Data article

Data on cost analysis of drilling mud displacement during drilling operation

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A B S T R A C T

The focus of this research was to present a data article for analyzing the cost of displacing a drilling fluid during the drilling operation. The cost of conventional Spud, KCl and Pseudo Oil base (POBM) muds used in drilling oil and gas wells are compared with that of a Reversible Invert Emulsion Mud. The cost analysis is limited to three sections for optimum and effective comparison. To optimize drilling operations, it is important that we specify the yardstick by which drilling performance is measured. The most relevant yardstick is the cost per foot drilled. The data have shown that the prices for drilling mud systems are a function of the mud system formulation cost for that particular mud weight and maintenance per day. These costs for different mud systems and depend on the base fluid. The Reversible invert emulsion drilling fluid, eliminates the cost acquired in displacing Pseudo Oil Based mud (POBM) from the well, possible formation damage (permeability impairment) resulting from the use of viscous pill in displacing the POBM from the well-bore, and also eliminates the risk of taking a kick during mud change-over. With this reversible mud system, the costs of special fluids that are rarely applied for the well-completion purpose (cleaning of thick mud filter cake) may be reduced to the barest minimum.

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### Value of the data

- These data describe the volume and material estimate needed for each hole section and the type of mud necessary to achieve smooth drilling operation in each hole section.
- The data showed the cost, the quantity of materials and sequence at which these materials are applied to achieve optimum displacement.
- These data can be used to study the economic analysis of new mud systems proposed by researchers and also help to compare if these mud systems are economically viable.
- These data can also be used to analyze and predict prices and/or build cost for drilling mud systems for a certain mud weight and daily maintenance expense.
- The data reveals that cost varies according to the different mud types and are dependent on the base fluid phase.

### Data

The type of drilling fluid systems and the volume of drilling fluid needed for each hole section is summarized in Table 1. The well was spudded with Bentonite/Polymer mud system. The mud was then converted to KCl/Polymer mud system by the addition of Pre-hydrated KCl into the system. The 12 ¼” hole section was drilled with Pseudo Oil Based Mud (POBM) system. The 8 ½” development hole section was drilled with Non-Aqueous Fluid system (NAF).

The volume of drilling fluids needed for three sections was estimated and presented in Tables 2–4. The cost and how successful an oil or gas well will be completed depends to a substantial extent, on the properties and characteristics of the drilling fluid (Amorin et al. [1]). A considerable number of drilling fluid formulations have been developed by researchers and the selection of the best fluid to meet the formation to be drilled conditions will minimize well costs.

The cost for drilling a typical well may be constant when drilled without any instability case. Instability during a drilling operation in wells can quickly escalate cost dramatically (Okoro et al. [2]). The materials and their cost for each drilling fluid systems are presented in Tables 5–7.
Table 1
Summary of mud types used during the drilling operation.

| Components          | Well sections |
|---------------------|---------------|
| Open hole diameter  | 24", 16", 13 5/8"  |
| Casing/liner diameter | 16", 13 5/8", 12 1/4" |
| Description         | Surface/conductor, Top hole, Intermediate, Reservoir section |
| Conventional mud type | SPUD, KCL, POBM, NAF |

Table 2
Volume estimate for the bentonite/polymer mud system (SPUD mud).

| S/N | Section               | Internal diameter, ID | ID square | Depth (ft) | Conversion factor | Volume of mud |
|-----|-----------------------|-----------------------|-----------|------------|-------------------|---------------|
| 1   | Surface volume        |                      |           |            |                   | 600           |
| 2   | 24" Casing to 400 ft  | 24                    | 576       | 400        | 1029              | 223,9067055   |
| 3   | 16" Open hole to 2000ft | 16                  | 256       | 1600       | 1029              | 398,0563654   |
| 4   | Washout 20%           |                      |           |            |                   | 244,3926142   |
| 5   | Losses behind casing 20% |                    |           |            |                   | 394,1613217   |
| 6   | PIT/transit losses 5% |                      |           |            |                   | 98,54033042   |
| 7   | Hole enlargement      |                      |           |            |                   | 39,80563654   |
| 8   | Total volume (bbl)    |                      |           |            |                   | 1567,259475   |

Table 3
Volume estimate for KCl/polymer mud.

