

1st National Iranian Drilling Industry Congress Under Balanced Drilling (Ubd) Technology

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Abstract

Non renewable natural oil and gas reserves in the world today necessitate applying new methods in exploration, exploitation and utilization of these reservoirs. Undoubtedly, the pressure drop due to large exploitation from these reservoirs makes the traditional over balanced drilling methods gradually lose their effectiveness. That is because over balanced drilling method causes irreparable damages to reservoir rock and excessive increase in costs. One of the main ways to achieve high efficiency in drilling and completion and maintenance of new and old wells without damaging the reservoir is under balanced drilling.

1. Introduction

Since 1898 that the first well was drilled in Masjed Soleiman, Iran, all operations of drilling and completing wells have been based on the traditional over balanced drilling methods. In this method, because of the higher fluid bottom hole pressure (BHP) than the matrix pressure, there were a rush of drilling fluid into the matrix.

Usually in the matrixes with CapRock, although the damages caused by the rush have no significant impact in the process of hydrocarbon production, they cause excessive drilling costs. But these damages in the matrixes under the caprock containing hydrocarbons (reservoir) lead to significant irreversible damage to the reservoir rock and thus reduce productivity index. To avoid these damages the rush of drilling fluid into the matrix should e prevented, however some forms of under balanced drilling methods such as air drilling, aerated mud drilling and ...have been used more than half a century but under balanced drilling in the reservoir as a modern and developed form began in the North Sea since 1988 using rotating control head devise [5].

Iranian oil fields that suffer from reservoir pressure declines as a result of many years of continuous production of the reservoir are considered suitable candidates for under balanced drilling including Gachsaran, Bibi Hakimeh, Koranj, Parsi, Labsefid, Dehloran, Danan, Sarkan and Malkouh.

Reservoirs of these oil fields have natural fractures and have relatively well-qualified permeability and porosity of rock. However, their pressure is declined in the recent years that using traditional over balanced drilling, all the fluid rushes inside the reservoirs and in addition to great damage to the tank, they

prevent continuing drilling procedure. Right now, the traditional over balanced drilling method is not used in Koranj and Parsi Fields anymore and although the productivity index of these fields is high and have a high potential to produce oil, it is not possible to have access to the production layers and the need for new under balanced drilling technology is highly felt. In Gachsaran and Bibi Hakimeh fields in which oil reservoirs are naturally fractured, bling drilling occurs at the bottom hole and in some cases the drill string gets stuck in the well and not released which leads to cutting, fishing operation and high costs.

Studies on under balanced drilling methods for oil fields of Iran began in 1998. In 2002, the studies continued specifically and operationally which resulted in choosing equipment and machinery in December 2004 under balanced drilling method was used in Gachsaran field for the first time by National Iranian Drilling Company personnel.

2. Under balanced drilling methods principles

Most oil and gas wells are drilled by rotating drilling in which the drill splits the rock. In this method, the drilling fluid is pumped through the drill string into the well and comes to the surface along with the cuttings by the annulus [18]. In over balanced drilling the drilling fluid includes other functions such as wellbore stability, cooling the drill and, most importantly, matrix fluids control. If the foundation fluid pressure and hydrostatic pressure of the drilling fluid in the well.

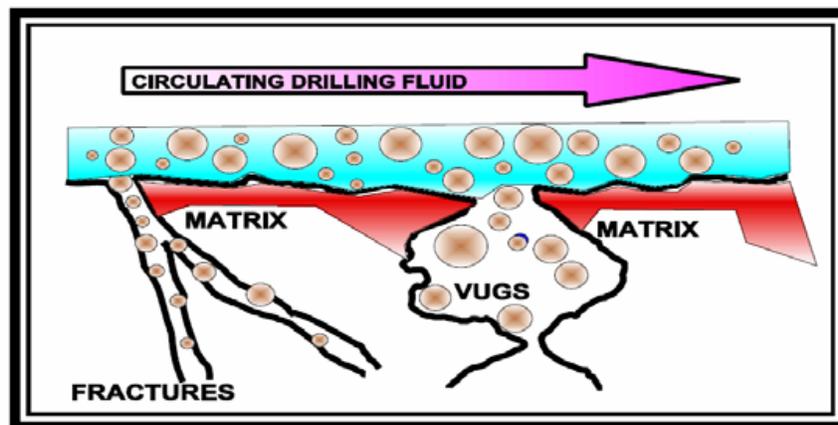


Figure (1). The schematic view of conventional drilling in terms of the direction of fluid flow of the matrix

Under balanced drilling is a type of drilling procedure in which the drilling fluid pressure inside the well is kept lower than matrix pressure in case of which a permeable layer is drilled and matrix fluids flow into the well. Accordingly under balanced drilling is also called “ongoing drilling”.

