ROTARY DRILLING MUD.

PART I. THE EFFECT OF TANNIN ON THE VISCOSITY.

By P. Y. Narayana.

INTRODUCTION.

Mud made by mixing clay and water is extensively used as a circulating fluid when drilling oil wells with a rotary drill, one of its functions being the removal of cuttings. For this purpose the viscosity must lie between certain limits, as it must be sufficient to carry up the cuttings and yet not too high to require excessive power for pumping and to cause undue wear and tear of the pumps. In certain cases a mud of high density is required to prevent the inflow of high pressure water or oil and this is secured by the addition of weighting materials such as barytes. A third requirement of the greatest importance is as a plastering agent to minimise the caving of the walls which occurs in certain strata especially those known as 'heaving shales'; this caving is so serious in some cases that the borehole becomes filled with fragments whenever the drill is removed for dressing and unless it can be prevented, drilling has to be abandoned.

It has been discovered that the viscosity of drilling muds can be profoundly modified by the addition of small quantities of reagents, usually of an alkaline nature, sodium hydroxide and sodium silicate being those most frequently employed. In general the viscosity falls to a minimum with the addition of 0.1 to 0.2 per cent. of the reagent and then increases with larger quantities as shown in Fig. 4 (page 175); the range in concentration over which the minimum persists varies with the clay and the nature of the reagent, and, this is an important factor in practice, a sharp minimum being undesirable as it necessitates very close control of the quantity of reagent. For the treatment of 'heaving shales' Doherty, Gill and Parsons (*Oil and Gas J.*, 1931, **30**, 52 and 86) have suggested the use of sodium tannate and cases of this substance having been used with success are reported from America and Assam.

The results so far obtained with viscosity reducing agents are almost entirely empirical and little is known regarding the relation between the chemical composition of a clay and the physical properties which are suitable for drilling purposes under various conditions. The present investigation is intended to examine in detail some of the factors affecting this complicated subject.

A problem of immediate importance is connected with sodium tannate, which cannot be used as freely as might be desirable owing to its high price. It seems not improbable that it might be replaced by a cruder and cheaper material and this communication deals with a preliminary investigation of the effect of tannin-containing materials on the viscosity of mud.

Of all the tannin-bearing materials, myrobalan powder brings about the greatest reduction in viscosity, the lowest value being only 6 per cent. of the original, which remained constant with larger additions of myrobalan. Mehta and Jatkar (*This Journal*, 1935, **18A**, 101) showed that the addition of myrobalan powder changed the pH of the mud in the manner analogous to its effect on viscosity, the range of constant viscosity corresponding to 7.5 pH. And they also showed that the initial effect of adding small quantities of myrobalan was equivalent to the tannic and ellagitannic content of the myrobalan which were estimated by electrometric titration.

The effect of addition of hydrochloric acid was to decrease the pH at first until it reached 7.83 pH. Further addition increased the pH to 8.71 due to the bound alkali solution being forced out owing to coagulation. Subsequent addition of acid did not materially change the pH. It was also noticed that the flat region of pH is 7.5 for both hydrochloric acid and equivalent quantities of myrobalan.

For every clay-water-electrolyte mixture there exists a certain pH (the isoelectric point) at which the rate of settling of the clay is a maximum and a pH at which the rate of settling was a minimum (a point of maximum deflocculation).

The rise or fall in viscosity due to small quantities of reagents depends upon the distance of the actual pH of the clay from its isoelectric point. Thus, Navias (*Colloid Chemistry* by Alexander, **3**, 313) cites the case of a Canadian ball clay of high pH, *viz.*, 8.0, as against 5.5 to 6.5 for deflocculating which, an exceptional procedure of adding an acid was adopted.

The marked change of aggregation of the clay particles at the isoelectric point described above, which corresponds to a considerable fall in the viscosity of the mud, would point to a pH control of the deflocculating agents. The case of sodium tannate, which is used in Burma and Assam, is worth mentioning. The curve obtained by the author for this substance shows a minimum, similar to that observed in the case of caustic soda. Analysis of the sodium tannate used showed that it contained 25 per cent. tannin and the rest alkali.

EXPERIMENTAL.

Materials.—A concentrated extract of avaram bark (*Cassia auriculata*) which had been prepared in quantity in the laboratory was used as one source of tannin. It contained tannins 35, soluble non-tannins 28 and insoluble matter 3 per cent. This was used either alone or after addition of 67 c.c. of 1N. sodium hydroxide to 10 grms. of extract which reduced the pH value to 11.5, the figure for a commercial sample of sodium tannate.

