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FURTHER INVESTIGATIONS OF THE PROPERTIES OF CLAY SUSPENSIONS.*

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Summary.

A number of clay suspensions have been examined in a capillary tube viscometer under different pressure gradients. Data were obtained on the relationships between rate of flow and pressure gradient, concentration and "viscosity," simple and complex suspensions, and on the effects of heating, "viscosity"-temperature coefficients and ageing.

The Hatschek concentric cylinder viscometer did not prove very satisfactory for examining these suspensions. The phenomenon of sedimentation under shear in a concentric cylinder viscometer was investigated.

Attempts to determine yield values directly by using cylinders and vanes in a torsion apparatus brought to light an interesting feature which is probably coupled with thixotropy.

Preliminary work on the estimation of the amount of water "bound" by different clays was undertaken, and apparently amounts up to 25% or more of the weight of the dry clay are held thus.

I. The Capillary Viscometer.

In an earlier publication[1] the results of viscometric measurements on suspensions of Stockolite and Aquagel were described. The same apparatus has been applied to examine a number of clays and shales, some of which have been used in drilling muds. Briefly, the viscometer was of the pipette type, with interchangeable capillaries, and employed suction to draw a known volume of mud into the measuring-bulb. The apparatus was simple and cheap to construct; it had no drainage error. On the other hand, a fairly large volume of mud was required (350 c.c.), and working losses occurred when the bulb was cleaned between the observations. These losses increased with increasing "viscosity" of the mud. There was an upper limit to the pressure gradient which could be applied when using a given capillary. The presence of a hydrostatic-head correction and probable errors in the form used fixed a lower limit to the pressure gradient which could reasonably be applied with a given capillary. This correction was an approximate one for a true liquid, and therefore probably rather less satisfactory for muds. Kinetic-energy corrections were applied to the data. Little is known about the value of the coefficient m of the kinetic-energy correction in the case of these anomalous fluids, but it seemed preferable to use an approximate form rather than to omit the correction. It was possible to shake or stir the mud almost immediately before a measurement. This was of service when the clay suspensions sedimented relatively quickly. The muds could be stirred during an observation, thus providing a simple test for thixotropy.

If Cunningham's work[2] really showed that small differences in pressure affected the "viscosity," and not merely thixotropic effects, as suggested

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* The greater part of the first two sections is summarized from a thesis approved for the Degree of Doctor of Philosophy in the University of London, 1936.

by McMillen,[3] and the effect does not reach its maximum instantaneously or in a few seconds at the most, it cannot appreciably affect the results in this apparatus; for the mud is kept under the same pressure right up to the moment of entering the capillary, whatever the pressure gradient used. It is clear, as Ambrose and Loomis,[4] and McMillen [5] point out, that if a thixotropic material does not attain equilibrium in a concentric cylinder rotating viscometer in 30 minutes, or more in some instances, it will scarcely be possible to reach equilibrium in a capillary of the usual length. Yet if a long period of shearing is necessary for the attainment of this equilibrium, the possibility exists that the thixotropic state during the passage through the capillary will not be far removed from that obtaining immediately before entering the capillary.

All the muds were made up with distilled water, the shales and clays being crushed where necessary, and they were screened to pass 60-mesh I.M.M. The concentrations have been expressed as the percentages by weight of the clays in the suspensions, and were determined by heating weighed samples to dryness at 110° C. Unless otherwise stated, the measurements were made at 20° C. The capillaries had the following dimensions:—

I N. Length: 11·580 cm
Radius: 0·0434 cm.

I W. Length: 11·644 cm.
Radius: 0·0638 cm.

II N. Length: 11·361 cm.
Radius: 0·0432 cm.

The data have been interpreted in two ways:—

(*a*) From the corrected pressure gradient and the time of filling of the bulb, the equivalent or apparent viscosity was calculated as that of a hypothetical normal liquid according to the following equation:—

$$\eta_e = \frac{\pi P R^4}{8V(L+nR)} - \frac{mV\rho}{8\pi(L+nR)}$$

where R and L are the radius and length of the capillary respectively, ρ is the density of the mud, $V = \frac{\text{measuring volume of viscometer}}{\text{time of filling}}$, m is the coefficient of the kinetic-energy correction, n the coefficient of the Couette end-correction, and P is the corrected pressure. The equivalent viscosity calculated for each observation was plotted against the corresponding mean rate of flow. The method is empirical. Nevertheless it is of service.

(*b*) The quantity $\frac{V}{\pi R^3}$ was plotted against $\frac{PR}{2L}$, after applying a kinetic-energy correction to the pressure gradient.

Since the rate of flow changed a little in each observation and the hydrostatic and kinetic-energy corrections were but approximate, it is to the relative, and not the absolute, values of the results that the chief attention must be paid. The equivalent viscosities have been expressed in terms of poises in order to give some idea of the magnitudes of the quantities involved.

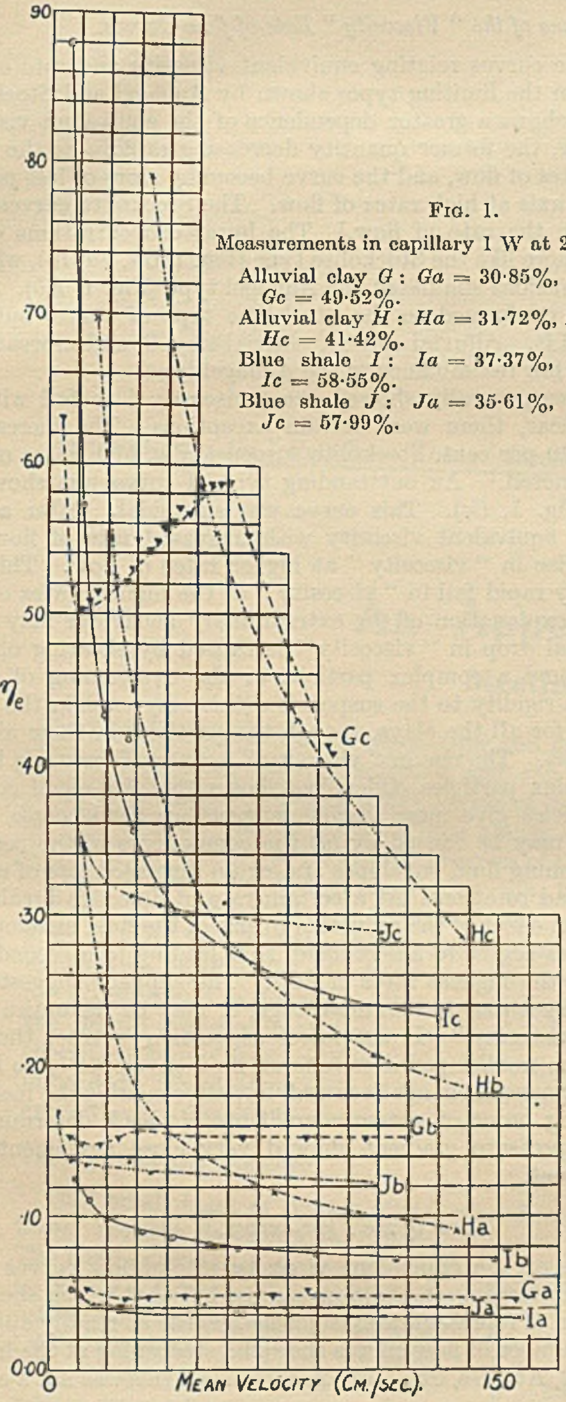


Fig. 1.

Measurements in capillary 1 W at 20° C. :—

Alluvial clay G : $Ga = 30{\cdot}85\%$, $Gb = 42{\cdot}70\%$, $Gc = 49{\cdot}52\%$.
Alluvial clay H : $Ha = 31{\cdot}72\%$, $Hb = 37{\cdot}65\%$, $Hc = 41{\cdot}42\%$.
Blue shale I : $Ia = 37{\cdot}37\%$, $Ib = 49{\cdot}16\%$, $Ic = 58{\cdot}55\%$.
Blue shale J : $Ja = 35{\cdot}61\%$, $Jb = 51{\cdot}11\%$, $Jc = 57{\cdot}99\%$.

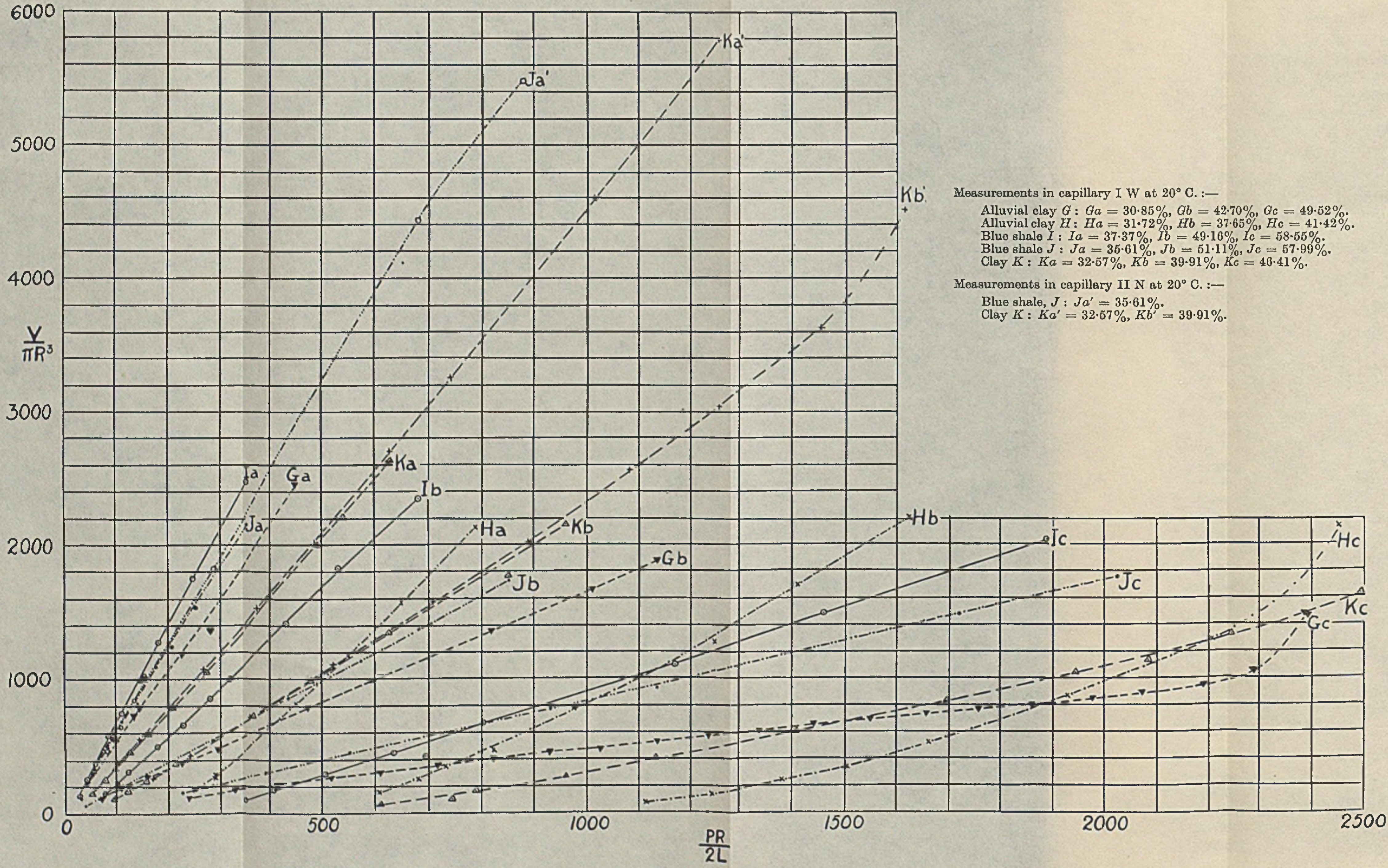
Forms of the "Viscosity" Rate-of-flow Curves.

The forms of the curves relating equivalent viscosity and rate of flow seem to lie between the limiting types shown by Aquagel and Stockolite. The Aquagel type shows a greater dependence of the equivalent viscosity on the rate of flow, the former quantity decreasing rapidly as the latter increases at low rates of flow, and the curve becoming more or less parallel to the rate-of-flow axis at high rates of flow. The Stockolite curves show less dependence on the rate of flow.[1] The lower concentrations of the clays gave curves more like the Stockolite type (Fig. 1, *Ga, Ja, Ia*), whereas the higher concentrations simulated the Aquagel type (Fig. 1, *Hb*). None of the clays quite conformed to the Stockolite type of curve, but blue shale *J* approached it. Alluvial clay *H*, alluvial clay *R*, and unweathered London clay had a fair resemblance to the Aquagel type.

Whilst the curves generally showed the "viscosity" to fall with increased rate of shear, there were certain exceptions. The increase in "viscosity" of a 40 per cent. Stockolite suspension at high rates of flow has already been noted.[1] An outstanding type of curve was shown by alluvial clay *G* (Fig. 1, *Gc*). This curve was sigmoidal. After a very rapid decrease in equivalent viscosity with increased rate of flow, the curve revealed a rise in "viscosity" at higher rates of flow. This was followed by a fairly rapid fall in "viscosity" at the highest rates of flow used. A possible explanation of the extraordinary behaviour may be as follows: The initial drop in "viscosity" is caused by shearing off of a fluid envelope around a complex particle, or the overcoming of forces which tend to give rigidity to the suspension (this may explain the "viscosity" reduction for all the clays, though the particles in them are not necessarily complex). The rise in "viscosity" is due to increasing breakdown of the complex particles (Oden has shown that for equal concentrations, fine particles give more viscous suspensions than coarse ones). In detail, the rise may be caused by (*a*) the components of the complex particles each assuming fluid envelopes and/or (*b*) increased loss of energy due to collisions and rotation. At a certain rate of flow this breakdown is complete, and the effect of the reduction in size of the fluid envelopes on the smaller particles begins to assert itself, thus leading to a second drop in "viscosity" at the highest rates of flow. The slippage suggested by Bingham [6] may play a part in this final stage, or may be the entire cause of the drop in "viscosity." If the latter suggestion is true, then the assumption that the smaller particles take on fluid envelopes is no longer necessary. No permanent change occurred, for, after making the measurements in decreasing order of pressure gradients, a check determination under the initial pressure gradient showed very close agreement with the first measurement.

Form of the Flow-curves.

The peculiarities of the equivalent viscosity–rate-of-flow curves have, of course, their counterparts in the flow-curves, but that which shows up well in the one form of representation is not necessarily so readily apparent in the other. A number of flow-curves showed a steepening at the highest rates of flow (Fig. 2, *Kb′, Hc, Gc*). In some instances this was not a change



Measurements in capillary I W at 20° C. :—

Alluvial clay *G* : *Ga* = 30·85%, *Gb* = 42·70%, *Gc* = 49·52%.
Alluvial clay *H* : *Ha* = 31·72%, *Hb* = 37·65%, *Hc* = 41·42%.
Blue shale *I* : *Ia* = 37·37%, *Ib* = 49·16%, *Ic* = 58·55%.
Blue shale *J* : *Ja* = 35·61%, *Jb* = 51·11%, *Jc* = 57·99%.
Clay *K* : *Ka* = 32·57%, *Kb* = 39·91%, *Kc* = 46·41%.

Measurements in capillary II N at 20° C. :—

Blue shale, *J* : *Ja′* = 35·61%.
Clay *K* : *Ka′* = 32·57%, *Kb′* = 39·91%.

Fig. 2.

[*To face p.* 537.

in mobility, but was at least partly due to air coming out of solution. The cases of a true increase in mobility were possibly examples of slippage or loss of fluid envelopes. In other instances the flow-curves became less steep at the highest rates of flow (Fig. 2, *Ja'*). This probably resulted from turbulence, with the possible additional factor of breakdown of complex particles.

Although some of the flow-curves were still straight at the lowest rates of flow used, many of them did show curvature towards the origin. The Bingham hypothesis demands such curvature even though slip be absent, and if slip be present, the curvature is greater, and the curve may even pass through the origin, as Buckingham assumed in the derivation of his equation, or may intersect the stress axis at a measurable value, as observed by Keen, Scott Blair, and Crowther.[7, 8]

Whilst the flow-curves of blue shale *L*, shale *P*, and clay *K* were essentially straight lines, except at the lowest rates of flow, some of the other clays, and especially the higher concentrations, gave flow-curves which curved throughout, with the result that a reasonable measurement of their slopes was difficult or impossible.

In conformity with the observations of Hall,[9] and Scott Blair and Crowther,[8] it was found that the slope of the part of the flow-curves corresponding to stage IV of the latters' curves was greater the narrower the capillary—*i.e.*, the mobility was higher in the narrow capillary.

Effect of Stirring, etc., on the Measurements.

In the bulk of the measurements the standard procedure was to stir the mud for 25 sec. immediately before the measurement, and at a steady rate during the measurement. This stirring was by no means vigorous, but it was found possible in most cases to obtain more consistent results with stirring during the measurements than when stirring was suspended. The exceptions were some very dilute suspensions of fractions of London clay and there, no doubt, the irregularities were due to turbulence.

Omitting the cases of fractions of London clay, stirring during a measurement was found to give a lower value for the " viscosity " or a higher value for the mobility than was observed in the absence of stirring. Thus stirring increased the mobility of a Stockolite–Aquagel suspension by about 10 per cent.

Any disturbance might be expected to tend to promote turbulent flow. Such a tendency would be greater the more vigorous the stirring, and for a fixed method of stirring it would be greater the less dense and the less viscous the fluid. If the fluid were thixotropic, the nett effect of stirring during a measurement would be manifest as an increase or decrease in the " viscosity," according as the apparent increase in " viscosity " resulting from any turbulence created exceeded or was less than any decrease in " viscosity " consequent on thixotropic breakdown.

It must be recognized that if any standard method of treatment is adopted with a thixotropic mud—*e.g.*, stirring during an observation, not stirring, or stirring vigorously before an observation—then, provided that the measurements are made in strict order of increasing or decreasing pressure gradients, the results may be expected to lie on a smooth curve, but the curve obtained for the increasing order of pressure gradients will not necessarily coincide with that obtained for the reverse order. The reason lies in the fact that the treatment, whatever its nature, will only in rare cases maintain the initial state of thixotropic breakdown during a series of measurements. In general it will either fail to maintain it, or it will increase it. Notwithstanding, under uniform treatment the change in thixotropic state may be expected to be gradual, and hence a smooth curve will result. On this account, mobilities and stress intercepts may differ a little according as observations are made in ascending or descending order of pressure gradients.

Relationships between Concentration and the " Viscosity " or Mobility of the Suspensions.

Although the " viscosities " at given rates of flow can be plotted against the concentration by weight, in attempts to find a relationship between " viscosity " and concentration, it is desirable to use a less arbitrary quantity, *e.g.*, the ultimate viscosity—the asymptotic value towards which the " viscosity "–rate-of-flow curves seem to tend in most cases—or the value, *i.e.*, the mobility, obtained from the slope of the flow-curves in stage IV when they are linear or nearly so. The reciprocal of the mobility has the dimensions of a viscosity. Furthermore, it would seem better to express the concentration in terms of volume rather than weight, for it is the size of the particles and their total effective bulk which, other things being equal, determine the " viscosity " of a suspension, and it is clear that the relationship between percentage by volume and percentage by weight is not linear unless the densities of the suspended material and the suspending medium are equal. There is an additional complicating feature in that the particles are probably intimately associated with a portion of the suspending medium, making their effective bulk appreciably greater than that of the particles alone. However, this feature has been omitted from the following simple discussion.

In order to calculate the concentration by volume from that by weight in the absence of direct determinations of the densities of the clay particles, a density value of 2·6 was used, which, while somewhat below a series of computed apparent densities, probably errs in the right direction.

Einstein's equation for the " viscosity " of a suspension of rigid spheres is $\eta_s = \eta(1 + 2{\cdot}5\phi)$, where ϕ is the volume fraction the spheres constitute of the entire suspension. This equation assumes that the spheres do not influence one another. The suspensions examined do not obey this linear relationship, but the " viscosity " increased at a greater rate, a result to be expected from the high concentrations used (Fig. 3). In addition, the particles were most likely platy, and may not have fulfilled the condition of rigidity. Bingham and Durham's work on infusorial earth and English china-clay led them to the conclusion that finely divided substances in suspension depress the fluidity $\left(\frac{1}{\text{viscosity}}\right)$ of the liquids in which they are suspended by amounts which are directly proportional to the volume of solid.[11] This may be expressed by the equation $\psi_s = \psi_w (1 - \phi k)$, where ϕ is the volume fraction of the solid.

The percentage by volume has been plotted against the mobility (Fig, 4). In no case was a straight line obtained. Nevertheless, the curvature was not great. Aquagel was found to approximate more closely to Einstein's equation than to Bingham and Durham's, whereas Stockolite and the other clays were, on the whole, nearer to Bingham and Durham's. The closer agreement of Aquagel with Einstein's equation was perhaps to be expected, since the maximum concentration was only 1·86 per cent., whilst the other suspensions went up to 35 per cent. of clay by volume.

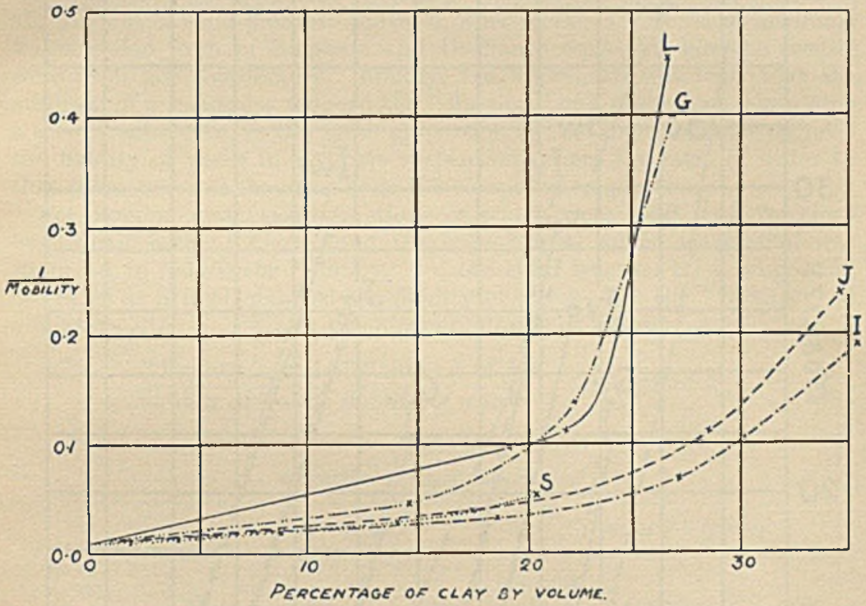


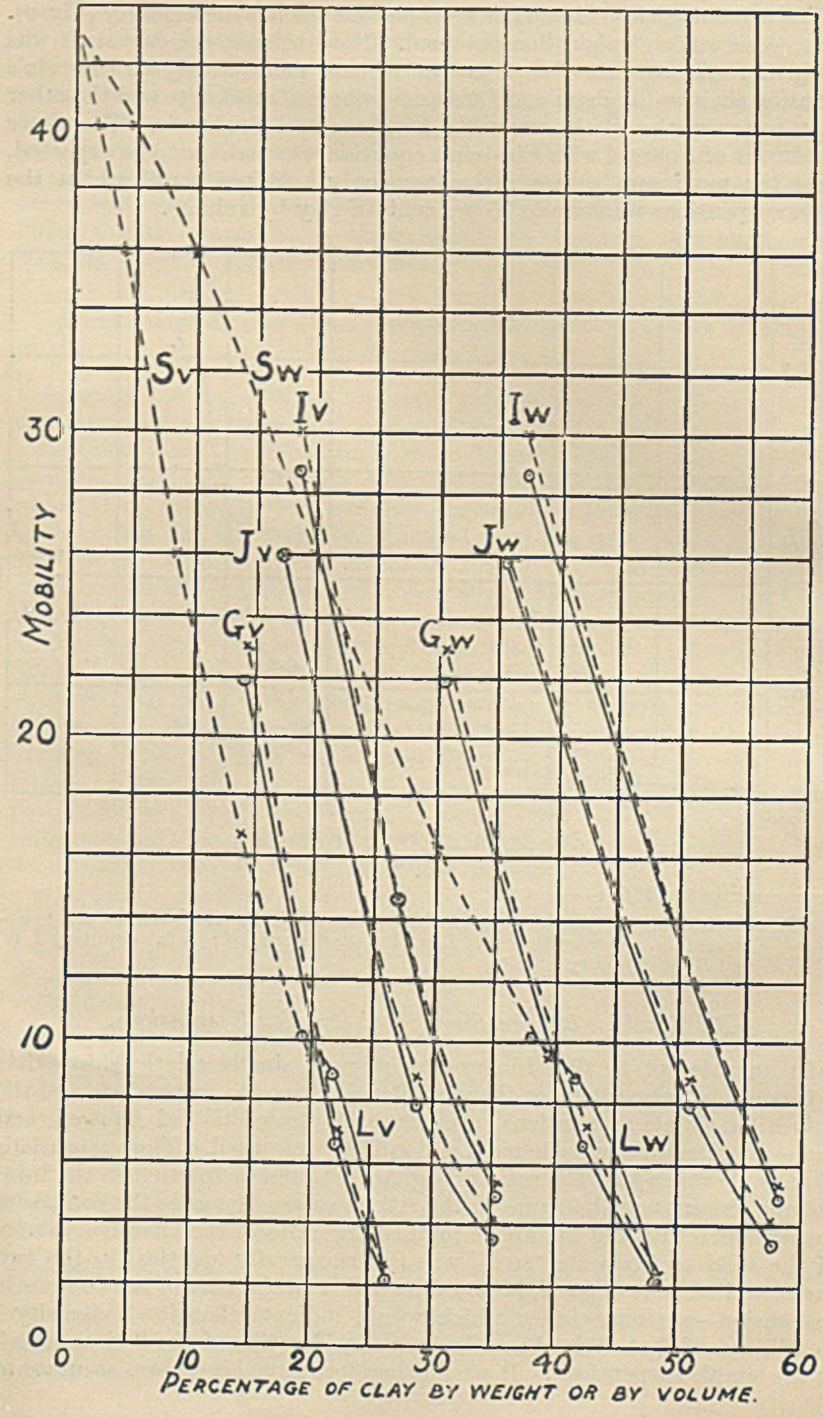
Fig. 3.

Measurements at 20° C. :—

G—alluvial clay *G*; *J*—blue shale *J*; *I*—blue shale *I*; *L*—blue shale *L*; *S*—Stockolite. Curves *G*, *J* and *I* are for capillary II N; *L* for capillary I W, and *S* for capillary I N.

Relationships between Simple and Complex Suspensions.

In an attempt to find if any approximate simple relationship exists between the " viscosity " or the mobility of composite suspensions and the values for simple suspensions, a mixture of Stockolite and Aquagel, and three fractions of unweathered London clay were used. The suspensions were made up so that the ratio of a given material or fraction to the total volume present was the same in the simple suspension as in the composite suspension. In using the above method the ratio of the effective volume of the solid to free-water space was not necessarily identical in the two cases, and when it differed, it would be higher in the case of the composite suspension—a circumstance which would indicate that its " viscosity " should exceed that derived merely from consideration of the " viscosities " of the simple suspensions. It would therefore have been more accurate to


Sv
Sw
Iv
Iw
Jv
Jw
Gv
Gw
Lv
Lw
Mobility
0
10
20
30
40
0
10
20
30
40
50
60
Percentage of clay by weight or by volume.

have made up the simple suspensions so that the ratio of the effective volume of solid to the volume of free water was the same as in the composite suspension, but lack of knowledge of the water-" binding " power of the various fractions precluded this.

The increments to the viscosity of water caused by the separate fractions or materials at given rates of flow were summed and added to the viscosity of water. The summate curve was found to lie well below that actually obtained for the composite suspension. This was not unexpected, for with every material the " viscosity " increased at a greater rate than the amount of solid present. Several other methods were tried, including an extended form of Bingham and Durham's equation, but the results were even less satisfactory. Finally, the hypothesis was used that the addition of a substance reduced the " fluidity " of a suspension containing a second substance, in the same proportion as the first substance reduced the fluidity of water in a simple suspension, where the ratio of water to that substance was the same as in the composite suspension.

For London clay, three fractions of which were used, two fractions were dealt with as above, and the hypothetical mixed suspension was supposed to reduce the " fluidity " of the third fraction by a proportion the same as it itself reduced the fluidity of water—*i.e.*, the " fluidity " of a mixture $A,B, \ldots X$ at a given rate of flow is as follows :—

$$\frac{\text{" fluidity " of } A}{\text{fluidity of water}} \cdot \frac{\text{" fluidity " of } B}{\text{fluidity of water}} \ldots \text{fluidity of } X,$$

TABLE I.