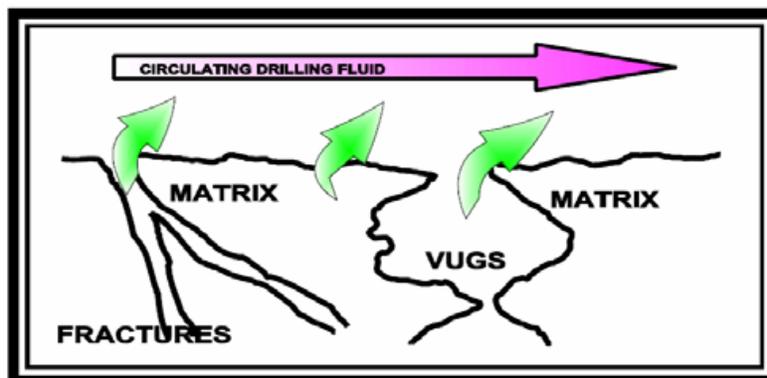


Figure (2) the schematic view of under balanced drilling in terms of matrix flow direction

3. Under balanced drilling advantages

Under balanced drilling advantages compared to over balanced drilling are as follows:

3.1. Reduced matrix damage:

The expected efficiency of a well is reduced by damaging the matrix around the well and low permeability. This damage may be due to entry of liquid, solid or both into the matrix. In UBD such damages do not exist, however, this does not mean that the possibility of matrix damage by drilling fluids is completely resolved because in some cases, , the chemical potential difference between drilling fluid and matrix fluid allows water to enter the matrix and leads to damage. Also in UBD at the time of cutting fluid circulation an over balance condition may occur which damages the matrix [9]. Also by performing UBD it is possible to prevent the damaging results of solids and fluids that change of rock wettability, relative permeability and clogging the pores of rock. These changes reduce the effective fluid permeability (oil or gas) in the reservoir. A sample well subject to OBD produces 100 to 150 barrels per day, while if the same well is drilled by UBD, it will produce 1,000 to 1,500 barrels per day.

3.2. Increased rate of penetration:

UBD increased the rate of penetration (ROP). That is why lighter fluids are used in UBD more than OBD because UBD prevents high balanced pressure in the rock under the drill. Removing this limiting pressure makes rock cutting by the drilling teeth easier and the generated cuttings are got rid of staying at the bottom of the well [17]. This phenomenon helps to clean the bottom of the well and increases the rate of penetration of drill and drilling speed.

3.3. Reduced drilling fluid loss:

UBD is an effective way to minimize the amount of lost mud in drilling oil and gas reservoirs that are naturally fractured or evacuated reservoirs. Usually loss of drilling fluid when the drilling fluid enters the open hole of the matrix is more than the time it returns to surface. This is more probable for the loss of drilling fluid when it enters into an area with high permeability [1]. The drilling fluid may enter the natural fractures that cut wellbore or the fractures appeared by excessive pressure of the drilling mud. The loss of mud in normal operation is very expensive because the lost fluid must be replaced and the loss should be eliminated by adding LCM materials. Therefore, since there is no any physical force to drive the drilling fluid into the matrix in the UBD, drilling fluid loss becomes minimal.

3.4. Increased drill life

If drilling mud is replaced by saturated drilling fluids, the life of drill will increase. Compressive strength of rock increases by the balanced pressure of the drilling fluid. The pressure limitation does not exist during UBD. Therefore, in comparison with conventional drilling, the rock can be crushed by the drill [14].

