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TECHNOLOGY OF DRILLING MUD AS DEVELOPED IN OIL INDIA

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1. Introduction

The region in which Oil India Ltd. carry out exploration for and production of oil and natural gas, lies in the N.E. corner of India. There are two producing oil fields at Nahorkatiya and Moran where slightly over 300 wells have so far been drilled. In addition, several wells have been drilled in the neighbouring areas and also exploratory drilling is being carried out at distances of 50-100 km from Nahorkatiya.

The depth of the well in the two fields ranges from 3000 to 3600 metres. Several exploratory wells have been drilled to depths of 4000 metres and there are plans for wells having depths of 4500 metres and more. Although the wells are deep, drilling in general, has been smooth and trouble-free and the rate of drilling has been quite fast; this success in drilling owes considerably to drilling mud, the technology of which has been developed by indigenous talent utilising indigenous materials.

2. Selection of clay

The first and foremost material s for making drilling mud is clay. Bentonite is the commonest clay mineral used throughout the world for making mud; however with bentonite alone it is not possible to make mud of specific gravity above 1.07. Barytes, another mineral having specific gravity 4.15 - 4.30, is used as an additive to raise the specific gravity of the mud to the required level. Both these minerals are found in abundant quantities in India and the qualities of the minerals as available are well suited to the drilling mud requirements. However

the principal deposits of bentonite being in Gujerat and those of barytes in Andhra situated at distances of 3600 and 300 km respectively from Oil India's fields of operation, the costs of transportation add to the costs of the materials considerably. As both of these materials are required in large quantities for oil well drilling, this also exerts much pressure on the transport system of the country. Accordingly emphasis has been placed on locally available clay thereby restricting the consumption of bentonite and barytes.

As the surface or near-surface clay deposits generally do not contain appreciable fractions of montmorillonitic (e.g. bentonite) materials, which are more suited for making mud, the quantities of clays required for preparation of good mud are much greater than those of bentonite. However this has an advantage viz. the specific gravity of the mud can be raised to even 1.3 with clay only without any barytes.

Samples of clay are taken by augering from vacant lands; they are subjected to mechanical analysis and detailed studies on the mud prepared from the clay are carried out; clay is selected on the results of both mechanical analysis and its mud properties. Attempts are made to find out suitable clay deposits in the nearby places.

It has been observed that at many places in this region, the clay deposits one or two metres below the surface, contain appreciable quantities of humus (humic acid) and are thereby black in colour. The higher is the humic acid content in the clay, the darker is the colour and better are the mud characteristics; therefore this type of clay is used for preparation of mud wherever feasible. Humic acid content of the black clay used at Nahorkatiya field is 5-6% on the dry weight. Mechanical analysis of a typical sample of this clay after removal of humus gives 65% clay (i.e. particles $< 2\mu$), 34% silt ($2-50\mu$) and 1% sand ($> 50\mu$). The mineralogical composition of the clay shows montmorillonite 10-15%, chlorite 10-15% and the rest illite and kaolinite; thus from the mineralogical angle, the quality of clay is not commendable for drilling mud, but due to presence of humic acid, the mud prepared from the clay has very good rheological and filtration characteristics and this justifies the elaborate method of finding out, excavation, transport of the clay and the lengthy process of preparation of mud.

3. Mud preparation

At Nahorkatiya and Moran, mud is prepared in the respective central mud plants but at other places in specially erected mud plants. Fresh water having total dissolved solid content 100 - 150 ppm (mostly bicarbonates of calcium and magnesium), for mud making is obtained from either the river or the shallow tube well drilled for the purpose. The clay being acidic due to presences of humic acid, caustic soda is added during the time of mixing with water to make pH of mud 8-9. The basic mud is prepared to specific gravity of 1.28 - 1.32 and kept in tanks for a day or more for settling of all sand and some silt at the bottom; after settling, the mud contains practically clay, i.e. particles having diameter 2 μ or less and a little silt and organic matter, mostly as sodium humate and has got sp.gr. ranging from 1.25 to 1.28. One ton of black clay yields usually 0.8 - 0.9 kl of fresh mud.

Transport of mud from the central mud plant to the well and vice versa is carried out through pipeline. In the central mud plant, the well-return mud having sp.gr. ranging from 1.20 to 1.28 is received back; as this mud has got variable compositions and properties it is cut back with water and mixed up with fresh clay to make further mud; humic acid content in the mud which goes down in the well due to various reasons, is again partially restored by this operation.

It will be clear from the above that preparation of mud with clay takes more time and labour than that with bentonite (+barytes); but this is not only in accordance with the policy of using locally available materials as far as practicable, but also has been found more economic.

For a 3000-3600 m well, the initial mud prepared is 300-350 kl. As drilling progresses, further mud is produced as a result of dispersion of shale and mudstone cuttings and consequent cutting back with water. The volume of mud so produced ranges from 100 to 200 kl per well.