Stockolite–Aquagel Suspension.

Rate of flow, cm./sec.	" Fluidity " (rhes).			" Viscosity " (poise).		
	Calc.	Obs.	% error.	Summation of visc. increm.	Observed.	% error.
30	15·6	16·3	−4·3	0·0442	0·0611	−27·9
60	17·9	18·1	−1·0	0·0408	0·0550	−26·0
90	19·2	19·2	0·0	0·0386	0·0520	−25·7
120	20·3	20·1	0·7	0·0371	0·0495	−25·0
150	21·1	20·9	1·6	0·0360	0·0480	−25·0
180	21·6	21·5	0·3	0·0353	0·0465	−24·0
210	21·9	22·0	−0·6	0·0347	0·0454	−23·3
240	21·6	22·7	−4·7	0·0337	0·0440	−21·0

all the data being for the same rate of flow, and the ratio of $A,B, \ldots X$ to water in the simple suspensions being the same as in the composite

FIG. 4.

v denotes curve for percentage by volume.
w ,, ,, ,, weight.
G is alluvial clay *G*; *J* is blue shale *J*; *I* is blue shale *I*; *L* is blue shale *L*; *S* is Stockolite.

Full lines are for capillary I W; broken lines for capillary II N, except in the case of Stockolite where the results are for capillary I N. The ordinates of the Stockolite curves have been halved.

TABLE II.

Unweathered London Clay.

Rate of flow, cm./sec.	" Fluidity " (rhes).			" Viscosity " (poise).		
	Calc.	Obs.	% error.	Summation of visc. increm.	Observed.	% error.
15	1·92	3·1	−38·0	0·222	0·322	−31·0
30	4·15	4·6	− 9·9	0·147	0·216	−32·1
50	5·8	6·3	− 8·0	0·117	0·159	−26·1
80	7·2	7·6	− 5·2	0·096	0·132	−27·3
110	8·1	8·7	− 6·9	0·087	0·115	−24·2
140	8·84	9·3	− 4·9	0·082	0·108	−23·9
170	9·5	10·1	− 6·0	0·078	0·099	−21·0

suspension. In Tables I and II the results so obtained are compared with those reached from the summation of " viscosity " increments.

Tables I and II show that the results reached by the last method agree more closely with observed values than do the summations of viscosity increments. The large error for the lowest rate of flow in Table II is probably due to inaccuracies in the experimental data, for it is most difficult to make the measurements at the lowest rates of flow with certainty.

A natural extension to the above hypothesis is its application to the relationship between concentration and mobility for a single clay. This gives $\log \psi_s = \log \psi_w + \frac{99C}{1-C} \cdot \log a$, where C is the fraction by volume of solid in the suspension and a is the ratio of the mobility of a suspension with 1 per cent. by volume of solid to the fluidity of water. Moderate agreement with this equation was shown by the Stockolite data, and those for blue shale *I*. Alluvial clay *G* and blue shale *J* gave curves of a similar form, and the latter showed quite good agreement with the extended form of the equation which makes some allowance for " bound " water (Fig. 5).

Stress Intercept.

The intercept on the stress axis obtained by extrapolating the stream-line portion of the flow-curves has received a variety of names. It has been called the " static rigidity " by Keen.[12] Terzaghi [13] criticized this, and suggested " shearing resistance." Buckingham has used " shearing strength," and Bingham " yield value." The significant physical factor is the critical shearing stress required to initiate flow as assumed in the Bingham hypothesis. This is three-quarters of the stress intercept, and in spite of the general application of the various terms to the stress intercept, it would seem preferable to reserve them for the quantity which is considered in the general theory. For the present purpose " yield value " will be adopted, and taken as three-quarters of the stress intercept.

Where possible, extrapolation of the stream-line portion of the flow curves was carried out, and yield values were measured, ranging from zero up to several hundred dynes/sq. cm. The values varied widely for

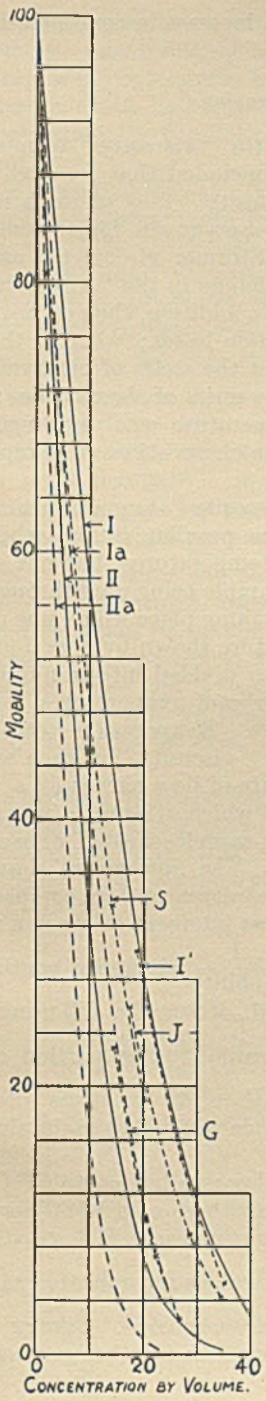


FIG. 5.

Curves I and II represent the equation $\psi_s = \psi_w a^{\frac{99C}{1-C}}$, where ψ_w is the fluidity of water at 20° C., and 'a' has the values of 0·95 and 0·90 respectively. Curves Ia and IIa represent the equation $\psi_s = \psi_w a^{\frac{99kC}{1-kC}}$, where k is the ratio of the effective volume of the suspended solid to its actual volume and is given a value of 1·5 here, and 'a' has values of 0·95 and 0·90 respectively. Curve *G* shows data for alluvial clay *G*; *I'* for blue shale *I*; *J* for blue shale *J*; *S* for Stockolite. Curves *G*, *I'*, and *J* are for capillary II N, and curve *S* is for capillary I N.

the different clays, and increased rapidly with increase in concentration of the clay.

Effect of Heating the Suspensions.

As a result of a series of measurements of the " viscosity " of muds at different temperatures, Craft and Exner ^{14} concluded that for high concentrations and also for bentonites the " viscosity " falls off with rise in temperature up to about 60° C., and then increases at still higher temperatures. These observations were made in a Stormer viscometer using a constant driving-weight; consequently any change in the " viscosity " of this type of medium would be exaggerated. In addition, they do not state what precautions were taken against evaporation losses; whether the one sample was kept in the instrument throughout the series of observations; whether the concentration increased during the series of observations; and whether the " viscosity " at the initial temperature was unchanged by heating and the same curve was obtained if the observations were repeated in descending order of temperatures.

Preliminary attempts to determine a " viscosity "–temperature coefficient for these clay suspensions led to some peculiar results when the measurements were made in rising order of temperatures, but not so for measurements in the reverse order, the same sample being used throughout. It was clear, therefore, that some change was taking place which was unlike the mere fall in viscosity with rise in temperature shown by true liquids.

A 16·69 per cent. suspension of clay *N* was divided into a number of parts, each of which was heated to one of a series of temperatures, ranging from 20° C. to 99° C., for a period of 7 hours. Evaporation losses were prevented, and after standing over-night, the " viscosity " of each sample was measured at 20° C. The " viscosity " rate-of-flow curves as a whole showed there was an increase in " viscosity " which attained a maximum in the samples heated to 70–80° C., and for samples heated above that temperature range the " viscosity " fell off. The flow-curves showed a fairly distinct division into three parts, but the inferences from comparisons of corresponding parts were similar. The stress intercept attained a maximum over the range 60–80° C., whilst the $\frac{1}{\text{mobility}}$ showed a continuous increase up to the highest temperature used. Over the full range the $\frac{1}{\text{mobility}}$ increased by 14–18 per cent., according to the portion of the flow-curves considered, and the maximum values for the stress intercept were 34–52 per cent. higher than for the sample which was maintained at a temperature of 20° C.

A 32·94 per cent. suspension of the same clay was heated to 55° C. and the " viscosity " measurements compared with those of a 16·69 per cent. suspension similarly treated. The percentage increases in " viscosity ", $\frac{1}{\text{mobility}}$, and stress intercept in terms of the values for unheated samples were much greater in the more concentrated suspension. Similar " viscosity " increases were observed to have taken place in other clay suspensions after heating to 40° C.

Tests on a suspension heated at 45° C. for varying periods showed that the change was probably complete after 6–10 hours. Finally, the permanence of the change was examined. For this purpose the 16·69 per cent. suspension which had been heated to 90° C. for 7 hours was re-examined after standing for a month. The results showed the change to be permanent.

It is clear that the hysteresis in the preliminary essays at measuring a "viscosity"–temperature coefficient was due to non-reversible changes which set in in previously unheated suspensions. It follows, therefore, that whether the "viscosity" will appear to increase or decrease as the temperature is first raised, will depend on the relative magnitudes of two factors which, in these cases, operate in opposite directions for the lower temperatures at any rate :—

(*a*) A normal decrease in "viscosity" (with rise in temperature) resulting from the decrease in viscosity of the suspending medium. This is reversed on reducing the temperature.

(*b*) A change in "viscosity" due to the heating which is not removed on lowering the temperature, and, as far as the present measurements go, is seemingly permanent.

This second factor will not appear in measurements made in descending order of temperatures, provided that the "viscosity" change has been allowed to attain its maximum at the highest temperature used. If that state has not been reached, the temperature coefficient may be exaggerated if heating raises the "viscosity." On the other hand, for observations made in rising order of temperatures on previously unheated suspensions, an apparently low or even negative value will be obtained in the presence of this factor.

The findings described seem to be at variance with those of the Burmah Oil Company,[15] but it may be that all clays do not behave alike. Yet, in the absence of information regarding the experimental details mentioned, the present work appears to offer a reasonable explanation of Craft and Exner's results.

Effect of Temperature on the Mobility and "Viscosity" of the Muds.

According to Hatschek,[16] the temperature coefficient of "viscosity" in suspensoid sols is merely that of the dispersion medium. In contrast, the temperature coefficient of emulsoid sols "is always markedly greater than that of the dispersion medium."

For 10 and 40 per cent. Stockolite suspensions the relative changes for the range 10–30° C. were slightly less than for water. The same was true of 20 per cent. Stockolite treated with 1·998 per cent. of caustic soda.

Two other clays were examined. Since their flow-curves were not linear in stage IV, but showed a small fairly uniform curvature, it was not possible to measure the $\frac{1}{\text{mobility}}$ in the usual manner. Consequently the data were compared empirically. The mean slopes of the curves for similar ranges of $\frac{V}{\pi R^3}$ (rates of shear) were measured, and from these the percentage changes in $\frac{1}{\text{mobility}}$ for the intervals 40 – 20° C., 30 – 20° C., and 40 – 30° C. were obtained and compared with the values derived from the equivalent viscosity–rate-of-flow curves and the viscosity changes for water. The changes calculated from the flow-curves approached more closely to those for water than did those obtained from the "viscosity" curves. In the former case, for a 59·91 per cent. blue shale *I* suspension the agreement was within a little more than 1 per cent., whilst for the 40·65 per cent. clay *K* suspension, which was probably more colloidal, the mean change was about 4 per cent. less than for water.

A 37·63 per cent. suspension of clay *N* had a $\frac{1}{\text{mobility}}$ at 55° C. which was 46 per cent. of its value at 20° C. The viscosity of water at 55° C. is 50 per cent. of its value at 20° C. Hence the change was slightly greater than that for water.

A sound opinion as to the effect of rise in temperature on the stress intercept cannot be given from the present data, for the flow-curves not being linear in stage IV rendered extrapolation unreliable.

Ageing.

Hall [9] found that "the consistency of a clay slip changes during the first two days, probably due to the swelling of gel colloids, and more on the first day than in later periods. All the determinations with one capillary must be made in one day due to the time effect on the consistency of the slip." Excepting the cases of the Stockolite suspensions, the "viscosity" measurements here described have not been made on the day on which the suspensions were prepared, and in only three instances—38·28 per cent. blue shale *L*, 51·11 per cent. blue shale *J*, and an Aquagel suspension—were measurements carried out on the first day after preparation. Naturally flow-curves were drawn only for data obtained on the same day.

Stockolite suspensions of concentrations 20, 30, and 40 per cent. were examined on the day of preparation and again after intervals of 35 days, 31 days, and 8 days, respectively, but no indication was found of any change in "viscosity" with age.

The increased effect of caustic soda and hydrochloric acid on Stockolite as compared with measurements made within a short time of adding the reagent has been noted.[1] For soda-treated Aquagel small irregularities in the curves frequently coincided with over-night intervals.

The suspension consisting of a mixture of 20 per cent. Stockolite and 2·925 per cent. Aquagel showed a very strong increase in "viscosity" or decrease in mobility with age. Comparing measurements made within a day or two of its preparation with those made nine months later, the latter revealed a "viscosity" increase of about 40 per cent. for observations under similar conditions, and examination of the flow-curves showed that not only had the mobility decreased, but the stress intercept had increased by 37·5 per cent. This suspension "set" slowly to a gelatinous mass with well-marked solid and elastic properties, yet a few moments' shaking converted it into the original liquid with no signs of any "solid" lumps.

Some clay suspensions showed no important differences in mobility between being a few days and several months old, whilst others showed considerable differences between being two or three days and ten days to several months old.

It is possible that the " viscosity " increases are concomitant with slight volumetric contractions, for a small increase in density was noted in a suspension of clay *K* between being three days and seven weeks old.

Distribution of Particle Sizes, Surface Factors and Inferences from the Chemical Analyses of some of the Clays.

An attempt was made to determine the approximate size distribution of the particles in a few of the clays, and thus to arrive at an estimate of the relative total surface per gram of each clay, with a view to finding whether or not this factor gives a clue to the fluid and other properties of the suspensions. The pipette method of mechanical analysis was adopted, using a suspension containing about 2 per cent. by weight of solids in distilled water. (The suspensions were prepared by diluting those used for " viscosity " measurements, which were all several months old.)

The assumptions involved in the application of Stokes' law to the mechanical analysis of sediments are well known. The bulk of the particles in a clay will be platy rather than spherical, and their " effective radii " are the radii of imaginary spheres of the same material which would sink in water with the same velocities as the particles in question. The specific gravities of the particles probably vary a little, and there may be adsorption of the suspending medium.

Fig. 6 shows the cumulative curves from which the size-distribution curves were derived by graphical methods. Using graphical methods again, surface distribution curves were obtained, and thence the relative total surface per gram of each clay was estimated. In this estimation the assumption was made that the particles were spherical and of uniform specific gravity. The effective radii of the cumulative curve were employed. If the particles were laminar rather than spherical, their falling velocities might be assumed to be, on the average, considerably less than for spheres of the same weight. The normal method of using Stokes' law would mean that a single laminar particle would be represented as more than one small sphere. Thus, whilst a laminar particle has a greater surface than a sphere of equal weight, the fact that its lower falling velocity leads to its interpretation as more than one small sphere will give a total surface factor nearer the truth than the small spherical particle of equal weight. Furthermore, if there is a fair degree of geometrical similarity in the particles of the different clays, relative estimates will not be so seriously disturbed by using spheres as the basis for calculation.

Joseph [17] has emphasized the importance of the silica–sesquioxide ratio as a guide to the plasticity of clays. The higher this ratio the greater the degree of swelling and dispersibility, the more viscous the suspensions, the greater the heat of wetting, adsorption of basic dyes and base exchange,[18] the higher is the electrokinetic potential when containing a given cation, in the absence of added electrolyte.[19] (According to Smoluchowski's equation, the " viscosity " of a suspension is a function of the square of the electrokinetic potential of the particles.) Mattson considered the hydration

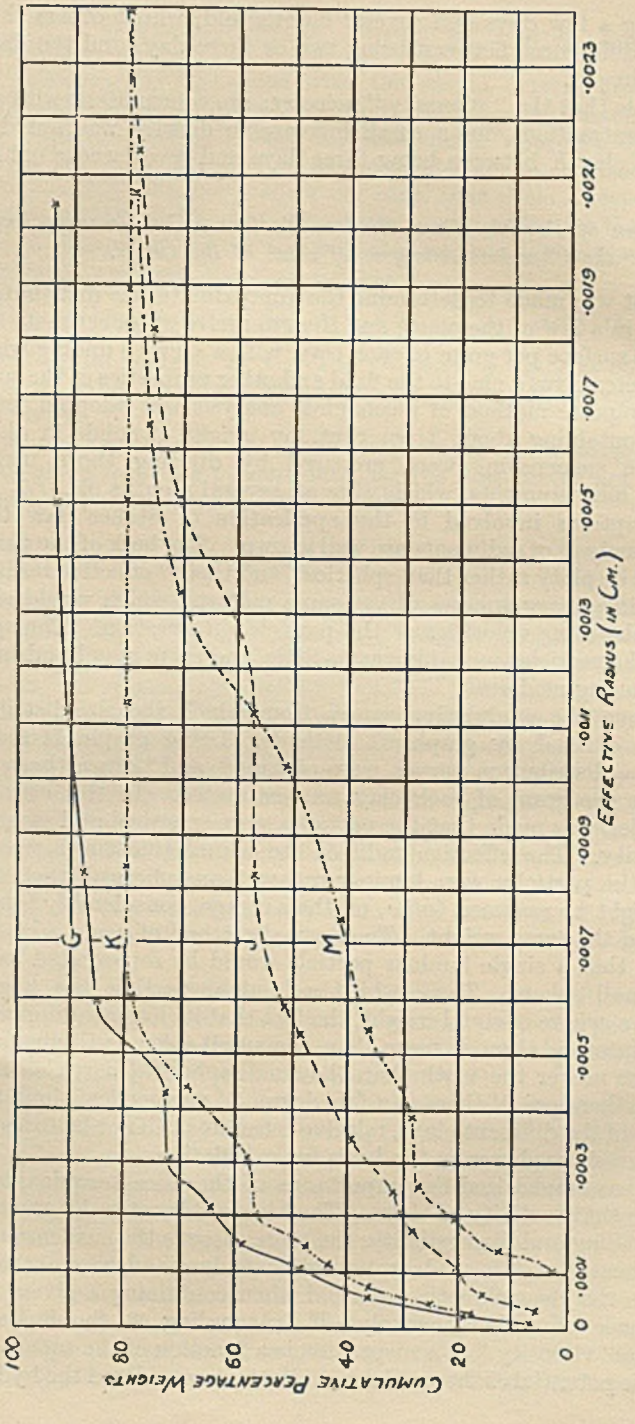


Fig. 6.

G—alluvial clay *G*; *K*—clay *K*; *J*—blue shale *J*; *M*—mottled clay *M*.

of the clay to increase with the exchange capacity—*i.e.*, with the ratio of silica to sesquioxides.

It will be apparent that these statements concerning the effects of silica–sesquioxide ratios require some qualification, particularly with regard to particle sizes.

In a few cases the fraction of a clay having a falling velocity of less than 1 mm./sec. at about 18° C. was separated by elutriation and sent for analysis under Dr. H. F. Harwood. However, three fractions embracing the whole of the London clay were analysed, and the silica–sesquioxide ratio was found to be highest in the coarsest fraction—a result to be expected, since most quartz was likely to be present in it. Yet it was equally clear that the finest fraction gave the most viscous suspensions. On the other hand, practically the whole of the Stockolite and the Aquagel was finer than 200-mesh I.M.M. (the actual size distribution was not determined). Stockolite is a high-grade china-clay, and analyses of typical china-clays give the silica–sesquioxide ratio as 1·13 to 1·22. Data in the Aquagel pamphlet put the ratio for that material at 2·26, and undoubtedly Aquagel formed the more viscous supensions.

In Table III are listed a number of the properties of four of the clays analysed. It is not possible to give relative values to some of the properties, and the clays can merely be placed in order in these respects.

TABLE III.

	Alluvial clay *G*.	Clay *K*.	Mottled clay *M*.	Blue shale *J*.
Decreasing order of "viscosity"-producing power . . .	4	3	2	1
Decreasing order of stress intercept-producing power . . .	1	3	4	2
Relative values of estimated total surface per gram of clay . .	6·7	6·3	1·0	2·8
Silica–sesquioxide ratio of fine fraction separated by elutriation .	1·89	2·99	2·82	2·42

The results of analyses put five clays in order of their "viscosity"-producing power, but a sixth was a marked exception. Furthermore, when the relative values of the estimated total surface per gram were considered, three clays fell in the order of their "viscosity"-producing power, whilst the fourth was outstanding. It seems, therefore, that many factors may have to be taken into account in order to predict the "viscosity"-producing power of a clay.

II. THE CONCENTRIC CYLINDER ROTATING VISCOMETER.

Ambrose and Loomis [20] used a concentric cylinder viscometer to examine a 5 per cent. bentonite suspension. Briefly, their conclusions were as follows: On a curve where torque was plotted against the rate of revolution, they found that when measurements were made at successively higher speeds, and then at speeds which decreased in steps, the former curve lay above the latter. In some cases the torque increased for a time at a constant rate of revolution. "A substantially constant deflection could be attained by subjecting the fluid to a constant angular velocity for thirty minutes up to several hours." The time necessary to break down the gel to equilibrium between angular velocity and shearing stress was shorter than the period of reformation of a gel which had been subjected to a high rate of shear. A 16 per cent. change in torque occurred in 50 minutes at a speed of 3·68 r.p.s.

Through the kind offices of Mr. L. G. Gabriel, it was possible to borrow a Hatschek concentric cylinder viscometer from Messrs. Colas Products, Ltd., but difficulties soon appeared in using it for the examination of clay suspensions. It was not feasible to fill it through the tap, as advised; air was apt to be trapped and the suspended cylinder displaced with the more viscous suspensions, and in the absence of a constant temperature chamber, temperature control was not very satisfactory. However, certain features of the suspensions were examined by using it.

Relaxation and Rigidity.

If the inner cylinder was twisted a little with the outer cylinder stationary, its deflection decreased with time, relatively quickly at first, and then more slowly, until it reached a value which, it seemed, could persist indefinitely unless the instrument was disturbed. The final value was not the zero observed on suspending the inner cylinder, showing that some muds are capable of supporting a measurable stress. Richardson,[21] and McDowell and Usher [22] have made similar observations. Their findings—(*a*) that the critical stresses were difficult to determine accurately,[21] and (*b*) that if the apparatus was disturbed the deflection dropped suddenly, but not necessarily to zero, and the relaxation curve (deflection plotted against time) continued parallel to the direction it was following before the disturbance [22] —were borne out. Thus, the instrument can be employed for the rough comparison of critical shearing stresses or "yield values."

Lag, Breakdown, Thixotropic Recovery, etc.

Various apparently anomalous results arose from the protracted lag of the suspended cylinder in taking up the deflection appropriate to the rate of rotation of the outer cylinder and the instantaneous "viscosity," and the position was further complicated at times by the suspended cylinder sticking and giving a fictitious instead of a true value for thixotropic equilibrium.

Increased Sedimentation under Shear.

On emptying the concentric cylinder viscometer, at times the suspicion arose that the material at the bottom was especially concentrated, even with seemingly stable muds, and samples taken after shearing one mud for 4 hours gave clay concentrations of 38·2 per cent. and 42·87 per cent. at the bottoms of the inner and outer cylinders, respectively. Theoretical considerations indicated that shearing was likely to increase sedimentation in these muds.

In order to investigate the matter further, a simple viscometer was constructed, consisting of two concentric glass cylinders, the inner one not quite reaching to the bottom of the outer one and being capable of rotation. A known weight of 80–120-mesh (I.M.M.) sand was added to a 4·19 per cent. Aquagel suspension and shaken well. Some of the mixture was poured into the viscometer, and a like quantity of the mixture was poured into a twin apparatus, the inner cylinder of which was not, however, rotated. When the material in the first instrument had been sheared for 40 minutes at 3·69 r.p.s., the material between the two cylinders was removed in each case, and afterwards that within the outer cylinder but below the inner cylinder was also removed. The percentage of sand in each of the four samples was determined.

TABLE IV.

	Percentage of sand.	
	Sheared sample.	Unsheared sample.
Upper portion between the cylinders . .	3·55%	7·70%
Lower portion below the inner cylinder .	14·95%	6·10%

In a second experiment crushed oil shale (80–120-mesh I.M.M.) was added to the Aquagel which was put in the viscometer. The dark colour of the shale rendered the movements of the particles very clear. Again a twin sample was set up, but not subjected to shearing. In the unsheared sample there were no signs of sinking of the shale particles; merely a little water separation on the surface of the Aquagel. In the sheared sample, at low rates of rotation of the inner cylinder, the shale particles sank along spiral paths and accumulated just below the bottom of the inner cylinder —*i.e.*, just below the zone of shearing. No change was seen in the material well below the inner cylinder. On raising the rate of rotation of the inner cylinder, a speed was attained above which a new phenomenon appeared. A series of parallel bands was observed in the suspension, towards the edges of which shale particles could be seen moving quickly upwards and downwards from the middle of the bands. These bands seemed to sink slowly down the cylinder, but were ever replaced by fresh bands at the top. No accumulation of oil shale was evident in the region below the inner cylinder. Undoubtedly this was a turbulent condition under which the particles did not sediment, whereas under stream-line conditions, which must be realized for ordinary viscometric measurements, sedimentation took place.

According to Barr,[23] Taylor has examined the general case of concentric cylinder viscometers in which both cylinders rotate in the same or opposite directions, and has obtained a formula which reduces to :—

$$\frac{\Omega_c^2 a^2 d^2}{\frac{1}{2}(a+b)v^2} = \frac{\pi^4 f}{0{\cdot}0571 f^2 + 0{\cdot}00056}$$

for the case where only the inner cylinder rotates. Ω_c is the critical speed of rotation of the inner cylinder for turbulence; v is the kinematic viscosity; a is the radius of the inner cylinder; b is the radius of the outer cylinder; $d = b - a$; $f = 1 - \frac{0{\cdot}652d}{a}$. The formula assumes that $\frac{d}{a}$ is small, but Lewis found critical speeds in excellent agreement with it up to $\frac{d}{a} = 0{\cdot}71$. Accurate centring and mounting of the cylinders is essential, and their lengths should be many times their diameters. When instability arises, it is three-dimensional, outward radial flow occurring at intervals of approximately $2d$ along the cylinders. This was about the width of the bands observed here.

One very viscous clay suspension failed to give any signs of separation, although turbulence was not apparent, but a second showed sedimentation, as is proved by the following data :—

TABLE V.

Time of shearing or standing: 4 hr.

Rate of revolution of inner cylinder in sheared sample: 2·3 r.p.s.

	Concentration.	
	Sheared sample.	Unsheared sample.
Upper portion between the cylinders . .	32·10%	38·57%
Lower portion below the inner cylinder .	50·54%	40·63%

Thus, although a concentric cylinder viscometer of the Hatschek type would, at first sight, seem superior to capillary instruments, since thixotropic equilibrium could be attained, in practice, in examining thick heterogeneous clay suspensions, many difficulties arise. Lag, induced sedimentation, and the length of time needed for a fair definition of the torque-rate of shear curve are among these, and its main value would therefore appear to be for demonstrating the presence of thixotropy.

III. DETERMINATION OF "YIELD VALUES."

The intercept on the stress axis obtained by extrapolation of the part of the flow-curve representing essentially stream-line flow is a function of the yield value as used in the Buckingham equation, being $\frac{4}{3}$ of that quantity. In a drilling mud the yield value is an extremely important property. Its direct measurement, and the investigation of its changes with time and other factors in thixotropic muds, are matters of no little consequence. To examine these points seems rather beyond the scope of the procedure used in the ordinary derivation of the stress intercept.

A number of workers have paid some attention to the direct measurement of yield values, but it is not improbable that the factor examined in some instances was not exactly that involved in the Buckingham equation, nor was it simply related to it. Meyer [24] used a thin plate which was allowed to fall edgewise in the mud. Investigation showed that this apparently simple method is fraught with many practical difficulties, and this is supported by the detailed work of Evans and Reid.[25] The disturbance of the mud by the falling plate is one undesirable feature. Evans and Reid's modification of the idea is an improvement.[25] A method which is capable of greater accuracy employs the twisting of the upper end of a wire carrying a cylinder or vanes suspended vertically in the material under test. This type of apparatus has been used by Schwedoff,[26] Hatschek and Jane,[27] McDowell and Usher,[28] Richardson,[29] Evans and Reid,[25] Russell [30] and others. Some measured the angle through which the torsion head could be turned before the suspended system began to twist; others moved the torsion head through a large angle and recorded the behaviour of the suspended system; a third group made observations which were a combination of the two preceding methods.