In other words eliminating the pressure limitation allows the drilling cuttings to follow the fluid easier and this minimized the task of re crushing the rocks by the drill. Therefore, the amount of work required for drilling a given volume of rocks decreases and increased drilling efficiency will increase the area of drilling before the end of drill life.

The well comparing the wells 33 and 132 of Bibi Hakimeh

Well	33	132
Tower (days)	159	66
The cost of mud	6,552,292,319	2,918,186,870
The cost of cement plug	500,000,000	0
The cost of Tower (days)	21,576,300,000	8,956,200,000
The cost of UBD	0	8,897,280,000
Total	28,628,592,319	20,771,666,870
Cost savings	---	982,000 \$

3.5. Minimizing differential pressure sticking

In conventional drilling methods, due to the deposition of drilling mud a Mud Cake is formed on the wellbore. In such cases the drilling string sticks to the Mud Cake due to higher drilling fluid pressure compared to the matrix pressure. In some cases in order to release the drilling string more axial pressure that the tensile strength of the tubes might be needed. Such cases are called “differential pressure sticking”. During UBD no mud cake is formed. Therefore differential pressure sticking does not occur in UBD [8].

3.6. Improved matrix evaluation

In UBD drilling the matrix that has hydrocarbon causes the hydrocarbon to total fluid volume ratio increase and come to the surface. As a result by direct observation of the returning drilling fluid, a device for the immediate detection of the hydrocarbon areas is provided. When the well is drilled by UBD some of these producing areas might be passed. Due to the fast return of the drilling fluid followed by fluid s and cuttings, the depth of oil and gas areas can be determined more accurately by UBD [8]. However in the OBD the areas with hydrocarbon are determined by drilling analyzers, the analysis of drilling cores and drill stem test. In addition, reduction or elimination of the effects of drilling fluid invasion to the matrix and its damage which is one of the advantages of UBD helps the better interpretation of the open hole charts.

3.7. Less need to stimulate wells

In In OBD after the completion of drilling operations, in order to increase well productivity, stimulation operations such as acidizing is performed. Thus, by reducing matrix damage in UBD additional costs of simulation are prevented.

3.8. The early production of oil

In UBD by providing the right surface equipment, it is possible to obtain hydrocarbons at the time of arrival in a productive region. As drilling continues to reach more productive areas, the produced oil is collected. In the wells drilled by UBD, there is a possibility of using them during the drilling.

3.9. Environmental advantages

UBD drilling prevents the possible pollution by drilling mud during and after drilling because the hydrocarbon fluids produced during UBD are closed, collected and separated by the surface systems and this minimizes the environmental pollution.

Achieving the above benefits depend on the characteristics of the reservoir and drilling matrix.

4. Wells candidate for UBD in Iran

Based on the results of this study, oil and gas reservoirs status and UBD advantages the candidate wells for UBD in Iran are as follows:

- 4.1. In exploration wells when the purpose of drilling is to reach the reservoirs located at depths of production areas with less pressure, conventional drilling leads to problems such as loss of drilling fluid and drill pipe stuck in the high areas. For example, in Bibi Hakimeh well 120 which was drilled to reach Fahlian reservoir after reaching the end of Asmari, 79000 barrels of polymer clay, 19,000 barrels of cell types and 4,000 barrels of cement slurry were wasted in the reservoir.

- 4.2. In the wells that the matrix pressure gradient and fracture pressure are close to each other.
- 4.3. Any matrix that has the possibility of damage especially the natural fractured reservoirs that are drilled either vertically or horizontally by the conventional drilling. Thus the wells in Gachsaran, Bibi Hakimeh and Dehloran are good candidates for using the UBD method. The notable point is that the damage to the fractures of the reservoirs can be very severe. Also lime and sand reservoirs are subject to damage in OBD.
- 4.4. Reservoirs that have the rocks with low permeability (less than 800 md for oil and 5 md for gas) and have high strength. Such reservoirs after drilling required hydraulic fracturing stimulation.
- 4.5. Reservoirs that have highly fractured rock using UBD provides continuous drilling after reaching the first fracture without any loss.
- 4.6. The matrixes that have been subject to reduced pressure after years of reservoir production. Conventional drilling in such depleted reservoirs makes all fluids rush into the reservoir and in addition to damage to reservoir prevents continuing drilling.
- 4.7. Matrixes with very high pressure. Such matrixes require drilling fluids, surface equipment and expensive Wellhead for the safety and fluid control.
- 4.8. Matrixes that do not require proper well pressure to maintain the well bore stability.
- 4.9. When you want to have the maximum production from a well based on a sales contract. Drilling of these wells by UBD can ensure reaching the maximum production.

