

COMPACTION AND SOME OILFIELD FEATURES.*

By G. D. HOBSON.

SOME years ago Ortenblad⁸ made a mathematical study of the problem of compaction in a sediment, and it seems to be of interest to apply his equations, together with certain modifications and allied considerations, to some of the oilfield features which may be connected with compaction. Qualitative and also *speculative* quantitative applications appear to be practicable, although obviously it is to the order of the latter results in most instances, rather than to the actual numerical values, that the most weight must be attached, due, among other factors, to the uncertainty concerning the degree of precision of the basic data used in the computations. However, the present deductions may lead to further calculations based on more accurate data on the physical constants of the sediments for a given set of circumstances, and also to the adduction of data concerning the various oilfield features to support, supplement, or contradict the deductions.

DEFINITION OF SYMBOLS.

w = hydrodynamic pressure, the pressure causing flow of the compaction fluids (gm./cm.²).

p = intergranular pressure (gm./cm.²).

h = reduced thickness of the compacting series, *i.e.* the thickness when the porosity is zero.

z = reduced height of a point, measured from the base of the compacting series.

γ = the apparent density in water of the sedimenting grains, *i.e.* the true density minus 1. Here γ is given the value of 1.7.

q = the rate of sedimentation expressed in grams weight in water/sq. cm./year.

$a = -\frac{dp}{d\varepsilon}$ = the modulus of compression.

k = permeability of the sediment (cm./year).

$c = \frac{k}{a}$. Terzaghi's experiments⁹ showed c to be practically constant, and here constancy is assumed unless otherwise stated.

e = base of Napierian logarithms.

$b = \frac{q}{\gamma c} = \frac{qa}{\gamma k}$.

H = true thickness of the deposit.

T = time, in years, which has elapsed since the cessation of deposition.

P = average porosity of the surface sediments, expressed as a fraction.

ε = the voids ratio—the ratio between the volume of voids and the volume of solid matter.

The significance of other symbols is explained where they are first employed.

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SOME OF THE FACTORS INVOLVED IN THE COMPACTION PROCESS.

In his mathematical investigation of the compaction process, Ortenblad dealt with a deposit of uniform grain-size range, laid down at a constant rate, and he also examined cases where a more permeable or a less permeable layer was incorporated, or where there was a load of more permeable sediment. He discussed two stages in the compaction process : (a) a stage during which sediment is being deposited, and (b) an ensuing stage during which compaction continues without further deposition. It was assumed, in formulating the basic equations, (1) that the permeability is constant, and (2) that it is a function of the degree of compaction. After investigating the first stage according to each of these assumptions, Ortenblad found, to his own surprise, that for the example which he examined numerically on the basis of his equations, the results were not significantly different, and he therefore concluded that the same would probably be true for the second stage. Consequently, he did not attempt to solve the differential equations for the second stage, using the assumption of changing permeability, and these equations seem likely to be soluble only with difficulty, if at all. It must be noted, however, that the thickness of the deposit in his numerical example was only 50 m.

In Ortenblad's investigation the water was assumed to be expressed by viscous flow alone, and no allowance was made for the change of the viscosity of water with depth of burial as a result of the increase in temperature and pressure. This was fully justifiable in the examples which he worked out numerically.

At temperatures below 30° C. the viscosity of water decreases with increased pressure up to about 1000 atmospheres, and increases thereafter, but above 30° C. there is a continuous increase of viscosity with increased pressure. The viscosity decreases with rise in temperature at a given pressure, and altogether it would appear that the viscosity of water will decrease continuously with increased depth of burial, due to the combined effects of rising temperature and pressure at small depths, and to the probable domination of the pressure factor by the temperature factor at greater depths.* The same remarks probably hold true for the saline waters which are likely to be present in the sediments. This decrease in viscosity is equivalent to an increase in permeability, thereby rendering Ortenblad's first assumption regarding permeability, in effect, more nearly correct than it would be otherwise. It is possible, however, that in very fine pores the viscosity of water may differ from the value for water in bulk. Terzaghi believes that the viscosity is higher in fine pores,† and his

* Hubbert's calculations (*J. Geol.*, 1940, 48, (8), 785) on the effect of depth of burial on the viscosity of water give the viscosity at a depth of 3000 m. as 0.284 centipoises if the viscosity at a temperature of 10° C. at the surface is 1.308 centipoises.

† In a stable paste under a pressure of 8 kg./cm.² the water films associated with clay particles may be about 3×10^{-5} cm. thick (F. H. Norton and F. B. Hodgdon, *J. Amer. Ceram. Soc.*, 1932, 15, 191), and Houwink ["Elasticity, Plasticity, and Structure of Matter" (Cambridge University Press, 1937)] considers that the viscosity of water in these films may be normal. He quotes experiments by Bowden and Bastow (*Nature*, 1935, 135, 828) on the flow of water between glass plates about 10^{-5} cm. apart, in which experiments the viscosity of the water was the same as that of water in bulk. This separation is of the same order as the maximum separation at which the viscosity increase begins to be appreciable according to Terzaghi's equations.

equations,¹¹ one of the attempts to express this difference quantitatively, give .

$$v_0' = v_0 \left(1 + \frac{6.02 \times 10^{-42}}{s^8} \right) \text{ to } v_0 \left(1 + \frac{2.42 \times 10^{-43}}{s^8} \right)$$

[v_0 = normal viscosity of water ; v_0' = viscosity of water in a slit $2s$ cm. in width] and show no appreciable increase in viscosity until s becomes about 0.00001 cm., but the viscosity increases very quickly for smaller values of s , being $4.58v_0$ for $s = 0.000006$ cm. If there is a viscosity increase of this nature it may affect the results considerably, for it would reduce the rate of loss of water, and so cause the porosity to be high, and at the same time it would defer the date at which compaction ceased.

The loss of water in the later stages of compaction may be wholly or largely by processes other than normal viscous flow, probably including the taking up of water in hydration or mineral transformation, which may make the pressure decay and compaction more rapid than might otherwise be the case, except in so far as a possible concomitant reduction in pore volume, by increase in size of the grains, hinders the passage of free water through the pores.

The conditions obtaining during the formation and compaction of any considerable thickness of sediments such as occur in oilfields are much more complicated than was assumed in Ortenblad's investigation, for there is usually an alternation of coarse and fine beds (highly permeable and less permeable beds); the rates of sedimentation may vary even during the deposition of a relatively thin section; there may be periods of non-deposition or erosion; the beds may not be of uniform thickness, and lateral variation or tilting may provide paths for fluid exit which markedly disturb the general vertical flow in some localities; the surface on which deposition starts may be irregular and/or permeable, and folding may take place. Furthermore, there are indications that even in a seemingly fairly uniform mass of compacting beds, the water movement may be concentrated to some extent at certain points,⁷ rather than be uniformly distributed. Nevertheless, it is probably of value to note the broader inferences to be drawn from Ortenblad's final equations, inferences which agree with conclusions reached without recourse to rigid mathematical analysis.

GENERAL INFERENCES FROM ORTENBLAD'S EQUATIONS.

(1) For sediments of identical grain size, but for different rates of sedimentation, those being laid down most slowly will be most compact.

(2) After sedimentation ceases the hydrodynamic pressure at a given point, *i.e.* the pressure component driving liquid from the sediment, and also the porosity at that point decrease with time, comparatively rapidly at first, and then more and more slowly. As the hydrodynamic pressure decreases the intergranular pressure increases correspondingly.

(3) At a given reduced depth the porosity in a thick deposit will be greater than at the same depth in a thinner deposit, until compaction ceases.

