UNDERBALANCED DRILLING IN BRAZIL – A FIELD CASE HISTORY (EXPL-04)

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SUMMARY

Underbalanced drilling has been extensively used in USA and Canada. In Brazil, only recently a few wells were drilled using this technology. This paper describes the project and execution of a well using Underbalanced Drilling (UBD) in South Brazil. Due to very hard formation in the intermediary section of the well and a very damage-sensitive reservoir, the use of UBD was considered mandatory for this field. New equipment were specially designed for use in the well including a liquid-gas separator and a new manifold. Since nitrified fluid was the drilling fluid, a membrane was used to on-site generation of nitrogen. The article gives field data obtained in the well and also shows comparison between the results obtained with UBD and conventional drilling. A description of the advantages, problems and shortcomings of the technique also is included in the paper.

INTRODUCTION

The use of light weight drilling fluids, although not recommended on every situation, can bring enormous advantages to the drilling process not only in terms of performance, but also for providing better conditions for formation evaluation and money and time savings. In the South Region of Brazil this technique has been used (1, 2) recently to drill very hard formations and also to penetrate possible reservoirs.

The use of Underbalanced Drilling (UBD) in hard rocks normally will provide a higher penetration rate which will result in less cost per foot. Also, use of the technique in possible oil and gas reservoirs will provide not only an improved rate of penetration but also will allow easier hydrocarbon detection at surface, avoid formation damage and produce improved formation evaluation results. Use of light weight fluids to drill exploratory wells, can also result in the discovery of hydrocarbon zones initially not predicted and that could, in the case of conventional drilling, not be detected even after logging the well.

Although the term underbalanced drilling (UBD) refers to the operations where the hydraulic pressure exerted by the drilling fluid over the formation is less than its pore pressure, the technique and procedures are the same when the operation is conducted at balance or slightly over balanced.

Normally on light weight fluid drilling operations a gas (air or nitrogen) is used, pure or combined with a liquid. The operation can be performed with air, aerated or nitrified mud (drilling fluid + air or nitrogen), foam or mist. In the project analyzed in this article it was used nitrified fluid.

The gas can be transported to the location (N_2 liquid) or generated on site by an equipment that separates the nitrogen from the air (nitrogen membrane). In the operations performed in Brazil's South Region liquid nitrogen was used in the first two wells and on the others it was used on site generation of nitrogen. The main advantage of generating nitrogen on site is that this procedure will avoid many logistic problems normally present when it is necessary to transport large amounts of N_2 to remote locations using roads that commonly present very poor conditions.

The main reasons for use of underbalanced drilling in this project were:
-improve drilling performance;
-improve detection of hydrocarbon (gas shows) at surface during drilling operations;
-minimize formation damage.
The basic layout of the light weight fluid drilling system is shown on Fig. 1.

PARANÁ BASIN

This area is an extensive plateau in the southwest Brazilian region where recently exploratory efforts have been increased. Since the exploratory wellsite is located in a remote area, a substantial logistic structure was arranged to support the drilling operation.

In the past, drill stem tests failed in both formations because of severe damages caused by conventional drilling in the reservoirs. Thus, the main objective of light weight fluid application in this scenario was to minimize formation damage and also to allow easy detection of hydrocarbon zones. In addition, the technology could also be tested drilling thick layers of hard formations located above the main objectives of the well, providing valuable information about the drilling performance and operational time savings.

PLANNING THE WELL – USE OF HYDRAULIC SIMULATORS

In order to determine gas and liquid flow rates to be used and also the expected surface and bottom hole pressures it was used the simulators SIMULT (from Petrobras) and Mudlite (from Maurer Engineering). Once an Equivalent Circulating Density (ECD) was chosen, the simulators were used to obtain the combined liquid and gas flow rates to produce at the bottom hole the desired ECD. On the simulator it was necessary to enter the following data:

- fluid data (liquid and gas);
- well geometry;
- temperature;
- drill string diameters
- well depth;
- expected rate of penetration.

The annular velocity should be above a minimum necessary to provide proper cuttings transport and hole cleaning. In the first well extensive circulation tests were done with registration of bottom hole pressures in order to check and calibrate the simulators.