In the present work both cylinders and vanes have been used. They were made of brass, and the overall dimensions of the vanes were almost the same as those of the cylinders. The cylinders or vanes were suspended centrally in a standard beaker containing the mud under test, and were immersed to a fixed point on the thin spindle connecting them to the supporting torsion wire.

Cylinder :	Length of cylinder	5·192 cm.
	Diameter of cylinder	1·577 cm.
	Length of spindle	2·575 cm.
	Diameter of spindle	0·409 cm.
	Length of spindle immersed	1·180 cm.
Vanes :	Length of vanes	5·164 cm.
	Diameter of enveloping surface	1·569 cm.
	Length of spindle	2·591 cm.
	Diameter of spindle	0·406 cm.
	Length of spindle immersed	1·196 cm.
	Diameter of expansion carrying the vanes	0·900 cm.
	Length of expansion carrying the vanes	4·700 cm.
	Thickness of the vanes	0·051 cm.

Six vanes were spaced equally around the circumference of the expansion, and they projected equal distances at the two ends of the latter.

Container :	Mean diameter of beaker	6·77 cm.
	Depth of filling	6·87 cm.
Torsion wire :	Length of torsion wire	40·95 cm.
	Diameter of torsion wire	0·0274 cm.

To twist one end of the wire through an angle of one radian when the other end was fixed needed a couple of 422 cm.-dynes.

The torsion head was twisted at a slow uniform rate (1° per second, unless otherwise stated) by an electric motor working through a reduction gear. The positions of the torsion head and the suspended system were shown by pointers moving over circular scales. Since the torsion head rotated at a uniform rate, it was usual to read the position of the suspended system for every 10° of rotation of the former. The twist (angular difference of rotation of the top and bottom of the torsion wire) was plotted against the total rotation of the torsion head. Such observations were supplemented by noting the angle at which the suspended system began to turn rapidly. Otherwise the maximum twist deduced could be in error by almost 10°.

On account of muds not being true liquids, in pouring a mud into the beaker it was necessary to prevent the suspended system from being carried out of centre. Hence stops were provided to hold the pointer and the suspended system in zero and central positions respectively, and the mud was introduced through a T-connection with outlets on opposite sides of the suspended system to assist in its uniform distribution.

Since the properties of a mud are a function of the mechanical treatment and the time of standing, the need for careful control of these factors in order to get consistent results cannot be too strongly stressed. Indeed, it would seem that to get the best results and to handle very thixotropic and highly viscous muds, a rather elaborate filling apparatus is desirable. Perhaps a piston which could be moved at a fixed rate to drive the mud through a fine screen (to give a uniform breakdown), and thence via a forked tube, such as is employed for dividing samples in agricultural laboratories, would meet the case.

From the nature of the measurements, it might be expected that the stress at which a cylinder begins to turn (or the plate ceases to move in the shearometers) is likely to show affinities with the point *A* at which plug-flow began in Scott Blair and Crowther's flow-curves. When Scott Blair made this suggestion,[31] Evans could offer no evidence to show whether it measured *A* or the yield value, but observed that the results were slightly less than would be expected from measurements of the yield value made by other methods. The published data show *A* to be much less than the yield value, and it is recorded that *A* is at the same point whether approached from higher or lower stresses. This seems to imply that *A* is independent of the time factor. Ordinarily the results obtained by twisting a cylinder will not escape the inclusion of time effects.

How far the value of *A* depends on the nature of the solid surface is uncertain, but it has been shown to be dependent on the condition of the surface.[33] Russell [30] used a vane to eliminate "the possibility of slipping," and it seems likely that the vanes measure a property more nearly comparable to the yield value than does a cylinder.

When the bob (*bob* will be used in speaking generally of the cylinder and vanes) is immersed up to a point on the spindle, two modes of yield at its upper end seem possible, these depending on the depth of immersion and the material under test, (*a*) yield along the surface of the upper end of the bob and the surface of the spindle; (*b*) yield along a cylindrical surface continuous with the surface of the enveloping cylinder, if the force necessary would be less than that required to cause yield as in (*a*).

The systematic examination of a series of clays has not yet been undertaken. Therefore the following results are merely intended to give some idea of the behaviour of clay suspensions in the instrument.

Elasticity, Relaxation and the Yield Point.

The first point of note is that as the torque was increased, and before the yield took place, the suspended system showed a small rotation which was roughly proportional to the torque. Undoubtedly this was due to elasticity in the mud. For the cylinder this elastic yield was usually about 3° per 100° of torque, and for the six-vaned bob approximately twice that amount was common. Near the yield point the elastic yield increased at an increasing rate. If the rotation of the torsion head was stopped before the yield point was reached, a limited relaxation occurred.

When the yield took place, the deflection fell. This fall was more rapid for the cylinder than for the vanes, and usually faster the higher the yield value and the more thixotropic the mud. In the case of the cylinder, when it had been dried and allowed to stand over-night, the yield point with a given mud was much higher than when it was dried and used again within a few minutes. Consequently, for consistency the cylinder was given a preliminary mud-wetting and drying before use. The vanes gave the same value whether dried over-night or wetted and dried immediately before use.

In general, with both the vanes and the cylinder the yield point was higher the longer the mud had stood in the beaker. Thus for one mud the times at which the experiment was commenced after starting to introduce the mud into the beaker were 212 sec., 332 sec., 600 sec., and 1800 sec., and the corresponding yield points with the cylinder were 168·5°, 169·5°, 179·0°, and 196·5°, respectively.

An instance was noted where the yield point decreased with increased time of standing. This may have been due to instability of the mud.

Since the cylinder when dried over-night gave a high yield point, it was decided to examine the effect of a relatively thick surface water-film. Both the cylinder and vanes were used, first wetted followed by drying in the standard manner, and then when dipped in water and not dried. The results, as was to be expected, showed that the presence of a relatively thick water film reduced the yield point with the cylinder (a 7 per cent. reduction was noted), but it seemed that the water had little or no effect in the case of the vanes. The indication is that the yield with the latter is not at the main surfaces of the vanes.

A further test was made in which a thick water film was produced electrically at the surface of the bob while it was in the mud under a torque equal to about one half of the yield point expected under normal conditions. The beaker containing the mud was lined with tinfoil and connected to the positive pole of a direct-current supply. The bob was connected to the negative pole (not via the torsion wire). The torsion head was set rotating, and on reaching a torque which was slightly less than half the yield point, the current was switched on. This set up electrophoresis,[34] and the water moved towards the negative pole, the clay towards the positive pole. Thus water accumulated around the bob. In two sets of experiments with the cylinder the following results were obtained :—

> 1(*a*) Normal yield point at 63·5°. Applied a torque of 31·5°, and then switched on a current of 0·6 amp. The torque fell almost immediately to 3·4°.
>
> 1(*b*) Normal yield point at 71·0°. Applied a torque of 35·5°, and then switched on a current of 1·0 amp. for a few seconds. The torque fell to zero.

In the case of the vanes the results were quite different :—

> 2(*a*) Normal yield point at 119·5°. Applied a torque of 51·0°, and switched on a current of 0·5 amp. for 50 sec. The torque fell only to 47°.

2(*b*) Normal yield point at 115·5°. Applied a torque of 51·0°, and switched on a current of 0·6 amp. for at least 20 sec. The torque fell only to 48·3°.

When the rotation of the torsion head was continued in 1(*a*) after applying the current, a yield occurred at 13°; in 2(*a*) continued rotation caused a yield at 157°. In the former experiment the time of the second yield was 1508 sec. (300 sec. after applying the current), in the latter 1430 sec. (280 sec. after applying the current).

The reproducibility of the yield point was not so good with the cylinder as with the vanes. Occasionally the cylinder gave results which differed by 15 per cent.

Using the same cylinder and vanes, tests were carried out to find the effect of varying the diameter of the mud container. The depth of filling was kept constant.

TABLE VI.

14·77% Clay *N*.

Diameter of container.	CYLINDER.			VANES.		
	Container filled in :	Started expt. at :	Yield point.	Container filled in :	Started expt. at :	Yield point.
6·77 cm.	56 sec.	600 secc.	72·0°	60 sec.	600 sec.	95·5°
4·05 „	25 „	600 „	100·0°	65 „	600 „	119·5°
3·05 „	40 „	600 „	104·0°	50 „	600 „	123·5°
6·77 „	53 „	900 „	73·5°	60 „	900 „	101·0°
4·05 „	41 „	900 „	108·5°	50 „	900 „	124·5°
3·05 „	47 „	900 „	103·5°	30 „	900 „	117·0°

In a narrow container the application of a given torque would set up a bigger strain than in a wide container. Hence yield might be expected to occur at a lower value. The fact that it did not do so is to be interpreted as showing that the strength of the gel-structure built up was greater in the narrow than in the wide container. The opposition of these two effects is perhaps indicated by the fact that on standing for 900 sec. the yield was slightly lower in the narrow than in the medium container.

Gross eccentricity of the bob gave a slightly higher yield point than the normal position.

Examination of the effect of the rate of rotation of the torsion head on the yield point, the observation being commenced at the same time in each case, showed a small decrease in the yield point with increased rate of rotation for the cylinder with one mud, but the results were inconclusive with a second mud and when the vanes were used. A slight decrease might be expected, since the torque increases more quickly under the higher speeds of rotation, and therefore a given torque will be attained earlier. On the other hand, if, when movement of the bob begins, it is very slow, then the tendency of the torque to increase due to the continued rotation of the torsion head may exceed the tendency towards its reduction resulting from the movement of the bob relatively to the mud. Such movement was always slower with the vanes than with the cylinder, and hence may partly explain the inconsistencies.

Although no systematic investigation of different clays has been undertaken, it is clear that the yield points vary widely for the different muds, and they increase very quickly as the concentration increases. This holds for both the cylinder and the vanes.

TABLE VII.

Cylinder : mud-wetted and dried immediately before each observation.

Material.	Beaker filled in :	Started expt. at :	Temperature, ° C.	Yield point.
41·13% Blue shale *I* . . .	50 sec.	600 sec.	10·1	23·0°
51·79% ,, ,, . . .	70 ,,	600 ,,	19·0	35·5°
34·04% Mottled clay *M* . .	60 ,,	600 ,,	22·0	12·0°
45·92% ,, ,, . .	1040 ,,	1200 ,,	23·7	158·5°
14·77% Clay *N*	56 ,,	600 ,,	16·3	72·0°
18·18% ,, ...	130 ,,	600 ,,	16·0	179·0°
29·15% Unweathered London clay	70 ,,	600 ,,	20·2	61·0°
20% Stockolite with 2·925% of Aquagel	60 ,,	600 ,,	17·4	10·0°
*5·36% Aquagel	400 ,,	600 ,,		256·0°

* (The cylinder was not given a preliminary mud-wetting and drying for this observation.)

TABLE VIII.

Vanes : Mud-wetted and dried immediately before each observation.

Material.	Beaker filled in :	Started expt. at :	Temperature, ° C.	Yield point.
14·77% clay *N*	55 sec.	300 sec.	18·0	109·5°
16·68% ,, ...	50 ,,	300 ,,	17·9	192·0°
28·49% clay *Q*	75 ,,	300 ,,	17·9	193·0°

For all the muds examined, the yield point with the vanes was higher than with the cylinder. The ratio of the yield point for the vanes to that for the cylinder apparently varied with the concentration of the clay suspension, for at 900 sec. it was 1·37 for a 14·77 per cent. clay *N* suspension, and 1·74 for a 20·35 per cent. clay *N* suspension, and at 600 sec. for the former suspension it was 1·33.

The Effect of Varying the Number of Vanes.

The standard vaned bob had six vanes. Russell [30] used a glass vane 1·5 cm. square. Therefore the question arose as to whether the number of vanes affected the results. A set of vaned-bobs was obtained which were of approximately the same over-all dimensions and differed only in the number of vanes—two, four, and eight. When used under similar conditions with several suspensions the least yield value was obtained with two vanes and the greatest with four vanes. The ascending part of the curves of torque against the angle turned through by the torsion head for the four- and eight-vaned bobs coincided almost to the yield point of the latter, but the two-vaned bob showed a larger elastic yield and a less sharp break.

Nature of the Curves beyond the Yield Point.

The ascending part of the curves and the yield point are not the only features of interest. The nature of the curves beyond the yield point also seems of importance, and has revealed at least one significant feature. Evans and Reid[25] noted that to obtain consistent values for the yield point was rather difficult. They used a cylinder and applied the torque by twisting the torsion head in steps of 5°. Presumably this was done at equal time intervals. After the yield they found that the torque fell rapidly to an almost constant value. (Their curve shows a slight fall as the total twist increases.) This value, θ_2, they found to be more consistent, and state that it should be about the true yield value. Their experiments gave slightly lower figures. One reason for this will become apparent shortly.

In the present apparatus, as a result of the continuous rotation of the torsion head, the extreme slowness of the initial motion when yield takes place, and the inertia of the suspended system, the torque may attain a value slightly in excess of the yield point. There is little doubt that this accounts, at least partly, for the descending part of the curve being steeper with the cylinder than with the vanes, and the break being sharper with the former. Also, due to its relatively high moment of inertia, the cylinder may swing to a position slightly beyond that at which the torque and rigidity of the mud would be in equilibrium. It is on this account that when an accidentally high yield point is recorded the break is sharper, and the suspended system swings to a lower value than usual. Hence a reciprocal relationship between θ_1 (the yield point) and the value of θ_2 immediately after the yield is to be expected, although the variations in θ_2 will not necessarily be so large as those in θ_1.

The present set-up is comparable to a concentric cylinder viscometer, employing very low rates of shear.* Consequently when equilibrium is reached the torque will be proportional to the "viscosity" at these low rates of shear. Indeed, in testing the apparatus with very viscous liquids, proportionality between torque and viscosity and between torque and rate of rotation was found to obtain approximately.

In using the cylinder with muds, two quite different types of curves were obtained. In the first, the curve, after the rapid fall following the yield, remained horizontal or declined a little to a steady value (Fig. 7). When the latter was reached, equilibrium existed between the rate of shear, the torque and the thixotropic condition. In a few instances the curve rose slightly to a steady value, due to the cylinder having swung too far.

The effect of different speeds on the final steady value is somewhat problematical. With a true liquid the torque at equilibrium will be proportional to the rate of rotation, in the absence of turbulence. However, with a thixotropic material an increased rate of rotation increases the thixotropic breakdown, thereby reducing the "viscosity." Hence, whether increasing the rate of rotation increases or decreases the final steady deflection depends on whether the tendency to increase the torque resulting from the higher speed is greater or less than the "viscosity" reduction

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* When the cylinder is moving relatively to the mud or other fluid, the torque and rate of rotation are balanced against a "viscosity" factor; when the cylinder is stationary, the torque is balanced against a rigidity factor.

due to thixotropic breakdown.* For similar reasons the effect of changing the diameter of the container whilst the speed was kept constant gave equally unpredictable results. These remarks are also applicable to the vanes.

In the case of a Stockolite–Aquagel suspension which was examined at intervals of several hours or of a day and more, the position of the almost horizontal parts of the curves rose with the time of standing, but the observations were not continued for a sufficient length of time to determine if ultimately they would all attain the same value. There were signs that such would be the case.

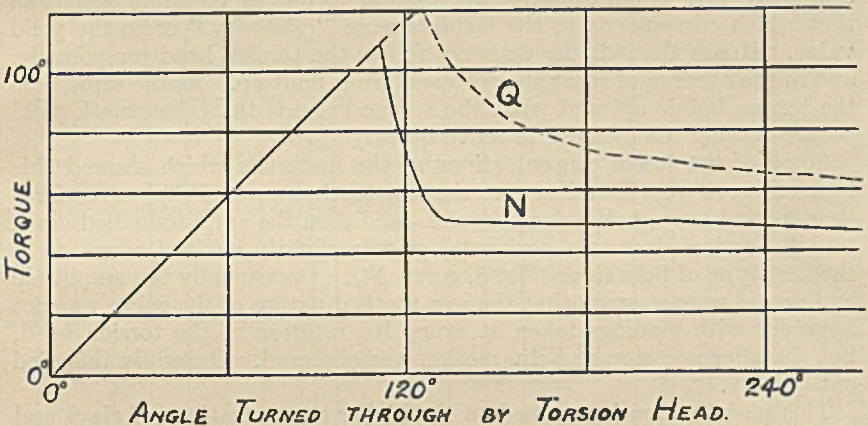

FIG. 7.

Cylinder mud-wetted and dried immediately before use; rate of rotation of torsion head—360° in 204 sec.; standard beaker as container.

Q—28·49% clay *Q*; beaker filled in 60 sec.; observation commenced at 300 sec.; temperature 17·8° C.

N—16·68% clay *N*; beaker filled in 55 sec.; observation commenced at 300 sec.; temperature 18·0° C.

The second type of curve was a little unexpected, and was shown by the more thixotropic muds. Some of Russell's results [30] seem to indicate a similar phenomenon. In this type of curve, at the end of the swing after the yield the cylinder remained stationary for a period, with the result that the torque built up. This continued until a second yield occurred (there was a slight elastic yield as before the initial yield), and then the cylinder turned rapidly. It halted again, and the cycle was repeated. The result was a saw-toothed curve with asymmetrical teeth (Fig. 8 curve *N*). It must be noted that the values at which these secondary yields took place were much less than that of the initial yield. Often there were a few

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* The exact nature of the yield with the cylinder has not been determined. If it is the same as point A on Scott Blair and Crowther's flow-curves, then the subsequent motion, provided it is not too rapid, will probably be a slip involving only a thin surface (water) film. However, when the rate of rotation exceeds a certain value, relative motion will occur between adjacent thin annuli of mud. The fact that the yield value increased when the diameter of the container was reduced, seems to show that if it is a question of the rupture of forces across a thin surface film, those forces are not independent of the conditions existing within the surrounding mass of mud.

irregularities in the curve before it settled down to the consistent saw-toothed form. After this phase there was a steady decrease in the values of the maxima and in the amplitude, although there were instances in which the maxima rose a little and the amplitude increased at first. Some of the more thixotropic muds persisted in this form of curve as far as the experiment was taken, the decline in the maxima and the diminution in amplitude both becoming smaller.

Obviously the cause of this behaviour lies in the alternate building up and breaking down of gel structure.* The momentum gained by the cylinder after a yield carries it a little beyond the point which would ordinarily give equilibrium. The residual torque is therefore less than that which corresponds to the instantaneous " viscosity " or to the yield value. Hence the cylinder does not follow the torsion head temporarily, and in the absence of shear the gel structure is built up. At the same time the torque builds up, and when the torque exceeds the gel strength yield occurs causing the cylinder to move quickly again.

Some of the lower concentrations of the materials which showed this type of curve were found to give the saw-tooth, stop-and-slip, curve for a short period—say, half a dozen cycles—and then the amplitude died down rapidly, giving place to a horizontal or only slightly inclined curve, as in the first type of behaviour (Fig. 8, curve *N'*). Occasionally the amplitude and period were so small that the saw-toothed nature of the curve was not apparent with readings taken at every 10° rotation of the torsion head, but the alternate stop-and-slip motion was observed. Generally this died out quickly.

This phenomenon is confined to the higher concentrations of clays and to those suspensions which are most thixotropic. Rapidity of gelation is essential, for although the Stockolite–Aquagel suspension set slowly to a very strong gel, it did not give a saw-toothed curve for rotation at 1°/sec. The occurrence of the stop-and-slip curve is also a function of the rate of rotation of the torsion head. Materials which showed it at low speeds might give the curves in which it died out, at intermediate speeds, and fail to exhibit it at high speeds, merely giving curves of the first type. (By high speeds a few degrees per second is implied.)

A possible third type of behaviour was noted with a 45·92 per cent. suspension of mottled clay *M* (Fig. 8, curve *M*). This was a very viscous mud. Here the cylinder did not stop, but moved for a time at an almost uniform rate more slowly than the torsion head. This phase was ended by the occurrence of a yield, followed by the cylinder moving more quickly than the torsion head, stopping momentarily, and then repeating the cycle.

The vanes showed but one type of behaviour. After the yield the torque fell rapidly for a short time and then more gently, or gently all the

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* Whether or not we assume that the initial and secondary yields occur in a mechanically similar manner, and that the yields are in any way comparable with A on Scott Blair and Crowther's flow-curves, it is clear that they are affected by thixotropy or some such phenomenon. The term " gel structure " has been used here, but it must be understood to imply the rigid forces across the thin water film postulated by Scott Blair and Crowther as the most likely explanation of *A*, if the yield with the cylinder is of the same nature as *A*, and/or the general gel structure of the mud mass if the yield disrupts the structure of the mud mass, and if the rate of rotation of the cylinder is sufficiently rapid to cause relative movement of the adjacent annuli of the main mud mass.

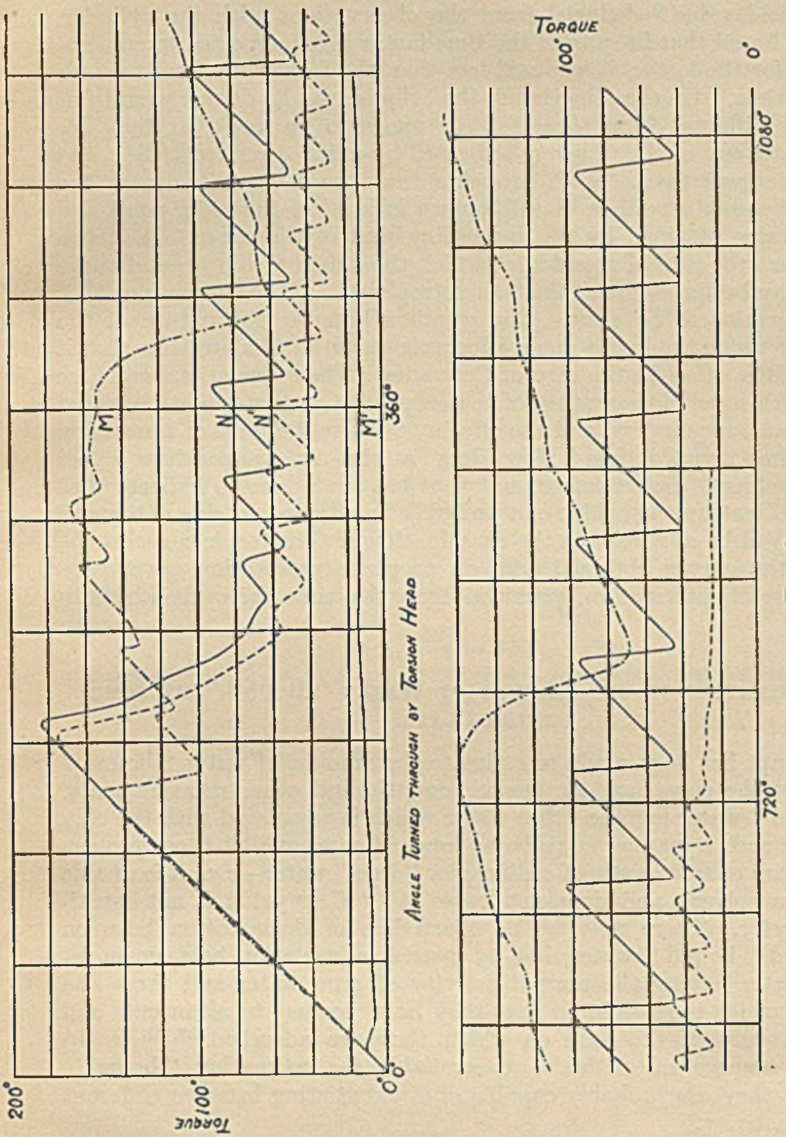

Fig. 8.

Cylinder mud-wetted and dried immediately before use; standard beaker; rate of rotation of torsion head—360° in 360 sec. Curve *M*—45·92% mottled clay *M*; beaker filled in 1040 sec.; measurement begun at 1200 sec.; temperature 23·7° C. Curve *N*—18·18% clay *N*; beaker filled in 65 sec.; measurements began at 900 sec.; temperature 17·3° C.; the saw-toothed curve persisted even after the torsion head had turned through 2520°; the mean level of the teeth had fallen slightly, and their amplitude had decreased gradually to 64% of the maximum value. Curve *N'*—17·87% clay *N*; beaker filled in 55 sec.; measurements begun at 600 sec.; temperature 19·5° C. Curve *M'*—34·04% mottled clay *M*; beaker filled in 60 sec.; measurements begun at 600 sec.; temperature 22·0° C.

time, until it came to an essentially constant value. Sufficient work has not been done to be absolutely certain, but it appears that the ultimate positions reached by the curves may be almost the same for the cylinder and the vanes (the overall dimensions of the bobs and other conditions being the same, of course), with the latter possibly a little the higher. The final level is much slower of attainment with the vanes.

For a few muds the yield value derived from the stress intercept of capillary-tube viscometric measurements has been compared with the initial "yield value" deduced from the observations with the cylinder, but it was found that in spite of the time factor being expected to enhance the value for the latter, it was still less than the former, tending towards one half or less. On the other hand, the cylinder results do not seem to be sufficiently different from those for the vanes to be sure that they are merely a measure of the property indicated by point *A* on Scott Blair and Crowther's flow-curves. It is probable that the more thixotropic the material the greater will be the difference in level of the yield point and the final value attained by the succeeding part of the curve. It is also possible that the rate of rotation at which the stop-and-slip type of curve appears may be a measure of the "thixotropicity" of the suspension.

Much remains to be done. One wonders how far the nature of the material of which the bob is made affects the results; it is probable that it will have little effect in the case of the vanes. The speculations on those points which involve the inertia of the suspended system might be tested by using hollow cylinders, and the effects of different depths of immersion also require investigation. How does a rise in temperature affect the yield values? Nevertheless, sufficient has been done to indicate that this type of instrument, which can probably be adapted to give automatic recording, will be of service in the examination of thixotropic suspensions, and that the curves obtained will, on proper interpretation, give quite a lot of useful information, provided that the time factor is carefully controlled.

IV. Estimation of the Amount of Water "Bound" by some of the Clays.

An attempt has been made to estimate the amount of water "bound" by some of the clays used in the viscometric and other measurements. By "bound" water is meant that water which is associated with the clay particles in such a manner as to be no longer free to exhibit those properties which are characteristic of ordinary or "free" water—*e.g.*, it is unable to act as a solvent and does not freeze at 0° C.,[35] yet it is not constitutional water. There may be no sharp line of demarcation between "free" and "bound" water, but an insensible gradation between molecules of water having the normal activity of pure water and those the activity of which is so reduced that they have become to all intents and purposes a part of the solid on which they are adsorbed.[36, 37, 38] In general, a number of methods are available for estimating "bound" water, and they are probably capable of differentiating between different degrees of activity.

In the present work the method used by Dumanski[39] was employed, with sucrose as the "tracer." It has been assumed that the presence of the sucrose did not disturb the water equilibrium in the clay–water system, but no evidence is available regarding the validity of this assumption.

A known weight of a standard sucrose solution (containing about 25 per cent. by weight of sucrose) was placed in a weighed super-centrifuge tube, fitted with a celluloid cap to prevent evaporation losses. Finely ground clay was added, and the amount introduced was determined by weighing. A sample of the clay was heated to 110° C. to find the amount of water driven off at that temperature, whilst a quantity of the sucrose solution was weighed and set aside to serve as a check on the strength of the sucrose solution used. Sets of tubes containing different clays or different amounts of a single clay were allowed to stand for a set time (for most a period of six days was adopted), after which they were centrifuged and then weighed to find the loss of water (if any) by evaporation. The refractive index of the clear sucrose solution was measured in an Abbé refractometer. The concentration of the sucrose was then obtainable from standard tables, and together with the various weighings and the concentration of the standard sucrose solution, enabled the amount of "bound" water per gram of clay to be calculated. Tests in which the ground clay was added to distilled water showed that any soluble salts which may have been present in the clay had no, or a negligible, effect on the refractive index of water.

The results obtained so far are not entirely satisfactory, nevertheless they are of considerable interest. It is probable that better agreement will be found if the sucrose and clay are stirred by a weighed stirrer kept in the centrifuge tube, for some of the clays (Aquagel in particular) are very difficult to disperse. Thus parts may not be properly wetted, leading to low values for the "bound" water. Experiment seems to show that four days, and possibly much less, are sufficient to yield the maximum value attainable without the more thorough mixing which will be achieved by stirring.

TABLE IX.

Approximately 3 gm. of Aquagel were used in each experiment, with 20 c.c. of "25%" sucrose solution.

Time of standing.	"Bound" water.
23 hr.	0·14 gm./gm. of clay.
94 ,,	0·28 ,, ,,
142 ,,	0·29 ,, ,,
213 ,,	0·15 ,, ,,
262 ,,	0·28 ,, ,,
310 ,,	0·27 ,, ,,

TABLE X.

