DETERMINATION OF MINIMUM WATER-AIR FLOW RATE REQUIRED FOR EFFECTIVE CUTTINGS TRANSPORT IN HIGH ANGLE AND HORIZONTAL WELLS.

(PROPOSAL)

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SPONSOR

- PDVSA/TUDRP

OBJECTIVE (Preliminary)

1. Determine experimentally the minimum flow rates for water and air that guarantee the hole cleaning while drilling horizontal and near horizontal sections.

2. Develop charts that help to establish minimum requirements of air and water injection rates to plan drilling of high angle and horizontal sections, using air-water system as drilling fluid (see Fig. 1)

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INTRODUCTION

Inadequate hole cleaning while drilling horizontal and deviated section could have a strong economical impact on the well and company budget. For this reason the issue of determining minimum flow mud rates to achieve sufficient hole cleaning has become an important part in the planning of a drilling project.

Improper hole cleaning can created several problems such as stuck pipe and increased torque and drag. The latter reduces the effective weight on the bit, which reduces the rate of penetration and the effective life of the bit. If the hole cleaning is ineffective, it is also necessary to use additional procedures to clean the hole, such as circulating pills of special drilling fluid. This does not only increase the budget related to the use of mud for the well, but it also leads to a considerable increase in operation time. All these consequences of ineffective hole cleaning have a negative effect on the most important goal of oil industry, which is to produce oil at the lowest cost per barrel.

In the past, cutting transport in horizontal wellbores has been studied using conventional drilling fluid systems. Measurements have been carried out to determine the minimum flow rates needed to avoid problems that are created by insufficient cleaning. The increasing application of aerated mud, foam and mist drilling, combined with high angle well bores, has created the need of understanding cuttings transport in those conditions. To fill this gap, this research is dedicated to the investigation of cuttings transport in horizontal and near-horizontal well bores, using an aerated mud system.

In times where the Oil Industry demands the use of new alternatives to develop its reservoir optimally, the underbalanced and near-balanced drilling techniques has become an excellent options to reduce drilling well costs and increased the well and reservoir productivity.

Underbalanced and near-balanced drilling techniques offer several significant benefits over conventional drilling and many of these applications involve deviated and horizontal wells. One of the most important benefits is a considerable reduction of the formation damage and the necessity of additional stimulation job to overcome that damage. Also these drilling techniques bring additional important benefits directly in the drilling well cost, by considerably increasing the rate of penetration, the bit life and reducing the probability of differential sticking of the drillpipe [1,2,3].

Aerated muds are also used to avoid lost circulation problems in areas where the use of conventional drilling fluids created high overbalance pressure against the formation, creating losses of drilling fluid into the formation. In some cases the use of lost circulation material, cements and proprietary additives have partially successful regaining circulation and for this cases aerated mud was a good option to be used as a drilling fluid.

Aerated muds represents an important element in the application of underbalanced and near-balanced drilling technologies but it is necessary to extend research in this area looking for a better understanding of the behavior of this type of drilling fluid systems.

SCOPE

The scope of this study is to investigate the effect that the variables presented in table 1 have on cutting transport:

INDEPENDENT VARIABLES	DEPENDENT VARIABLE
Air flow rates	Equivalent mud weight.
Water flow rates.	Pressure drop.
Hole inclination	Flow patterns

Table 1- Variables

The following preliminary test matrix is proposed:

Liquid Flow Rate (GPM)	Air Flow Rate (SCFM)	Inclination (°)	ROP (ft/h)
150 - 250	0-1250	55-90	10-30

Table 2- Test Matrix proposal

Volumetric flow rate of gas at field condition is given by the real gas law as:

$$Qgasfc = Qgaslc * \frac{Plc}{Pfc} * \frac{Tfc}{Tlc}$$

Cuttings injection rate is given by:

$$Cin(lb/\min) = ROP(ft/h) * Ah(ft^2) * Cden(lb/ft^3)/60(\min/h)$$

LITERATURE REVIEW

Larsen (1990) [4], conducted several experiments using a low pressure, low temperature, flow loop at TUDRP to study the effect of inclination, annular flow, mud rheology, drill

pipe eccentricity, cutting size, mud weight, drilling rate, and drill pipe rotation on the critical fluid velocity needed to avoid cutting bed formation. He developed empirical correlations to predict bed height and critical cuttings transport velocity. In the experiments Larsen could observe that in angles between 40° and 90° the flow requirements were strongly dependent of the angle of inclination, whereas for high angles the eccentricity has no significant effects on the critical velocity for cuttings transport. Also he could determine that smaller cutting particles are more difficult to clean and the annular critical transport velocity increases with the rate of penetration.

In 1993, Jalukar [5] studied the effect of hole size on the critical and sub-critical velocities. The objective of this study was to develop empirical correlation for correction factors to incorporate hole geometry into the Larsen's model. The most important conclusion was that for subcritical flow, the effect of hole size on cuttings bed was insignificant.

In 1997, Sanchez [6] presented his results on the effect of pipe rotation on bed erosion. The main conclusion was that pipe rotation also enhances bed erosion. This is important because it is a common field practice to continue circulation after drilling has stopped to clean some of the cuttings before tripping out. Pipe rotation (without centralizers) also causes instability in the bed, causing moderate to significant variations in its height along the test section. This is one of the major limitations that annular flow simulators have since they only model a constant cross section.