| S/N | Section               | Internal diameter, ID | ID square | Depth (ft) | Conversion factor | Volume of mud |
|-----|-----------------------|-----------------------|-----------|------------|-------------------|---------------|
| 1   | Surface volume        |                      |           |            |                   | 600           |
| 2   | 24" Casing to 5000 ft | 24                    | 576       | 5000       | 1029              | 223,9067055   |
| 3   | 16" Open hole to 9386 ft | 16                  | 256       | 4386       | 1029              | 1146,899903   |
| 4   | Washout 20%           |                      |           |            |                   | 394,1613217   |
| 5   | Losses behind casing 20% |                    |           |            |                   | 98,54033042   |
| 6   | PIT/transit losses 5% |                      |           |            |                   | 39,80563654   |
| 7   | Hole enlargement      |                      |           |            |                   | 114,6899903   |
| 8   | Total volume (bbl)    |                      |           |            |                   | 2972,359572   |

Table 4
Volume estimate for POBM mud.

| S/N | Section               | Internal diameter, ID | ID square | Depth (ft) | Conversion factor | Volume of mud |
|-----|-----------------------|-----------------------|-----------|------------|-------------------|---------------|
| 1   | Surface volume        |                      |           |            |                   | 600           |
| 2   | 13 3/8" casing @ 5000 ft | 13.375             | 178.89063 | 5000       | 1029              | 869,2450194   |
| 3   | 12 1/4" open hole to 9386 ft | 12.25             | 150.0625  | 4386       | 1029              | 639,625       |
| 4   | Washout 20%           |                      |           |            |                   | 421,7740039   |
| 5   | Losses behind casing 20% |                    |           |            |                   | 421,7740039   |
| 6   | PIT/transit losses 5% |                      |           |            |                   | 105,443501    |
| 7   | Hole enlargement      |                      |           |            |                   | 63,9625       |
| 8   | Total volume (bbl)    |                      |           |            |                   | 3121,824028   |
Figs. 1 and 2 illustrates the cost per barrel and cost per feet drilled respectively for the mud systems used in the drilling operations.

The build cost for a drilling fluid system is the price for the individual components and mixing requirements. The total build cost includes purchasing the initial drilling systems materials and the expenses involved with conditioning the drilling mud system in the well as it is drilled.

2. Experimental design, materials, and methods

The water-based mud in the wellbore from the previous hole section is displaced and replaced with POBM drilling fluid. The first step is to lower the viscosity and gel strength of the water-based mud. The suggested method is to dilute the fluid with water to obtain a low rheology [Patel [3]]. The optimal thinning of the water-based mud will dictate how easy the mud will be displaced out of the hole. The spacer is pumped first, followed by the POBM mud at maximum pump rate to get the mud in the annulus moving (Table 8).

| Table 5 | Spud mud material estimate. |
|---------|-----------------------------|
| Products | Unit size (kg) | Cost/unit (USD) | Conc.: lbs/bbl | Units | Total cost (USD) |
| Bentonite (1mt) | 1000 | 605 | 25 | 18 | 10890.00 |
| Caustic Soda | 25 | 75 | 0.25 | 8 | 600.00 |
| Soda Ash | 25 | 32 | 0.25 | 8 | 256.00 |
| CMC HV | 25 | 124 | 2 | 57 | 7068.00 |
| CaCO3 fine | 50 | 21 | 10 | 143 | 3003.00 |
| CMC LV | 25 | 124 | 2 | 57 | 7068.00 |
| Drilling surfactant | 55 | 945 | 0.5 | 7 | 6615.00 |
| Ultra seal | 25 | 100 | 2 | 57 | 5700.00 |
| Mica | 25 | 36.3 | 2 | 57 | 2069.10 |
| Total cost (USD) | | | | | 43269.10 |
| Total volume (bbl) | | | | | 1567.26 |
| MD (ft) | | | | | 2000.00 |