	"Bound" water (gm./gm. of clay).			
	Using 5 gm. of clay.		Using 8 gm. of clay.	
Alluvial clay *R* . .	0·012		0·012	
Mottled clay *M* . .	0·039	0·127	0·066	
Blue shale *L* . . .	0·065		0·048	0·065
Alluvial clay *G* . .	0·080		0·057	0·105
Clay *K* . . .	0·053		0·053	
Blue shale *J* . . .	0·029		0·029	
Alluvial clay *H* . .	0·039	0·118	0·063	
Unweathered London clay	0·059		0·053	0·091
Shale *P* . . .	0·101		0·087	0·139
Clay *N* . . .	0·093		0·081	0·123

A value of 0·022 gm./gm. was obtained for Stockolite.

The facts that a measurable amount of water is bound by the clays, and that the highest value is associated with Aquagel and the lowest, with the exception of alluvial clay *R*, with Stockolite, seem significant. If this " bound " water can be partly or wholly sheared off or distorted under shear, it offers a possible partial explanation of the reduction in " viscosity " of these clay suspensions with increased rate of shear. Whilst the figures are suggestive, they require checking, and they are not of the magnitudes which would seem consistent with some of the properties of the clay suspensions. However, it may be that the sucrose disturbs the clay-water equilibrium, or only reveals the most tightly bound water.

Acknowledgments.

The author is deeply indebted to Professor V. C. Illing, for it was at his suggestion, and under his kindly supervision, that the investigation of clay suspensions was undertaken. He also wishes to thank Mr. S. E. Coomber for assistance rendered in many ways; the various departments of the Imperial College of Science and Technology which have loaned apparatus, and the Department of Scientific and Industrial Research for a grant during the session 1933–34.

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ABSTRACTS.

AUTHOR INDEX.

The numbers refer to the Abstract Number.

The original papers referred to in the abstracts marked with an asterisk may be borrowed by Members from the Institute Library.

Geology and Development.

1518.* Oil-field Waters of Wyoming and their Relation to Geological Formations. J. G. Crawford. *Bull Amer. Ass. Petrol. Geol.*, **24**, 1940, 1214–1329.—This paper gives tabular and graphic analyses of waters from the oil- and gas-fields of Wyoming, excepting those areas where lenticularity of beds, severe faulting, and other factors have prevented free migration of water.

In the Rocky Mountain region oil-field waters are exceptionally low in concentration as compared with other regions. The salinity of most Wyoming waters is so low that little, if any, connection can be made with connate waters. Analyses suggest that all the oil-field waters of Wyoming have been considerably modified by the infiltration of surface water.

Post-Chugwater waters are essentially solutions of sodium salts; pre-Chugwater sediments, however, yield water in which calcium and magnesium sulphates predominate.

Frontier waters are solutions of sodium chloride and sodium bicarbonate in varying proportions, sulphate and alkaline earths occurring only as surface or drilling water contamination.

"Dakota Group" waters are solutions of sodium salts, although they contain appreciable amounts of sulphate. Oil from the sands of this group is obtained from the deeper-seated beds where a higher chloride water occurs.

Generally, Sundance waters are solutions of sodium salts and are similar, except for concentration, to Frontier and "Dakota Group" waters. The chief Sundance sandstone is much more uniformly distributed than the sands of the Frontier and "Dakota Group," and is the youngest formation water that contains hydrogen sulphide.

The Chugwater formation provides a dividing line between the primary waters of the formations above and the secondary waters of the beds below. Chugwater water is usually concentrated, and ranges from 30,000 to 50,000 parts per million.

The youngest subsurface waters are the Embar waters, in which secondary salinity is prominent. Hydrogen sulphide is usually present, particularly in the waters associated with black oil.

In most Tensleep waters secondary characteristics dominate the chemical system, with secondary salinity usually occupying 40–70%. Many Tensleep waters are characterized by very low bicarbonate content, a feature which ordinarily enables them to be differentiated from Embar water.

Madison water resembles Tensleep, except that it is usually marked by a somewhat higher secondary salinity.

Twenty-four figures accompany the paper. G. S. S.

1519.* Paleogene of Barbados and its Bearing on History and Structure of Antillean-Caribbean Region. A. Senn. *Bull. Amer. Ass. Petrol. Geol.*, 1940, **24**, 1548–1610.—Six-sevenths of Barbados is covered by Pleistocene reef-limestones known as Coral Rock, which in the northern half of the island has been elevated to form a dome-like structure reaching a height of more than 335 metres. The roof of the dome has been partly removed by erosion. The remaining portion of the island consists of older formations underlying the Coral Rock. This region has been called the "Scotland District" on account of its mountainous character with highly dissected ridges and numerous ravines and valleys. It contains the best exposures of the older rocks, and these receive special attention from the author.

The oldest sediments in Barbados have been termed the *Scotland formation*, and this has been subdivided into a Lower (or St. Andrew's Beds) and an Upper series. The older beds, in which shales predominate, are regarded as Lower Eocene in age, and the younger, consisting mainly of sands, of Middle Eocene age.

Overlying these are the *Jones River Beds*, consisting mainly of pebbly silts with inclusions of hard greenish clay traversed by numerous cleavage planes containing free inspissated oil. The rocks are derived from various parts of the Scotland formation, although the greater part of the silts certainly originates from the Lower Scotland.

Lying with a strong angular unconformity on these older beds is the *Oceanic formation*, and a general and detailed type section is given of this formation occurring at Mt. Hillaby. It consists essentially of Radiolarian earth and marlstone, has a total thickness of 620 ft., and is Upper Eocene and Lower Oligocene in age.

Bissex Hill Marl. This was originally included in the Oceanic formation, but is now regarded as quite separate and different from it, not only in lithological characters, but also in age. Consisting chiefly of a yellow to orange-coloured sandy Globigerina marl, it has a thickness of approximately 50 ft. and is of uppermost Oligocene or Lower Miocene age.

Correlation of all these beds with other parts of the Caribbean is discussed.

The paper concludes with a summary of the geological history of the Antillean–Caribbean Region, and it is considered that during Upper Cretaceous and Eocene times a land or shallow-water connection linked the Caribbean and European Mediterranean regions, a connection, however, which was broken during the Upper Eocene orogeny.

A large correlation chart of the Tertiary and Cretaceous formations of the Antillean–Caribbean region accompanies the paper. G. S. S.

1520.* Palaeozoic Limestone of Turner Valley, Alberta, Canada. W. D. C. Mackenzie. *Bull. Amer. Ass. Petrol. Geol.*, 1940, **24**, 1620–1640.—The Palaeozoic Limestone, commonly referred to as the "Madison lime," and the probable equivalent of the Madison in Montana, is responsible for practically all the gas and oil production in the Turner Valley field. It is correlated with the Rundle formation of the Banff section and is of Mississippian age.

The main producing zones are the upper and lower porous zones of the limestone, both being dolomitic and crystalline. The extent of these is estimated in a profile which accompanies the paper.

The porosity and permeability of the rock show wide variations from well to well. Such variations, due to the presence or absence of secondary calcite in the porous zones and to fractures in certain areas, make the estimation of reserves on the volumetric method deceptive. G. S. S.

1521.* Lower Ordovician Sand Zones ("St. Peter") in Middle Tennessee. K. E. Born. *Bull. Amer. Ass. Petrol. Geol.*, 1940, **24**, 1641–1662.—This paper discusses the present status of the "St. Peter" in Tennessee, and gives data and suggestions concerning possible correlations with the standard Lower Ordovician section.

A number of the deeper wells in the Central Basin and Highland Rim areas of Tennessee have penetrated sandy zones in the Lower Ordovician. These zones, which average less than 10 ft. in thickness, are made up of subangular to well-rounded pitted and frosted quartz grains associated with magnesian limestone and dolomites and often cherty material.

From an examination of thirty well samples it is shown that (1) although sandy zones do occur in the pre-Stones River rocks, no true quartz sandstones have been proved; (2) these zones definitely occur in the upper part of the Knox dolomite group, thereby fixing a Canadian age for the "St. Peter" zone, and (3) that they do not occupy a definite stratigraphical position with reference to established subsurface markers. It is concluded, therefore, that the "St. Peter" of middle Tennessee is a sporadic development of sandy zones in the upper part of the Knox dolomitic group.

Thus, since the name "St. Peter" has become both misleading and confusing, the author recommends its rejection in the Upper Cumberland district. G. S. S.

1522.* Tuscaloosa Discovery Heightens Oil Interest in Mississippi. G. Weber. *Oil Gas J.*, 19.9.40, **39** (19), 62.—Commercial oil has been found at 6,110–6,115 ft. in the Tuscaloosa at Tinsley, Mississippi. The overlying Eutaw and Selma are productive at Tinsley and the Eutaw at Pickens. A number of wells have penetrated the Tuscaloosa in Mississippi but few have been proper tests.

The Tuscaloosa outcrops in South Tennessee, north-east Mississippi, and across Alabama to Georgia. It dips south-south-west, and is within easy reach of the drill in the centre of the state. It is absent in the extreme west-central part. The Tuscaloosa is predominantly sandy, but has gravel and pebble beds, and red and maroon mottled clay shales are common. There are lignite seams, but a marine section is known in the lower third. At the outcrop in West Alabama the thickness is estimated at 1,000 ft. It thins northward to 270 ft. in north-east Mississippi. Some geologists correlate the Tuscaloosa with the Woodbine of Texas, whilst others correlate it with the overlying Eagleford.

Only four closed Tuscaloosa structures have been drilled—Tinsley, Jackson, the Hatchetigbee anticline and the Quitman fault structure. The Tuscaloosa is absent on top of the Jackson structure, and a test showed oil in an igneous rock. On the Hatchetigbee anticline oil showings were found in Tuscaloosa sands, but on the Quitman fault structure the Tuscaloosa showed no oil although there were impregnations in the overlying Eutaw. On the Midway salt dome of south Mississippi a well encountered 100 ft. of asphaltic sand in a sand correlated with the basal Tuscaloosa. G. D. H.

1523.* Lolita Field One of Texas' Most Active. N. Williams. *Oil Gas J.*, 3.10.40, **39** (21), 16.—Up to 7th September, seventeen producing wells had been completed at Lolita. This field is expected to be quite good, and oil has been proved over an area more than 1¾ ml. from east to west and over ½ ml. from north to south without the edges having been defined. At present there are two producing areas, one round the discovery well and the other round the second well about 1¼ ml. to the west. The gap between these is gradually being filled. There are indications that they represent two local structures, or that they are separated by a major fault, for they have different water levels, and a definite gas cap has been shown so far only in the western area. The structure is apparently an east–west anticline, with two producing sands at 5900 ft. and 6400 ft. in the Frio.

The discovery well had a potential of 335 brl./day of 34-gravity oil on a $\frac{3}{16}$-in. choke. Production is restricted and development is on a basis of one well to 10 acres.
G. D. H.

1524.* Well Logs and Field Data of Prospective Oil Areas : Western South Dakota. Anon. *Oil Gas J.*, 10.10.40, **39** (22), 88B.—A few wildcat wells have been drilled in the area covering western South Dakota and the adjacent States, but it is virtually unprospected. Cretaceous and younger beds are at the surface, except in the Black Hills region, where all the formations in the district outcrop together with the pre-Cambrian. Small structures are known along the Missouri river, and there is also the Baker–Glendive anticline, which has given gas for years, and on which oil-shows have been found in the Madison and Jefferson limestones.

The Lance Creek field of Wyoming is the most important oil-field in the area. It yields oil from the Dakota, Sundance, and other sands.

Drift renders the location of structure difficult, but there are doubtless favourable structures. The absence of good reflecting horizons reduces the effectiveness of geophysical methods. In all probability there are many unconformity and stratigraphic traps, although the oil possibilities of some of the beds are somewhat discounted by the unfavourable feature of fresh water therein. G. D. H.

1525.* Well Logs and Field Data of Active Oil Areas—South-west Michigan. Anon. *Oil Gas J.*, 24.10.40, **39** (24), 36B.—Muskegon, the first oil-field in South-west Michigan, was brought in in 1927, and has given 6,700,000 brl. of oil from the Dundee limestone. Since 1926 a number of fields have come in.

Much of the area is covered with glacial drift, rendering the determination of structure difficult. Moreover, this factor has caused geophysical work to be only partly successful. This area forms the south-west flank of the Michigan basin, and is underlain by the Mississippian. There is a series of sub-parallel anticlinal ridges on which the oil occurs. The main production is from the Traverse (Devonian) limestone, but oil is also obtained from the Monroe and Dundee.

The area is not fully prospected and may well yield additional oil-fields.
G. D. H.

1526.* California Experiencing Lean Discovery Cycle. Anon. *Oil Wkly*, 30.9.40, **99** (4), 16.—No major additions to California's crude-oil reserves have been made for more than a year. Field extensions and deeper discoveries seem to hold out most promise. The major-discovery periods in California have run in cycles for 35 years.

After each lean period a discovery cycle has added adequately to the diminishing reserves.

The chief exploratory interest still centres on the San Joaquin Valley, which is about 50% tested. Deeper discoveries have carried production down to more than 13,000 ft. Geophysical work revealed twenty structures in less than three years, and seven of the first nine drilled gave oil or gas, but recent wildcatting has not been so successful. Prior to the discovery of Wilmington the Loss Angeles basin was considered to be 90% prospected. Geophysical work has not been very satisfactory in some parts of the basin. The present known reserve is but a fraction of the 2,600,000,000 brl. of oil already produced.

The Santa Maria valley still remains an important oil reserve, but there, too, there has been a lack of discoveries. The Sacramento Valley is regarded as an important potential oil reserve, although development has been limited to tests which for the greater part stopped short of conclusive depths.

New Eocene production has been developed on a nose or extension east of the old Coalinga field. Oil-bearing formations will probably be found to a depth of more than 20,000 ft. at Ventura Avenue, the Miocene not having been tested there.

Under present proration several years may be required to obtain the full return on the discovery costs. Since 1920 about 3100 dry holes have been drilled, and one oil- or gas-field has been found for each fifty-three dry holes. The cost of finding a new field has been more than $5,000,000, but the average value of all fields found in that time has been several times the discovery cost.

A table gives the production to the beginning of 1940, the estimated reserves, and proved acreage for all the fields of California. G. D. H.

1527.* This Year Indicated as Third Most Active in Drilling. Anon. *Oil Wkly*, 7.10.40, 99 (5), 12.—In 1920 33,911 wells were drilled in response to a $3 price for crude, and 33,112 in 1937. If field work continues at the present level to the end of 1940, about 31,000 new wells will have been drilled in U.S.A. 23,445 wells had been drilled there up to the end of September. The natural decline of Illinois has considerably reduced the threat of over-production.

Tables and diagrams give data about the daily and monthly completions in recent years. Marked increases in well completions this year have been shown by Mississippi, Indiana, Pennsylvania, Kansas, South Louisiana, Texas Panhandle, West Central Texas, Montana, Wyoming, Illinois, Oklahoma, Ohio, and New Mexico. G. D. H.

1528.* Mississippi's Potentialities still Undetermined. Anon. *Oil Wkly*, 28.10.40, 99 (8), 10.—In the twelve months following the discovery of Tinsley, exploratory drilling results in Mississippi have been disappointing on the whole, for only one further small field (Pickens) has been discovered. However, many of the wells drilled have had a questionable geological background, and numbers of them have stopped short of decisive depths. Many of the Mississippi formations are irregular and lenticular, and geophysical interpretation of the area has not been easy. About 75% of the geophysical work has been of little value because of the rush for quick results.

All three of Mississippi's major geological provinces seem favourable for oil and gas, but production has been established only in the central province. The Palaeozoic, probably the Mississippian, may prove productive in the north-east province, for there are gas reserves at several points, and the Hartsell sand has several strong oil-shows. The central province gives oil from the Selma and Eutaw, and the Tuscaloosa at Tinsley. The Jackson gas-field and the Pickens oil-field also lie in this province. The coastal province has many prospects, but so far has given no oil.

Geophysical activity has declined considerably during the last few months. Most of it has been done with the gravimeter and the seismograph. Features of relatively low relief are now being sought. The Tinsley structure is believed to have been formed by an igneous intrusion, with some salt flowage over it. It is essentially an anticline with extensive cross-faulting. The oil reserve is put at 25,000,000 brl., exclusive of the Tuscaloosa. Details are given of the various producing sands.

Pickens gives oil from the Eutaw. The closure is only 120 ft. G. D. H.

1529.* Measurement of Compressibility of Consolidated Oil-bearing Sandstones. C. B. Carpenter and G. B. Spencer. U.S. Bur. Mines. Report of Investigations No. 3540. October 1940.—It has long been apparent that subsidence of ground surface overlying producing fields does take place as a result of subsurface mining operations, and the opinion has been expressed by many engineers and geologists that the weight of earth formations overlying oil-bearing reservoirs causes compression and compaction of the reservoir sands and rocks as oil and gas are withdrawn from them. A large number of oil-producing rocks are sandstones, consolidated by natural cementing materials, but hitherto few experimental data have been available concerning their compressibility.

This paper embodies the results of studies of subsidence in certain Texas Gulf Coast oil-fields and of experimental work undertaken to determine reduction in volume and compressibility of consolidated oil-bearing sandstone cores under pressures up to 8000 lb. per square inch.

During the course of these investigations attempts were made to reproduce as nearly as possible conditions and forces in operation in a petroleum reservoir as oil and gas are withdrawn. Results showed that in so far as the rocks tested were concerned, a differential hydrostatic pressure of 8000 lb. per square inch caused a maximum reduction of 1·084% in gross volume and a maximum reduction of 3·608% in pore space. Thus it was deduced that compressibility was not sufficiently large materially to influence estimates of reservoir content and ultimate recovery. Maximum pressure applied during these tests was equivalent to the normally contemplated differential pressure in wells at a depth of 14,134 ft. As most wells in this field do not exceed 8000 ft. in depth, it was concluded that maximum compressibility of the oil-bearing rocks could safely be ignored.

Finally, the hypothesis was advanced that subsidence of ground surface overlying oil-fields is in many cases due not to changes in volume occurring within the reservoir itself as oil and gas are withdrawn, but results from dehydration and consequent shrinkage of shale-beds adjacent to oil-bearing reservoir rocks. H. B. M.

1530.* 525 Million Barrels in Sight in Illinois. G. F. Moulton. *World Petrol.*, June 1940, **11** (6), 30.—Since March 1940 the daily production of Illinois has exceeded 425,000 brl., placing the State third to Texas and California in oil output.

The Illinois basin has great thicknesses of marine sediments which have been only slightly disturbed by folding. Beneath glacial drift are Pennsylvanian and older rocks. The Mississippian is variable in thickness, and the Chester series has seven productive horizons. In the lower Mississippian limestones predominate, and oil is obtained from the McClosky and St. Louis limestones. Limestone in the Upper part of the Devonian has proved productive. Other deeper horizons are expected to yield oil, including basal Devonian sandstones, Silurian dolomite, the Trenton limestone and the St. Peter sandstone.

The old eastern Illinois fields are on the La Salle anticline, and the fields of the Centralia district are on the DuQuoin anticline. There are other anticlinal trends with local highs giving oil accumulation. Related to the Rough Creek fault is an east–west fault zone, the oil prospects of which, however, do not seem as good as elsewhere in Illinois.

Most of the Illinois fields are associated with anticlines, but in the sandstones lenticularity does play a part, and porosity conditions in the limestones are similarly important.

Many formations remain to be tested. That part of the basin east of the DuQuoin anticline seems very favourable, although many of the structures are relatively small. Stratigraphical traps may be important immediately west of the eastern fields. On 1st June, 1940, estimates placed the reserves at 525,000,000 brl., with 75% of the total in fields on the western side of the Illinois basin. At present discoveries are keeping pace with production. Much depends on the results of testing the Trenton in the Centralia district and on the investigation of the Devonian limestone in the old eastern fields. G. D. H.

Geophysics.

1531.* History and Development of Seismic Prospecting. B. B. Weatherby. *Geophys.*, 1940, **5** (3), 215–230.—A brief survey is made of the early work from the time of Mallet in the 1840's until 1914, when Mintrop applied for his patent covering refraction profiling. The Seismos Gesellschaft started work in Mexico in 1923 and in the Gulf in 1923–24. Fan-shooting was developed in the Gulf on account of the great difficulty of interpreting profiles. Electrical detectors and amplifiers were developed in 1926, as was also the use of radio communication between shot-point and detector. These improvements made the instruments many times more sensitive than the German mechanical types, and greatly increased speed and reduced costs. There resulted a period of intense activity in the Gulf, accompanied by the discovery of many domes. The method had little success in California, however, mainly because of the absence of high-speed uplifts, such as salt, which could be discovered by fan-shooting. Refraction profiling was partly successful in the West Texas Permian Basin.

The reflection method developed from the use of artificial seismic waves for depth-finding. Successful experimental work was carried out in 1921, and one of the first reflection projects was on the Nash Dome in 1926. In 1927–30 successful work was carried out on the Seminole plateau of Oklahoma, using the Viola Lime as marker. Dip-shooting was developed in the Gulf in 1929. Since then considerable improvements in instruments and technique have been made, and the number of reflection crews in the U.S.A. increased from four to about 250 in 1937, but no changes of a fundamental nature have been made. The development of the reflection method has been entirely American. S. E. C.

1532.* Brief History of the Gravity Method of Prospecting for Oil. E. A. Eckhardt. *Geophys.*, 1940, **5** (3), 231–242.—The early gravity measurements were made by pendulum. The first gravity survey for oil was probably that made by Eötvös Balance over the Egbell (Czechoslovakia) field in 1916. The first torsion balances in the U.S.A. were imported in 1922, and the first oil structure discovered by the method was the Nash Dome in 1924. An intensive campaign of torsion-balance surveys followed, and this lasted until the end of 1936. After that it fell off, and the amount of torsion-balance work now being done in the U.S.A. is negligible.

Pendulum measurements and anomalies observed in mountainous areas led to the theory of isostasy. The first pendulum survey for prospecting purposes was carried out in Kansas and Oklahoma in 1925–26. Improvements designed to increase precision led to the development of minimum-period pendulums constructed of fused quartz. However, whilst the pendulum has the advantage of speed and insensitivity to local surface irregularities as compared with the torsion balance, the best equipment has a probable error of 0·25 mg. in routine work and requires considerable skill to operate it. As a result, the gravimeter was developed, and the number of gravimeter parties in the field of stations observed have rapidly increased. S. E. C.

1533.* Typical Electrical Prospecting Methods. W. M. Rust. *Geophys.*, 1940, **5** (3), 243–249.—The measurement of natural earth potentials, apart from its use in electrical well logging, is more applicable to the search for metallic ores than petroleum. The basic direct-current method is the equi-potential map method, and various modifications of this are in use. Low-frequency alternating-current methods are essentially the same as direct-current methods.

Sundberg's electromagnetic method, in which the field is induced by moderately high-frequency alternating current, has been successful in prospecting for ores, but has not received general approval in petroleum prospecting.

Many experiments have been made, especially in Germany, on the use of radio waves for prospecting. Theory indicates that, except in very arid regions, the effective depth of penetration is very small, and at present there is not sufficient data to justify optimistic hopes.

Transient methods involve the use of a rapidly changing direct current. Theoretically these methods should give all the information which can be supplied by electrical methods, but, in general, they have received no wider acceptance in petroleum prospecting than the other electrical methods.

The most favourable sign for electrical prospecting for petroleum is the evidence which is accumulating to support the theory of secondary effects in the upper strata over a deposit of oil and gas. S. E. C.

1534.* Fifteen Years of Geophysics; a Chapter in the Exploration of the United States and Canada, 1924–39. J. B. Macelwane. *Geophys.*, 1940, **5** (3), 250–258.—Discovery of oil-bearing structures by geophysical methods began in 1924, and opened a new era of geophysics in America. 1925–29 was a period of rapid expansion of seismic refraction reconnaissance. The reflection method was introduced in the Mid-Continent in 1929, and its use became general in the Gulf Coast in 1932. The magnetic method came into extensive use in 1927, but its popularity for oil work has waned since 1930. The application of gravitational methods falls into two periods : the torsion balance era from 1924 to 1937 and the gravimeter era from 1938 to the present. Electrical methods have been most useful in the mining field. S. E. C.

1535.* A Perspective of Exploration for Petroleum. E. E. Rosaire. *Geophys.*, 1940, **5** (3), 259–271.—The first prospecting technique was based on the recognition of visible seeps of oil and gas, and was rational and direct. Its exhaustive application led to diminishing returns. Geological prospecting followed, and resulted finally in structural prospecting. Then diminishing returns again ensued. Geophysical prospecting, which appeared on the scene in 1923, finally took on an aspect of structural prospecting and led to a renaissance of that method. In both its geological and geophysical aspects it is a rational but indirect method. Its exhaustive application is leading to diminishing returns. The success of the structural method has stifled the natural development of geochemical prospecting from geological prospecting, and has directed geophysical prospecting into an unduly narrow path. Geochemical prospecting, which depends on the chemical and physical measurements of one or more of the geochemical manifestations of a petroleum deposit, is a rational and direct approach to petroleum exploration and, in its turn, will revolutionize prospecting to at least the extent of the previous methods. S. E. C.

1536.* Some Neglected Aspects of Chemical Exploration. R. T. Sanderson. *Geophys.*, 1940, **5** (3), 284–294.—Soil analysis, to be of value, should measure the concentration of hydrocarbons leaking to the surface. The difficulties in making such measurements, as distinct from merely detecting the presence of hydrocarbons in the soil, are indicated, and it is pointed out that in the first place the accuracy of the analysis is not certain and, secondly, that on account of differences in soils and conditions of sorption, the interpretation of such results is even more difficult. The solution of these problems may be very difficult, and it is suggested that a return to the earlier method of soil-gas analysis would overcome many troubles. S. E. C.

1537.* Partnership between Geology and Geophysics in Prospecting for Oil. E. A. Eckhardt. *Geophys.*, 1940, **5** (3), 209–214.—The presidential address at a joint meeting of the Society of Exploration Geophysicists and the American Association of Petroleum Geologists.

A mutual understanding, at present insufficiently developed, should exist between geologists and geophysicists in order that the two sciences may be co-ordinated and produce the best results. In the past, geophysical data have been better than the use which has been made of them. The success of geophysical prospecting depends on the co-operation of executives, geologists, and geophysicists.

The best results in research and development are to be obtained by judicious and continual transfer of men between field operations and research and development work. S. E. C.

1538.* Well Logging by Radioactivity. W. G. Green and R. E. Fearon. *Geophys.*, 1940, **5** (3), 272–283.—The amount of radioactive material deposited in a sediment depends on the nature of the fragments of primary rock and on the remains of small marine organisms which are deposited. It is believed that certain micro-organisms have the ability to concentrate radioactive elements. In general, therefore, a higher radioactive level is to be expected in shales than in limestones or sandstones. More important, however, is the fact that the levels of radioactivity in any one section carry over a considerable area.

There is evidence which indicates that the gamma-ray method of logging may prove to be better than any other method for tracing the continuity of strata over long distances. Definite contrasts can be observed in shales, and unconformities can be located without reference to other wells. It is possible that the same may be true of faults.

The recording apparatus is based on the measurement of gamma rays by means of an ionization chamber. The penetrative power of gamma rays is so great that logs can be made in wells lined with two or three strings of casing of normal thickness.
S. E. C.

1539.* Formulas and Curves for the Interpretation of Certain Two-dimensional Magnetic and Gravitational Anomalies. H. H. Pentz. *Geophys.*, 1940, **5** (3), 295–306.—Two cases are considered : the two-dimensional " dike " and the two-dimensional " step ". Curves are given which provide an easy solution of anomalies due to such structures.
S. E. C.

Drilling.

1540.* Drilling in Trinidad. R. G. Bennett. *Petrol. Engr*, October 1940, **12** (1), 58.—Rotary rigs are used on all drilling operations in the southern portion of Trinidad, where most of the oil is at present found. These rigs range from the heavy-duty, four-speed, locally-unitized, old-headboard type, Diesel rigs to small 1500-ft. gasoline-driven rigs.

The average depth of most wells is between 3000 and 4000 ft., although good production has been obtained from shallow depths of 1000–1500 ft. The deepest well drilled was slightly in excess of 10,000 ft. in depth.

The time taken to drill these wells is somewhat long, because of steeply dipping strata and frequent changes of formations, making it difficult to maintain a straight hole. The holes are, however, almost vertical, and the maximum deviation is not more than 3° off at bottom of 3000-ft. wells. Frequent round trips are necessary for changing bits where thin, hard strata are met intermediate with clays and sand, and this adds considerably to drilling times.