Hence, it seems likely that unless compaction is complete soon, in geological terms, as assumed by Hedberg, a single depth-porosity relationship cannot be expected if the ages, thicknesses, and rates of sedimentation

of the series differ, even though they may be identical in all other respects. The older and/or more slowly deposited or thinner series will be the more compact.

RESERVOIR PRESSURES.

For the base of a deposit Ortenblad's equations give :

$$w = \gamma h - \frac{\gamma}{b} \left(1 - \frac{1}{e^{bh}} \right)$$

when sedimentation is just complete. Therefore, as the permeability approaches zero, the hydrodynamic pressure, w , will approach, by increasing, the ultimate value of γh . Consequently, the maximum pressure attainable at the base of a compactible series is $\gamma h + H$, the density of water being taken as unity. Thus the theoretical maximum pressure attainable is somewhat greater than the weight of the rock solid, for that is $h(\gamma + 1) = \gamma h + h$, and since $H > h$, $\gamma h + H > \gamma h + h$.

Similarly, as h increases, or as the rate of sedimentation increases, w again approaches the limiting value of γh . Since the ratio $\frac{H}{h}$ decreases as h increases, the relative excess of the actual pressure over the rock weight decreases, i.e. $\frac{\gamma h + H}{\gamma h + h}$ approaches unity by decreasing.

TABLE I.

Hydrodynamic Pressure and the Rate of Sedimentation.

$a = 0.00024 \text{ cm.}^5/\text{gm.}$; $k = 0.25 \text{ cm./yr.}$; $h = 5880 \text{ m.}$

| | Rate of sedimentation 0.2 gm./cm. ² /yr. 5,000,000 years of sedimentation. | Rate of sedimentation 0.02 gm./cm. ² /yr. 50,000,000 years of sedimentation. |
|---|--|--|
| w —hydrodynamic pressure at end of sedimentation | 985 kg./cm. ² | 850 kg./cm. ² |

TABLE II.

Hydrodynamic Pressure and Compressibility or Variation in c .

$q = 0.02 \text{ gm./cm.}^2$; $k = 0.25 \text{ cm./yr.}$; $h = 588 \text{ m.}$

| Compressibility a . | $c = \frac{k}{a}$. | Hydrodynamic pressure. |
|-------------------------------|---------------------|---------------------------|
| 0.00012 cm. ⁵ /gm. | 2083 | 15 kg./cm. ² |
| 0.00048 „ | 521 | 45 „ |
| 0.00192 „ | 130 | 81 „ |

Ortenblad's equation for the hydrodynamic pressure after any period T subsequent to the commencement of the second stage of compaction is approximately :

$$w = \frac{16\gamma h^2 b}{\pi} \cdot \frac{\frac{2hb}{\pi} + e^{-bh}}{4h^2 b^2 + \pi^2} \cdot e^{-\frac{c\pi^2}{4h^2} T} \cdot \sin \frac{\pi}{2h} (h - z)$$

This is the first term of a rapidly converging series, and for the base of the deposit it reduces to :

$$w = \frac{16\gamma h^2 b}{\pi} \cdot \frac{\frac{2hb}{\pi} + e^{-bh}}{4h^2 b^2 + \pi^2} \cdot e^{-\frac{c\pi^2}{4h^3} T}$$

w decreases exponentially for a given deposit as T increases, and the above equation may be re-written as $w = Xe^{-KT}$, where

$$X = \frac{16\gamma h^2 b}{\pi} \cdot \frac{\frac{2hb}{\pi} + e^{-bh}}{4h^2 b^2 + \pi^2} \text{ and } K = \frac{c\pi^2}{4h^3}.$$

The more accurate relationship for w may be written in a contracted form as :

$$w = X_1 e^{-KT} + X_2 e^{-9KT} + X_3 e^{-25KT} + \dots$$

so that w , the hydrodynamic pressure, is the sum of a series of terms which decrease exponentially as the time, T , increases.

TABLE III.*

The Decay of the Hydrodynamic Pressure at the Base of a Sedimentary Series after the Cessation of Deposition.

$$a = 0.00024 \text{ cm.}^5/\text{gm.}; \quad q = 0.02 \text{ gm./cm.}^2/\text{yr.}$$

| Number of years since end of deposition. | Hydrodynamic pressure. | | | |
|--|------------------------------|-------------------------------|------------------------------|-------------------------------|
| | Permeability 0.25 cm./yr. | | Permeability 0.025 cm./yr. | |
| | 5,000,000 yr. of deposition. | 50,000,000 yr. of deposition. | 5,000,000 yr. of deposition. | 50,000,000 yr. of deposition. |
| 0 | 27 kg./cm. ² | 770 kg./cm. ² | 77 kg./cm. ² | 810 kg./cm. ² |
| 5,000,000 | 0.7 " | — | 53 " | — |
| 10,000,000 | 0.02 " | — | — | — |
| 50,000,000 | — | 530 " | 1.9 " | 780 " |
| 100,000,000 | — | — | 0.05 " | — |
| 150,000,000 | — | 120 " | — | 730 " |
| 500,000,000 | — | — | — | 560 " |
| Reduced thickness | 588 m. | 5880 m. | 588 m. | 5880 m. |

* The hydrodynamic pressures given in Table III were computed by means of the approximate relationship: $w = Xe^{-KT}$. Consequently the values are lower than would have been obtained by using the more accurate relationship: $w = X_1 e^{-KT} + X_2 e^{-9KT} + X_3 e^{-25KT} + \dots$. The hydrodynamic pressure when sedimentation is just complete ($k = 0.25$ cm./yr.; $q = 0.02$ gm./cm.²/yr.; $h = 5880$ m.) is given as 770 kg./cm.² in Table III, whereas the hydrodynamic pressure calculated for the same conditions using the relationship $w = \gamma h - \frac{\gamma}{b} \left(1 - \frac{1}{e^{bh}}\right)$, is 850 kg./cm.² (Table I). However, when the first five terms of the relationship $w = X_1 e^{-KT} + X_2 e^{-9KT} + X_3 e^{-25KT} + \dots$ are used in the calculation, the hydrodynamic pressure is found to be 852 kg./cm.².

The pressures shown in Table III are the amounts by which the pressures at the base of the deposits (thickness listed) may exceed the hydrostatic head at the dates given.

The rate of deposition assumed in the computations for Table III is higher than some of the figures quoted by Holmes,³ but it is approximately that given by Jones⁴ for a Cambrian shale sequence. The value of a is that employed by Ortenblad, whereas lower values of k than those used by Ortenblad were selected. Terzaghi's figures¹⁰ for the permeability of clays at low liquid contents ranged from zero up to about 0.5 cm./year.

It is clear from Table III that even if Ortenblad's equation is only an approximation to the truth, there is a strong possibility that the pressures in the fluids deep down in a thick sedimentary series may be considerably in excess of hydrostatic, in spite of the fact that a long period of time may have elapsed since sedimentation ceased. For a sedimentary sequence 5880 m. in reduced thickness the hydrostatic pressure will exceed 588 kg./cm.², so that even after the lapse of 50,000,000 years, the pressure in the fluids at the base of a relatively highly permeable series may be of the order of 50% or more above hydrostatic.

GEOLOGICAL TIME SCALE (Moore⁵).

| | | | |
|-----------------------|------------------------|-------------------------|-------------------------|
| Pleistocene | 2×10^6 years | Triassic | 185×10^6 years |
| Pliocene | — | Permian | 223 " |
| Miocene | — | Carboniferous | 309 " |
| Oligocene | — | Devonian | 354 " |
| Eocene | 60×10^6 years | Silurian | 381 " |
| Cretaceous | 125 " | Ordovician | 448 " |
| Jurassic | 157 " | Cambrian | 553 " |

EFFECT ON HYDRODYNAMIC PRESSURE OF CHANGE IN PERMEABILITY WITH DEPTH.