During the operation, liquid and gas are pumped independently with the mixing occurring at the injection line. At the return line (flow line) the flow is diverted by the rotating head to the separator that, after separation, directs the liquid and cuttings to the shakers and the gas to the burner.

FIELD DATA

Well 3-BB-2D-PR was a directional well with a 60 degrees slant. It was drilled from the same location of a previous vertical exploratory well and its main objective was to check the extension of the gas reservoir discovered by the previous well. In the well planning, as a contingency plan, there was a prevision to drill a horizontal section at the end of the well if the production did not reach the level expected.

The nitrified fluid was used when drilling the 8 ½" and 6 ½" sections of the well. In the 8 ½" section underbalanced drilling was used to increase rate of penetration mainly when drilling two very hard layers of diabase. The ECD used was 7.5 ppg. This phase was initiated at 2,490 meters with the KOP at 2,523 meters. Another interesting point in this phase of the well was the use of a motor (PDM) that was powered by the nitrified fluid. The flow rates used were 500 scfm of gas and 250 gpm of liquid. The rate of penetration obtained in the diabase was 3.2 m/h, that is almost three times the rate obtained with regular drilling fluid. The 8 ½ " phase was drilled up to 3,794 meters where a 7" liner was set. The inclination was 55 degrees. The liquid phase of the fluid was a poliacrilamide mud with 8.8 ppg.

The 6 ½" phase was totally drilled with light weight fluid with flow rates of 500 scfm of gas and 200 gpm of liquid. The ECD was calculated to approximately equilibrate the formation pressure (on balance drilling). Since it is not possible to keep always the same pressure on the bottom of the well, during certain parts of the operation there was production of formation gas (that was burnt) simultaneously with the drilling operation.

During the directional drilling it was not possible to use the MWD equipment. On UBD operations there is at least a float valve installed inside the drill string, which will impede the readings of inclination and direction with conventional MWD equipment. In this well the directional control was made using wireline magnetic single shot.

DIVERTER SYSTEM - ROTATING HEAD

An important part of the light weight drilling system is the rotating head. This equipment allows the well to be drilled with the annular closed and eventually with some pressure in the well head. The rotating equipment can be a rotating head or a rotating BOP. In the operations on South Brazil in Paraná Basin rotating heads were used. The rotating head will be placed on top of the BOP stack and will divert the flux from the well to the separator. For the well 3-BB-2D-PR a rotating head Williams model 7000 was used See Fig. 2). This equipment has dual seal (dual rubber) and can be operated with up to 100 RPM and 1,500 psi. On static conditions a pressure of up to 3,000 psi is admissible.

Although the rotating equipment is capable to handle some pressure, it does not substitute the regular BOP and should be installed on top of the annular BOP. In order to minimize leaking problems during the operation the stack (BOP + rotating head) must be aligned with the center of the rotary table to avoid premature wear of the rubbers. The return line from the well (flow line) is connected to the lateral of the rotating head and goes to the top of the separator.

SEPARATION SYSTEM

For the drilling of well 3-BB-2D-PR it was built a new gas-liquid separator designed by UNICAMP (Campinas State University) and Petrobras Research Center. This equipment is a cylinder (diameter 48 in. height 11 meters) that internally has two concentric pipes (see Fig. 3). The fluid enters the cylinder tangentially in the upper part of the separator and is forced down the annular of the two internal pipes in a helical trajectory where the separation between liquid and gas occurs. The gas goes to the line of the burner and the liquid and cutting are then deviated to the shakers.

A liquid seal is always present internally in the separator to avoid the gas to travel to the shakers. There is an automatic control with sensors for the liquid level that will activate the pumps in order to keep the level of the liquid seal within certain limits.

In the flow line, between the rotating head and the separator, there is a manifold that will restrict the flow to control sudden increases in pressure due to slugs that normally occur in this kind of operation.

CONCLUSIONS

After use of UBD technique in four wells in Paraná basin and many others in various regions of Brazil the main conclusions are:

- Use of UBD em hard formations normally will improve the rate of penetration and consequently will reduce the total cost of the well. In the case of the well described in this article, the rate of penetration on the hard formations above the reservoir was almost three times the ones obtained in similar wells drilled in the area with regular drilling fluid.