The mud problem is a difficult one, but a central mud system, with specialized mud engineers in constant attendance and control, appears to have solved it. Any type of mud as regards weight and colloidal properties may be obtained from these central plants at any time during day or night. The mud engineer is entirely responsible for the type and weight of mud to be used on the various rigs. This fact gives confidence to the driller and helps better drilling practices. Mud weight of 110 lbs./cu. ft. is usual, and on heaving shales being met the weight is sometimes increased to 120 lbs./cu. ft.
A. H. N.

1541.* Cementing Casing Under Adverse Conditions. W. A. Sawdon. *Petrol. Engr*, October 1940, **12** (1), 67.—The paper deals with cementing practices and difficulties met on oilfields which are outside the U.S.A., where supplies and tools are limited in variety, and where ingenuity and skill must fill the gaps thus created to obtain successful cementing jobs.

The properties of cement and the effects of such variables as the water–cement ratio, temperatures and pressures on the setting time and the strength of the cement are discussed. Increasing the water–cement ratio will lengthen the thickening time considerably, and it is frequently possible to use a ratio that will give the necessary thickening rate without excessively decreasing the ultimate strength of the cement. The effect of pressure on cement is favourable under almost every condition, and is of particular advantage when high water–cement ratios have to be used. The extra requirements for water when using bentonite with cement are discussed. Thus a widely used water–cement ratio for neat cement is 5·5 gals./sack of cement ; but if 5 lb. of prepared bentonite is to be added to make a gel-cement, the total water content in the mix should be about 8·5 gals./sack of cement. Mixing heavy materials with cement to increase its weight is not a general practice, but a recent admixture consists of a treated metallic substance which tends to impart mobility as well as weight to the slurry.

Various methods of cementing are described and illustrated, and the problem of removing the mud sheath from the walls of the hole is discussed.
A. H. N.

1542.* Mud Characteristics and Drilling Efficiency. W. A. Sawdon. *Petrol. Engr*, October 1940, 12 (1), 90.—The study of mud characteristics and application is becoming increasingly a province of the chemical engineer, as mud control embraces the use of many chemical ingredients to obtain the appropriate mixture. The paper discusses the weight and colloidal requirements of drilling muds and methods of testing and controlling them.

After a review of the qualities and tests required, it is concluded that these vary so much throughout the fields all over the world that no general rule could be formulated for mud control in every case. Complete testing and conditioning are not always possible, but there are certain qualities of the mud that should be given greatest consideration after evaluating the importance of the different properties. Even the transportation of the basic clay, the mixing, and other factors are often serious problems in certain remote districts.

In controlling one property of the mud—say weight—it must not be forgotten that other qualities in the mud may have a definite bearing on that property—weight in this case—to make it effective. Thus in many fields greater weight is probably used than would be necessary if other properties of the mud were properly maintained.

In addition to the usual tests, which are discussed, the sand content should sometimes be determined. The sand content is usually reported in volume % of approximately 200-mesh sand. The salt content of the fluid is sometimes determined by titration with silver nitrate and reported in grains/gal. A. H. N.

1543.* Clean-out Devices Actuated by Hydrostatic Pressure Facilitate Fishing Operations. W. A. Sawdon. *Petrol. Engr*, October 1940, 12 (1), 109.—Hydraulic bailers are studied, with particular regard to their use for fishing out small objects from the bottom of a well. Each bailer or fishing-tool consists in general of an air- or suction-chamber containing air at atmospheric pressure; a means for suddenly opening a valve into this chamber when the tool has reached the desired position; a load-receiving chamber, and a bottom in which is positioned a flapper-valve to hold the load until the equipment returns to the surface, where it may be dumped. The working of the tool is detailed and illustrated.

Three general designs are described: the rod, the disc, and the valve-section types. The bailer was originally designed for removing sand, mud, and other detrital material from the hole, but is now further used for fishing and for perforation-washing. The perforation in wire-wrapped screen is usually so small that it is almost impossible to pull sand from behind it. It is therefore necessary, to drive the sand away from the wall of the liner. This can be accomplished by allowing the air-chamber to fill from a point above a packer supported by slips. The fluid column is thus given a velocity downward, and this velocity is suddenly checked when the air-chamber is filled. The pressure waves set up in the fluid are stopped at the packer and diverted through the screen against the formation. A. H. N.

1544.* Pre-packed Liners Broaden Scope of Gravel-Packing Applications. W. A. Sawdon. *Petrol. Engr*, October 1940, 12 (1), 118.—The method of packing liners with gravel by circulation after the pipe is set in place is briefly described and illustrated. The pre-packed liner is run into the well in lieu of conventional slotted, perforated, or screened pipe. It can be set opposite one or more productive zones, and intermediate strata in multiple-zone completions can be cemented off. Gravel-packing by either method is used where the well is making too much sand.

Four designs of pre-packed liners are described. A recent type is made with a drillable metal gravel retainer supplied with vertical slots. This type has drillable metal end-collars, which are not welded to the pipe but are attached by set-screws. It is particularly adaptable for use on flush-joint liners. The purpose of the drillable metal outer covering is to provide for drilling-up with wash-over equipment if subsequent conditions make it desirable.

Gravel size should be governed by the formation sand, and it has been the practice either to analyze the sand at the well or to send it to the manufacturer of the liner. Outside the U.S.A. the size of the gravel mostly used has been from 0·093 to 0·110-in. or 0·110 to 0·131-in. In California gravel of smaller size has been used, with the smallest reported being 0·075 to 0·093-in. All gravel should have high strength, be acid resistant, and of proper size and shape.

Dimensions and other details are given for setting pre-packed liners and cementing intermediate formations. A. H. N.

1545.* Close Control of Verticality Reduces Drilling Time and Cost. W. A. Sawdon. *Petrol. Engr*, October 1940, **12** (1), 123.—One of the principal objectives of controlled vertical drilling is to obtain the use of the most efficient speed and weight on the bit over the greatest possible percentage of the total depth to which the hole is being drilled. The control is accomplished by using accurate instruments for indicating the weight carried on the bit, the speed of rotation, and the mud-pump pressure; and by frequent, properly spaced, accurate checks of the inclination of the hole. Certain operators during the last two years have increased the rotating speed and reduced the weight, with a resultant increase of hole-making speed and less tendency to deviate from the vertical. Procedure for inclination readings determination is outlined.

Citing a deep well as an example of controlled vertical drilling, one such well that was drilled to a depth of nearly 13,000 ft. in California was completed with a maximum deviation of only 1° 15′, and with the final reading taken at 12,000 ft. recording zero. It is believed that this well at this great depth was completed within the area directly below the derrick floor. Details of weight on bit and procedure of drilling and controlling the deviation of this particular well are given.

Due to the fear that long drill-collars may flex, certain operators prefer to use stabilizers below and above a comparatively short drill-collar to attain a vertical hole. If the well is brought back to vertical after only small angles of inclination, trouble is generally a minimum, as the drill string acts as a plumb bob. A. H. N.

1546.* Purpose of Drilling Fluid Used in Rotary Wells. H. F. Simons. *Oil Gas J.*, 26.9.40, **39** (20), 46–48.—There can be no all-purpose drilling mud, because the tasks imposed on the mud are different in each well and with each operator. In one case the mud may be designed primarily to increase the rate of penetration, in another it may be to prevent blow-outs, and in a third case it may be to prevent caving. The best mud in any case is the one which will allow drilling to proceed as rapidly as possible with the minimum possibility of trouble.

The tendency at this time is to develop a mud plan for each particular field, the objects being to reduce the cost and time required to drill a well and the elimination of difficulties while working in the hole. The problem is strictly an economical one, although all the items involved are difficult to evaluate.

In addition to the primary purpose of the mud to remove cuttings from the hole, the mud must also: (1) prevent blow-outs; (2) keep the fluid from entering the formation penetrated; (3) suspend the cuttings in the hole while the pump is shut down; (4) eliminate caving of the hole; (5) reduce the weight of the drill-pipe or the casing to be handled by the hoist; and (6) clean, cool, and lubricate the bit. Settling of the cuttings from the mud in the pits must also be easy. These items are briefly discussed.

Mud systems and types of pits are discussed in greater detail, and a diagram illustrates one type of mud-pits with a baffle which forces the mud to go underneath it. The carrying power of streams is stated to be in proportion to the sixth power of the speed, but in actual practice is often found to vary more nearly with lower powers, even as low as the square of the speed. Yet even at these low carrying powers speeds should evidently be as slow as possible in pits if sand and other cuttings are to be removed. A. H. N.

1547.* Surface and Mechanical Factors Affecting Drilling Fluids. H. F. Simons. *Oil Gas J.*, 10.10.40, **39** (22), 88.—In this second of a series of papers on rotary drilling muds, mechanical equipment used in preparing and maintaining adequate mud supplies is discussed, together with the quantity of mud needed and the work of the mud pumps and factors affecting the quality of the mud.

The use of jets in pits is illustrated and the addition of water to mud is treated in detail, with particular emphasis on the harm done by allowing the mud to lose too much water and then adding considerable quantities of fresh water in sudden and excessive operations. Degassing muds should be done by a positive and an independent method, and not be left entirely to the screens. Similar studies are made and cautions given regarding the colloidal material of the mud and its control and maintenance.

The hopper-type mud-mixers are fully described and a drawing is given of a typical unit. In adding admixtures to the mud *via* the mixers, the rate of addition should be as slow as practicable, and not in sudden batches of excessive quantities.

The quantity of mud circulated in the system will depend on the size and condition of the pits and depth, size and condition of the hole. A formula is given for calculation purposes. Similarly the power required by the pumps is discussed and typical figures of pressures are given.

A bibliography is appended. A. H. N.

1548.* Bulk-Type Oil-Well Cementing. Anon. *Oil Wkly*, 30.9.40, **99** (4), 20–21.—This new method of handling, storing, and transporting cement to the wells is presented pictorially with short explanations. Several advantages are claimed for it. Spoilage of the cement by weather during the period it was formerly stacked in sacks on the ground at the well location is eliminated, as is waste due to breakage of sacks while mixing the cement. It is claimed that bulk cementing provides more uniform and faster rate of feeding into the mixer than is possible by the conventional method. The equivalent of 1500 sacks of cement were mixed in a certain case in 31½ min.

A. H. N.

1549.* Increased Foundation Height Eliminates Drilling Cellar. Anon. *Oil Wkly*, 14.10.40, **99** (6), 24–25.—The derrick floor is 14 ft. above a heavy concrete mat which acts as a ground-level foundation in this type of rig which has no cellar. The concrete mat supporting the derrick and substructure is 14 in. thick, and concrete piers support the engine foundations.

An advanced feature on the derrick floor is the use of an hydraulic-type brake which disengages while drill-pipe is being pulled out from the hole, thus saving brake lining and shop-work on the drum-shaft.

All blow-out equipment is above ground level, and this constitutes a marked advantage over those installed in cellars. A. H. N.

1550.* Directional Drilling. W. A. Sawdon. *Petrol. Engr*, October 1940, **12** (1), 42.—Directional drilling is employed for two general purposes: (1) for drilling new wells which cannot be located directly above the desired completion point on the productive zone because of economic, topographical, or structural conditions: and (2) for reconditioning or bringing back to production old wells by abandoning a portion of the hole and deflecting it to a different position in the producing zone. These two general classes are detailed by citing examples of drilling for locations under water, or under man-made obstructions like buildings, or for such structural conditions as exist in drilling for the exploitation of flanks of salt domes.

Methods and equipment are briefly reviewed. Whipstocks are used almost exclusively for changing angle and direction, except with slight changes that can be made without mechanical means, and single-shot instruments recording both angle and direction in a horizontal plane are employed to guide the work. The whipstock is oriented into the well to set at a position determined from the single-shot reading. This causes the bit to start off in the direction desired. By proper procedure all dog-legs in the hole are avoided, and in a hole put down by controlled directional drilling no more trouble should be experienced in running casing than in the average vertically drilled hole. A. H. N.

1551.* Solution of Complete Casing-Strings. W. C. Main. *Petrol. World*, September 1940, **37** (9), 27–30.—The paper describes the method of making up a nomographic chart so that complex casing-strings may be analysed and worked out, and also the manner in which this chart can be used. The chart is based on a paper given before the American Petroleum Institute.

One of the chief factors involved in solutions of casing problems is the mud weight.

For use of this chart the weight must be known within fairly close limits. In proven fields this figure may be obtained beforehand; but in wildcatting it is important that a convenient and rapid method be at hand of checking and altering the amounts of each weight to fit conditions which do not accord with those assumed in the calculations. This is shown to be possible with no delay in setting pipe.

An example is worked out in detail to illustrate the various points discussed. The example requires the design of a string of casing for a depth of 11,200 ft., mud weight of 75 lb. cu. ft., using 7-in. casing and keeping a factor of safety of 1·25 at all critical points. Various combinations of weights and grades are possible, and these are studied and finally a correct combination is chosen. A. H. N.

1552. Drilling. F. J. Spang. U.S.P. 2,216,462, 1.10.40. Appl. 25.2.37. Method and apparatus for die-forging drill-bits for percussion drilling systems.

J. F. P. Farrar. U.S.P. 2,216,468, 1.10.40. Appl. 6.4.38. Method of making a coupling connection for hoses.

H. Hügel. U.S.P. 2,216,554, 1.10.40. Appl. 8.6.39. Spring mechanism for oil-well devices adapted to be operated in bore-holes for recording purposes.

J. Fentress. U.S.P. 2,216,686, 1.10.40. Appl. 7.5.36. Coupling and method of making same for hoses.

G. F. Le Bus. U.S.P. 2,216,819, 8.10.40. Appl. 14.10.38. Removable-end filler for cable-winding devices or drums.

A. C. Hoffman. U.S.P. 2,216,839, 8.10.40. Appl. 15.5.39. Interlocking sleeve-coupling for hose connections.

T. B. Wayne. U.S.P. 2,216,865, 8.10.40. Appl. 18.9.37. Treatment of drilling fluids with an ester of phosphoric acid.

T. H. Stancliff. U.S.P. 2,216,894, 8.10.40. Appl. 12.10.39. Rock-bit of the rotary class.

J. C. Stokes. U.S.P. 2,216,895, 8.10.40. Appl. 6.4.39. Rotary under-reamer actuated by fluid pressure to expand reaming blades.

F. J. Hinderliter. U.S.P. 2,216,945, 8.10.40. Appl. 20.2.39. Upset pipe-joint with special features to minimize the tendency for breakage to occur in the vicinity of the last thread.

T. V. Moore. U.S.P. 2,216,955, 8.10.40. Appl. 24.12.36. Oil-base drilling fluid and method of preparing same. The method consists of stabilizing the fluid by adding sulphuric acid.

B. W. Sewell. U.S.P. 2,216,962, 8.10.40. Appl. 25.11.38. Pressure coring device with valves which close on retracting the barrel.

A. C. Sinclair. U.S.P. 2,216,963, 8.10.40. Appl. 9.10.39. Means for cutting windows in well-casings.

V. M. Vesely. U.S.P. 2,217,147, 8.10.40. Appl. 20.9.39. Bailer bottom element.

J. T. Ledbetter. U.S.P. 2,217,175, 8.10.40. Appl. 20.8.38. Method of testing drilling fluid to determine its ability to prevent loss of liquid to the penetrated formation.

A. W. Gelpcke. U.S.P. 2,217,202, 8.10.40. Appl. 19.10.39. Percussion drill having three spiral bands.

F. F. Hill. U.S.P. 2,217,203, 8.10.40. Appl. 6.7.36. Core-barrel with a ball-valve of the same density as the mud used for drilling.

C. C. Gallgher. U.S.P. 2,217,400, 8.10.40. Appl. 24.4.39. Rope-clamp.

A. E. Krick and W. C. Starkey. U.S.P. 2,217,592, 8.10.40. Appl. 1.8.38. Wel-reamer for rotary drilling. A. H. N.

Production.

1553.* Automatic Rod-Line Knock-off Cuts Operating Cost. T. P. Sanders. *Oil Gas J.*, 26.9.40, **39** (20), 67–68; cf. also *Oil Wkly*, 7.10.40, **99** (5), 46.—The task of shutting down wells, including time spent in going to and from the hook-off locations and in waiting for the proper time to disconnect each well, often requires one-half of the pumper's total working time. Since 50% of the revenue from a stripper lease must sometimes go to pay pumpers' wages, it is not uncommon for the job of shutting down wells on a centrally-powered lease to cost 20 to 25 cents/brl. of oil produced. An automatic rod-line knock-off device will therefore save the operator almost 25% of the revenue utilized. The surface effect of pounding in the barrel is utilized in this device. When the barrel is completely full, the rod-line will sag under a weight on the downstroke. When the barrel is not completely full, then on a part of the downstroke the rod-line is in tension. Thus a weight placed on the rod-line will cause a sag in the rod-line until pounding occurs, when the taut line will raise the line. The weight is made to strike a hinged finger which protrudes downward from a sliding rod placed above the rod-line. Thus the upper rod is forced back, causing the release of a heavy drop-bar, which falls into position on the notched hook-off bar. When the hook-off bar is stopped in this way on the downstroke, the rod-line releases itself by means of a link at the power end of the bar. It is necessary for the pumper to connect the well manually.

A. H. N.

1554.* Hydraulic Pumping Cost Data. D. Cox. *Oil Gas J.*, 3.10.40, **39** (21), 37–38.—Figures are given for cost data for hydraulic pumping at rates ranging from 174 to 3190 brls./day. The figures were obtained from the records of eleven hydraulic pumping units, and are neither claimed to be criteria of efficiency nor to be reliable in every case.

The accounting factors involved in the cost figures should include amortization of capital investment, lease-rental expense, depreciation of equipment, depletion of natural oil reserves, production costs such as general expenses on salaries, advisors, etc., prospecting, development, lifting, treating and other miscellaneous field expenses such as lease roads, salt water disposal, housing facilities, etc. In this paper lifting and repair expenses are studied in detail and figures are given for lifting and average repairing costs in dollars.

A. H. N.

1555.* Procedure for Cleaning Slotted Liners Developed in California. T. P. Sanders. *Oil Gas J.*, 3.10.40, **39** (21), 40.—A recently introduced procedure for cleaning slotted liners has shown conspicuous success on many of the 180 wells on which it has been used in the Californian fields. This method combines mechanical with hydraulic action.

A patented tool is fitted with a series of narrow blades which are supported by coil-springs controlling the thrusting pressure of the blades. Being free to tilt upward or downward or to retreat into the tool, the blades readily slide in a folding position inside the liner. Each time a blade is in line with a slot it is thrust through the slot in the liner to a distance of 1¼ to 1½ in. beyond the outside diameter of the liner. The design of the blades causes the tool to rotate very slowly as it descends or is pulled out, and a swivel joint prevents this rotation from being transmitted to the sand-line.

In order to obtain a washing action to aid the blades in cleaning the slots, a swab is run immediately above the mechanical tool. Since the use of a swab is often considered dangerous in Californian fields, in case too much sand is drawn into the well, a special type of swab, fitted with a relief valve to limit the vacuum to a safe maximum of value, is incorporated.

A. H. N.

1556.* Pumping Set-up Anticipates Future Servicing. Anon. *Oil Wkly*, 30.9.40, **99** (4), 23–24.—A steel-based pumping unit is set on a concrete derrick floor with an elevation flush with the ground level. All flow-lines are recessed into this concrete flooring, and an open concrete-lined cellar provides space for well-head connections and is covered with an easily removable, close-fitting metal grating. Hold-down loops for well-pulling and clean-out tools are installed, and are the only obstacles, with the exception of the Christmas tree and pumping unit, that rise above the floor of the derrick.

As a majority of these wells respond to agitation, flowing through both the tubing and the casing outlet, connections are made below the ground surface to the casing outlet with the floor-line rising to a point just below the level of the ground.

The lead line from the tubing is made up of two convenient lengths of pipe having a ground-joint union, and dropping a short distance to connect with the flow-line from the casing-head, both using a common line leading to the oil and gas separators at the flow-tank battery.

Details of construction are given. A. H. N.

1557*. Modern Well Studies. Part I. F. Briggs. *Oil Wkly*, 7.10.40, **99** (5), 15.—The first part of this paper deals with the selection of pumping-wells equipment when no dynamometer cards are available for calculation, the calculations being based on the volume rate requirement, depth of well, and properties of fluid. The discussion consists almost entirely of an example which is solved in detail.

Computations of plunger travel are made by means of Rieniot's formula, the derivation of which is given in Part 3 of the paper. From load calculations adequate sizes of sucker-rods and sufficient power requirements from power equipment are calculated.

The methods and operations adopted illustrate the calculations required for choosing the plunger diameter and travel and an operating speed at which the maximum load will be a minimum possible for such travel and volume rate. Methods of adjusting the sucker-rods' diameter, in this case made of two sizes of sucker rods, so that corrosion and load conditions may be met adequately, are detailed. The design of walking-beams should be left in general to the manufacturer, but the requirements are calculated here for the sake of illustration. End loads, shear load at the centre, and bending moments are thus calculated. The gears are designed to withstand the maximum torque imposed by the pumping operation, and finally the horse-power and selection of a prime mover are discussed. The paper is well illustrated. A. H. N.

1558.* Removing Air Pockets with Suction Pumps. F. R. Cozzens. *Oil Wkly*, 7.10.40, **99** (5), 50.—It is sometimes found that certain wells which have been receiving air readily for a considerable period in a stripper lease, refuse to take air even at a pressure of 1000 lb./sq. in. in sufficient quantities to be observed in nearby wells. This fact is believed to be due to sudden release of pressure on the well in a previous repressuring operation which results in water, sludge, and oil rushing in to fill the vacuum, and thus encircling and trapping large volumes of air in various sections of the sand. This air, once surrounded by liquid, appears to be unable to escape of its own accord and can seldom be forced by pressure.

A method found helpful in curing this trouble is to apply vacuum to the well, and thus enable the air in the immediate vicinity of the well to break the bonds imposed on it by the liquids. When the air breaks through to the suction pump, it has been known to register 100 lb./sq. in. or more at the casing-head. Usually one operation on one well is sufficient to clear a large tract of sand of entrapped air; but in certain conglomerate fields where air is entrapped in numerous small pockets vacuum applications to many wells are necessary before all the sand is clear of entrapped air. The average time for breaking up air pockets in a field is 10 days, but wide variations have been observed. A. H. N.

1559.* Modern Well Studies. Part II. F. Briggs. *Oil Wkly*, 14.10.40, **99** (6), 26.—This part of the paper deals with instruments used in well studies.

Surface dynamometers are of three types: mechanical, hydraulic, and electrical strain gauge. These three types are well illustrated by photographs and line drawings, and their action and characteristics are explained in detail. The mechanical type measures the stretch in the polished rod at every part of the cycle, and a stylus records this stretch on a drum-chart which is synchronous with the stroke-cycle. In the hydraulic type a part of the load acting on the polished rod is transmitted to a pressure-chamber and the variation in the pressure is impressed upon the recording mechanism by means of fluid in a flexible hose. In electrical dynamometer, an oscillograph responds to the stretch in the polished rod, and a recorder, which may be taken a considerable distance from the strain-gauge, records the load and the part of the cycle in which it occurs.

A bottom-hole dynagraph is similarly detailed, and a typical card illustrates various parts of its operation. The record is of the stretch of the rod connected to the plunger at every part of the stroke-cycle.

Finally, bottom-hole pressure gauges and a fluid-level determining device are described and their actions are discussed. Either one or the other may be used for measuring the pressure at the sand-face. A. H. N.

1560.* Primary and Secondary Recovery Methods. H. L. Flood. *Petrol. Engr*, October 1940, 12 (1), 39–40.—A short review is given of the application of primary and secondary recovery methods in the field. Recovery methods are classified under three headings: normal, primary, and secondary. Normal methods are considered to include all the devices and measures which may be employed to obtain as much oil or gas from a formation as possible without resorting to any artificial method of replacing, displacing, or augmenting the natural contents of the reservoir. Normal methods thus include natural flow, pumping, and gas-lift—the last being included because the lifting effects on the oil are confined to the well-bore and do not affect the reservoir.

Primary recovery methods embrace all methods which may be instituted during the early life of a field to increase the total amount of oil recovered from the reservoir above the volume which would be yielded if only normal recovery methods had been employed. Repressuring by gas or water drives in the early stages of a field are considered as primary recovery methods.

Secondary recovery methods are similar methods to the primary ones, except that they are applied in the latter stages of the life of a field. The difference in the two methods is not merely a matter of time, but also a difference in the extent to which pressures have been allowed to drop. A. H. N.

1561.* Use of Acids and Other Chemicals in Oil-Production Problems. H. L. Flood. *Petrol. Engr*, October 1940, 12 (1), 46.—The chief chemical engineering practices found in the production of oil are acid treatment of wells, the use of chemical agents for plugging sands to control or exclude water, the use of substances which reduce the surface tension of water and thus prevent it from displacing the oil in the pores of the sand, the use of various cements and chemicals added to them and chemically removing wax and mud from sand-faces. Recently a new acid has been found successful for demudding sand-faces because it is reactive with the silicates as well as with the carbonates, but is non-injurious to iron and most other metals used in oil-well equipment.

Addition agents are added to this acid to accelerate its action on dolomites and retard it on limestones, to reduce its surface tension, and to enable it to wet or penetrate the oil-soaked zones. The action on the silicates is facilitated by the evolution of hydrofluoric acid from the interaction of this 15% HCl acid on sodium fluoride at the sand-face, thus eliminating the hazard of using HF itself.

Chemicals used to lower the surface tension of water to a figure nearer that of the oil than originally are new in the industry, and the most important of these appear to be certain esters of sodium sulphosuccinic acid, such as the dioctyl, methylamyl, and diamyl esters, and an alkyl sodium naphthalene sulphonate.

Their use in completion so that the oil can easily displace the mud is also discussed. References are given. A. H. N.

1562.* Multiple-Zone Completions. H. L. Flood. *Petrol. Engr*, October 1940, 12 (1), 50.—Multiple-zone completions in which several formations are to be segregated usually require: (1) as many producing channels (tubing-strings, annular spaces, etc.) leading to the well-head as there are formations; (2) packers of appropriate types and design to separate the formations; (3) beans or chokes to control the rate of flow from or to each formation; (4) check-valves when necessary to prevent intercommunications between the formations; and (5) a way of obtaining access to cased-off formations either through the casing or by removing it completely.

Two-zone or three-zone completions predominate in multiple-zone completions;

although four-zone completions are possible, they involve additional complications. The size of the hole sets an upper limit to the number of completions, because of requirement (1) above.

Currently, greatest interest is being shown in the use of multiple-zone completions in the deep producing wells of Texas and Louisiana, particularly in distillate fields where it is necessary to return gas to the formation as an essential part of efficient exploitation of the distillate-type of reservoir. The considerable expense of drilling wells to depths of 8000 to 11,000 ft. to serve only as input wells has prompted operators to develop a method of using a single well for the dual purposes of producing distillate and of returning the stripped gas to the formation.

It is expected that multiple-zone completions may be employed in the future to use high-pressure gas or water to repressure an oil formation or to build a water-drive in the oil reservoir. A. H. N.

1563.* Pressure Data Obtained with Formation-Tester. W. A. Sawdon. *Petrol Engr*, October 1940, **12** (1), 55.—The normal method of formation-testing for fluids is described and illustrated. In certain recent methods pressure data are taken and the record kept for future zone. Thus in an area with three producing sands, the uppermost sand being of lowest pressure, and lowest sand possessing the highest formation pressure, the well was completed to produce from the lowest sand only until the pressure in this sand decreased to a value equal to that in the intermediate sand. The intermediate sand was then tapped by gun perforation, and the two sands continued to flow simultaneously until the pressure decreased to the value obtaining in the third sand, which was similarly perforated. The well then produced from all three sands. Other studies of the value of pressure records obtained during testing formations are made in conjunction with core analysis, and these studies prove to be extremely valuable.

Formation-testing is also used in connection with water shut-offs, and routine tests are outlined. These tests are further checked by pressure records, and also by analysis of the salinity of the water. The three tests thus made can ensure a perfect shut-off job; otherwise a failure would be traced in a more certain manner.

The formation-tester may be used, in this connection, for testing water shut-offs when the cement job has been done above the shoe, as in the case of cementing combination strings or blank casing or liner sections between producing zones. The procedure is described, and involves only perforation near the cement parts as an additional step. A. H. N.

1564.* Analysis of Well Performance as Basis for Gas-Lift Operation. H. L. Flood. *Petrol. Engr*, October 1940, **12** (1), 104.—Gas-lift operations are reviewed. The outstanding trend in recent times appears to be a stress on the importance of intelligent analysis of well performance, both before and after gas-lift installation has been made, and not a change in the basis of design of gas-lift.

The more important basic well characteristics which influence the design and performance of a specific gas-lift installation appear to be: (1) reservoir or static pressure; (2) productivity index; (3) formation gas–oil ratio; (4) per cent. water; (5) depth; (6) size and condition of casing; and (7) size and condition of liner.