If the permeability, k , instead of being constant, is simply related to the reduced depth, it is of interest to modify Ortenblad's differential equations accordingly, and then to obtain an expression for the intergranular pressure, from which the hydrodynamic pressure may be deduced, since $w = \gamma h - p$.

When k is variable, the fundamental differential equation is as follows :

$$\frac{\partial p}{\partial t} = -c \frac{\partial^2 w}{\partial z^2} - \frac{1}{a} \frac{\partial k}{\partial z} \cdot \frac{\partial w}{\partial z}.$$

Ortenblad obtained an approximate solution for this equation when $a = \frac{\alpha}{p + \beta}$ and $\frac{k}{a} = c$ (α and β are constants determined by experiment),^{8,9} but the final equation, involving p implicitly, is rather formidable.

(a) Suppose that an exponential relationship holds between the permeability and the reduced depth, so that $k_z = ke^{nz}$, where n is a constant and k_z , k and z are respectively the permeability at a given point, the permeability at the base of the deposit, and the reduced distance of the given point

above the base. On appropriately modifying the fundamental differential equation, solving and introducing the boundary conditions (that $p = 0$ when $z = h$, and that $\frac{dw}{dz} = 0$ and $\frac{dp}{dz} = -\gamma$ when $z = 0$), the following relationship was obtained:

$$p = \frac{\gamma^2 nc}{q + \gamma nc} (h - z) - \frac{q\gamma^2 c}{(q + \gamma nc)^2} \left[e^{-h\left(\frac{q + \gamma nc}{\gamma c}\right)} - e^{-z\left(\frac{q + \gamma nc}{\gamma}\right)} \right],$$

which reduces to:

$$p = \frac{\gamma^2 nch}{q + \gamma nc} - \frac{q\gamma^2 c}{(q + \gamma nc)^2} \left[e^{-h\left(\frac{q + \gamma nc}{\gamma c}\right)} - 1 \right]$$

for the base of the deposit (p is the intergranular pressure when deposition is just complete).

(b) In the case where there is a linear relationship between permeability and reduced depth, i.e. $k_z = k(1 + mz)$, m being a constant and k_z , k and z having the same meanings as before, it has not yet been possible to solve the resulting differential equation.

The permeability relationships suggested in (a) and (b) are, of course, merely assumptions which conform to the actual state of affairs in so far as they indicate a decrease in permeability with increased depth, but there does not appear to be any evidence as to which supposition is the more nearly correct.

Let q be 0.02 gm./cm.²/year, a 0.00024 cm.⁵/gm., and let the permeability at the top and bottom of the deposit when sedimentation ceases, be (1) 0.458 and 0.042 cm./year, (2) 0.429 and 0.071 cm./year and (3) 0.26 and 0.24 cm./year; in each case the arithmetic mean value is 0.25 cm./year. Table IV gives the values of the hydrodynamic pressure, w , computed from the above data by means of the relationship developed in (a), as well as values calculated by Ortenblad's equations in which k is constant and equal to 0.25 cm./year, the first equation covering the first stage of compaction, and zero time being substituted in the second equation which refers to the second stage of compaction.

TABLE IV.

$h = 588$ m. (i.e. sedimentation proceeded for 5,000,000 years).

| Equation used in calculation. | Law governing value of permeability. | Permeability. | | Mean value of permeability when sedimentation is just complete. | Hydrodynamic pressure |
|--|--|-----------------------------------|-----------------------------------|---|--|
| | | $z = 0$ m. | $z = h$ m. | | |
| Equation derived in (a) | Exponential relationship between permeability and reduced depth. | cm./yr. 0.042 0.071 0.24 | cm./yr. 0.458 0.429 0.26 | cm./yr. 0.25 0.25 0.25 | kg./cm. ² 15.0 16.9 26.3 |
| $w = \gamma h - \frac{\gamma}{b} \left(1 - \frac{1}{e^{bh}} \right)$ | k constant | 0.25 | 0.25 | 0.25 | 27.0 |
| $w = \frac{16\gamma h^2 b}{\pi} \cdot \frac{\frac{2hb}{\pi} + e^{-bh}}{4h^2 b^2 + \pi^2} \cdot e^{-\frac{c\pi^2}{4h^2} T}$ when $T = 0$. | k constant | 0.25 | 0.25 | 0.25 | 27.3 |

It would be preferable to extend the modifications suggested in (a) and (b) to the second stage of compaction, although in the absence of such an extension it seems reasonable to assume that there will be an exponential hydrodynamic pressure decay as has already been indicated by Ortenblad's equation based on the simple assumption that the permeability is constant.

THE DIRECTION OF FLUID MOVEMENT IN COMPLEX SEDIMENTARY DEPOSITS, AND ABNORMALLY HIGH PRESSURES.

In the preceding discussion a uniform deposit with the compaction fluids flowing vertically upwards has alone been considered. Generally the sedimentary sequence is more complex, and while the same mechanisms are operative, the direction of fluid flow may be other than vertical, or even upwards in parts, leading to hydrodynamic pressures and degrees of compaction different from those predicted for a uniform deposit.

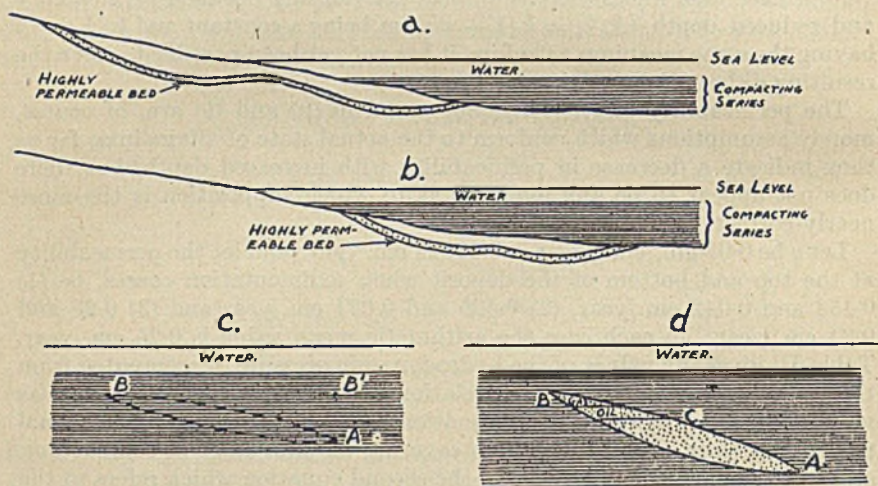


FIG. 1.

The possible considerable excess of fluid pressure above that corresponding with hydrostatic is of importance in a number of connections. If a highly permeable bed outcrops on the surface on which the compactible sediment is being laid down, and if it also outcrops on the land surface (Fig. 1a), it may act as a channel through which water passes into the sediment at first (*cf.* submarine springs), and that water, seeping upwards, may reduce the rate of compaction in the zone of sediment overlying the area where water is escaping from the highly permeable bed.*

According to Ortenblad, experiment shows that $\epsilon = -\alpha' \log_e (p + p_1)$

* Burt (*J. Geol.*, 1927, 35 (7), 663) has noted that quicksands are supersaturated with water, the excess water being largely expressible by pressure, and both Burt and Gow (*Canad. Eng.*, 1920, 39, 392) have observed that some, at least, of the quicksands, are intimately associated with springs. It seems possible that the upward flowing water could be derived either from a compacting clay or from a highly permeable water-transmitting bed which outcrops on the base of the quicksand.