The cheapest form of tannin being evidently the raw material in which it occurs if it can be used directly, experiments were made with well-dried myrobalans (*Terminalia chebula*) ground to pass through a 120-mesh sieve. The tannin content was 30 per cent. Sodium tannate was purchased from a reliable firm but was found to contain only 10 per cent. of tannin and over 50 per cent. of ash. Commercial samples of this material appear to vary greatly in their composition and this is another disadvantage attending their use.

Most of the experiments were made with a grey clay from Masimpur, Assam, which is extensively used for well boring. A the original material was by no means homogeneous, about 50 kg were ground to a coarse powder and thoroughly mixed. Its chemical composition was as follows :—

Moisture	Further loss on ignition	SiO$_2$	FeO	Fe$_2$O$_3$	Al$_2$O$_3$	CaO	MgO
4·8	9·45	55·8	2·30	0·0	26·60	0·35	1·40

Density and Viscosity.—The density of the mud was determine with sufficient accuracy by filling a 100 c.c. beaker with a flat to and a plate glass cover and weighing the whole. The volume was determined by repeating the experiment with water.

The measurement of viscosity was a more difficult problem owing to the large alteration (often to 2 or 3 times the original value) which occurred when the mud was allowed to stand. The instrument used by the Burmah Oil Company (*Trans. Min. Geol. Inst. India* 1936, **32**) known as the Digboi viscometer, consists of a vertical spindle carrying four paddles immersed in a vessel containing the mud. The viscosity is taken as being proportional to the weight required to cause the paddles to revolve. This apparatus has given good results in commercial practice but in some cases is unsuited for laboratory work because, even if steps are taken to secure uniform results by measuring the exact rate of rotation and by stirring the mud in a definite manner, the quantity of material required for each

experiment (6 litres) is so large, that the supply of clay of uniform nature and its transport becomes a serious problem if the laboratory is distant from the source of supply.

Experiments were consequently made with a rotating cylinder viscometer of the Searle type. This had the advantage that the mud was subjected to a shear, much as it is in practice and the rate of shear could be measured, but concordant results were difficult to obtain as the mud tended to set on the cylinder walls. This instrument required 700 c.c. of fluid which was more than desirable and its use was abandoned in favour of the suction capillary type of viscometer similar to that described by Lottermoser and Schmidl (*Z. anorg. Chem.*, 1931, **203**, 129). As shown in Fig. 1 this consisted of a cylindrical
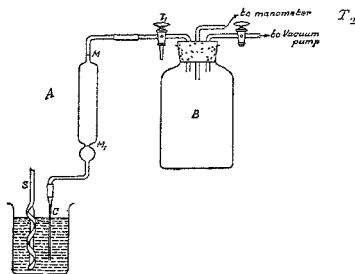

Fig. 1.

Apparatus for viscosity measurements.

tube A, 10 c.c. in volume constricted at the ends to 3.5 mm. and furnished with two marks M_1, M. To the lower extremity a narrow tube C, 10 cm. long and 2 mm. in diameter, was attached by rubber tubing. For every viscous muds, a 2.5 mm. tube was employed. At the upper end A was attached to a 2-way tap T_1, connected to a 15 L. bottle B. This could be evacuated through the tap T_2 by means of a water pump and the pressure measured on the manometer.

To use the apparatus, T_1 was closed and the pressure in the bottle reduced to 200 mm. below that of the atmosphere. 100 c.c. of the mud were placed in a beaker standing, if necessary, in a vessel of water for temperature control, and stirred at a constant rate with the stirrer S. The Capillary C was immersed in the mud to a fixed mark and T_2 closed and T_1 opened so that the mud was sucked into

the tube A. The time taken for the mud to rise from M_1 to M was taken as a measure of the viscosity.

It was found that the viscosity of freshly prepared mud was higher than that of the same mixture after standing for some time, a minimum value being reached in about 2 hours, after which the viscosity rose to its original value or even more. On account of this property, measurements were made as far as possible 2 hours after mixing (*cf. Trans. Min. Geol. Inst. India,* 1936, **32**, 130).

Preliminary experiments showed that the time of flow varied by 2.1 to 2.4 per cent. of the value at 25° for each degree change in temperature between 20° and 30° according to the composition used, as shown in Fig 2. In this diagram the vertical scale of the
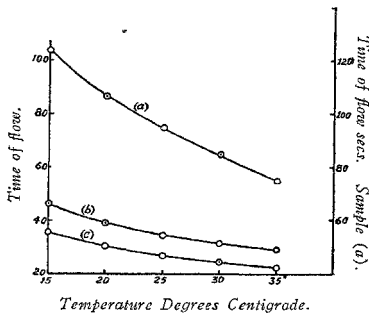

Temperature Degrees Centigrade.