| Table 6 | KCl/ polymer mud material estimates. |
|---------|-----------------------------|
| Products | Unit size (kg) | Cost/unit (USD) | Conc.: lbs/bbl | Units | Total cost (USD) |
| Bentonite (1mt) | 1000 | 605 | 18 | 25 | 15125.00 |
| Caustic soda | 25 | 75 | 0.25 | 14 | 1050.00 |
| Soda ash | 25 | 32 | 0.25 | 14 | 448.00 |
| PAC-R | 25 | 150 | 2 | 108 | 16200.00 |
| Borhamyl starch | 25 | 62.5 | 4 | 216 | 13500.00 |
| PAC-L | 25 | 150 | 1 | 54 | 8100.00 |
| XCD polymer | 25 | 312 | 1 | 54 | 16848.00 |
| KCl (1mt) | 1000 | 1450 | 21 | 29 | 42050.00 |
| CaCO3 F/M | 50 | 21 | 10 | 270 | 5670.00 |
| Soltex | 25 | 108 | 4 | 216 | 23328.00 |
| Surfactant (gal) | 1 | 945 | 1 | 8 | 7560.27 |
| Mica fine | 25 | 36.3 | 2 | 108 | 3920.40 |
| Ultra seal LCM | 25 | 100 | 2 | 108 | 10800.00 |
| Barite (1mt) | 1000 | 400 | 50 | 68 | 27200.00 |
| Paraffin (bbl) | 36 | 266.65 | 2 | 24 | 6399.60 |
| Total cost (USD) | | | | | 183074.27 |
| Total volume (bbl) | | | | | 2972.36 |
| MD (ft) | | | | | 5010.00 |
After drilling and prior to running completion hardware, the fluid in the borehole is often displaced to a water-based completion fluid, usually a solution of various salts. During this displacement, chemical washes and viscous spacers are placed in the solution to make surfaces water-wet, while helping to remove oil mud and residual oil-wet material from the borehole (Ali et al. [4]).

The viscosity and gel strengths of the POBM are low prior to displacement. The suggested method was to dilute the fluid with premix, base fluid or a thinner to obtain the low rheology if this is necessary. The optimal thinning of the POBM fluid will dictate how easy the mud will be displaced out of the hole.

### Table 7
POBM mud system material and cost estimate.

| Product                                | Unit size | Unit price (USD) | Conc.: ppb/bbl | Sxs/drm/bbl | Total cost (USD) |
|----------------------------------------|-----------|------------------|----------------|-------------|------------------|
| EDC 99 DW (1 bbl)                      | 0.5       | 266.65           | 0.64           | 8           | 2133.20          |
| Primary emulsifier (gal)               | 4         | 535              | 6              | 49          | 26215.00         |
| Secondary emulsifier (gal)             | 4         | 715              | 3              | 24          | 17160.00         |
| Organophilic clay (kg)                 | 25        | 88               | 8              | 454         | 39952.00         |
| Lime (kg)                              | 25        | 13.5             | 4              | 227         | 3064.50          |
| Soltex (kg)                            | 25        | 108              | 4              | 227         | 24516.00         |
| CaCO3 F/M (kg)                         | 50        | 21               | 8              | 227         | 4767.00          |
| Barite (mt)                            | 1000      | 400              | 219            | 311         | 124400.00        |
| Calcium chloride (kg)                  | 25        | 24.35            | 30             | 1700        | 41395.00         |
| Rheology modifier (gal)                | 4         | 810              | 1              | 8           | 6480.00          |
| Wetting agent (kg)                     | 55        | 590              | 0.85           | 22          | 12980.00         |
| Fresh water (1 bbl)                    | 0.5       | 0                | 0.236          | 3           | 0.00             |
| **Total cost (USD)**                   |           |                  |                |             | **303062.70**    |
| **Total volume (bbl)**                 |           |                  |                |             | **3122.08**      |
| **MD (ft)**                            |           |                  |                |             | **9386.00**      |

**Fig. 1.** Cost per barrel for each mud systems.

**Fig. 2.** Cost per feet drilled for each mud systems.
The volume of drilling fluid needed for each section was obtained using the equation below:

$$Volume \ (bbl) = \frac{ID^2}{1029} \times D$$

(1)

Where,

$ID$ = Hole Internal Diameter, inch  
$D$ = Hole Depth, ft

Eqs. (2) and (3) were used to estimate the product units needed in gallons and kilogram respectively;

$$Gallons = \frac{ppb \times volume \ of \ mud \ (bbl)}{Specific \ Gravity \times 8.33ppg}$$

(2)

$$Unit \ (kg) = \frac{ppb \times Volume \ of \ mud \ Unit \ (kg) \times 2.205}{Material \ Unit}$$

(3)

Eq. (4) was used to convert the quantity of additives used from lb/bbl to sxs:

$$\frac{\frac{lb}{bbl} \times Required \ Volume \ (bbl)}{Unit \ Size \times 2.205} = Number \ of \ sxs$$

(4)

Where,

$sxs$ = Sacks  
$lb/bbl$ = Pound per barrel  
$bbl$ = Barrel

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**Transparency document. Supporting information**

Transparency data associated with this article can be found in the online version at [http://dx.doi.org/10.1016/j.dib.2018.05.075](http://dx.doi.org/10.1016/j.dib.2018.05.075).
Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at http://dx.doi.org/10.1016/j.dib.2018.05.075.

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