$-\beta'(p + p_1) + C$, or approximately $\epsilon = -\alpha \log_e(p + \beta) + C$, since β' is very small⁸. But $p = \gamma h - w$. Therefore, $\epsilon = -\alpha \log_e(\gamma h - w + \beta) + C$. Consequently, if the hydrodynamic pressure, w , is large, $\alpha \log_e(\gamma h - w + \beta)$ will be small, and ϵ , the voids ratio, will be large.

At first the hydrodynamic pressure will be high, since it will be determined largely by the height above sea level of the land outcrop of the highly permeable bed. The high hydrodynamic pressure will hinder compaction, causing the porosity of the sediment to be higher than would be the case in the absence of the highly permeable bed. However, as the thickness of the sediment increases (at the same time the land outcrop of the highly permeable bed may be expected to have been reduced in elevation by erosion), the hydrodynamic pressure, as influenced by the weight of the compacting sediment, may become of such a magnitude as to reverse the direction of fluid flow, and fluid from the lower part of the sediment may, instead of passing upwards through the sediment, flow downwards into the highly permeable bed (*cf.* possible explanations of some unconformity oil accumulations). It seems possible that when this phase of the process has been in action for some time, the porosity of the region of the compactible bed affected by it will be less than it would have been if the reversal of flow had not taken place. This statement naturally refers to the state of affairs before compaction ceases entirely.

Highly permeable beds which do not outcrop on the land surface and which are within or below the compacting series (Fig. 1b) may provide conditions suitable for fluid movement similar to the second phase noted above, provided that there are differences in the thickness of the compacting beds over parts of the highly permeable bed, due to inclination of the latter or to a non-horizontal surface of the compacting sediment.

Consider two points, A and B (Fig. 1c), at different depths in a compactible series. Then, if B is the shallower, the hydrodynamic pressure at B will be less than that at A ; it will be equal to that at B' vertically above A , if B' is at the same level as B . However, if B and A are connected by a path of high permeability—a sand—the hydrodynamic pressure required to drive water from A to B at any rate which is likely to obtain, will be less than the difference in hydrodynamic pressure between A and B' , even though the distance AB may be much greater than the distance AB' . On this account, where a highly permeable connection exists between A and B , the hydrodynamic pressure at B may be substantially in excess of the value to be expected from B 's depth of burial.

Two important points arise from the above conception: (1) The state of compaction in the zone of sediment overlying B will, for a time, be less than it would be in the absence of the highly permeable connection, while at points overlying those where liquid is entering the highly permeable bed, the state of compaction, especially in the lower part, though the whole zone of the compactible bed above will be affected, will temporarily be higher than it would otherwise be. (2) If there is a considerable difference in level between A and B , and the connecting bed has a high permeability yet comparatively little fluid to transmit, the hydrodynamic pressure at B may be little less than at A , and altogether the pressure at B will appear anomalous with regard to B 's depth. The presence of the highly permeable

connection will, on the other hand, reduce the hydrodynamic pressures at *A* and *B'* to some extent.

If the upper part of the highly permeable bed becomes filled with oil and gas, the point *C* (Fig. 1*d*) at which the water leaves it to escape upwards will gradually become lower as oil and gas accumulate.* *C* will be at the oil-water contact zone, provided that the oil and gas zone does not contain connate water-filled patches capable of transmitting much water. Thus the region where the rate of compaction is temporarily reduced by abnormal hydrodynamic pressures will tend to overlie the oil-water contact zone (cf. 'haloes' in geochemical prospecting). As *C* moves downwards, compaction above *B*, i.e. above the oil and gas zone, will be accelerated, since the only water which will have to be transmitted will be that derived in the main from the section overlying *B*.

It is obvious that fluids will enter the highly permeable bed at all points which will give an advantageous relationship as regards hydrodynamic pressures.†

Orogenic stresses, in so far as they affect the pressures in the fluids in the sediments, can be considered as equivalent to deeper burial. Hence the hydrodynamic pressure will be in excess of that appropriate to the depth of burial of the point in question and to the ordinary loading compaction considerations. Nevertheless, the hydrodynamic pressure decay with time may still be expected to obey an exponential law, although the decay rate may possibly be somewhat greater than for the pure sedimentation-compaction process, as the thickness of sediment that the water has to traverse is less than would correspond with the porosity, permeability, and hydrodynamic relationships in a series involving pure sedimentation-compaction alone and having the same hydrodynamic pressure.

The foregoing concepts regarding the direction of fluid movement in a non-uniform sedimentary series are by no means new, but they have generally been described without adequate reference to the differences of hydrodynamic pressure which provide the motive power.

DEDUCTIONS FROM DEPTH-POROSITY CURVES.

If a depth-porosity relationship for a sedimentary series is known from measurements, or assumed, a true depth-reduced depth curve can be

* The coarse-fine interface (V. C. Illing, *J. Inst. Pet. Tech.*, 1933, 19, 229-260; 1939, 25, 201) prevents the passage of the oil and gas by bulk flow from the highly permeable reservoir bed into the adjacent more fine-grained beds, until the pressure differential between these fluids and the water in the fine-grained beds has built up to a critical value which depends on the pore sizes of the two adjacent beds, and on the interfacial tension of the oil and gas against the connate water in the sediments.

† When a well is drilled into a deeply buried clay in which the hydrodynamic pressure in the contained water is high, and which still has a high porosity, an easy path is provided for the escape of some of the water in the clay immediately around the well. The rate of water escape in this manner will be small, and the effects of this escape are not likely to be readily observable. However, if the well penetrates a highly permeable bed just above or just below the clay, opportunities are presented for the easy escape of water from the clay into the highly permeable bed over a large area, and for a corresponding flow of water from the highly permeable bed into the well, because of the increased pressure drop between the clay and the highly permeable bed which generally arises as a consequence of the presence of the well. In such circumstances accelerated compaction of the clay may become possible, and the effects of this may be noticeable.