FIG. 2.

Temperature Coefficient of the Viscosity of Clays.

(a) 144 : 100 clay. Sp. gravity 1.45 treated with sodium tannate.
(b) 116 : 100 clay. Sp. gravity 1.37 pure clay.
(c) 116 : 100 clay. Sp. gravity 1.37 treated with reagents.

upper curve is double that of the others. Most of the measurements were made in the neighbourhood of 25° and corrected to this temperature by assuming an appropriate temperature coefficient. Exact determinations of this quantity were not made for every mixture since the error arising from an inaccurate temperature correction was negligible compared with other uncertain factors determining the viscosity.

Fig. 3 indicates the relation between the time of flow and the composition of the mud and shows that a very rapid increase in viscosity takes place when the density exceeds 1.40. Untreated muds

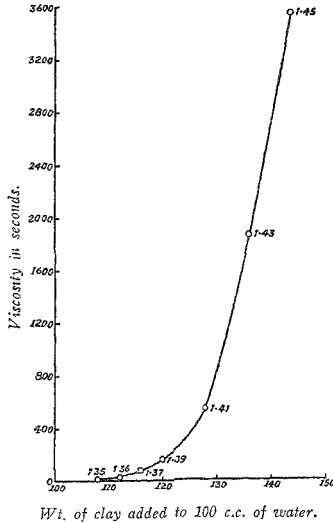*Wt. of clay added to 100 c.c. of water.*

FIG. 3.

Composition-viscosity curve.

of a greater density than this are far too thick to be used in drilling, the optimum range in practice being about 12–30 seconds on the arbitrary scale employed. The actual viscosity corresponding with this range determined from the calibration of the capillary tube is 50–150 centipoises.

Fig. 4 shows the reduction in viscosity of muds of different densities brought about by the addition of commercial sodium tannate and powdered myrobalans. In every case there is a drop in viscosity with about 0.1 per cent. of the reagent and this is more marked with the heavier muds.

In the case of the mud of density 1.43 the minimum viscosity is only 4 per cent. of the initial, corresponding values for the remaining 5 mixtures being 9, 11, 40, 60 and 71 per cent. The addition of larger quantities of myrobalan powder raised viscosity only very slightly, and this, as already indicated, is a desirable property. Sodium
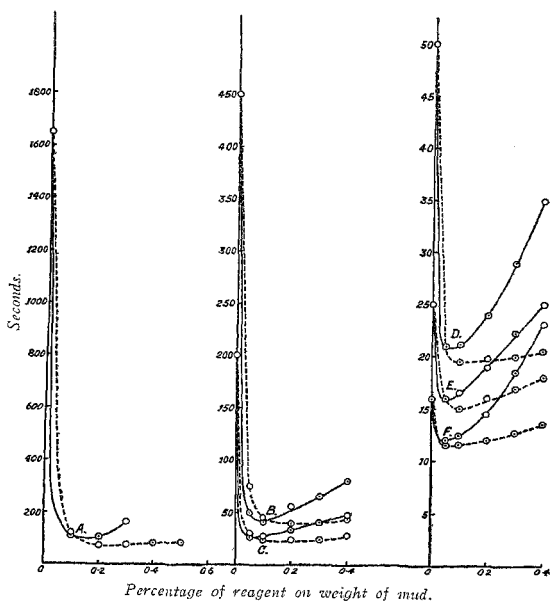
FIG. 4.

Reduction in viscosity of muds of different densities on the addition of reagents.

o—o represents the effect of a commercial sample of sodium tannate.

o--o represents the effect of Myrobalan powder.

tannate, in common with other alkaline materials, raised the viscosity when added in excess, the rise for 0.4 per cent. of the reagent being 60 to 100 per cent. of the minimum viscosity. In the case of the heavier muds this change is small when compared with the total reduction, but with the more dilute mixtures it is large, the mud of density 1.36 having its initial viscosity restored, and the thinnest mud actually increasing in viscosity.

