Company, Houston, Texas.

8. Lee, J., Wattenbarger, R.A. (1996): Gas Reservoir Engineering, SPE textbook series, Vol. 5, © Society of Petroleum Engineers Inc.

9. Mattar, L. and Mcneil R., Fekete Associates Inc. (1998): The "Flowing" Gas Material Balance; The Journal of Canadian Petroleum Technology.

10. Project Implementation Unit, Petrobangla (1994): Titas Gas Field Reservoir Engineering Report Based on 1992 and 1993 Pressure Surveys.

11. SPE Web site: http://www.spe.org/spe2/oilgastech/reserves.html