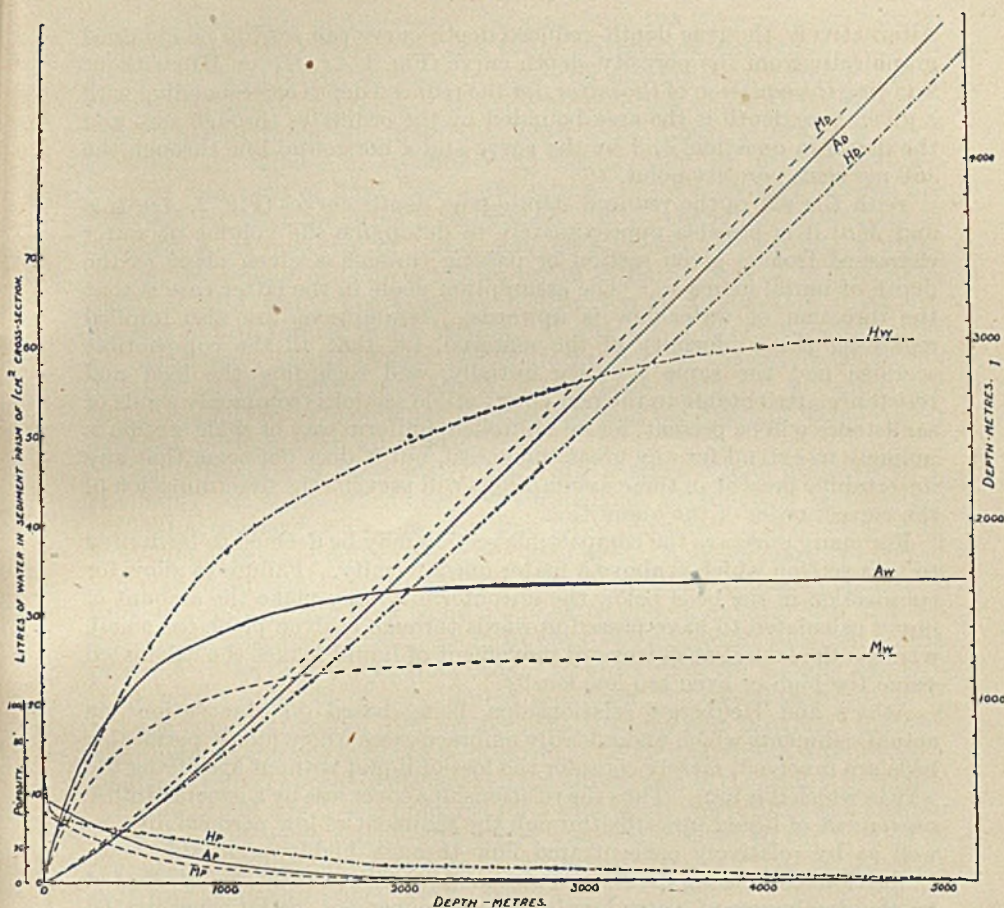


FIG. 2.

A_p , H_p and M_p ARE CURVES OF POROSITY PLOTTED AGAINST TRUE DEPTH. A , H and M ARE CURVES OF REDUCED DEPTH PLOTTED AGAINST TRUE DEPTH. A_w , H_w and M_w ARE CURVES OF THE VOLUME OF WATER IN A 1 CM.² PRISM PLOTTED AGAINST THE REDUCED DEPTH. A INDICATES THAT THE SEDIMENT OBEYS ATHY'S COMPACTION LAW, H THAT IT OBEYS HEDBERG'S LAW, AND M THAT THE SEDIMENT HAS 30% OF NON-COMPACTIBLE BEDS, THE COMPACTIBLE BEDS OBEYING ATHY'S LAW.

constructed, for the reduced depth is simply the amount of solid matter of zero porosity down to the depth considered. Using Athy's equation¹ the reduced depth is

$$\int_0^H (1 - Pe^{-yH}) dH = H + \frac{P}{y} (e^{-yH} - 1)$$

where y is a constant for a given series. Hedberg's equation² is a discontinuous function, which, if used to compute the reduced depth numerically, must be integrated between the limits proper to the various stages.*

* Both Athy's and Hedberg's equations and observations are open to criticism, but the experimental and observational difficulties associated with the determination of a porosity-depth relationship are of considerable magnitude.

Alternatively, the true depth-reduced depth curve can readily be obtained graphically from the porosity-depth curve (Fig. 2, *AP*, *HP*, or *MP*) without knowing the equation of the latter, for the reduced depth corresponding with a given true depth is the area bounded by the ordinates through zero and the depth in question, and by the curve and a horizontal line through the 100 per cent. porosity point.

With the aid of the reduced depth-true depth curves (Fig. 2, *AD*, *HD*, and *MD*) it is possible approximately to determine the volume of water expressed from a given section or passing through a given plane as the depth of burial increases. The assumption made in the latter case is that the direction of water-flow is upwards. Assumptions are also implied regarding the uniformity of the material, i.e. that all the compactible sections had the same porosity initially, and regarding the load and resistance attributable to the non-compactible sections (commonly sands or sandstones will be present, for an unbroken, uniform clay or shale section is unlikely to extend for any great thickness), but it does not seem that any uncertainty present in these assumptions will prevent the determination of the correct order of the quantities.

For many purposes the compactible section may be deemed to be limited to that section which is above a major unconformity. Failure to allow for compaction in the beds below the unconformity may make the amount of liquid calculated to have passed upwards through a given plane too small, whereas the lateral or downward movement of liquid makes the calculated value too high or even too low, locally.

Athy's and Hedberg's relationships, being based on observations on actual sediments which undoubtedly embrace cases where highly permeable beds are involved, merely consider the loss of liquid without specifying the way in which it is lost. Thus the relationships cover loss by a general diffuse movement of liquid upwards through the sediment of low permeability, as well as by relatively concentrated flow through highly permeable beds. Deductions concerning the state of compaction will not be markedly affected by the dominance of water loss by diffuse movement, or by concentrated movement, but the amount of water flowing through a given cross-section will be largely dependent on local conditions. It is not possible readily to make satisfactory allowances for such local conditions—the presence or absence of a highly permeable bed or other disturbing influence—and so the figures calculated for the volume of water flowing upwards across a given horizontal plane merely constitute a general average which will be exceeded in the vicinity of highly permeable beds, and not attained where they are lacking. The proportional decrease in the rate of flow with increased depth of burial may be similar in the two cases, with the possibility that a rather greater proportion of the out-flowing water may travel by way of the highly permeable bed as compaction proceeds.

(1) *The Time of Oil Formation and Primary Migration*.—One of the most debated points in petroleum geology is the time of oil formation. Some maintain that oil must be formed soon after the sediments are laid down, otherwise they find it difficult to visualize a way in which the oil can be transferred from the fine-grained source rock (low permeability) to the coarser reservoir rock (high permeability). Others claim that oil formation occurs long after burial of the parent organic matter through the agency of

rise in temperature and pressure resulting from the large rock load on it. The holders of the former view look to the water expressed during compaction, which is naturally greatest in bulk and moving most quickly during the early stages of compaction, to carry oil from the source to the reservoir rock, whereas those who hold the latter view must believe that other processes are capable of accomplishing this transfer, or at least that the amount and rate of fluid flow quite late in the compaction process are sufficient to cater for primary migration. It is, therefore, interesting to estimate what quantity of water may be expected to pass into a given section from older beds for a known depth of burial, and so be available, together with water expressed by contraction of the section itself, for flushing out oil formed in the section. A number of variable factors must be considered: the thickness and characteristics of the source series, its distance above a major unconformity (the beds below the unconformity being assumed to be completely compacted), and the depth of burial (time) at which oil formation takes place.

The estimation is most easily made for a series which obeys Athy's, Hedberg's, or some other one law throughout, although it is probably preferable to consider a series more like those encountered in oilfields, with 20 or 30 per cent. of non-compactable beds in it. A curve relating reduced and true depth can be deduced for a given percentage of non-compactable beds, the compactable beds being assumed to obey a definite law, and the load-depth relationship being assumed not to be materially changed by the presence of the non-compactable beds. In order to avoid making assumptions, which would be of very limited use, about the actual distribution of the non-compactable and compactable beds, it seems best to assume that the same ratio of the two types of beds exists at all depths, which is probably a sufficiently good approximation when the alternation of the beds is frequent.

Curve *MD* of Fig. 2 was prepared for a case where the ratio of the volume of solid, which when mixed with water was compactible, to the volume of non-compactable sediment (solid plus water) was 70 : 30. The compactible part was assumed to obey Athy's law.

The amount of water in a 1-cm.² prism extending down to some stated depth is shown by the difference true depth minus reduced depth corresponding with the depth considered, and the values thus derived are most useful when plotted against the reduced depth (Fig. 2, curves *AW*, *HW*, and *MW*).

Suppose that the source bed is 100 m. thick when its deposition is just complete, that its base is then 1000 m. above a major unconformity, and that the beds obey Athy's compaction law ($P = 0.48$ and $y = 0.00143$ in Fig. 2). When the deposition of the source bed is just complete, its reduced thickness, read from the reduced depth-true depth curve, is 54 m., and its water content is 4.6 litres in a 1-cm.² prism. The reduced depth of the 1100 m. of beds (source bed 100 m. + 1000 m. of beds below) down to the unconformity is 835 m., with the consequence that the reduced thickness of the beds underlying the source bed is $835 - 54 = 781$ m., and the water content of the beds below the source rock is $(110,000 - 83,500) - (10,000 - 5,406) = 26,500 - 4,600$ cc. = 21.9 litres.