- In some regions, with depleted or low pressure reservoir, the light weight drilling fluid technique will be the only way to drill the wells without losing enormous amount of fluid to the formation and causing severe formation damage. In some of the wells in Brazil it was possible to drill with an ECD as low as 3.0 ppg.

- UBD technique allows much more reliable hydrocarbon indication at surface due to the low ECD. In the case of the wells drilled in Paraná Basin, the most important feature of the light weight drilling technique was that underbalanced (or near balanced) condition allowed several gas shows to be detected in different formations making clear the importance of this technique in detection of hydrocarbon zones.

- The performance of the separator was considered very satisfactory. The separator besides its good performance and low cost has also the advantage of occupying little space on the rig site.

A great improvement for the oil industry will be the adaptation of UBD techniques for use in offshore deep water wells drilled from floating vessels. At the moment a project with this purpose is being developed in Brazil with the sponsorship of many international oil companies (3).

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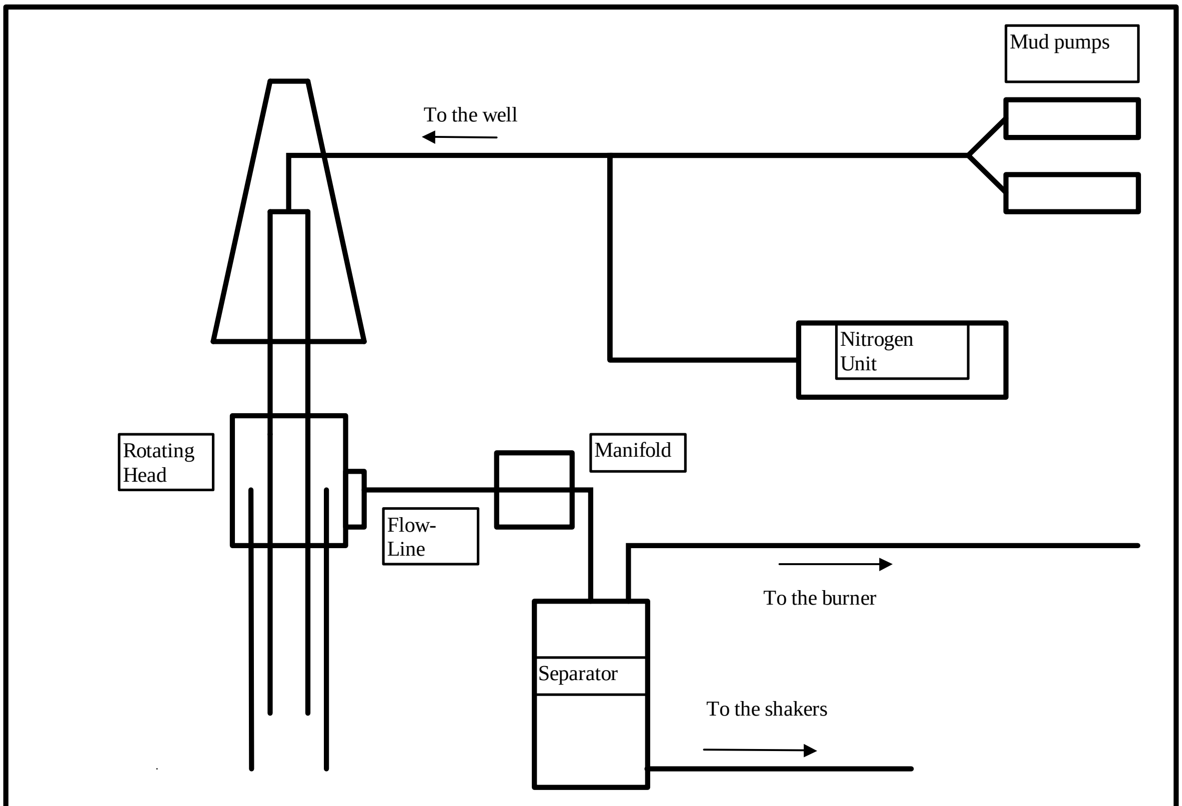