A factor which is assuming an increasing degree of importance is the back pressure imposed against the face of the formation, and to reduce this pressure a number of devices have been evolved. The usual method of isolating the formation from the back pressure is to employ a sub-packer type of installation which consists of a packer to seal off the casing and a standing valve in the lower end of the tubing or chamber.

Flow-valves for intermitting systems are studied in a general manner. An interesting innovation is the installation of bottom-hole chokes or discs in the lower end of tubing string to control the rate of oil entering the tubing, so that the allowed daily production will be obtained in a steady flow throughout the 24 hours. The system is detailed.
A. H. N.

1565.* Gun-Perforating Technique in Production Problems. W. A. Sawdon. *Petrol. Engr*, October 1940, **12** (1), 114.—The bullets most widely used in gun-perforating oil-well pipes are from 0·45 in. to 0·50 in. in diameter; smaller and larger sizes than these are available for special jobs. The sharp-nose-type bullet creates a hole as nearly clean cut as possible through the pipe and is used most generally; but operators occasionally use a type of bullet which tends to rip the liner as it penetrates through.

Various gun-perforating practices connected with selective completion of sands are described. Squeeze-cementing jobs which require gun-perforations are briefly mentioned. An illustration shows tubing gun-perforated to admit gas from the annulus between tubing and open hole which contains a gas sand overlying shale and an oil sand, the shale being packed off with an open-hole packer; thus the gas from the overlying sand helps in lifting the oil from the lower oil sand.

Gun-perforating of limestone formations before acidizing has resulted consistently in an increased production, as compared with similar offset wells which have been similarly acidized, with the exception that in the procedure they were not perforated first. The bullets fracture the lime and provide a greater surface on which the acid can act. Although specific well conditions govern the spacing of perforations, it is found good practice to space holes approximately 1 ft. apart for this work.

Production has been increased, or re-established when lost, on perforating badly clogged liners. A. H. N.

1566.* Pressure Distribution about a Slotted Liner in a Producing Oil Well. Part II. F. G. Miller. *Petrol. Engr*, October 1940, **12** (1), 134.—In this part experimental procedure and results are given for the pressure losses in the vicinity of a slot for various rates of flow. The graphs of the head loss are curves, and not strictly straight lines.

Experiments on an electrical model of the system are then detailed. Six copper strips, representing slots in a liner, were used in an electrolyte, and the voltage drop per unit rate of current-flow represented the pressure drop per unit rate of water-flow in the permeability tests. The theory of the analogy is worked out and the formulæ are given in detail. The flow in the electrical model was made two-dimensional in three strips and three-dimensional in the other three. The graphs are straight lines.

The last part of this section of the paper deals with the combination of fluid-flow and electrical analogy results. The dimensional similarity is first shown. As the electrolytic-conduction system was geometrically similar to the fluid-flow system, ratios from one system could be applied in computing the value of variables in the other. Thus the ratio of voltage drop to the product of current and conductivity in the electrolytic model is directly used for calculating the pressure drop in a similar slot in the fluid-flow system. The difference in this value of pressure drop and the actual pressure drop is taken to be the loss in head due to convergence of the stream-lines and turbulence just outside the slot. Similar calculations made on the other slots are tabulated.

Other parts of the paper will be published later; hence no conclusions are possible in this abstract. A. H. N.

1567.* Selecting a Casing and Tubing Programme. J. E. Brantly. *Petrol. World*, September 1940, **37** (9), 31–32.—The selection of the correct tubing size to be used is dependent on the rate of production, depth of oil horizon, bottom-hole pressure and temperature, density, viscosity and surface tension of the oil-gas mixture, the effect of gravity and the pressure loss per unit length, and the artificial lifting method to be used after the flow has ceased. No formula is known to take all these factors into consideration. Trial-and-error methods are still the only rules.

A single problem is discussed in detail to show the effects of certain of these conditions on the selection of tubing. It is shown in this problem that tubings of larger sizes than that selected add nothing to the efficiency of production under the maximum allowable rate assumed, and are not justified.

Having selected the tubing size, a satisfactory casing diameter must be chosen. The manner of choosing such a diameter is similarly shown by solving for the same problem.

It is pointed out that if casing sizes were generally reduced and internal flush joint-drill pipes more generally used there would be a saving on salvaging the drill pipe and using it as a casing. Similarly externally upset tubing could be used for drilling. A. H. N.

1568.* Must we Look for a New Reservoir Control? S. C. Herold. *Petrol. World*, September 1940, 37 (9), 55–56.—Dr. Herold assumes knowledge of the principles discussed in his book on production of oil, gas, and water, and points out the three controls described: hydraulic, volumetric, and capillary controls. Hydraulic control is taken here to be a special case of volumetric control, as in the latter rain-water does not enter the field in sufficient quantities to replace the fluids produced, whilst in the former entry of rain-water and production of fluids proceed at the same rate. Thus the problem of controls is reduced to two types: volumetric and capillary.

In volumetric control the rate of production is proportional to the square root of the effective working pressure—*i.e.*, the difference between the closed-in pressure and the back pressure against which production takes place. In capillary controls, the rate of production is proportional to the power $\frac{3}{2}$ of the effective working pressure. The question raised by the paper is whether there is a third control, intermediate between volumetric and capillary, where the rate of production is linear with the effective working pressure.

No solution to the problem is given, but it is pointed out that work based on Darcy's Law assumes such a control. It is not argued that such a system is not possible; it is merely indicated that this should be proved without delay. A system of fluid mechanics should be solved in a complete form based on this law of flow.

Two equations are primarily necessary, the first already stated—*i.e.*, rate of production—is proportional to the first power of effective working pressure. The second equation must involve time as a function of delivery, and this requires experimentation. It is contended that experiments with a block of sandstone represents not a reservoir, but an orifice. Experiments with a long tube of sands are suggested to approximate more nearly a natural reservoir. A. H. N.

1569. Method for Determining the Water Content of Oil-Sands. D. B. Taliaferro and G. B. Spencer. U.S. Bur. Mines. Report of Investigations No. 3535. September 1940.—The authors of this paper accentuate the importance of being able accurately to estimate total water content of oil-sands. Such calculations have a direct bearing on estimations of total oil in place per unit of reservoir volume; on efficiency of oil recovery by common production methods; and on the dynamics of reservoir behaviour.

Petroleum engineers have from time to time evolved satisfactory methods of determining the water content of products, but, owing to the presence of crude oil and water of crystallization in oil-sands, these methods have not been generally applicable to core specimens. Recently, however, the Bureau of Mines has adopted a modification of the A.S.T.M. method for determining water in petroleum products to ascertain the water content of oil-sands. Departures from A.S.T.M. procedure include alteration in size and shape of the trap to facilitate reading of the volume of water collected; replacements of corks by ground-joints; and the use of toluene as a solvent in place of gasolene.

The chief advantages of the method described are its accuracy, simplicity, and low cost of equipment. Moreover, the method is especially suitable for the small samples on which the staff of all core laboratories have to work. H. B. M.

1570. Production. G. F. Turechek. U.S.P. 2,216,144, 1.10.40. Appl. 8.3.39. Sealing-disc for gun-perforators.

G. F. Turechek. U.S.P. 2,216,145, 1.10.40. Appl. 8.5.39. Gun-perforator for well-casings.

B. Barnum. U.S.P. 2,216,151, 1.10.40. Appl. 8.5.39. Gun-type casing perforator with a special type of bullets.

A. C. Fritsche. U.S.P. 2,216,268, 1.10.40. Appl. 29.1.37. Method and means for testing wells utilizing a removable packer and fluid under pressure to indicate loss of pressure.

C. R. Anderson. U.S.P. 2,216,288, 1.10.40. Appl. 26.4.38. Pipe perforating device for shop-perforating jobs.

F. J. Svoboda. U.S.P. 2,216,302, 1.10.40. Appl. 2.5.38. Pipe perforating device applied to outside of pipe.

C. H. Barnes and J. Young, Jr. U.S.P. 2,216,336, 1.10.40. Appl. 15.7.39. Multiple ring-packer.

L. Spencer. U.S.P. 2,216,358, 1.10.40. Appl. 24.12.38. Well-packer with multiplicity of packing-rings which are compressible to expand radially.

L. Spencer. U.S.P. 2,216,359, 1.10.40. Appl. 22.5.39. Gun-perforator for oil-wells.

E. C. Wolferz. U.S.P. 2,216,481, 1.10.40. Appl. 12.11.38. Coupler for pipes.

M. Miller and L. N. Davis. U.S.P. 2,216,674, 1.10.40. Appl. 11.6.39. Well-cleaner with a scraper.

M. B. Thomas. U.S.P. 2,216,967, 8.10.40. Appl. 18.2.38. Gas-lift valve with means sensitive only to the gravity of the fluid for fixing the position of the valve.

T. R. Alley. U.S.P. 2,217,038, 8.10.40. Appl. 20.5.38. Tiltable ring-packer with concave annular plates of packing material.

A. Boynton. U.S.P. 2,217,043, 8.10.40. Appl. 4.10.38. Well-testing tool with packer and a drill stem releasably connected to the shell.

C. J. Coberly. U.S.P. 2,217,215, 8.10.40. Appl. 24.1.38. Gravel-packing for wells, the wells having sand-grains in the walls thereof.

J. F. Sisson. U.S.P. 2,217,238, 8.10.40. Appl. 15.4.39. Sucker-rod wrench for oil-wells.

T. E. Bryan. U.S.P. 2,217,305, 8.10.40. Appl. 24.1.38. Apparatus for removing liquids from wells with intermitter valve.

G. A. Zeidler. U.S.P. 2,217,327, 8.10.40. Appl. 17.9.38. Method of producing well-screens.

N. Johnston. U.S.P. 2,217,370, 8.10.40. Appl. 8.8.39. Screen-wrapped perforated-liner-pipe for oil- and water-wells.

See also Abstract No. 1529.

Gas.

1571. Patent on Gas. E. L. Hall. U.S.P. 2,217,250, 8.10.40. Appl. 4.11.38. Improvement in the production of gas and by-products from petroleum oils by pyrolysis in intermittently heated checker-work, with removal of and collection of the gas formed and recovery of by-products.
H. B. M.

See also Abstract No. 1620.

Hydrogenation.

1572. Patent on Hydrogenation. M. Pier and E. Donath. U.S.P. 2,215,190, 17.9.40. Appl. 21.7.37. Production of hydrocarbon compounds from products obtained by extracting solid carbonaceous materials with organic solvents by adding an organic diluent to the mixture of extract and solvent, subjecting to distillation, and subjecting the remaining mixture of extract and diluent to a treatment with hydrogenating gases.
H. B. M.

Polymerization.

1573. Patent on Polymerization. R. M. Deanesly. U.S.P. 2,216,549, 1.10.40. Appl. 16.5.40. Improvement in the process of polymerizing an olefinic C_3 to C_6 hydrocarbon fraction containing impurities naturally associated therewith.
H. B. M.

Synthetic Products.

1574. Patent on Synthetic Products. H. E. Potts. E.P. 526,814, 26.9.40. Appl. 11.3.39. Synthesis of hydrocarbons with more than one carbon atom in the molecule from mixtures of carbon monoxide and hydrogen. H. B. M.

Refining and Refinery Plant.

1575.* Condenser-Tube Alloy Tests show Corrosion Conditions Need Study. R. W. Moore and S. Kleinheksel. *Nat. Petrol. News*, 29.5.40, 32 (40), R.186.—In examining the corrosion-resisting properties of a number of alloys in use in condensers, test specimens were inserted at each end of experimental condensers placed in parallel with large condensers at significant points in a refinery. Admiralty metal has been found to be satisfactory under the most severe conditions. It is contended that a study of corrosion conditions and means of remedying them would be valuable, since copper-base alloys, do not show a degree of superiority which would justify their adoption. H. G.

1576.* Filter-Clay Efficiency Affected by Water, Carbon, and Porosity. L. M. Henderson, C. M. Ridgway, and W. B. Ross. *Nat. Petrol. News*, 29.5.40, 32 (24) R.193.—The water present in filter clays is recognized, arbitrarily, as of two types. " Adsorbed " water is removed by heating the clay to 450° F., and " Bound " water by heating to 1800° F. The investigation was carried out on Florida fuller's earth and Pennsylvania cylinder stock and bright stock. Such a clay absorbs moisture from the air at a rate dependent on the temperature, the rate being negligible above 275° F. The humidity of the air is of less significance than the temperature. With clay not previously used the proportion of " bound " water is without effect on the percolation yield, provided the " bound " water content is above 2% and " adsorbed " water is absent. In this investigation clays were recovered after use by burning at 1075° F., and with such clays percolation yield decreased with decrease of bound water—that is, with the number of " burns." Adsorbed water in a clay affects the " haze " of the filtrate, but " bound " water is without effect. The presence of carbon in the clay affects the yield and cast of cylinder stocks of 8 N.P.A. colour, but with 5 N.P.A. bright stock the effect is much smaller. The filter efficiency of Florida clay increases with porosity, inasmuch as the specific area is a function of porosity. H. G.

1577.* Collects Sulphuric Acid Fog by Bubble-Phase Absorption. Anon. *Nat. Petrol. News*, 29.5.40, 32 (24) R.200. *Abstract of Paper by D. W. Bransky and F. F. Diwoky at 10th Mid-Year Meeting of A.P.I. at Fort Worth* 29.5.40.—Sulphuric acid is removed from stack-gases by scrubbing in a bubble-tower with an aqueous solution of a foam-forming substance. The most efficient foam-forming agent consists of the sulphonic acids—" green acid "—derived from acid sludge. A 10% solution is claimed to be efficient in removing 93—95% of the available acid in 10—11 sec. The solution retains its foam-forming efficiency until 10% of acid has been absorbed. H. G.

1578. Patents of Refining and Refinery Plant. A. H. Schutte. E.P. 526,744, 25.9.40. Appl. 27.2.39. Separation of wax from wax oil or wax–wax mixtures by emulsifying the mixture with a non-reactive liquid. The emulsion is thereafter chilled so that the higher-melting-point waxes are solidified, and the remaining constituents are thereafter separated from the solidified waxes.

Aktiebolaget Separator. E.P. 526,852, 26.9.40. Appl. 27.3.39. Continuous refining of oil with alkali characterized in that the oil-containing soap separated from the oil is mixed with oil-containing soap-water separated from the refined oil.

J. G. Fife. E.P. 527,030, 1.10.40. Appl. 28.3.39. Separation of the components of a mixture of polar organic isomeric compounds with the aid of two solvents which are insoluble or only slightly soluble in each other, the components of the mixture distributing themselves in different proportions in the solvents.

N. Levy. E.P. 527,031, 1.10.40. Appl. 28.3.39. Method of production of nitroparaffins in which nitrogen peroxide and one or more paraffins are heated in the gaseous phase in the presence of catalysts consisting of arsenic or antimony or materials containing the same.

Standard Oil Development Co. E.P. 527,299, 7.10.40. Appl. 30.3.39. Process for operating a countercurrent solvent-treating tower containing contacting and distributing means and in which one phase is introduced at the top of the tower and another at the lower portion. Impulses are imparted to the phases in the tower by varying periodically the rate of feed of one or both phases and/or the rate of withdrawal of the phase collecting at the bottom of the tower.

M. W. Kellogg Co. E.P. 527,307, 7.10.40. Appl. 1.4.39. Continuous catalytic conversion of hydrocarbons in vapour phase. The hydrocarbon vapours heated to reaction temperature are passed continuously through a reaction zone filled with a compact bed of granular catalyst. After intimate contact of the hydrocarbons with the catalyst, the latter is continuously withdrawn from the reaction zone, reactivated and returned to the zone.

E. I. Du Pont de Nemours & Co. E.P. 527,316, 7.10.40. Appl. 4.4.39. Production of alcohols by the direct catalytic hydration of olefines in the presence of an aqueous solution of a mineral acid. A dilute alkaline solution is introduced into the alcoholic vapours, and leaves the reaction zone in such proportion that the crude condensate obtained on cooling the vapours has a p_H value of not less than 6·0.

Consortium für Elektrochemische Industrie G.m.b.H. E.P. 527,423, 9.10.40. Appl. 24.9.38. Hydration of vinyl acetylene using acid metal catalysts. The reaction temperature is kept constant at boiling point so that heat is removed by evaporation of the reaction liquid.

A. W. Hixon. U.S.P. 2,216,009, 24.9.40. Appl. 17.12.36. Refining of petroleum oils containing paraffinic and naphthenic constituents by contacting the oil with a solvent having preferential affinity for non-paraffinic constituents of the oil; separating the solvent with the dissolved naphthenic constituents from the undissolved oil constituents; and thereafter contacting the solvent–oil phase with a second solvent which is substantially immiscible with the first solvent. Thereafter the oil fractions are recovered from each oil phase.

S. Musher. U.S.P. 2,216,711, 1.10.40. Appl. 17.11.40. Method of decreasing sludge formation and corrosion tendencies of lubricating oils. The oil is treated with a small amount of lecithin and an aromatic compound selected from the group consisting of polyhydroxy aranes, polyamino aranes, aminohydroxy aranes, monoamino-polynuclear aranes and monohydroxy-polynuclear aranes at an elevated temperature.

G. H. Short, U.S.P. 2,216,856, 8.10.40. Appl. 13.5.38. Stabilization of hydrocarbon oil which has been sweetened with a reagent containing copper by intimately contacting it with an aqueous solution containing ferrocyanide ions.

H. G. Vesterdal. U.S.P. 2,216,968, 8.10.40. Appl. 28.5.38. Refining of heavy hydrocarbon oils by treating with dilute aqueous caustic soda under sufficient pressure to maintain the oil and caustic soda liquid at the operating temperature (300° F.) and below the decomposing temperature of the hydrocarbon oil. Thereafter the dilute caustic soda is removed together with the extracted material by decantation.

W. G. Horsch. U.S.P. 2,217,368, 8.10.40. Appl. 12.3.38. Removal of low-temperature sludge from dielectric mineral oil compositions by adding thereto a substance selected from the group of diphenyl and diphenyloxide. H. B. M.

Chemistry and Physics.

1579. Structure and Energies of Some Hydrocarbon Molecules. J. E. Lennard-Jones and C. A. Coulson. *Trans. Faraday Soc.*, 1939, **35**, 811–823.—The effects of resonance on energy content and interatomic distances are shown in various hydrocarbon molecules, the structures of which are correlated with these effects. In many cases, especially in conjugated hydrocarbons, the valence electrons must be considered mobile, and free to move throughout the molecule. The consequent modifications of the properties of the links are outlined. Calculations of the energy, order, and length of links are given and tables for various hydrocarbon molecules, including open conjugated chains, condensed rings, and free radicals, are given. Where comparison with experiment is possible, the lengths and energies agree excellently. E. H. W.

1580. Activation Energies of Reactions Involving Conjugated Systems. M. G. Evans. *Trans. Faraday Soc.*, 1939, **35**, 824–834.—The activation energy of reactions involving conjugated molecules is discussed. It is suggested that the low activation energy for the dimerization and polymerization reactions is due to the large resonance energy in the transition state. The resonance energy is discussed in terms of the behaviour of the mobile electrons in the conjugated systems. E. H. W.

1581. Critique of the Pair Theory of Mesomerism. E. H. Lloyd and W. G. Penney. *Trans. Faraday Soc.*, 1939, **35**, 835–841.—An improved mode of presentation of the theory is given. The type of calculation which may be expected to lead to results of accuracy comparable with experiment is discussed. Mention is made of other types of calculation in which the theory is incapable of yielding such results.

The butadiene, benzene, allene, and diacetylene molecules are discussed in the light of the theory. E. H. W.

1582. Application of the Nitric Oxide Method to the Investigation of Reaction Chains in the Decomposition of Hydrocarbons. L. A. K. Staveley and C. N. Hinshelwood. *Trans. Faraday Soc.*, 1939, **35**, 845–849.—From the retarding effects of small quantities of nitric oxide on the reactions of certain organic compounds, indications are given of the existence of a chain mechanism, and the proportion of molecules taking part in such a mechanism is deduced.

The decomposition of several hydrocarbons have been studied in this way, and there is a discussion on the decomposition of ethane. E. H. W.

1583. Decomposition of Hydrocarbons Induced by Free Radicals. F. O. Rice and O. L. Polly. *Trans. Faraday Soc.*, 1939, **35**, 850–854.—A free radical theory proposed by one of the authors (*J. Amer. Chem. Soc.*, 1931, **53**, 1929; 1934, **56**, 284) is applied to the thermal decomposition of a pure organic compound. The kinetics of the proposed reaction are given. The apparatus used to verify their theory is described and results of an investigation with *n*-butane are given. E. H. W.

1584. Reaction of Hydrogen Atoms with Propane and the Mechanism of the Paraffin Decompositions. E. W. R. Steacie and N. A. P. Parlee. *Trans. Faraday Soc.*, 1939, **35**, 854–860.—The reactions of ethane and ethyl radicals with hydrogen are reviewed and the importance of the reaction $H + C_2H_5 = 2CH_3$ from the standpoint of the Rice theory is emphasized. Experiments on the reaction of hydrogen atoms with propane by the Wood–Bonhoffer method are described. At high temperatures the products of the reaction are methane, ethane, and ethylene, but methane is the only product at low temperatures. The results are discussed, and it is concluded that they offer strong evidence that the reactions $H + C_2H_5 = 2CH_3$ and $H + C_3H_7 = C_2H_5 + CH_3$ occur readily at room temperatures. E. H. W.

1585. Pyrolysis of 2-Carbon and 3-Carbon Paraffin and Olefine Hydrocarbons. M. W. Travers. **Part I. Equilibrium Mixtures.** *Trans. Faraday Soc.*, 1939, **35**, 860–864.—The investigation of the pyrolysis of 2-Carbon hydrocarbons starting with equilibrium mixtures of ethane, ethylene, and hydrogen is described. Similar work was done on propane, propylene, and hydrogen mixtures. Various theories on the production of methane in these reactions are discussed.

Part II. Pure Ethane. M. W. Travers and J. A. Hawkes. *Ibid.*, 864–868.—Continuing their work on these lines, these authors now studied the pyrolysis of ethane using a new technique. Results are given, and it is shown that propylene is not an important product, as had been claimed by other authors. The primary decomposition is shown to be influenced by the surface. Primary and secondary processes are shown in these experiments to become quickly of equal importance.

Part III. The Influence of Nitric Oxide on the Secondary Decomposition of Ethane. M. W. Travers and J. A. Hawkes. *Ibid.*, 868.—From the results of this investigation the authors show that the theory advanced by Hinshelwood and Staveley on the decomposition of ethane is somewhat unsatisfactory.

E. H. W.

1586. Kinetics of the Thermal Decomposition of Tetramethyl Methane (Neopentane). T. J. Gray and M. W. Travers. *Trans. Faraday Soc.*, 1939, **35**, 868–870.—Because of the results obtained on the thermal decomposition of the methylamines, the authors decided to investigate the reaction involved by the compounds obtained by replacing the hydrogen in the methyl group by successive methyl groups. So far only the formation of hydrogen and methane has been measured. Results are discussed, and the work is being continued.

E. H. W.

1587. Homogenous Thermal Decomposition of some Cyclic Hydrocarbons. L. Küchler. *Trans. Faraday Soc.*, 1939, **35**, 874–880.—The thermal decompositions of *cyclo*hexane, *cyclo*hexene, and methyl*cyclo*pentane have been investigated. *cyclo*Hexane primarily decomposes in two parts, forming, partly *cyclo*hexene and hydrogen, and partly two molecules of propene. *cyclo*Hexene gives primary products of ethylene and butadiene. The decomposition of methyl*cyclo*pentane is very similar to that of *cyclo*hexane, but detailed analyses are not available here.

E. H. W.

1588. Existence of Methylene in Hydrocarbon Reactions. R. F. Barrow, T. G. Pearson, and R. H. Purcell. *Trans. Faraday Soc.*, 1939, **35**, 880–889.—This paper consists of a summary of the available knowledge on the presence of the methylene radical. Its presence having been postulated to account for analytic and kinetic data concerning the decomposition, oxidation, and polymerization of hydrocarbons. Proof has been difficult to obtain, and its existence in these reactions is not yet generally accepted. Particular reference is made to the decomposition of methane. The trend of results leads to the conclusion that methylene radicals are the primary product, reacting readily to give methyl radicals.

The authors conclude that, while the evidence they submit tends to be confusing, methylene has nevertheless been definitely isolated and shown to exist as an intermediate in numerous reactions. There is no experimental proof that methylene contains bivalent carbons, but none of the evidence submitted conflicts with this, and it therefore remains the author's present view. From reactions shown, the rapid disappearance of methylene in systems containing hydrogen and hydrocarbons is explained.

E. H. W.

1589. Stability of Hydrocarbon Biradicals and Their Reactions. C. E. H. Bawn and J. Milsted. *Trans. Faraday Soc.*, 1939, **35**, 889–897.—The preparation of methylene and biradicals containing up to six carbon atoms is discussed. The reactions of methylene are noted, including the reaction with hydrogen at 300° C. to give methane. There was no evidence for the formation of ethylidene. The decomposition products of tetra-, penta-, and hexa-methylene radicals are given, and the stability of these compounds is discussed.

E. H. W.

1590. Influence of Temperature on the Stability of a Mineral Oil. F. P. Bowden, L. Leben, and D. Tabor. *Trans. Faraday Soc.*, 1939, **35**, 900–904.—These authors show that if a mineral oil is heated in air, compounds are formed in it which improve the lubricating properties. The frictional behaviour is changed from "stick-slip" to continuous sliding, with a consequent reduction in wear.

The rate of formation of these compounds is much more rapid when the oil is in a thin film on a steel plate, than when it is in bulk. The rate of formation of these substances rapidly increases with temperature, until at 300° C. other substances are formed which seriously interfere with the lubricating properties of the mineral oil. The improvements in the lubricating oil by heating are compared with the addition of small amounts of fatty acid.

E. H. W.

1591. Polymerization of Hydrocarbons. M. W. Perrin. *Trans. Faraday Soc.*, 1939, 35, 1062–1067.—The mechanism and behaviour on polymerization of certain unsaturated hydrocarbons are compared, and the differences between them discussed. The correlation of the properties and the molecular structure of certain high-molecular-weight polymers is described. The existence of a three-dimensional or two-dimensional structure is shown to account for the mechanical and thermal behaviour. The detailed constitution of the molecule explains the differences in the elastic properties of the long-chain polymers. E. H. W.

1592. Butadiene Polymers ; Elucidation of Structure by Ozonolysis. R. Hill, J. R. Lewis, and J. L. Simonson. *Trans. Faraday Soc.*, 1939, 35, 1067–1073.—These experimenters obtained succinic acid, butane 1 : 2 : 4-tricarboxylic acid, and resinous acids from the ozonolysis of a butadiene polymer. The polymerization of butadiene in aqueous emulsion is described. It is shown from the results that under these conditions butadiene polymerizes by all the possible additive mechanisms, but a quantitative discrimination between them is not possible. E. H. W.

1593. Butadiene Co-Polymers; Elucidation of Structure by Ozonolysis. R. Hill, J. R. Lewis, and J. L. Simonson. *Trans. Faraday Soc.*, 1939, 35, 1073–1079.—The formation of a polymer of butadiene and methyl methacrylate in aqueous emulsion is described.

From the ozonolysis of this polymer 2-methyl-1 : 2 : 4-tricarboxylic acid was isolated, thus establishing a co-polymer structure. The products obtained show that more than half of the polymer consists of alternate units of butadiene and methyl methacrylate. The butadiene is shown to polymerize by a 1 : 4 addition. Differences in structure and properties between the co-polymer and the butadiene polymer are correlated. E. H. W.

1594. Patents on Chemistry and Physics of Petroleum. H. Beller. U.S.P. 2,216,222, 1.10.40. Appl. 20.4.38.—Process of oxidizing high-molecular paraffinic hydrocarbons by adding to the initial material a solution of a catalyst in a solvent selected from the group consisting of water, a water-soluble organic solvent, a mixture of water and a water-soluble organic solvent. The ingredients are thereafter mixed, the solvent removed, and the mixture subjected to oxidation by means of an oxidizing gas containing oxygen at an elevated temperature.

R. L. Rude. U.S.P. 2,217,636, 8.10.40. Appl. 24.8.39. Method of effecting a change in a hydrocarbon fluid flowing in a continuous path and interposing in the said path at least one flow-responsive element; determining the weight-rate of flow of the fluid through the element and correlating the manifestation of the flow-responsive element with the weight-rate in order to determine *in situ* the density of the hydrocarbon at the locality of the element. H. B. M.

Motor Fuels.