When the top of the source rock is buried to 500 m. true depth, the source bed itself extends from 328 m. reduced depth, corresponding with

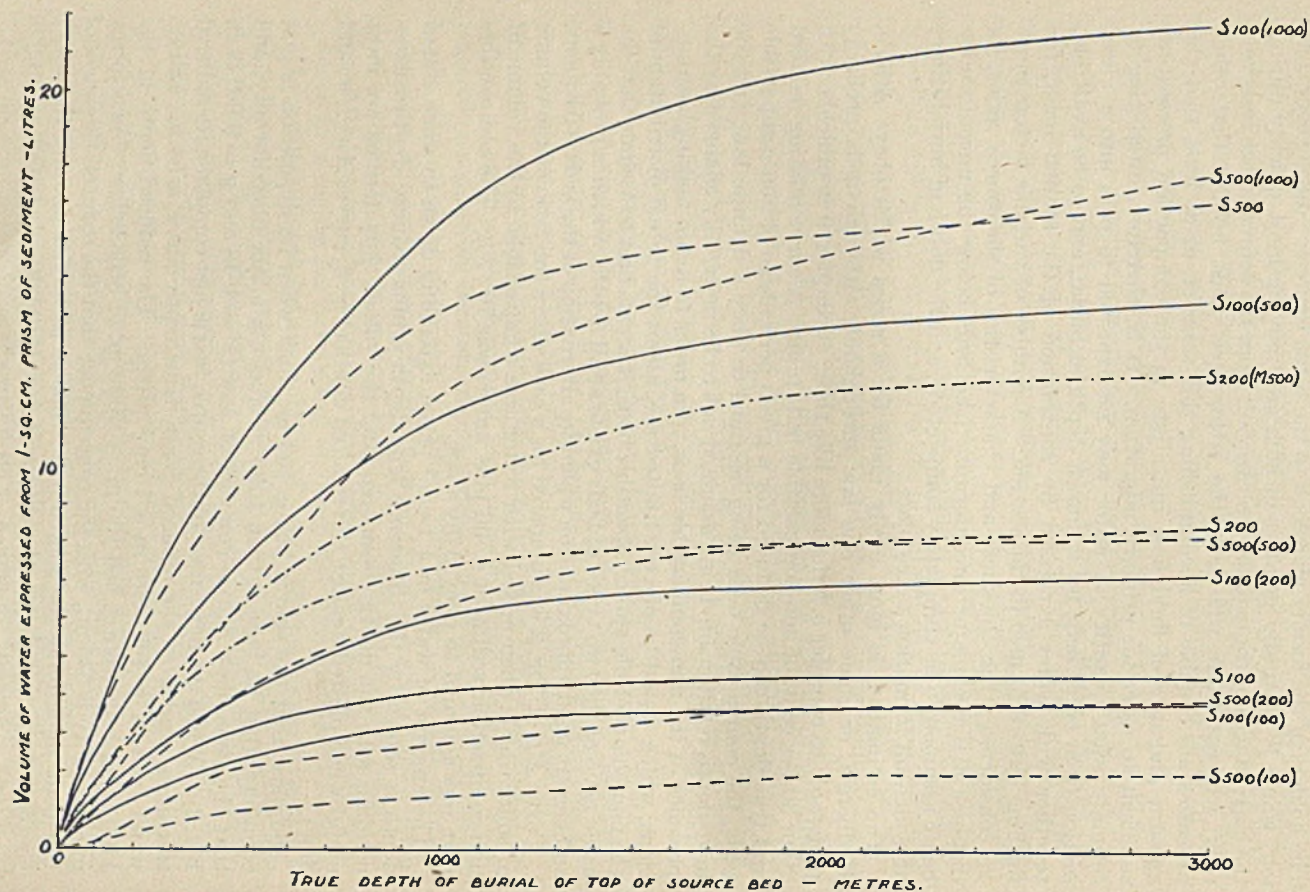


FIG. 3.

500 m. true depth, to 382 m. reduced depth, and the beds beneath it extend from 382 m. to 1163 m. reduced depth, *i.e.* $382 + 781$ m. At this stage the amount of water remaining in the source bed is $(56,900 - 38,200) - (50,000 - 32,800) = 18,700 - 17,200$ cc. = 1.5 litres; and the water remaining in the beds below the source bed is $(146,000 - 116,300) - (56,900 - 38,200) = 29,700 - 18,700$ cc. = 11.0 litres. Therefore, by the time that the source rock has been buried 500 m. deep, it has lost $4.6 - 1.5 = 3.1$ litres of water per 1-cm.^2 prism, and $21.9 - 11.0 = 10.9$ litres of water per cm.^2 will have entered its base from the underlying beds, *i.e.* $10.9 + 3.1 = 14.0$ litres of water per cm.^2 will have left the top of the source bed. In this way estimates can be made for different sets of conditions, either directly from the reduced depth-true depth curve or with the additional assistance of a water content-reduced depth curve.

The curves of Fig. 3 show the amounts of water lost from a 1-cm.^2 prism of the source bed or of the underlying beds for different depths of burial, thicknesses of source bed and thicknesses of beds between the source bed and a major unconformity. The steepness of the curves is a measure of the rate at which water was being lost. The curves, based on Athy's data, show that for the series of combinations of circumstances selected, a substantial part of the compaction fluids passes into and through the source rock relatively early. Indeed, 75 per cent. of the possible compaction fluids has passed before the top of the source bed has been buried 1500 m. (true depth). This figure is more than 75 per cent. of the volume of the fluids likely to pass. In some cases 75 per cent. of the fluids has passed during burial to 750 m. only.

The volumes of liquid computed for a given set of circumstances vary with the compaction law employed, but the general indications are similar for Athy's and Hedberg's laws, and for the case where a proportion of non-compactable beds is included in the sedimentary series.

Estimates can also be made of the rate of flow of the water expressed in compaction, again making use of the depth-porosity curves and curves derived therefrom. The curves of Fig. 3 may be replotted with reduced depth instead of true depth as abscissae (Fig. 4, curves *A* and *B*). These are for the case of 100 m. of source bed, the base of which was 500 m. above a major unconformity when deposition of the source rock was just complete. *A* shows the water expelled from the beds below the source rock; *B* shows the total water expelled from the source rock and the beds below). If it is assumed that the bulk of the compaction took place during the time when sedimentation was proceeding, that the rate of deposition of the beds

FIG. 3.