5. Wells not appropriate for UBD

In some matrixes UBD is not appropriate including

- 5.1. Matrixes with low strength. Such matrixes need the pressure to maintain wellbore.
- 5.2. Swallowing matrixes that increase the well diameter such as Pabadeh and Gurpi Matrixes.

6. Choosing two-phase drilling fluid:

The selected gas fluid used for drilling cannot be the air because a high percentage of the oxygen in the air creates a flammable combination in pressure conditions and adjacent to the hydrocarbon gases produced in the matrix. The required spark for the explosion is created by grinding drill string with wellbore. Due to the neutralized nitrogen gas, which is used as a gas-phase, the liquid phase of drilling fluid is proportional to the reservoir rock properties, for example if the rock is Wet Water, the liquid phase can be gasoline of crude oil and if it is wet oil, the liquid phase is water or salt water.

For the oil wells in the south of Iran such as Gachsaran, Bibi Hakimeh, Koranj and Parsi that are good candidates for UBD, the reservoir rock is wet water. Therefore, the liquid phase of the injected fluid must be gasoline or crude oil. To prevent borehole combustion and casing and drilling corrosion problem management the nitrogen gas drilling fluid should be selected.

7. Calculating the optimum flow for two phase drilling

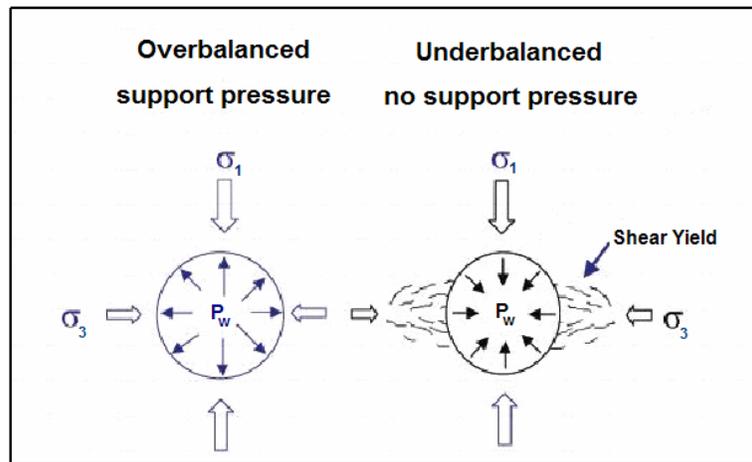
7.1. Wellbore instability

In the conventional method of drilling due to higher hydrostatic pressure of the drilling fluid than the matrix fluid, the wellbores have higher stability. But in UBD this stability is reduced and as the differential pressure of drilling fluid and matrix is increased, the instability of the well increases. This difference in pressure creates a low-pressure for the drilling fluid the lower pressure of which makes continuing UBD impossible. This UBD depends on the matrix internal stress, matrix strength, reservoir pressure and the schematics of the wellbore.

$$J_2^{1/2} = \sqrt{\frac{1}{6}[(\delta_1 - \delta_2)^2 + (\delta_2 - \delta_3)^2 + (\delta_3 - \delta_1)^2]} \quad (1)$$

$$S - p_f = \frac{1}{3}(\delta_1 + \delta_2 + \delta_3) - p_f \quad (2)$$

Figure (3) instability of wellbore as a result of high UBD difference



7.2. Moment Imbibe process

The liquid phase of the drilling fluid might enter the matrix for capillary rise even in UBD. In 1993 Benion et al showed that this operation may damage the matrix. Capillary pressure is created by the forces between solid gas and liquids surfaces and it is a pressure that prevents the removal of the fluid that wets the rocks in the matrix inside the porous environment. Capillary forces depend on the composition of the fluids and rock matrix and signify which fluid inside the porous environment is the wetting phase.