1595. Patent on Motor Fuel. F. J. Sowa. U.S.P. 2,212,992, 27.8.40. Appl. 22.6.38. Preparation of a fuel for use in internal-combustion engines and consisting of a liquid hydrocarbon fuel and a material selected from the group of compounds consisting of alkyl silicols and alkyl silicyl ethers.

F. W. McCurry. U.S.P. 2,214,749, 17.9.40. Appl. 21.11.38. Preservation of the antiknock value, colour, and transparency of a hydrocarbon motor fuel by incorporating therewith an activated oxidised glyceride in the ratio of one part of the glyceride to 1000 to 80,000 parts of the fuel.

B. H. Lincoln. U.S.P. 2,214,768, 17.9.40. Appl. 5.2.38. Production of a motor fuel consisting of a volatile combustible liquid with a boiling range of the order of commercial gasoline and a small amount of a mixture of substantially less volatile mineral and a halogenated carbon ring compound. H. B. M.

Diesel Fuel.

1596.* Rating of Diesel Fuels. P. H. Schweitzer and J. S. Chandler. *Aut. Eng.*, 1940, **30**, 135–141.—This paper describes tests made on a range of fuels in the C.F.R. laboratory C.I. engine and in a number of high- and low-speed engines to determine whether the laboratory ignition-quality rating is a true index of the performance of a fuel in commercial engines. The test procedure for determining the ignition quality of the fuels was based on the ignition delay criterion, and followed the laboratory procedure as much as possible, and the average of twenty-two ratings by fourteen laboratories on the C.F.R. engine was taken as the reference point for laboratory ratings. Three test methods were used—*viz.*, the R.C.R. method, in which the compression ratio is adjusted until the ignition lag becomes 15°; the air-throttling method, in which the air intake is throttled until a predetermined lag is obtained; and the variable-lag method, in which the engine is operated under normal conditions and blends of reference fuel are determined which give the same lag as the fuel under test. Full details of an improved apparatus for measuring ignition lag are given. This apparatus was developed by Schweitzer and Hetzel in 1935.

The authors conclude that the C.F.R. laboratory method underrates fuels by an average of 3 cetane numbers in comparison with the commercial engines. The average deviation between various commercial engines is about 2 cetane numbers. The accuracy of the variable-lag method is inferior to that of the R.C.R. and air-throttling methods. The type of engine has a greater effect on ratings than the method used to rate the fuels. Commercial engines may be compared by noting the slope of the ignition-lag *v.* ignition-quality curves; the flatter the curve the less sensitive the engine to ignition quality, a flat curve being an advantage in service engines.

C. H. S.

Lubricants and Lubrication.

1597. Evaluation of Lubricating Oils Used in Aeroplane Engines. S. Sintori and F. Pomella. *Olii. Min.*, 1940, **20** (5), 49–52.—The difficulty of obtaining a representative sample is described, as are methods for analysing used aviation oils. The asphalt is determined by precipitation and filtration, the free carbon being subsequently estimated by oxidation in the presence of copper oxide and absorbing the CO_2 formed. The residual ash can then be analysed, if required. In order to determine quantitatively the inorganic constituents, a large sample, 200–300 g., is ashed in a platinum crucible. When burning has finished, sodium and potassium carbonates are added and the organic material is destroyed by heating. Methods are outlined for estimating iron, aluminium, lead, copper, zinc, silica, bromide, and sulphate, a typical analysis being given. The analysis of deposits is dealt with in a similar manner to that employed for used oils, the only difference being the estimation of oil with normal benzine and subsequent estimation of asphalt with boiling benzene. A typical analysis of such a deposit is quoted.

The use of photomicrographs to determine the type of carbon formed and its possibility of obstructing oil-ways is described. This method is used in conjunction with carefully controlled single-cylinder engine tests. The viscosities of these used oils can also be determined after filtration through a Jena G.3. sintered-glass crucible.

H. L. W.

1598. Patents on Lubricants and Lubrication. J. Robinson. U.S.P. 2,215,362, 17.9.40. Appl. 10.3.38. Process of decolorizing viscous lubricating oil by heating a mixture of viscous lubricating oil and liquified normally gaseous hydrocarbon solvent to a temperature corresponding to a solvent vapour pressure in excess of 150 lb. per sq. in. under sufficient pressure to maintain the solvent in liquid state. Thereafter the mixture is passed through a bed of adsorbent decolorizing clay under sufficient pressure to maintain the solution in liquid state.

C. F. Swinehart. U.S.P. 2,215,432, 17.9.40. Appl. 1.6.38. Preparation of a sulphur compound adapted for addition to lubricating oil. This is composed of sulphur, a substance of the group consisting of naphthalene and diphenyl, and an aromatic amine. The amine is present in a smaller proportion than the sulphur.

G. M. Maverick. U.S.P. 2,215,590, 24.9.40. Appl. 20.7.35. Preparation of a lubricating composition containing a major proportion of a viscous hydrocarbon lubricating oil and a minor proportion of a phthalic ester.

J. F. Nelson. U.S.P. 2,215,591, 24.9.40. Appl. 20.5.39. Preparation of a lubricant in which is incorporated a small quantity of an oil-soluble organic substituted cyanamide of formula $X=N=CN$, in which X is an organic divalent radical combination.

G. H. Davis. U.S.P. 2,216,230, 1.10.40. Appl. 30.1.37. Preparation of a lubricating oil consisting of a heavy oil containing constituents which tend to vary its pour point and a small quantity of benzidene to stabilize the pour point.

R. Rosen. U.S.P. 2,216,752, 8.10.40. Appl. 3.4.37. Production of petroleum lubricating oil for use at high temperatures, containing as an oxidation inhibitor a small amount of an oil-soluble compound with an aromatic nucleus.

B. H. Lincoln and W. L. Steiner. U.S.P. 2,127,173, 8.10.40. Appl. 19.2.36. Preparation of stabilized, high film-strength lubricating oil consisting of a major proportion of hydrocarbon oil, 0·5–10% by weight of an aliphatic ester having chlorine in chemical combination therewith and from 0·001 to 1% weight of pinene.

H. B. M.

Asphalt and Bitumen.

1599. Physical and Chemical Properties of Petroleum Asphalts of 50/60 and 85/100 Penetration. R. H. Lewis and J. J. Welborn. *Proc. Assoc. Asph. Paving Tech.*, 1940, 2, 86–157.—It is stated that standard specifications which were considered to control the quality of asphaltic bitumen have been questioned since the introduction of bitumens from new crude sources and new refining processes. In order to determine how present bitumens conform to specifications, the Public Roads Administration requested producers to submit samples to the Federal specifications, and these were examined according to the Federal, A.S.T.M., Assoc. of American State Highway Off. specifications and by other methods used for control of quality. The investigation was confined to asphalt cements of 50/60, and 85/100 penetration, forty samples of each grade being examined; the results are tabulated and crude source and method of refining indicated.

Seven samples of 50/60 grade and six of 85/100 failed to meet one or more of the Federal requirements, one of each grade did not meet all requirements of A.A.S.H.O., and one sample of 50/60 grade did not meet the tentative A.S.T.M. specifications. The above specifications have been modified in some respect by most States, and twenty-eight of the 50/60 cements would be rejected by the various States. In the discussion of the test requirements and results obtained, the following comments are made: Four samples of each grade were lower than the Federal minimum limit for specific gravity. The minimum flash-point limit is 100° F. below the lowest figure recorded and more than 200° F. lower than the average. The average penetration was in the middle of the specified range. The softening-point limits are 104–140° F. for both grades, and the 50/60 bitumens ranged from 118° to 137° F. and the 85/100 bitumens from 111° to 123° F., the average in both cases being in the middle of the extremes. Although the minimum ductility specified by Federal is 40 cm. and by A.S.T.M. and A.A.S.H.O. 30 cm., only eight samples of 50/60 and none of the 85/100 bitumen were below 100 cm.; one sample of 50/60 was below 30 cm. ductility, whilst one sample was a little higher than 40 cm. Many samples were above 250 cm. ductility and average values were 176 and 180 for the 50/60 and 85/100 bitumens. The average loss on heating was 0·07% for the 50/60 and 0·09% for 85/100 bitumens. The penetration of the residue from the loss on heating test is required to be at least 60% of the original, and the values ranged from 70 to 94% for the 50/60 grade and from 65 to 88% for 85/100. One sample of both grades failed to meet the Federal and A.A.S.H.O. requirement of 99·5% solubility in carbon disulphide, whilst two samples of both grades failed to pass the Federal requirement of 0·2% maximum organic insoluble. All samples passed the limit of 90% minimum solubility in carbon tetrachloride.

It is stated that the data do not afford definite information regarding the source or method of refining the bitumen, whilst uniformity of supply cannot be controlled and no indication is given as to measures necessary to prevent deterioration during mixing, construction, and in service.

In a discussion of various methods of expressing susceptibility it is pointed out that the use of the factor obtained from penetration tests at 115° F., 77° F., and 32° F. is limited owing to the fact that many materials are too soft at 115° F. One State requires that the penetration at 39·2° F., 200 gm. 60 sec. must be greater than 30% of the penetration at 77° F. 100 gm. 5 sec., and this would mean the rejection of four out of five Californian bitumens of both grades and four out of five Oklahoma and one Texas bitumen of 85/100 grade. Penetration determinations with load of 100 gm. for 5 sec. at 9° F. temperature intervals from 32° to 104° F. gave linear relationship between temperature and log. of penetration. Extrapolation showed that the penetration at the softening-point temperature ranged from 540 to 1060 for the 50/60 grade and from 620 to 1300 for the 85/100, and thus did not confirm the assumption of Pfeiffer and van Doormal that the penetration at the softening-point is 800 for all bitumens. The extrapolated values were checked on several samples by determining the penetration at 115° F. using a 6-in. needle.

It is thought that the slope of the log penetration-temperature curve is a true index of susceptibility, whereas the penetration index distorts the results. The fluidity factor is thought to be unsatisfactory for identifying the crude source, for which it was originally proposed, and while viscosity at high temperatures is of value in connection with mixing operations, a susceptibility factor based on viscosity at these temperatures may not adequately indicate change of consistency at service temperatures. The fluidity factor of 140 minimum in certain specifications would exclude a large number of the bitumens. The minimum float-test index of 90 specified for bitumens of 40/70 penetration was not met by twenty-four samples.

The various susceptibility factors when plotted against the slope of the log-penetration-temperature curve are said to show that the empirical factors are only approximate measures of susceptibility which might be used to control uniformity of supply and for identification of source of bitumens.

The ductility test under normal conditions is said to give little information on the ductility characteristics of bitumens and a comprehensive study was made of effect of temperature and rate of pull. A special machine in which temperature could be controlled, rate of pull varied over a wide range and ductilities up to 250 cm. measured. At a given rate of extension all bitumens were found to have a maximum ductility, and in most cases the ductility decreased rapidly above 95° F. Bitumens having identical ductilities with a given penetration differed widely at a different penetration. The source and method of manufacture were found to influence greatly the ductility characteristics.

A set of Mexican bitumens of varying penetration was tested for penetration and ductility at various temperatures, and it was found that the log-penetration-temperature slope was the same for each bitumen, whilst ductilities were essentially the same at the same penetration. In the low-temperature tests no relation between ductility and temperature or rate of pull common to all bitumens or to bitumens from a particular source was exhibited.

Fourteen samples of 50/60 gave positive spots in the Oliensis test, and, of these, three had xylene equivalents less than 16 and three more than 60, whilst fifteen samples of 85/100 were positive, with nine having xylene equivalents less than 16 and two more than 60. The bitumens having high xylene equivalents also failed to pass Benson's film weathering test.

It is stated that the Californian bitumens failed to pass the greatest number of requirements, and the Mexican, with one exception, the least. Bitumens of high xylene equivalents fail to pass larger number of requirements than homogeneous or slightly heterogeneous bitumens. Next to Mexican, the Venezuelan bitumen having negative spots and Arkansas bitumens show least number of failures. The authors conclude that the failure to pass many of the special requirements of bitumens from sources considered satisfactory justifies the discouragement of use of discriminatory tests that do not measure quality.

No definite correlation between test data and performance of the bitumens in service was found to indicate that any of the tests are true measures of quality or durability.

A. O.

1600. Measurement of Resistance of Oil Asphalts to Changes in Penetration and Ductility at Plant-Mining Temperatures. C. L. Shattuck. *Proc. Assoc. Asph. Paving Techn.*, 1940, 2, 186–203.—It is pointed out that work of various investigators shows that petroleum bitumens gradually decrease in penetration when exposed to oxidizing conditions during manufacture of hot-mix paving materials, and while the softening-point increases in fairly constant ratio with decrease in penetration, the ductility loss varies considerably with different bitumens.

The author is of the opinion that resistance to change in ductility when bitumen is exposed to oxidizing conditions is of greater importance than retention of penetration.

An attempt was made to correlate cracking of pavements with change in the asphalt cement due to mixing operations, and tests were made on bitumens recovered, by the Abson method, from samples of sheet asphalt taken from satisfactory and badly cracked sections of streets which had been in service under similar traffic conditions for the same period.

The results indicated that the low-ductility danger point appeared to be 50 cm. at 77° F. and 10 cm. at 60° F. for pavements reported as in very good condition and 25 cm. at 77° F. and 5 cm. at 60° F. for pavements in good condition, whilst pavements were very badly cracked when ductility was less than 25 cm. at 77° F.

The penetration drop is said to be less than would be expected if cracking was due to low penetration, although pavements were in a badly cracked condition when the penetration was lower than 20.

Tests on streets constructed in 1935 with plant having latent control features were very satisfactory; the ductility of recovered bitumen was + 110 at 77° F. and 60° F. in two samples, whilst in two other samples the ductility at 60° F. had decreased from + 110 to 10 cm. It is considered that the ductility at 60° F. is of more value in comparing bitumens than the test at 77° F.

Details are given of a test to determine the effect on penetration and ductility when bitumen is submitted to mining operations; this consists in mixing 1880 gm. of Ottawa sand at 400° F. with 120 gm. bitumen at 300° F. in a small pug-mixer heated to 275–300° F., for 1 min. The mixture is then placed in a metal pan, having dimensions 7″ × 11″ × 1¼″, and heated in an oven at 350° F. for 30 min., after which it is spread on hard paper to cool and the bitumen finally recovered by the Abson method.

Tests made on a number of bitumens with Ottawa sand and with standard sheet asphalt aggregate showed that results in two laboratories were in good agreement and that hardening was greater with the Ottawa sand.

In order to confirm that the mixing test with Ottawa sand was more severe than plant-mixing, tests were made on a number of paving mixtures taken after laying. The temperature of mix, length of haul, and time from mixer to laying are recorded with tests on the recored bitumen. A. O.

1601. Analytic Mechanical Testing of Bituminous Mixes. V. A. Endersley. *Proc. Assoc. Asph. Paving Techn.*, 1940, 2, 158–185.—The author states that asphaltic engineering has slowly changed from use of expensive full-scale experiments to empirical tests intended to evaluate behaviour of bituminous mixtures, and it is thought probable that mechanical tests will be placed on a true analytic basis in the near future.

It is considered that as all failures of bituminous pavements result in loss of load-carrying ability there is no basis for scientific predetermination of quality until mechanical tests become accurately related to traffic load capacity.

The method of analysis should be able to examine the factors contributing to failure or success separately, and steps in the solution of the problem are as follows: use of a method of mechanical testing which will show the different interval resisting factors separately. Evaluation of the physical and physico-chemical factors which affect the internal resistances by use of different combinations. Correlation of the factors with traffic, exposure, subgrade conditions, thickness of pavement, etc. The method which the author believes to fulfil the first requirement, and which has enabled progress to be made on the other two steps, is discussed.

In the stability test employed, known as the triaxial test, a cylinder of material surrounded by a liquid under pressure is compressed, and the relationship between the vertical loading and the lateral hydraulic pressure gives the resistance of the material. Pressures are determined at two or more levels, and the results are analysed by means of the Mohr Circle diagram. The fundamental principles of the latter are discussed. A. O.

1602. Physico-Chemical Factors of Importance in Bituminous Soil Stabilization. H. F. Winterborn and G. W. Eckert. *Proc. Assoc. Asph. Paving Techn.*, 1940, **2**, 204–253.—The paper describes investigations which were undertaken for the purpose of demonstrating and analysing physico-chemical factors of importance in the bituminous stabilization of cohesive soils.

The work included the study of six soils, showing a wide variation in physical and chemical character, and eighteen bituminous materials of different origin, method of processing, and physical and chemical characteristics. An investigation was also made of the behaviour towards water of soil–bitumen systems consisting of all possible variations of the soils, including ionic modifications, and bituminous materials.

The bituminous materials were identified by means of the standard physical tests, Marcusson analysis, qualitative solubility tests, heterogeneity in various solvents. Benson heterogeneity and quantitative extraction tests. Certain modifications were made in the Marcusson procedure, and in addition to the usual Marcusson classifications the materials were grouped according to the volume of benzene required to give clear solutions in alcohol, the colour of the asphaltenes and resins and dispersability of asphaltenes in aniline.

It is pointed out that although a single qualitative test is of no value, the data obtained from examination with a series of solvents under specified conditions is useful in indicating functional relationships between materials.

In making the solubility tests ¾ gm. of bitumen was placed in a test-tube with 10 ml. solvent and examined after shaking at intervals for 3 days. Alcohols had little action on the materials, while nitrobenzene and carbon tetrachloride failed to differentiate between them. The materials were separated into two distinct groups and a third group in which members were related to each other and to members of the other groups.

Tests for heterogeneity were made by vigorously shaking the tubes and, after allowing them to stand for 1–2 hrs., pouring a drop of the supernatant liquor on to a filter paper.

Note was made whether the spot was homogeneous and of the colour intensity. Simple and differential functions were established, but did not give additional information to the solubility tests.

Successive extraction of the materials was made in a Soxhlet type of apparatus using various acetates and benzene and carbon tetrachloride.

The results are said to show that groups termed oils, resins and asphaltenes in the Marcusson separation do not possess a definite meaning, and different groups of materials having different properties may be wrongly classified.

The stabilized soil specimens were prepared by grinding the soil to pass the 40-mesh sieve, adding water to bring it to the plastic limit and 7·5% of bitumen on the air-dry soil; this was mixed until no oil clots could be detected. The mix was then manually compacted in a circular mould 1 in. high and 1½ in. diameter, taking sufficient in one portion to prepare the specimen. After removal from the mould the specimen was slowly dried at room temperature to constant weight.

The specimens were next immersed in distilled water and weighed after periods of 1 to 36 days, after which the penetration was determined with the bitumen penetrometer using 100 gm. for 10 secs. The results obtained are tabulated and the effect of the various properties of the materials is discussed.

It is concluded that the success of bituminous soil stabilization is a function of the general character of the soil and its exchange cations, and of the character of the bituminous material employed. A. O.

1603. Avoiding Trouble in Design and Control of Oil-Aggregate Mixtures. F. R. Olmstead. *Proc. Assoc. Asph. Paving Techn.*, 1940, **2**, 258–289.—The author discusses the procedure adopted by the Michigan State Highway Department in oil-aggregate construction, using slow curing asphaltic oils, on approximately 750 miles of secondary roads. A. O.

1604. Graphical Presentation of Constituent Material Percentages and Resulting Stabilities of Sheet Asphalt Mixtures. R. W. Gamble and T. T. Rodgers. *Proc. Assoc. Asph. Paving Techn.*, 1940, **2**, 290–301.—The authors desired to obtain a picture of the data obtained from determination of Hubbord–Field stability of a large number of sheet asphalt mixtures, and the method eventually adopted was to represent the percentage composition of the mixtures by means of a triaxial diagram drawn on a piece of plyboard and stability by means of pieces of wire cut to scale and inserted in the board perpendicular to the plane. A shadow-graph was then obtained by photographing the shadows cast by the wires on a ground-glass screen A. O.

1605. Development of a Maximum Density Curve and its Application to the Grading of Aggregates for Bituminous Mixtures. W. H. Campen. *Proc. Assoc. Asph. Paving Techn.*, 1940, **2**, 302–314.—The paper describes the construction of a maximum density curve for bituminous aggregates up to 2½ screen size. A. O.

1606. Gradation of Mineral Aggregates for Dense Graded Bituminous Mixtures. F. N. Hueem. *Proc. Assoc. Asph. Paving Techn.*, 1940, **2**, 315–339.—In investigating the influence of aggregate gradation on behaviour of oil-mix surfacings it appeared that satisfactory surfaces could be constructed with little regard to gradation, providing the bitumen content was adjusted for the particular aggregate and gradation. The author therefore compared gradings of various mixtures which have been proposed, in an attempt to find some common feature. The data were plotted on semi-logarithmic charts, when it was found that all of the gradings passed close to the point corresponding to 31% of the material passing a size equal to 0·031 of the maximum size of the gradation, and this information was made the basis for the construction of charts for the design of mixtures. A. O.

1607.* Analysis of Bituminous Materials. R. Preston. *J. Soc. Chem. Ind.*, 1940, **59**, 99–108.—This paper is concerned with the analysis of mixed road materials, with special reference to binder contents. Since variation in the binder content is considered of greater importance than any of the other factors in the "life" of a road, it is necessary to determine accurately how closely it follows specification. The solvents generally used are discussed, and it is pointed out that trichlorethylene can only be used if the properties of the recovered binder are not required. Errors in sampling mainly arise when the bulk sample is taken, and may be due to variations in temperature, stoppages in the plant, variations in the stock pile of aggregate, time of mixing and change of composition of the mix. In the case of samples taken at the roadside, especially if open-textured and with a soft binder, the errors may be considerable. The use of a U-shaped sampling scoop is recommended and the best procedure described.

Variation in analysis results may be due to the preparation of the sample for analysis, the characteristics of the binder and aggregate, the possibility of absorption and adsorption of binder, the effect of water, and to the charges occurring in aggregate and binder during mixing or in the operations of analysis. Since analyses of synthetic mines are in general lower than expected, experiments were carried out which showed that, as the particle size of the material decreased, the difference between observed and true values for the bitumen content increased, but not proportionally. It was found that pyridine would remove further bitumen from the stone after "complete" extraction with carbon disulphide, and it was demonstrated by further experiments that some of the bitumen was adsorbed on the aggregate. This adsorption effect was not so pronounced with damp aggregate. It was further shown that the proportion of bitumen adsorbed decreased as the concentration of bitumen increased, in conformation with the Freundlich isotherm down to 0·2% bitumen for the materials used. It was also concluded that selective adsorption of the bitumen (*e.g.*, asphaltenes) does not occur. It was found that the use of a suitable mixture of solvents (*e.g.*, 1 of ethyl alcohol to 5 of carbon disulphide by volume) removed more than half of the adsorbed bitumen, and further work will be carried out on this mixture.

Sampling errors occurring in the laboratory during division of the bulk sample were found to be very small, and triplicate 500 gm. samples are recommended. Errors may arise owing to omission of the correction for water in the sample, since complete removal of the moisture by direct drying is impossible in most cases. The method of hot extraction with toluol is preferred for rapidity and ease of control in analysis and a suitable apparatus designed to recover the solvent is described. Tables of a large number of results obtained with various types of common road surfacings show that the methods of analysis give results within the standard tolerance permitted. The errors inherent in the process of manufacture and in sampling are greater than those of the analysis. Where, however, an accuracy greater than the Standard is required, it is suggested that a correction (*c*) be added to the result obtained, by application of the empirical formula $C = (0{\cdot}03A + 0{\cdot}1S + 0{\cdot}2F)/100$, where $A = \%$ by wt. of stone, S that of sand and F that of filler. H. G. W.

1608.* Control of Bituminous Road Materials by Analysis. G. H. Fuidge and R. Preston. *J. Soc. Chem. Ind.*, 1940, **59**, 108–114.—While the road-binders are manufactured under close control, only a small proportion of the mixtures of these binders with aggregates is subject to similar control, and these are mainly asphalt mixtures. It was soon found that carefully graded thin carpets could give satisfactory service without surface dressing, but it is pointed out that this only arises in general if the mixes are scientifically controlled. Characteristic type of failure occur if the mixture is too fat or too lean. The permissible binder range is called the " binder latitude," and this becomes smaller the finer the aggregate grading. For a normal thin carpeting to give three years' service the latitude should not exceed ± 5%—*i.e.*, 0·5 gall./ton on a binder content of 10 galls./ton. Examples are given showing the wide variations sometimes obtained because of the general insensitiveness of the measuring devices, the development of definite inaccuracies, or inefficient operation. Results show that there is a strong case for the general application of scientific control to all bituminous mixtures used on the road, for the increased cost would be more than justified by the improved " life." No simple mechanical tests are yet available that can be generally applied in a few minutes, and thus permit hour-to-hour control. Analysis is therefore left, and using the hot extraction method (Road Research Board Report, 1936, 52) the complete result can be obtained in 24 hrs., even with tar if suitable corrections are made. Under most conditions daily samples are probably advisable, but if a plant is working efficiently less frequent sampling may be adequate. It is best to take as a sample a number of small increments from several batches on the plant. The authors quote further examples to show the value of analysis in detecting serious and unsuspected departures from the specification, the probable cause, and thus the necessary corrective measures. It is shown from these examples that when careful control is exercised, the specified mixture can be readily obtained. Periodical test, with overhaul and renovation to maintain the efficiency of the mixing plant as soon as required, are therefore advised as sound economy. H. G. W.

1609.* Stability of Emulsions. Part II. Emulsions Stabilized by Hydrophilic Colloids. A. King and L. N. Mukherjee. *J. Soc. Chem. Ind.*, 1940, **59**, 185–191.—The size-frequency technique described in the previous paper (*J. Soc. Chem. Ind.*, 1939, **58**, 243) has been applied to that important industrial group of emulsions stabilized by hydrophilic colloids. Previous work on this type of emulsions is discussed and the lack of quantitative comparison of their emulsion stabilities is indicated. Using kerosene and olive oil it has been found that most of these colloids form emulsions considerably coarser than the soap-stabilized systems, but often more stable. The smallest particles are much more stable than the larger ones at higher temperatures due to the decrease in viscosity of the continuous phase. As with soap emulsions, the analyses of the freshly prepared emulsions give little or no indication of the stability, and in this case, as well, the time of half-break may be quite misleading—*e.g.*, with lecithin-stabilized emulsions. The stability was therefore measured during both the initial rapid change and the secondary slow change, and no single numerical value could be obtained to express it (as with soap emulsions). It is pointed out that high stability alone will not characterize a good emulsion. Contrary to soap-stabilized emulsions, hydrophilic colloid emulsions vary with the nature of the oil, probably due to the greater mobility of some (*e.g.*, kerosene, which gives finer emulsions initially). These emulsions are less fine, but superior in many ways to soap emulsions, since, only with lecithin is there any separation of free oil on ageing, probably since it

gives much less viscous emulsions than with gelatin, agar agar, and the gums tragacanth and acacia, which were especially good. On the addition of calcium chloride it was found that emulsions of high viscosity (*e.g.*, gum tragacanth) were scarcely affected by the presence of calcium ions, whilst the more mobile systems (*e.g.*, lecithin and saponin) coarsened rapidly. Similar results were obtained with hydrochloric acid. In general, those agents which form very viscous emulsions or gels at ordinary temperatures give coarse stable emulsions, but if the conditions cause a decrease in viscosity (*e.g.*, heat) or a gel–sol transformation the emulsion deteriorates immediately (*e.g.*, agar agar at 85° C.). They conclude that the efficiency of these emulsifying agents is due to their power of forming a solvated membrane of considerable strength at the oil–water interface, whilst a considerable amount remains in the dispersion medium.
H. G. W.

1610. Patent on Asphalt and Bitumen. V. L. Shipp, A. H. Boenau, and J. W. Ramsay. U.S.P. 2,215,074, 17.9.40. Appl. 21.3.40. Production of an asphaltic material of relatively low temperature susceptibility and high ductility by selecting a bituminous material comprising a substantial amount of asphaltic matter and oil of relatively low viscosity index.
H. B. M.

Special Products.

1611. Patents on Special Products. National Oil Products Co. E.P. 526,699, 24.9.40. Appl. 23.3.39. Production of sulphonated fatty materials which includes subjecting a washed and neutralized sulphonated animal or vegetable oil, fat, or fatty acid to dehydration under reduced pressure.

Wingfoot Corporation. E.P. 526,743, 25.9.40. Appl. 16.2.39. Preparation of carbon sulphoselenide by reacting hydrogen selenide with an aryl isothiocyanate or an aryl thiourea and afterwards separating the resulting carbon sulpho-selenide.

Winthrop Chemical Co. E.P. 526,747, 25.9.40. Appl. 2.3.39. Manufacture of a new water-soluble sulphonamide compound by condensing *p*-aminobenzene-sulphonamide with maltose in the presence or absence of a trace of ammonium chloride.