CURVES S100, S200 AND S500 REPRESENT THE VOLUME OF LIQUID EXPRESSED FROM SOURCE ROCK SECTIONS, WHICH WERE RESPECTIVELY 100, 200 AND 500 M. THICK AS DEPOSITED, WHEN THEY ARE BURIED TO THE DEPTHS SHOWN. CURVES WITH A NUMBER IN BRACKETS REFER TO THE WATER EXPRESSED FROM THE ROCK SECTION BELOW THE SOURCE ROCK AND ABOVE A MAJOR UNCONFORMITY, THE NUMBER GIVING THE THICKNESS OF THE ROCK SECTION WHEN DEPOSITION OF THE SOURCE ROCK WAS JUST COMPLETE. THE SOURCE ROCK AND BEDS BELOW ARE ASSUMED TO OBEY ATHY'S LAW, BUT THE CURVE S200 (M500) HAS 30% OF NON-COMPACTIBLE BEDS IN THE SERIES BELOW THE SOURCE ROCK. THE NUMBER BEFORE THE BRACKETS SHOWS THE INITIAL THICKNESS OF THE SOURCE ROCK OVERLYING THE COMPACTING BEDS.

overlying the source bed was constant, and that the whole series obeys the same compaction law, the reduced-depth-of-burial scale can be converted to a time scale by assigning a reasonable value to the rate of deposition. On fixing a value for the rate of deposition the reduced-depth-of-burial scale

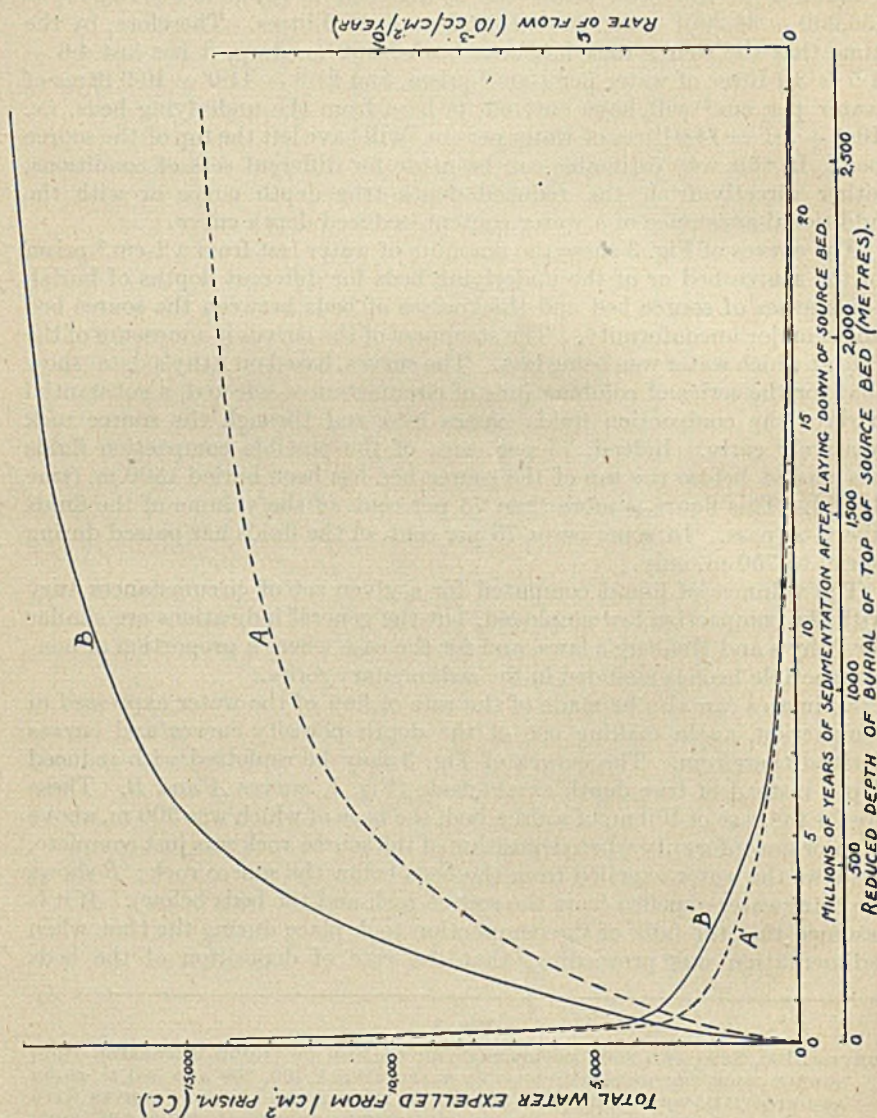


FIG. 4.

can be converted directly to a time scale by multiplying throughout by a calculable factor. In Fig. 4 the conversion has been made by using a rate of deposition of 0.02 gm. (weight in water)/cm.²/year. The slope at any point on curve A or curve B gives the rate of flow across a 1-cm.² section into the bottom or out of the top of the source bed, respectively, at any

time up to the end of deposition, if the bulk of the compaction occurs before deposition ceases. Thus, differentiation of curves *A* and *B* gives curves *A'* and *B'* which show respectively the bulk rate of flow of water per 1 cm.² into the bottom or out of the top of the source bed. The bulk rate of flow of water into and out of the source bed clearly falls off quite rapidly at first as the depth of burial increases. It is also dependent on the thickness of the source-bed and the thickness of the beds below the source bed; and if much compaction takes place subsequent to the cessation of deposition, the rate of flow derived in the above manner will fall in accuracy, even though correct values may have been assigned to the other quantities about which assumptions have had to be made. The relative values of the rate of flow at different times will carry greater weight than the absolute values, and assuming that the conversion of a depth scale to a time scale has been good, the rates of flow obtained will probably tend, in general, to be maximum values.

It certainly appears that the opportunities for primary migration are, in every way which concerns compaction fluids as the motive power, extremely favourable during the period before the source bed becomes deeply buried. Both the volume of fluid available and its bulk rate of flow decrease as time passes, while the pores diminish in size, thus making primary migration effected by compaction fluids increasingly more difficult, with the consequent implication that oil and gas must migrate, and therefore must be formed, early.

(2) *Closure Developed by Compaction over Buried Hills.*—The reduced depth-true depth curves can also be used to determine the amount of closure to be expected in structures formed by compaction over buried hills. Again, assumptions have to be made about the constitution of the compacting series in terms of compactible and non-compactible sections, but the direction of flow of the compaction fluids is no longer so important, except that locally and temporarily it may affect (increase or decrease) the rate of compaction. All that matters ultimately as regards the form of the beds is that the fluids are lost.

Let there be a hill on the buried landscape rising 200 m. above the general level of the surrounding country (Fig. 5), and let its crest be covered by sediment to a depth of 300 m., with deposition up to 500 m. over the surrounding area, so that the top of the sediment is level at this stage. After deposition of a marker bed, let the thickness of sediment be increased to 800 m. over the crest of the hill and to a maximum of 1000 m. in the surrounding region, i.e. at the close of deposition and compaction the surface of the sediment is horizontal. It is required to find the structural closure produced in the marker bed as a result of compaction.

Assuming that the compacting series obeys Athy's law, the reduced depth corresponding with 1000 m. true depth is 744 m.; that corresponding with 500 m. true depth is 327 m. The difference of 417 m. in reduced depth corresponds with the amount of sediment laid on top of the marker bed in the area around the hill, and it is equivalent to 610 m. true depth, i.e. the depth of the marker bed after compaction is 610 m. Over the top of the hill 800 m. true depth corresponds with 570 m. reduced depth, and 300 m. true depth corresponds with 181 m. reduced depth. The difference in reduced depth of 389 m., which is equivalent to 575 m. true depth, is the

amount of cover over the marker bed in this region. Hence the closure developed in the marker bed by compaction of the enclosing series is $610 - 575 = 35$ m.

The closure determined graphically for the same conditions using Hedberg's law is 22 m., and if the series has 30 per cent. of non-compactable beds, the compactible beds obeying Athy's law, the closure is about 32 m.