4. Mud additives

For drilling at shallow depths to 900-1200 m, the mud as prepared needs hardly any additive except in cases where deviation drilling is carried out. As drilling goes to greater depths, treatment of mud with various additives becomes a necessity. Emphasis being on use of indigenous

materials as stated earlier, simple inexpensive materials as available in the country are used for maintenance and modification of mud. The mud additives which can broadly be divided into five categories according to their effects on mud are being discussed.

(i) Rheology control

Although bentonite is not used as a basic clay for making mud, it is a frequently used additive to adjust the rheological properties; it is also used to reduce the filtration loss of mud to some extent.

Polyphosphates are manufactured in the country and can be used as thinners for circulating mud at relatively low temperatures. But as the temperatures in the deeper part of the well are higher than 60°C, at which polyphosphates begin to break down to orthophosphate, it has been decided not to use polyphosphates in these fields.

Tannins are well known for their ability to reduce the viscous properties of mud. Quebracho, a tannin obtained from the heartwood of Schinopsis lorentzi, is used throughout the world for the same. As this plant is not known in India, a similar tannin has been found in cutch which is obtained from the plants, Acacia catechu, Acacia chundra and Acacia catechuoids, all belonging to the family of Leguminosae, grown in large numbers in several regions of the country. Cutch is obtained from the aqueous extract of the heartwood of the plants after separation of catechin which is insoluble in cold water; catechin known as 'Kattha' is a relatively costly product in Indian household and cutch is, thereby, a less expensive commodity. Commercial cutch contains upto 70% tannin, the type of the tannin falling under condensed catechol group, the same as that of quebracho. As a mud additive, cutch is as effective as quebracho and it has been used very successfully not only with fresh water mud but also with oil emulsion mud, calcium and/or lime mud. No quebracho is used in Oil India's operations.

It is known that only one type of dispersant is not satisfactory for all conditions; therefore other dispersants such as ferrochrome lignosulphonate, chrome lignite etc. have been evolved and used extensively in other countries. They have also been used in some quantities in a few exploratory wells here. Simultaneously efforts have been directed to evolve materials from indigenous sources.

As a result of the effort, ferrochrome derivative of a tannin, myrobalan, has been prepared. Myrobalan tennin is obtained in large quantities in the country from the dried flesh of the fruit of the plant Terminalia chebula, family Cambretacae. As the tannin belongs to pyrogallol group, it is appreciably different from cutch and is not as effective dispersant as cutch. However ferrochrome derivative of the tannin has been found to be a good dispersant in the laboratory and is now being tried in wells; the preliminary results are satisfactory.

(ii) Filtration loss

Both bentonite and cutch reduce the filtration loss of mud to some extent and for depths to 1500 m or so, use of either or both of them serves the purpose. For reduction of filtration loss to low values as required for greater depths, carboxymethyl cellulose, the well known additive is also used here; it is manufactured in the country and the quality of the product is as good as any imported product.

(iii) Lubricating action

Oil is usually added to the mud to impart lubricating property to the mud. The quantity of oil varies from 6 to 12% by volume, the increased percentage being maintained near the bottom 400-500 metres of a well; however in deviated wells, it is kept much higher ranging from 13 to 20% by volume during drilling of the deviated part of the hole. In most of the wells, the oil used is the field crude, but in exploratory and outstep wells, light diesel oil is sued to avoid masking of fluorescence of oil in rock cuttings, if present, by added crude oil; the crude has been selected as it has got good sticking tendency and high specific gravity and viscosity. Linseed oil is also used to the extent of 1-2% of mud volume in some wells especially deviated ones to avoid sticking of pipe.

(iv) Weighting agent

Barytes is used as the weighting material as elsewhere. As mentioned earlier, the quality of barytes available in the country is quite good for this purpose and weighting mud with it to specific gravity as high as 2.2 has not posed any problem.

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(v) Other chemicals

For calcium muds, either calcium chloride or gypsum is used and foaming of such muds, as sometimes observed, is controlled with aluminium strearate. All these materials are available in the country.

5. Temperature effect

The geothermal gradient in this region is moderate, for example, the temperature at a depth of 3400 metre or so is 100°C only. As a result, the temperature in the well has not posed any serious problem to maintenance of mud properties. However for deeper wells of 4500 m, the problem will be cropping up; studies are in progress to see if ferrochrome tennate will be effective in such conditions. It is planned to use sodium dichromate indigenously available in addition to other chemicals, to arrest the deterioration of mud properties at high temperatures.

6. Mud performance

Desander is used throughout drilling to remove sand from the mud; however, due to very fast drilling and high circulating volume to about 1000 m ± 200, the sand content which cannot be reduced very much, ranges from 6 to 2%. As the drilling rate and circulating mud volume decrease, the sand content also can be reduced; it ranges from 4 to 1% in the depth range 1000 to 2000 m and 1.5 to 0.2% below 2000 m.