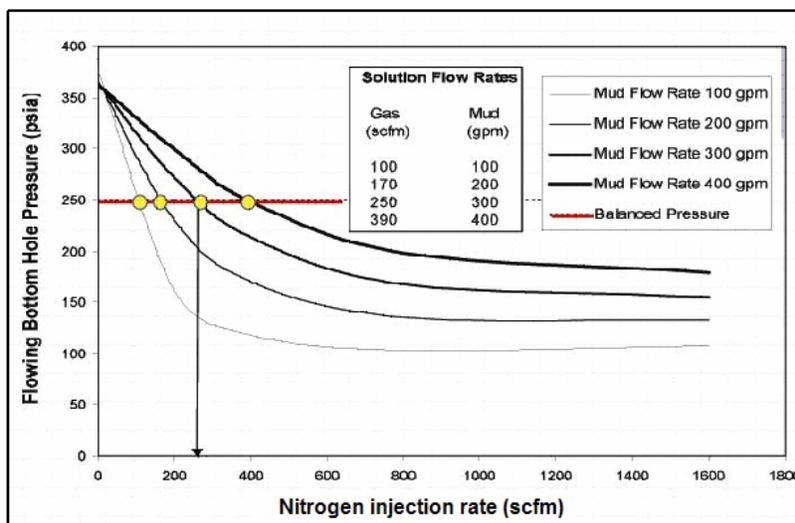
Some reservoir rocks are naturally wet. It means that when they are saturated in oil and floated in water, the water is more willing to enter the porous environment.

In UBD the pressure difference between drilling fluid column and the fluid inside the matrix is equal or more than the capillary force of the reservoir rock so that the, for example, wet water reservoir rock does not make the drilling fluid imbibe. In a porous environment the capillary force is obtained as follows:

$$P_c = \frac{2\sigma \cos \theta}{r_p} \tag{3}$$

The UBD pressure required to prevent the entrance of drilling fluid water to the wet water matrix depends on the initial saturation and the size of pores. Strong wet oil matrixes do not make water and the wet water matrixes do not make hydrocarbon imbibe. The matrixes including gas in case of containing minerals such as, sulfur, asphalt, pyrobitumen, heavy bitumen or when in case of replacing an initial column of oil by gas, their saturation level is reduced to the non reducible level, are strongly wet oil.

Figure (4). The combination of two phase fluids that leads to UBD pressure



7.3. The ability to rise the cutting and cleaning the well:

In two-phase fluid flow due to gas expansion the speed of cutting transfer increases significantly. The critical area of the well cleaning is an area in which the well angle changes from 45 to 60 and the other one is the area under the drill. The reservoir influent increases the liquid phase and cleanness of the well but in the area under the drill due to limited influent the rate of liquid phase is subject to pumping drilling fluid inside the drilling fluid. Also in the bi phase flow, the gas phase increases the turbulent flow that prevents the deposition on the walls [3].

Based on the last results the lowest annulus rate required for the liquid phase to raise the drilling cuttings is 165 feet per minute for vertical wells and 177 feet per minute for wells with deviation of more than 10 degrees.

7.4. Wellbore washout:

The highest allowed velocity of the two phase fluid to prevent wellbore washout equals:

$$V_m = \frac{Q_m}{A} \tag{4}$$

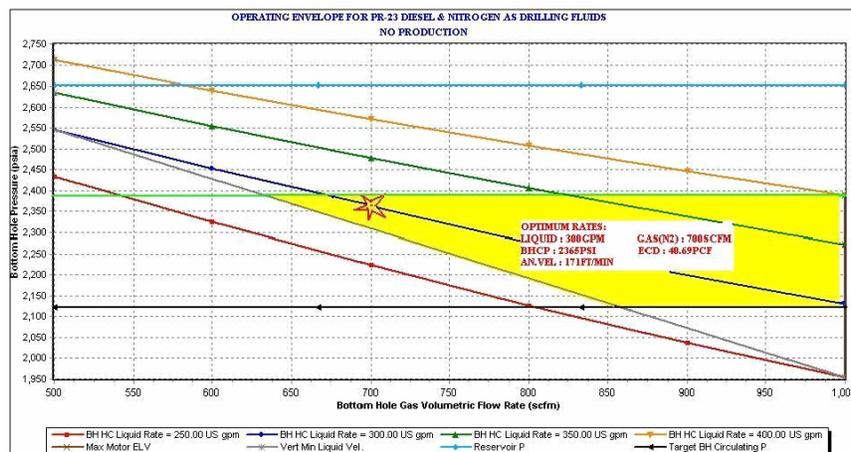
ft^3/min : The highest allowed discharge of the fluid