Figure 1 - Layout of the Injection System

Figure 2 - Rotating Head Williams Model 7000

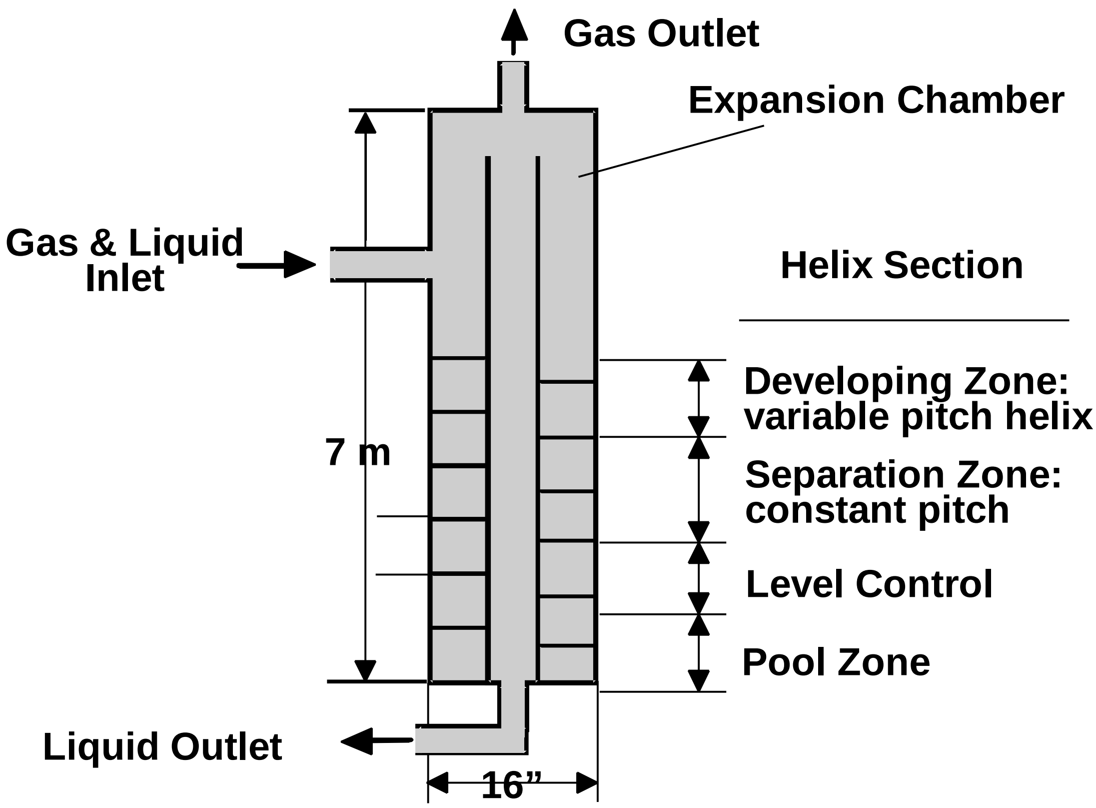

Figure 3 – Separator (schematic)

Figure 4 - Gas-Liquid Separator

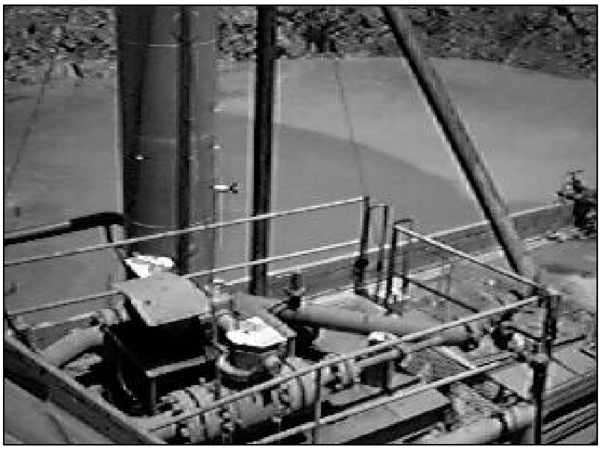

Figure 5 - Separator and manifold