B. E. D. Kilburn. E.P. 526,960, 30.9.40. Appl. 24.3.39. Production of sulphonated fatty materials by dispersing a crude sulphonation mass consisting of sulphonated animal, vegetable or marine oil, fat or fatty acid, in at least an equal volume of a substantially anhydrous organic solvent. Subsequently the sulphonation mass is neutralized, the inorganic salts precipitated, and the solvent and residual moisture removed by distillation.

F. Hoffmann-La Roche & Co. A.G. E.P. 527,006, 30.9.40. Appl. 18.3.39. Production of trimethyl-hydroquinone monophytyl ether by reacting a phytyl halide with trimethylhydroquinone in approximately equimolecular proportions in the presence of an alkali.

Imperial Chemical Industries, Ltd. E.P. 527,317, 7.10.40. Appl. 4.4.39. Manufacture of thiolactams by reacting hydrogen sulphide with a primary monoaminomononitrile.

E. I. Du Pont de Nemours. E.P. 527,366, 8.10.40. Appl. 5.4.38. Preparation of a viscous hydrocarbon oil having incorporated therein a small proportion of at least one heterocyclic compound of specific formula.

T. L. Cantrell and J. S. Stockhardt. U.S.P. 2,214,875, 17.9.40. Appl. 25.6.38. Preparation of an oil-soluble organic compound suitable for use as an improvement agent for hydrocarbon oils. The compound is prepared by reacting an olefine and a phenol in the presence of a catalyst and treating at least a portion of the resultant product with a phosphorous oxychloride in the presence of a catalytic amount of phosphorus sesquisulphide.

W. H. King. U.S.P. 2,215,472, 24.9.40. Appl. 2.4.40. Production of partly oxidized products of normally liquid aliphatic hydrocarbons by introducing the hydrocarbons in vapour phase, together with an oxidizing agent, into a reaction chamber at a temperature of 250–500° C. The materials are then reacted for 15 secs. in the presence of tetraethyl lead, the reacting materials removed, together with the reaction products, from the chamber while still in vapour phase, and the unreacted hydrocarbon and oxidation products condensed under non-reacting conditions.

W. H. King. U.S.P. 2,215,473, 24.9.40. Appl. 2.4.38. Production of partly oxidized products of normally liquid aliphatic hydrocarbons by introducing the hydrocarbons in vapour phase, together with an oxidizing agent, into a reaction chamber at 250–500° C. and reacting the materials for a period not exceeding 15 secs. in the presence of copper oleate.

W. H. King. U.S.P. 2,215,474, 24.9.40. Appl. 2.4.38. Production of partly oxidized products of normally liquid aliphatic hydrocarbons by introducing the hydrocarbons in vapour phase, together with an oxidizing agent, into a reaction chamber at 250–500° C. and reacting the materials for a period not exceeding 15 secs. in the presence of nitrobenzene. H. B. M.

Detonation and Engines.

1612.* Progress in Light Aircraft Engines. C. F. Backle. *J. Soc. aut. Engrs*, 1940, **46**, 243–249.—Progress in the production rate of light aircraft in the last few years indicates that the 1940 production will be double that of 1939 if the recent rate of increase is maintained, which would give a figure of about 6,500 aircraft in the present year. Two types of light aircraft are the most popular—viz., the 50-h.p. class and the higher performance types up to about 90 h.p. Details are given of the means adopted to increase the output of one 50-h.p. engine, which ran at 1900 r.p.m. with 65 octane fuel and 5·4–1 compression ratio, to 90 h.p. running at 2700 r.p.m. with 80 octane fuel and 7·5–1 compression ratio. This entailed modification of cylinder-head design, exhaust valves and seats, pistons and rings, valve mechanism, and fuel injection equipment. A detailed discription of the fuel injection equipment is given, and the merits of fuel injection are dealt with. C. H. S.

1613.* Engine Deposits—and the Effect of some Fuel Additives. J. A. Moller and H. L. Moir. *J. Soc. aut. Engrs*, 1940, **46**, 250–261.—This article describes apparatus used and procedure followed in extensive tests made to examine the manner in which fuel-residue deposits are built up and dispersed, and the effect of various fuel additives on such depositions. The data obtained on a number of engines of various types were found to be relatively comparable, and for the sake of brevity the result from one engine and from one type of additive only are dealt with in detail. A laboratory apparatus for determining gum-solvency effect of additive compounds is described which consists of a carburettor connected to an electrically heated chamber in which is placed a plate with a known weight of gum. Fuel is drawn through this chamber and condensed, the collecting flank being connected to a vacuum line. The "gum solvency" properties of the fuel are determined by loss of weight of the coated plate.

To facilitate the examination of engine deposits at frequent intervals during a test, special pistons with removable heads were used.

Many photographs are reproduced which show how the engine deposits build up in wave-like formations and become dispersed, the dispersal presumably being due to mechanical blowing away of loosened particles, or to burning of the deposit because it had lost its ability to dissipate heat after severing its bond with the metal. The effect of varying load and speed is dealt with at some length.

Road tests were made to determine the effect of deposits on octane-number requirement of various cars over extensive mileages with and without additives in the fuel.

It is shown how carbon deposits reach equilibrium conditions and how the use of the proper quantity and type of additive makes it possible to obtain and maintain minimum deposition, with consequent improvement in engine condition. C. H. S.

1614.* Status of Fuel Performance Tests in Aviation Engines. R. F. Gagg. *J. Soc. aut. Engrs*, 1940, **46**, 271–272.—The author contends that single-cylinder engines using full-size cylinders often give misleading results in rating aviation fuels because of unavoidable dissimilarity in the single-cylinder and multi-cylinder operation, and thinks that such test units should be employed only as a pilot for full-scale testing until the results of the two kinds of tests are in substantial agreement and are validated by actual service experience. The procedure for detonation rating tests of fuels in aircraft engines already developed by the Co-operative Fuel Research groups has proved quite satisfactory for measuring fuel characteristics at cruising powers, but it seems clear that no fuel test or comparison at a single power-output level can provide all the information needed to judge its qualities for take-off operation. To make a series of test runs similar to the cruising rating test, but at increasing power output values, is slow and cumbersome, although it would supply the necessary data. A procedure is outlined and actual test data are given showing results obtained by running only the " end-points " of the mixture control runs previously mentioned. In these tests the throttle is gradually opened with other engine conditions held constant until the fuel begins to exhibit signs of distress. The procedure is repeated at various mixture strengths, and curves are thus established showing maximum permissible power outputs at varying mixture strengths. This type of test does differentiate between fuels for use at take-off power conditions, a result which cannot be accomplished by the single test used for cruising rating. C. H. S.

1615. Criterion for Knock in Petrol Engines. R. C. Plumb and A. C. G. Egerton. *J. Instn. Mech. Engrs*, Sept. 1940; *Proc.*, 1940, **143** (4), 247–260.—The customary methods of rating fuels for their knocking characteristics—*i.e.*, by determining their highest useful compression ratio or by comparing them with standard reference fuels—are depending on standardized engine conditions; the results are not always valid for widely different engine conditions. The authors' problem was to correlate the knocking tendency of a fuel with the physical conditions in the cylinder which cause the knock, and with its ignition qualities in a bomb. The method of approach was to find a function of the physical conditions, such that the attainment of a critical value during the stroke by this function would be a criterion of knock. This critical value should depend solely on the fuel–air mixture used, and be entirely independent of engine conditions. Consideration of the physical conditions affecting the tendency of the end-gas to knock at any instant t leads to the conclusion that the criterion should be of the form : (amount of peroxides present) × (some function of the physical conditions at the instant t).

Engine tests were made on two blends of technical *iso*-octane and *n*-hexane, and on a commercial gasoline. The octane numbers were 57, 81, and 75, respectively. The engine used was a single-cylinder unit; the compression ratio was varied in steps between 4·9 and 8·23 : 1. Knocking conditions were detected by means of a cathode-ray oscillograph. The method of test was to determine a series of operating conditions—compression ratio, air–fuel ratio, etc.—which would cause incipient knock; for each set of conditions indicator diagrams were recorded photographically.

The form finally selected for the criterion was

$$F = \rho P \int_0^t r(P - P_0)dt,$$

where ρ denotes mean gas density in the cylinder at time t from the start of reaction, P the absolute pressure at time t, r the surface/volume ratio at time t, and P_0 the absolute pressure at which reaction, leading to the formation of peroxides or other intermediate products, starts. The method of evaluating F is explained; it is shown that, for each fuel under conditions of incipient knock, the maximum value of F approaches a constant independent of the running conditions. In another engine the numerical values would be different, but the form probably very similar. The accuracy of the calculation and of the form of the criterion are discussed. It is suggested that this work may be a step towards the establishment of a more rational method of knock rating.

Ignition experiments in a bowl indicated that the same critical value of the same function is a criterion of auto-ignition, and they suggested a similarity between the mechanism of knock in an engine and auto-ignition in a bomb. K. A.

1616.* Oil Filtration. A. H. Stuart. *Auto. Engr*, 1940, **30** (399), 213.—The theoretical considerations of a filter are first dealt with, the effect of viscosity, etc., pressure, and fineness of mesh being noted. Filtering efficiency without qualification is stated to be meaningless, as in general a compromise has to be struck between rate of filtering and the degree of removal of unwanted material. Even although a used I.C. engine oil has been filtered and "looks like new," much unwanted and harmful material is left behind. A description is given of possible contaminants, particularly those which are not in general removed by filters—namely, those caused by high-temperature reactions at the cylinders walls or on the pistons.

Considering the types of filters in use, it is shown that an increase in pressure will not always cause an increase in the rate of filtration, and may even cause a considerable reduction. Gauge, edge, and cloth type filters are discussed, as well as those using paper. The surface action of filter papers is dealt with, and an experiment is described showing how important is the p_H of the filter in relation to the filtering power of the unit—*i.e.*, whether it causes flocculation or not. This surface action is particularly noticeable in filters incorporating Fuller's earth or activated charcoal. Although the oil from these units may appear extremely clean, it is pointed out that actually this may be undesirable, as active constituents, especially added to the oil, may have been removed. It may be argued that once this surface activity is satisfied, no more adsorption can take place; experiments with oilclay have shown, however, that even after repeated circulation through the filter the surface action continues to remove decreasing amounts of the graphite at each circulation. The rate of filtration in this experiment actually increased with increasing time in circulation.

Lubrication experts are endeavouring to increase the usefulness of lubricants by incorporating small amounts of active ingredients; on the other hand, certain filters are being designed to "refine" the oil in the crankcase. Unless some co-operation can be achieved between these antagonistic endeavours, further improvements in lubricating oils will be obstructed. Recent papers have dealt with this subject, and stressed the danger of some types of filters removing essential additions. It would appear that the best results would be achieved by the use of a full-flow filter with the minimum of absorptive properties combined with frequent renewals of the oil. In the latter connection it has been shown that the bearings of engines operating with frequent renewals of oil were in better condition than those using less frequent changes but more efficient filtration. H. L. W.

1617.* Road Performance of Gasoline Obtained in Laboratory Tests. Anon. *Nat. Petrol. News*, 29.5.40, 32 (40), R.202. *Abstracts of Paper by H. G. Smith at 10th Mid-Year Meeting of A.P.I. at Fort Worth* 30.5.40.—A full-scale engine-laboratory test method for indicating the average road performance or road octane numbers is being expanded to larger use after 3 years of experimental work which has indicated the reliability of the method. The method is known as the A.I.L. (acceleration-inertia-load) test. Studies already carried out indicate that a reduction of the cooling-water exit temperature is accompanied by a decrease in the octane-number requirement, whilst a substitution of water for dilute alcohol as the cooling medium has the reverse effect, owing to the decreased heat capacity of alcohol. Empirical formulæ for converting octane numbers (A.S.T.M./C.F.R.) into A.I.L. ratings are given. The conversions involve the acid-heat value (A.S.T.M.). H. G.

Economics and Statistics.

1618. Petroleum Statistics, 1935–38. G. R. Hopkins. U.S. Bureau of Mines, Economic Paper 20.—G. R. Hopkins, Assistant Chief Economist of the Petroleum Economics Division, U.S. Bureau of Mines, provides a useful history of petroleum statistics of the United States. There are also particulars of the form in which they are now presented, and of the sources from which they are derived. Prior to 1925 statistics were collected by the Geological Survey. On 1st July, 1925, the work was transferred to the Bureau of Mines. The historical development can be summarized as follows :—

1882.—Annual figures of crude-oil production by States and fields published by Geological Survey. Subsequently fewer and fewer figures by fields became available, owing to difficulties of obtaining details of pipe-line runs; data are now limited to a few of principal fields.

1883.—Pipe-line stocks, back to 1871, first published.

1917.—Bureau of Mines commenced statistics of refined products (production and stocks). This was primarily a military measure.

1921.—Data on producing wells published by Geological Survey. Subsequent information is obtained from *Oil & Gas Journal*, *Standard Oil Bulletin* and American Petroleum Institute.

1925.—Bureau of Mines took over Geological Survey statistical work. Tables of supply and demand for all oils first published. Statistics of imports and exports obtained from Bureau of Foreign and Domestic Commerce.

1926.—Annual figures of fuel-oil distribution started.

1927.—Figures first published of production of gasoline by cracking.

1933.—First issue of *Minerals Yearbook*, in which all petroleum statistics were assembled.

1934.—First figures obtained of crude-oil stocks by States of location, subsequently incorporated in weekly figures.

1939.—Bureau of Foreign and Domestic Commerce established new classifications for import and export data, which agree more closely than previously with Bureau of Mines classification.

Each of the series of statistics referred to above is illustrated in the paper by monthly and annual figures relating to the years 1935–1938. S. J. A.

1619.* Crude Petroleum and Petroleum Products. A. G. White, G. R. Hopkins, and H. A. Breakey. U.S. Bur. of Mines. Chapter (preprint) from *Minerals Yearbook*, 1940, Review of 1939, with Final Statistics for 1938. 100 pp. 15 cts.—The chapter on crude petroleum and petroleum products to be included in the *Minerals Yearbook* for 1940 has already appeared as a separate publication. Apart from detailed statistics on reserves, supply, demand, production, consumption, and prices of crude petroleum and refined products, it contains some interesting data in summary form.

In 1939 world production of crude petroleum amounted to 2077 million barrels, and represented an increase of 38 million barrels over the previous peak figure attained in 1937. The United States was responsible for 61% of the world total, as in previous years, but there were increases of 18 million barrels in Venezuela, 4 million barrels in Netherlands Indies and 8 million barrels in Soviet Russia. Production in Rumania again declined, and was 15 million barrels less than in 1935.

Incidence of the war in September 1939 had less effect on the oil industry in the United States than had been anticipated, although the last quarter of that year was characterized by a very active fuel-oil market. The fact remains, however, that large foreign war demands did not materialize, and, in consequence, there was at that time a large excess production of gasoline.

Changes in regard to world oil consumption due to war conditions were somewhat clarified during the first quarter of 1940, it then becoming apparent that much of the increase in war demands could be offset by restrictions of civilian consumption. As far as the United States were concerned, certain important markets were cut off by blockade ; exports to many neutral countries were reduced and legislative restrictions affecting movement of American ships into war zones diverted the demand for oil to other sources. Thus total exports were approximately 23% less in the first quarter of 1940 than in the same quarter of 1939.

The total demand for oils in 1939 of 1418 million barrels established a new record, and was about 75 million barrels higher than the previous peak figure attained in 1937. Domestic demand largely accounted for the increase, it being 92 million barrels greater in 1939 than in 1938. H. B. M.

1620. Natural Gas. F. S. Lott and G. R. Hopkins. Chapter (preprint) for *Minerals Yearbook*, 1940. U.S. Bur. of Mines.—The estimated consumption of natural gas in the United States during 1939 was $2{\cdot}435 \times 10^{12}$ cu. ft. This was 6% more than in 1938. Conspicuous increases occurred in Pennsylvania, Ohio, and West Virginia, in consequence of expansions in the steel and related industries, induced by the European war. The average value at points of consumption was 22 cents per thousand cubic feet.

A brief review is given of legislation, employment, completed and producing gas-wells, and a more detailed account of exploitation in different fields and of pipe-line developments. Following an analysis of principal consumers, it is stated : " Among recent applications of natural gas to industrial processes may be mentioned the production of inert atmospheres from products of gas combustion. These inert gases are useful in the manufacture and storage of a number of materials, notably paints and varnish, to prevent or reduce oxidation. The greatest potentialities for the future, however, are indicated by new chemical techniques and discoveries that will utilize natural gas as a raw material. The manufacture of such bulk products as fabrics, a variety of plastics and synthetic rubber is emerging on a commercial scale."

Reference is made to U.S.B.M. Circular 7108, H. M. Smith on Utilization of Natural Gas for Chemical Products. (See Abstract 923, Oct. 1940.) S. J. A.

1621. **Natural Gasoline and Liquefied Petroleum Gases.** G. R. Hopkins. Chapter (Preprint) from *Mineral Yearbook,* 1940. U.S. Bureau of Mines.—The production of natural gasoline in U.S.A. during 1939 was about 3% less than in 1938. This was largely accounted for by diminution of exports. No spectacular advances in established production methods are reported, but use of the re-cycling process continues to expand rapidly. Much progress was also made in producing high-octane gasoline from the lighter hydrocarbons.

The demand for liquefied petroleum gases continued to increase. Approximately equal proportions of propane, butane, and propane–butane mixtures are sold. Domestic uses account for about 40% of consumption. Pentane is principally used in chemical manufactures. An appreciable quantity (30,000,000 gal.) is used as motor fuel.

S. J. A.

ERRATUM

Abstracts Nos. 1093 *and* 1257. For Slater read Sclater.

PUBLICATIONS RECEIVED.

Cylinders for Compressed Gases (Fuel for Motor Vehicles). Regulations of Home Department, issued 18 Nov. 1940. Statutory Laws and Orders, 1940, No. 2009. H.M. Stationery Office, 3*d*.

These Regulations apply to cylinders containing coal gas, carbon monoxide, hydrogen, or methane, when fitted to a motor vehicle for use as fuel. The General Specification requires that such cylinders be solid drawn or made from seamless steel tube, by an approved cylinder manufacturer. Detailed Specifications refer to two types as under :

	Specification A.	Specification B.
Mark.	GP.	GPM.
Maximum working pressure for which cylinder is designed.	3000 lb. sq. in.	1800 lb. sq. in.
Thickness of cylinder walls (" *t* ").	0·035 *D*,	0·03 D,
	where *D* is ext. diam. in inches.	
Tensile test (on material of finished cylinder) :		
Yield stress.	Not less than 45 tons sq. in.	Not less than 26 tons sq. in.
Ultimate stress.	Not less than 55 tons sq. in.	42 to 48 tons sq. in.
Elongation.	Not less than 7%.	Not less than 15%.

Chemical composition, notched-bar tests, and bend tests are specified.

In addition, each completed cylinder shall be subjected to a hydraulic stretch test, preferably by the water-jacket method. The proof pressure for Specification A cylinders is 4500 lb. per sq. in.; for Specification B cylinders 1⅔ times the designed working pressure. For Specification A cylinders one in every 200 shall be hydraulically tested to destruction (minimum bursting pressure : 7800 lb. per square inch).

At the time of filling, the gases must be free from hydrogen sulphide, and the interior of the cylinder free from oil, grease, grit, etc. Cylinder valves must be of forged steel, brass, or bronze, in accordance with the Third Schedule of these Regulations. Provision is also included for marking and painting, fusible plugs, or bursting discs, and for re-testing at intervals of not less than one year.

British Standard No. 789A–1940 : Steel Tubes and Tubulars—Light-weight and Heavy-weight Qualities. (Revised Weights.) Pp. 23, British Standards Institution, 28, Victoria Street, London, S.W.1. Price 2*s*. net.

A War Emergency British Standard Specification, to meet the urgent need for the utmost economy in the consumption of steel, superseding B.S. No. 789, and prepared at the request of the Ministry of Supply.

The specification provides for the replacement of the three qualities of tube provided in B.S. No. 789—namely, gas, water, and steam qualities—by two qualities designated respectively " light weight " and " heavy weight." The " light-weight " quality is one gauge lighter than the " gas " quality of B.S. 789, and the " heavy-weight " is the same gauge as " water " quality of B.S. 789.

The specification incorporates changes to clauses in B.S. 789, and among the clauses affected are those concerning : percentage of lengths joined together, tolerances, hydraulic test, marking for indication of quality and longscrews.

Dimensions of sockets are unaffected.

British Standard No. 902-1940 : Methods of Testing Latex, Raw Rubber and Unvulcanized Compounded Rubber. Pp. 29, British Standards Institution, 28, Victoria Street, London, S.W. 1. Price 3*s*. 6*d*. net.

The British Standard Methods of Testing Latex, Raw Rubber, and Unvulcanized Compounded Rubber have been based on those of the London Advisory Committee for Rubber Research (Ceylon and Malaya) and those of the Research Association of British Rubber Manufacturers as published in *Rubber, Physical and Chemical Properties*.

The methods of testing latex—*i.e.*, a suspension or emulsion of rubber globules in a water liquid or serum—cover sampling, analysis, and colour measurement. A standard colour chart (containing one substantially white shade, three grey shades, and one yellow shade) is included in the specification.

The methods applicable to raw rubber—*i.e.*, the crude material obtained on coagulation of latex, and found in sheet, crepe, lump and powder forms—and to unvulcanized compounded rubber—*i.e.*, the mixtures obtained from raw rubber by the incorporation of various ingredients, cover chemical analysis and physical test.

These methods require reference to British Standards Nos. 381, 410, 612, 627, and 902.

Tests for ammonia content and stability of latex and a vulcanization test for the evaluation of raw rubber are under consideration for incorporation in a future edition of these methods.

INSTITUTE NOTES.

December, 1940.

MEMBERS SERVING WITH H.M. FORCES.

Corrections and additions to the first list of members serving with H.M. Forces, published in the October *Journal*, are given below. The Secretary will be pleased to receive additional information from time to time.

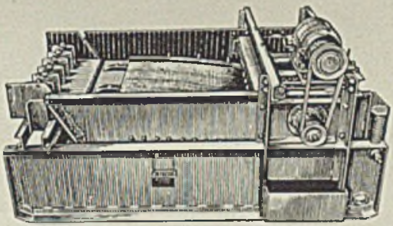
Adlington, R. E., promoted Major, R.A.
Rowntree, W. B., promoted Major, R.A.S.C.

Brooking, M., Flying-Officer, R.A.F.
Caplan, B., R.A.F.
Ellis, D. W. V., Lieut., S.A.E.C.
Evans, F. N. S., Lieut., R.A.S.C.
Newton, E. J., Sergeant, R.C.Sig.
van Sickle, R. K., Major, R.E.
Watling, R. A., Corporal, R.E.

AWARD OF SCHOLARSHIP.

The Institute scholarship of £40 per annum, tenable at the University of Birmingham, has been awarded to Alan Henry Baldwin, Stud. Inst. Pet., at present studying in the Department of Oil Engineering and Refining.

ARTHUR W. EASTLAKE,
Honorary Secretary.



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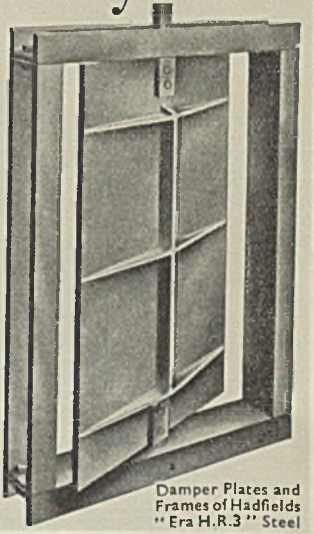

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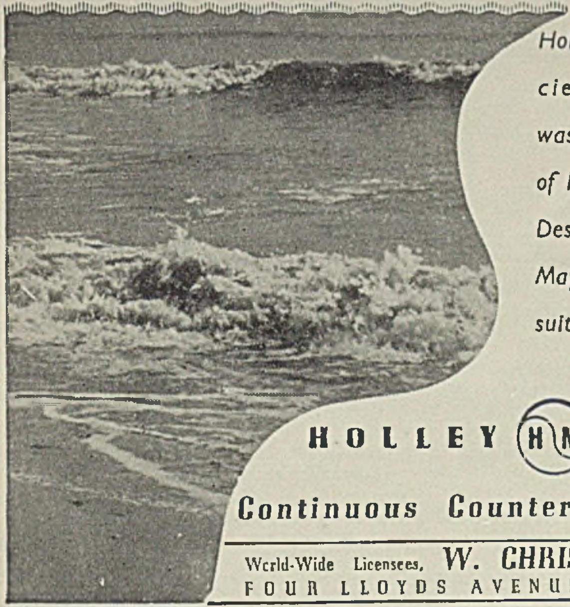

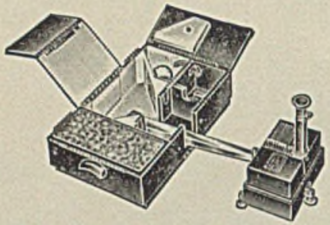

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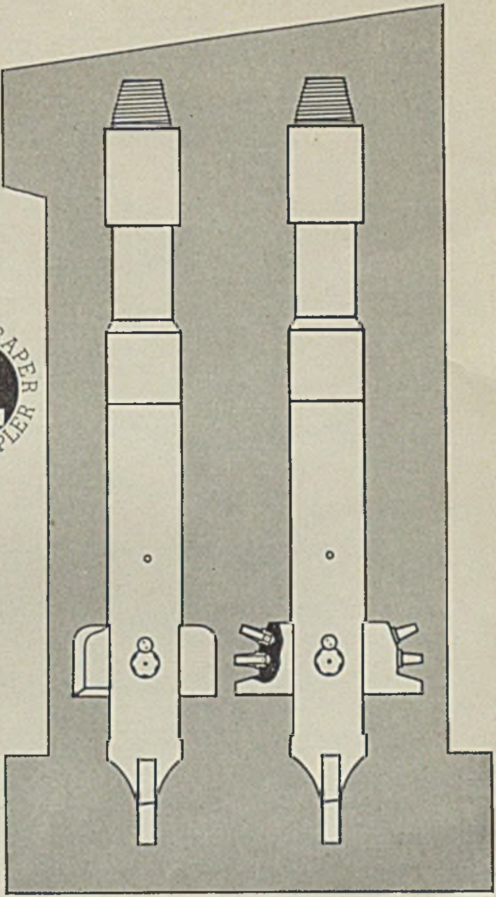

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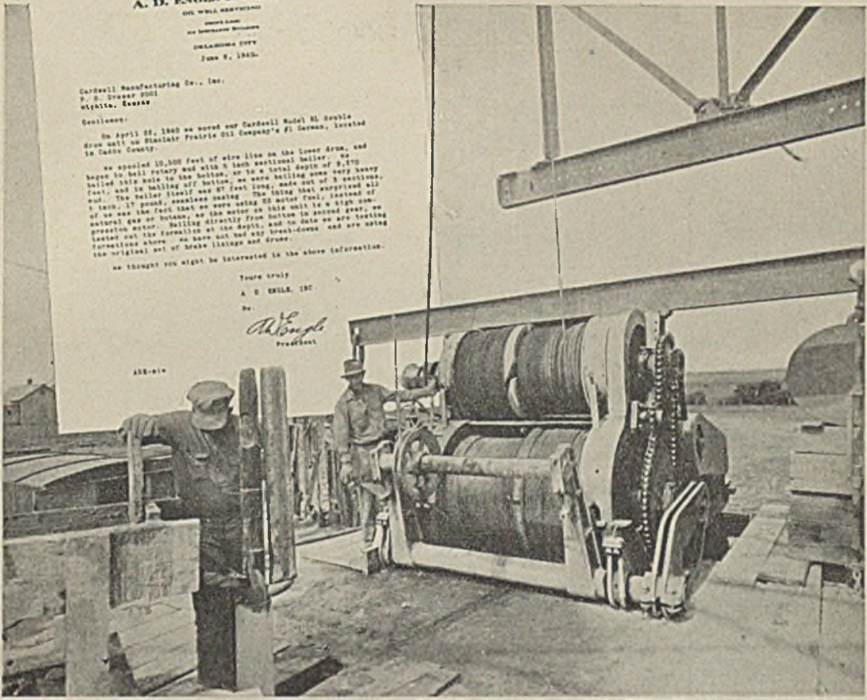

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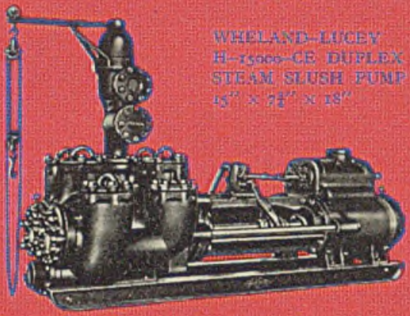

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