A: flow path cross section

In^2 = Highest allowed velocity ft/s

The highest allowed two phase velocity is obtained by field study:

Figure (5) The software calculations to determine the optimal point of UBD



8. Conclusion

According to the studies:

- 8.1. If the volume fraction of the liquid phase returning the well is high, a closed system for the separate, collect and convert them to the reservoirs for the reuse should be used. Usually the returning fluids include three or four phases that for the separation of the phases a separator with suitable capacity and pressure should be used.
- 8.2. For the wells in oil fields in southern Iran such as Gachsaran, Bibi Hakime, Koranj and Parsi that are good candidates for UBD the rock is often water wet thus, the liquid phase of the injected phase must be petroleum gas or crude oil.
- 8.3. To avoid borehole combustion and to reduce the problem of drill string, the gas phase of drilling fluid is nitrogen.

- 8.4. In this study, according to the calculations on Parsi field using Wellflo and the information available, the maximum required discharge of nitrogen for Prsi and Koranj wells are 1200 cubic feet per minute
- 8.5. The pump capacity that transfers the liquid to the tower considering the safety coefficient and the type of pumps is considered as 300 GPM and 50 psi pressure.
- 8.6. Nitrogen booster capacity should be equal to the capacity of the nitrogen producer devise i.e. 1500 cubic feet per minute.
- 8.7. The pressure lowering network required for the UBD in Iran's oil fields includes: rotating control head, and push/ pull machine in the live wells presented in Figures (6 and 7).

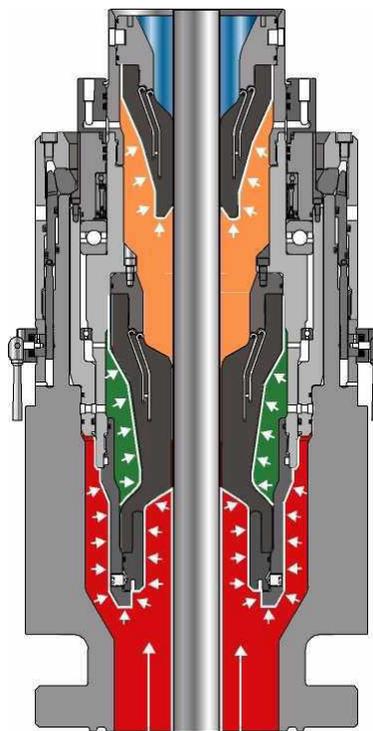


Figure (6) UBD rotating control head

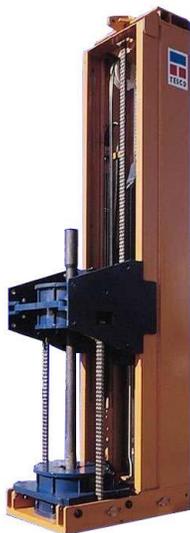


Figure (7) push/ pull machine in high pressure well

- 8.8. The work pressure of rotating control head in the static mode must be equal with tower rotating control i.e. 5000 psi. But its rotating pressure must be proportional to the reservoir pressure (the existing rotating control head has the static pressure of 3000 psi and the rotary pressure of 1000 psi).
- 8.9. The work pressure of push/ pull machine in live wells must be similar to rotating control head.
- 8.10. Important equipment used in UBD is the four phase separator. The capacity of this separator must be proportional to the productivity index of oil wells and the ratio of oil to gas. Since the productivity of South field wells is within the range of 10000 to 15000 barrels per day, the separator capacity must be selected within the same range. Also based on gas to oil ratio (GOR) in the mentioned fields the four phase separator capacity to gas ratio should be 40 million cubic feet per day.
- 8.11. Finally the solids discharged from the separator must be transferred by the rotational pumps as slurry to the appropriate place.