Fig. 5 shows the comparative effects of different reagents on a heavy mud of density 1.45 and initial viscosity 3,600. Myrobalan
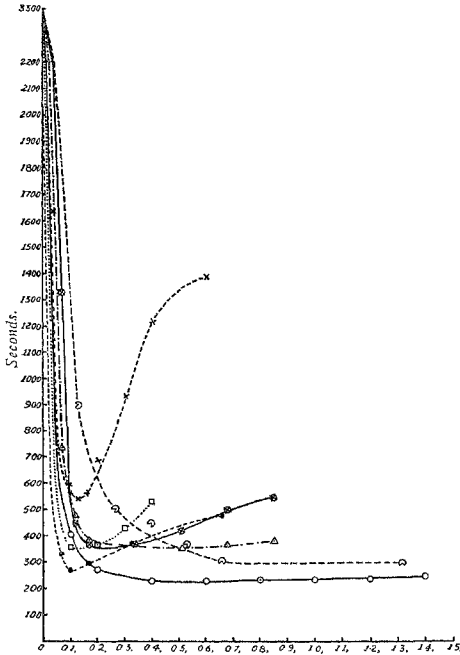
Proportion of the reagent, expressed as per cent. of the clay by weight.

Fig. 5.

Results relate to Expts. done with drilling muds of the following description:—
  (i) 145 gms. powdered clay: 125 c.c. of water in addition to any added
     reagent),
  (ii) 3 hrs. after preparation.
  (iii) Temperature of the mud being either kept at 25° C. or corrected to 25° C.
     by means of the temp. coefficient data.
  (iv) Sp. gravity 1.46 or 91 lbs. per cu. ft.

       o——o Finely ground myrobalan powder (150-mesh).
       ∎——∎ Water glass (commercial Na-Silicate).
       •----• Na-Tt. from Hopkins Co.
       ᴓ---ᴓ Tannin extract (alone) from Avaram bark.
       ✕----✕ Sodium hydroxide.
       ▲--·--▲ Na-Tt. from Avaram bark extract.
       ◻······◻ Sodium carbonate (washing soda),

powder brings about the greatest reduction in viscosity the minimum value being only 6 per cent. of the original. Avaram extract is nearly as efficient, and in both cases there is practically no rise in viscosity on adding comparatively large quantities of the reagent. Commercial sodium tannate and alkaline avaram extract are both good viscosity-reducers but increase the viscosity when added in excess, although the latter does not do so to a marked extent. Sodium hydroxide alone brings down the viscosity to 15 per cent. of the original value and the minimum is very sharply defined.

The two curves (Fig. 6) refer to a mud weighted with barytes to a density of 1.76, the initial viscosity of which was of the
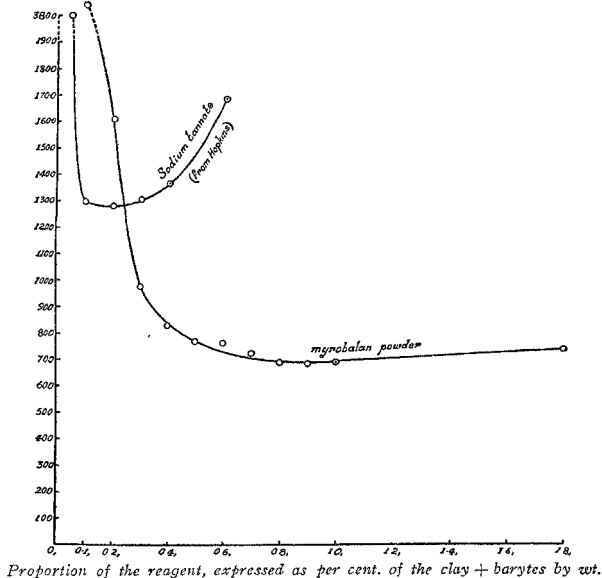

Proportion of the reagent, expressed as per cent. of the clay + barytes by wt.

Fig. 6.

Loaded Muds.

(i) 145 gms. of clay: 100 gms. of barytes: 125 c.c. of water (+ any added reagent).

(ii) 3 hrs. after preparation.

(iii) Temp. of the mud being corrected to 25° from the temp. coefficient data.

(iv) Sp. gravity 1.76 or 110 lbs. per cu. ft.

order of 6,000. The lower curve is for myrobalan powder and the upper for sodium tannate. These illustrate clearly an effect which may be observed in other cases but is not so well defined, this being the fact that the viscosity reduction on adding successive amounts of the powder is more gradual than with the alkaline medium, or in other words, a larger quantity of the plain powder is required. In practice, it would probably be found advantageous to add a small amount of alkali insufficient to produce a sharp minimum. The optimum amount would depend upon the relative prices of the two reagents and would have to be determined in each particular case.

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Department of General Chemistry,
Indian Institute of Science,
Bangalore (India).