EXPERIMENTAL FACILITY

For the experimental work, the TUDRP Low Pressure-Low Temperature flow loop will be used. General views of the flow loop are shown in figures 2 and 3. A schematic drawing of the TUDRP-LPAT flow loop is shown in figure 4. The current test section is approximately 100 ft long and consists of an 8” inside diameter transparent acrylic pipe with 4 1/2” OD inner pipe which can rotate from 0 to 200 rpm. The loop is resting on a rigid body and can be inclined at any angle between 0-90° from vertical. The mud is stored in a 1000 gallon tank with the option to store an additional 800 gallons in a second tank. The drilling fluid is pumped into the annulus by using a centrifugal pump with current capacity of 750 gpm. The drilling fluid flow rate is measured using a mass flow meter. For the air flow rate injection, the loop have a compressor with working capacity of 0-125 psi and 0-1600 scfm. The compressed air is also stored into an accumulator wich is used to supply air to the pneumatically operated equipment. The air will be measured using the flow meter with capacity of 0-125 psi, 50-1600 scfm, and controlled using a Masoneilan control valve. A check valve in the air line will allow the flow of air in one direction and will not allow liquid entering the air flow pipe. The cuttings are injected from a hopper tank that is capable of storing 22 bbl of mud and cuttings. The cuttings injection tank can be loaded with 2000 lb of cuttings (2.564 gm/c.c) and it is capable of running for 2-3 hours with an injection rate of 40-50 ft/hr. Part of the flow rate is diverted to the top of the hopper to maintain a constant positive pressure and facilitate the injection of cuttings. The control room located near the test section has data acquisition system. The control and measurement of the flow rates of the different

phases, drill pipe rotation speed, inclination and valves can be done from the control room.

NOMENCLATURE

Qgasfc = Gas flow rate at field conditions (scfm)
Qgaslc = Gas flow rate at loop conditions (scfm)
Pfc = Pressure at field conditions (psi)
Plc = Pressure at loop conditions (psi)
Tfc = Temperature at field condition (ºF)
Tlc = Temperature at loop condition (ºF)
ROP = Rate of penetration (ft/h)
Ah = Hole area (ft^2)
Cden = Cuttings density (lb/ft^3)

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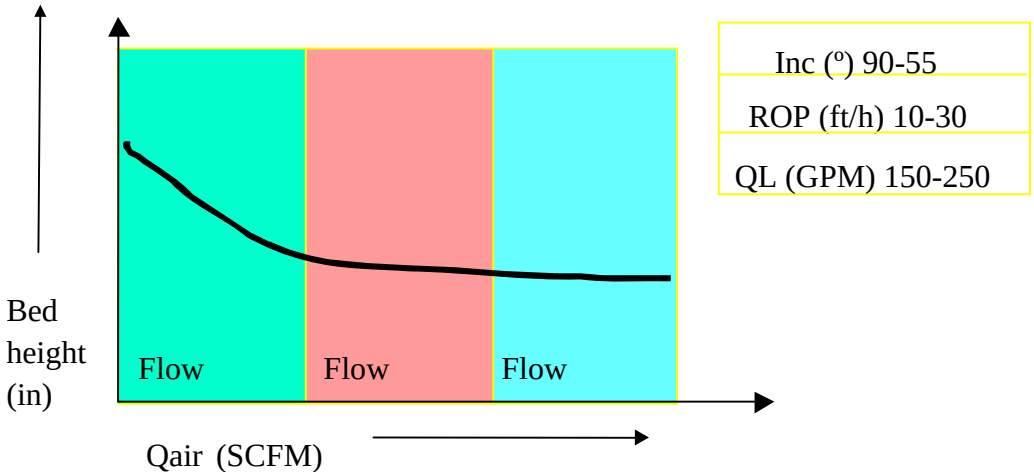

1- Preliminary chart proposal

Fig. 2- Loop in the horizontal position

Fig. 3- Loop in the vertical position

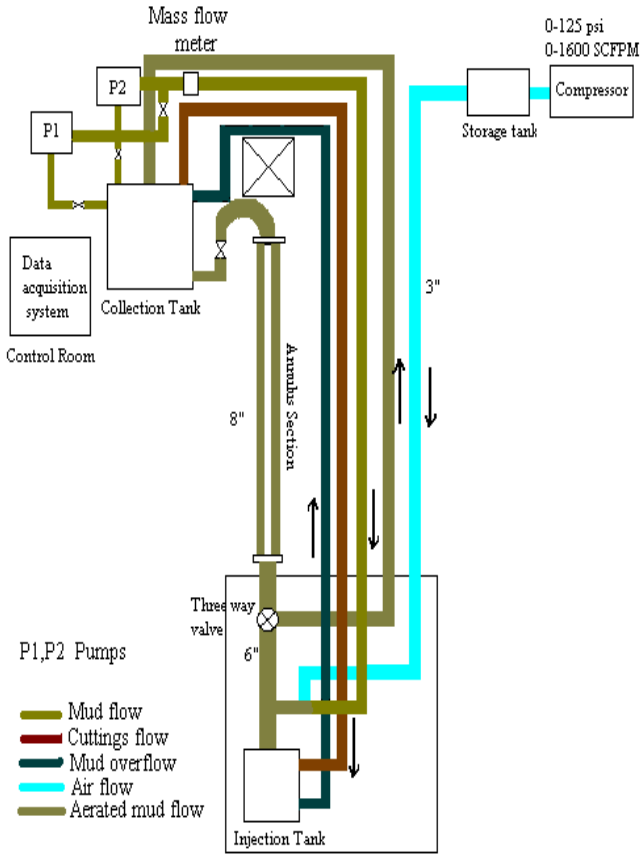

Fig. 4- Overall Diagram of Flow Loop