9. References

- Engineer.h.Tangaki, Expert institute oil industry (ripi), Tehran iran, Bolvar-e-Gharbi-stadium-e- adi zar 1394.
- Enginer.h.Pendar, Oil and Gasengineer Teaditional, Gachsaran, Iran, Azar 1394.
- Mr. Salehi Laboratory Manager rock properties bp oil companies in America, author of rock and fluid properties
- 10. (1) Guo, B. and Ghalambor, A., "Gas Volume Requirements for Under balanced Drilling" Published by Pennwell Publishing Company, Tulsa, Oklahoma, USA, 2002.
- 11. (2) Gas Research Institute, "Under Balanced Drilling Manual" Gas Research Institute Publication, Chicago, 1997.

12. (3) Lyons, W.C., Guo, B., and Seidl, F. A., "Air and Gas Drilling Manual", 2th ed. McGraw Hill Book Company, New York, USA, 2001.
13. (4) Lyons, W. C., et al., "Standard Handbook of Petroleum and Natural gas Engineering", Volume 1., Gulf Publishing Company, 1996.
14. (5) Supan, S. B. and Adewumi, M. A., "An Experimental Study of the Annulus Pressure Drop in a Simulated Air- Drilling Operation", SPE Drilling & Completion Journal, Sept. 1991.
15. (6) Guo, B. "Use of Spreadsheet and Analytical Models to Simulate Solid, Water, Oil and Gas Flow in Under Balanced Drilling", Processing, IADC/SPE Middle East Drilling Technology Conference, 2002.
16. (7) Tian, S. and Adewumi, M. A., "Development of Hydrodynamic Model Based Air Drilling Design Procedures", Drilling Engineer, 23 Jun. 1992.
17. (8) Guo, B. and Rajtar, J. M., "Volume Requirements for Aerated Mud Drilling", SPE Drilling and Completion Journal, Jun. 1995.
18. (9) Griffin, D. R. and Lyons, W. C., " Case Studies of Design and Implementation of Under Balanced Wells", Rocky Mountain Regional Meeting, Society of Petroleum Engineers, SPE Paper, 55060, 1999.
19. (10) Guo, B., Hareland, G. and Rajtar, J., "Computer Simulation Predicts Unfavorable Mud Rate and Optimum Air Injection Rate for Aerated Mud Drilling", SPE Drilling & Completion Journal, Sept. 1996.
20. (11) Guo, B. and Ghalambor, A., "An Innovation in Designing Under Balanced Drilling Balanced Flow Rates: A Gas – Liquid Rate Window (GLRW) Approach", Asia Pacific Drilling Technology Conference, SPE Paper, 77237, 2002.
21. (12) Herzhaft, B., "Aqueous Foams for Under Balanced Drilling", SPE Paper, 62898, Annul Technical Conference and Exhibition , Texas, 2000.
22. (13) Rehm, B., "Practical Under Balanced Drilling and Workover ", Published by Petroleum Extension Services, The University of Texas at Austin, USA., 2002.
23. (14) Bork, K., "The Rotary Rig and its Components", Published by: Petroleum Extension Services, Volumes 1, 2, 3, 8 and 9, The University of Texas at Austin, USA., 1995.
24. (15) Jan, G., Mudler, S. and John Son, D., "Progress Continues in Under Balanced Well System", Published By: Weatherford UB Services, Aug. 2001.
25. (16) Jan, G., Mudler, S. and John Son, D., "Progress Continues in Under Balanced Operation Technology", Presented at The AADE, Houston, Texas, Feb. 2000.
26. (17) Lynch, P. F., " A Primer in Drilling and Production Equipment, Published by: Gulf Publishing Company, Houston, Texas, 1981.
27. (18) Dorenbos, R. and Ramalho, J., "Under Balaced Drilling Primer", Published by: Shell International Exploration and Production B. V.,Jun. 2002.]
28. (19) Santpere, S. and Maocillat, Y., "Hole Cleaning Capabilities of Drilling Foams Compared to Conventional Fluids, SPE, 63049, 2000.