In most of the wells, the mud used is a simple oil emulsion mud without any sophisticated chemical treatment; cutch, carboxymethylcellulose, bentonite, caustic soda and oil are the common additives; caustic soda is added to maintain pH at the desired level, generally 8-9. In the development wells of Nahorkatiya and Moran, this treatment has given satisfactory performance. The relevant data of a typical well viz. Nahorkatiya 250 are given in the Appendix.

It will be seen that the mud parameters are satisfactory and the consumption of chemicals/additives is moderate. The mud parameters are carefully controlled so that the problems in drilling resulting from mud are rare in Nahorkatiya and Moran fields. Even in cases where due to

accidents, drilling had been suspended and mud could not be circulated, the holes were found in good condition even after several weeks. The damage to the productive formation by mud as found out from later production and bottom hole pressure analysis, is low to moderate. Thus the mud can be considered very satisfactory.

7. Special muds

In some outstep and exploratory wells having depths of 4000 metres, special types of muds such as moderately saline mud, calcium chloride mud with/without lime, gypsum mud etc. have been used. Ferrochrome lignosulphonate with or without chrome lignite has been used as dispersant in such cases. In all such cases muds have been maintained in excellent condition. The Well KJN-3 which was drilled with calcium chloride treated mud to 3982 m may be taken as a typical example; the specific gravity of the mud had to be raised to 1.36 to control high pressure formation gas. A few mud properties for the last 1000 m as given below shows good parameters inspite of high calcium content.

Yield value	... 1 - 6.5 lbs/100 sq.ft
Plastic viscosity	... 13 - 30 cp.
Filtration loss (API)	.... 4.2 - 6.7 cc
Filtrate calcium	...2240 - 3700 ppm.

The two principal objects of using special types of muds in these wells have been to prevent damage to the oil bearing zones which have got poor permeabilities at greater depths and to prevent caving of shale which has been quite common. The first object has been well achieved as later analysis of bottom hole pressure showed negative damage near the well bore of KJN-3. However the second has not been realised.

The extent of caving in different wells had been moderate to heavy mostly in zones below 3000 m (3550 to 3875 m in KJN-3); however in no case, hole cleaning had been a problem and in all cases casing could be lowered and cemented. One common feature of the caving phenomenon has been that it starts after some major disturbance in the well such as

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pipe sticking, drillstem testing, high pressure inflow etc. The problem is under investigation from different angles. The shale problem is common throughout the world and uptil now no general solution has been found elsewhere.

8. Mud cost

The cost of mud including additives ranges from 2 to 4% of the total well cost in Nahorkatiya and Moran fields; the higher proportion pertains to the well where the hole is deviated or diesel oil has to be used in place of crude oil; it has been observed that diesel oil wherever used forms 25 to 35% of the total mud cost. The cost is always higher by 1% where ordinary clay is used in place of black clay as the consumption of chemicals is higher with ordinary clay.

The cost of special types of muds in exploratory wells has varied from 3.6 to 7.3% of the total well cost, the increased proportion resulting from the use of special chemicals particularly imported ferrochrome lignosulphonate and chrome lignite and barytes for increasing specific gravity of mud to 1.35 - 1.40.

9. Concluding remarks

The drilling mud technology in Oil India's operations is simple, sound and inexpensive; it has been built up over many years through regular scientific studies. As sophisticated chemicals are not produced in the country, investigations have been directed to use of indigenous materials and the results uptil now have been encouraging. Small quantities of chemicals are still being imported. Simultaneously attempts are being made to develop new products in collaboration with a few research laboratories of the country.

10. Acknowledgement

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APPENDIX

SOME RELEVANT DATA OF NAHORKATIYA WELL NO. 250

A. No. of days to reach the bottom - 29
No. of days to completion - 36

B. Mud Parameters

Depth range, m	0 - 1074	1074 - 2345	2345 - 3031	3031 - 3608
Sp. gr.	1.35 - 1.25	1.27 - 1.21	1.24 - 1.22	1.24 - 1.22
M.F. viscosity, seconds	40 - 36	38 - 33	46 - 34	53 - 40
Plastic viscosity, cp.	10 - 8	8 - 6	18 - 8	22 - 16
Yield value, lb/100 sq.ft	5 - 3	4 - 2	9 - 2	10 - 6
Filtration loss (API), cc	16 - 10	14 - 6	6.2 - 3.6	3.7 - 3.0
Mud sheath, mm	2 - 1.5	1.5 - 1	1 - ∠1	∠1
pH	8.8 - 8.3	9.6 - 8.6	8.7 - 8.0	8.3 - 8.1
Sand, percentage wt.	8 - 1	4 - 0.2	0.5 - 0.2	0.4 - 0.2
Oil, percentage volume	5	10 - 6	11 - 9	12 - 10

C. Chemicals consumed

Barytes	... 25 metric tonnes
Bentonite	... 2.8 " "
Cutch	... 4.7 " "
Carboxymethyl cellulose	... 3.0 " "
Caustic soda	... 0.5 " "
Crude oil	... 69.4 kiloliters

D. Total cost of well ... Rs. 2,375,457

Cost of mud including chemicals Rs.52,327 = 2.2% of the total cost.