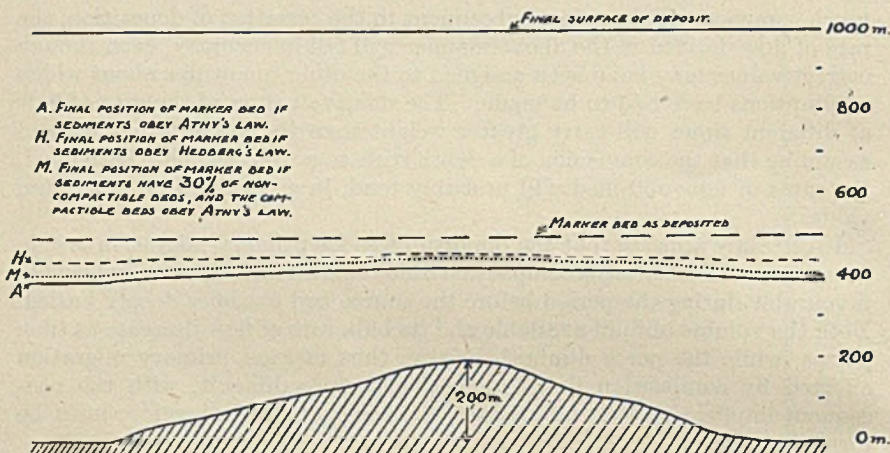


FIG. 5.

STRUCTURAL CLOSURE FORMED BY COMPACTION OF BEDS OVER A BURIED HILL.

If the sediment does not attain the level upper surface postulated above, the marker-bed and other beds will have initial dips which will be changed by further deposition and compaction. The changes in the initial dips as a consequence of compaction are still determinable from the curves of Fig. 2.

Peters¹ has given methods for calculating the closure on the basis of Athy's law, methods which depend on the use of the first few terms of the expansions of exponentials as approximations to the values of the exponentials. The present graphical method appears to be of a degree of accuracy adequate to the problem under consideration, and can be applied with equal facility in cases where a mathematical expression is not available for the relationship between depth and porosity.

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THE ANALYSIS OF TRINIDAD CRUDE OILS.*

By F. MORTON † and A. R. RICHARDS.†

SUMMARY.

The methods developed in the laboratories of Trinidad Leaseholds, Ltd., for the analysis of crude oils are described in detail. The normal crude-oil evaluation methods have been extended to include detailed analysis of a number of fractions obtained by precise fractionation of the naphtha (F.B.P. 200° C.). The graphical representation of this analysis is shown to be characteristic of the oil, and can be used for the correlation of crude oils, as well as for the detection of minor differences in crude oils produced from the same zone. Details are given of the characteristics of the crude oils from the established producing horizons at the Forest Reserve Field of Trinidad Leaseholds, Ltd.

INTRODUCTION.

TRINIDAD crude oils, as might be expected from the complex geological conditions existing in southern Trinidad,¹ ‡ show marked differences in characteristics.² Classified by the method of Lane and Garton,³ the bulk crude oils fall between intermediate and naphthenic base types.² More detailed examination by crude evaluation methods developed in these laboratories⁴ shows that this broad classification is incorrect, and that the crude oils vary from the paraffinic oils of Guayaguayare and Tabaquite,^{1, 5} to the naphthenic oils of the Forest and Upper Cruse series. Between these extremes lie a number of mixed-base crude oils. In certain areas, notably in the vicinity of the Los Bajos Fault and at Lizard Springs, distillate oils and freak oils of high aromatic content are encountered.⁶

The methods of crude-oil analysis described hereinafter were originally developed to assist in the segregation of crude oils designed to facilitate refinery operations. The detailed naphtha analysis, necessary for the planning of a commercial precise-fractionation programme, proved to be of value in assisting the interpretation of geological data in the areas under examination. The characteristic graphs are used in a somewhat similar manner to the correlation index of Smith⁷ or the gravity-interval pattern of Barton,⁸ with the additional advantage that they can be used in assessing the value of the naphtha for the production of special products.

METHOD FOR ANALYSIS OF CRUDE OILS.

The method developed in the laboratories of Trinidad Leaseholds, Ltd., for the detailed examination of crude oils consists essentially of three separate analyses designated: (a) Primary Evaluation, (b) Naphtha Characterization, and (c) Supplementary Analysis.

* Received 28th October.

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‡ Figures refer to bibliography on pages 73-74.

Primary Evaluation.

A charge of 8 litres of crude oil is blown into the insulated metal stillpot (A, Fig. 1) of 10 litres capacity. Heat is supplied by a hot-plate controlled by a Variac transformer. The stillpot is fitted with a fractionating column packed with 12 inches of 25-mm. Stedman packing.⁹ The initial product rate is fixed at about 5 ml. per minute, and the boil-up rate so adjusted that the column operates below flood-point. The heating coil round the column does not supply sufficient heat to maintain adiabatic conditions, and the resultant dephlegmation is used to provide reflux. The reflux ratio thus slowly increases, and product rate slowly decreases as the distillation proceeds. The distillate is collected in bulb B (capacity 4 litres),

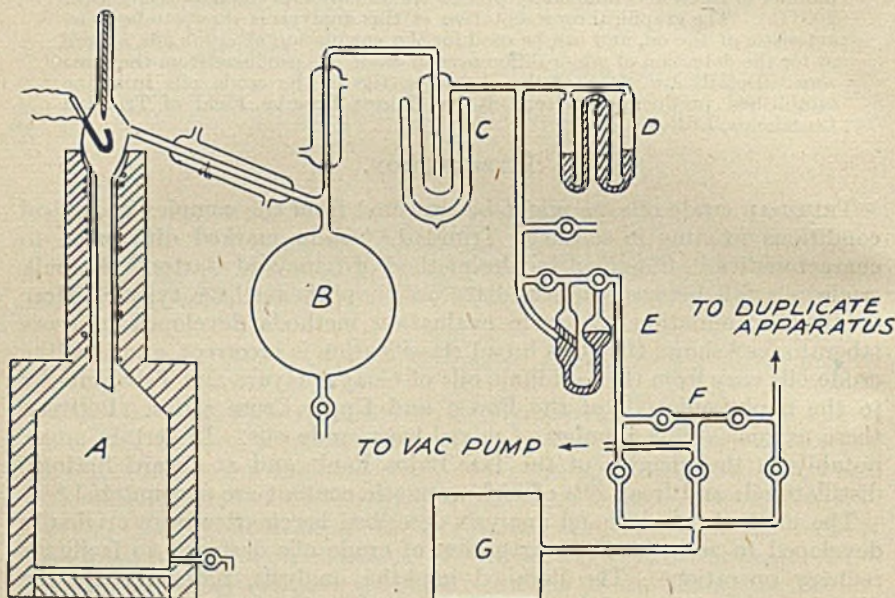


FIG. 1.

and any low-boiling fractions which may escape condensation are trapped in vessel C cooled to -10°C . by a surrounding medium of solid carbon dioxide in gasoline. When the overhead temperature reaches 100°C . the heat is switched off from the stillpot and column by means of a thermostat, which at that temperature operates a relay opening the heater circuits. By means of hand-switches in these latter circuits, the heaters are prevented from cutting-in again when the temperature falls below 100°C .

The contents of the stillpot are then cooled, the pressure in the apparatus reduced to 15 mm., and the heaters again switched on. The pressure is recorded by the Zimmerli gauge D¹⁰, and controlled by the manostat E. This latter is a modified form of that described by Lewis¹¹ with the replacement of one cylindrical globe by a bulb which removes the necessity of adjustment for each distillation. The entire apparatus consists of duplicate units (Fig. 1), and provision is made for maintaining a pressure of 15 mm. in either one or both units by means of the vessel G, previously evacuated

and connected through the stop-cock manifold *F* to whichever apparatus is required.

When the overhead temperature again reaches 100° C. under a pressure of 15 mm., the heaters are switched off by the thermostat control. The heating control circuit is so constructed that a warning light appears when the temperature reaches the prescribed limit.

Naphtha Characterization.

The naphtha fractions obtained in the primary evaluation are blended and dried over anhydrous calcium chloride. 1200–1400 ml. are charged

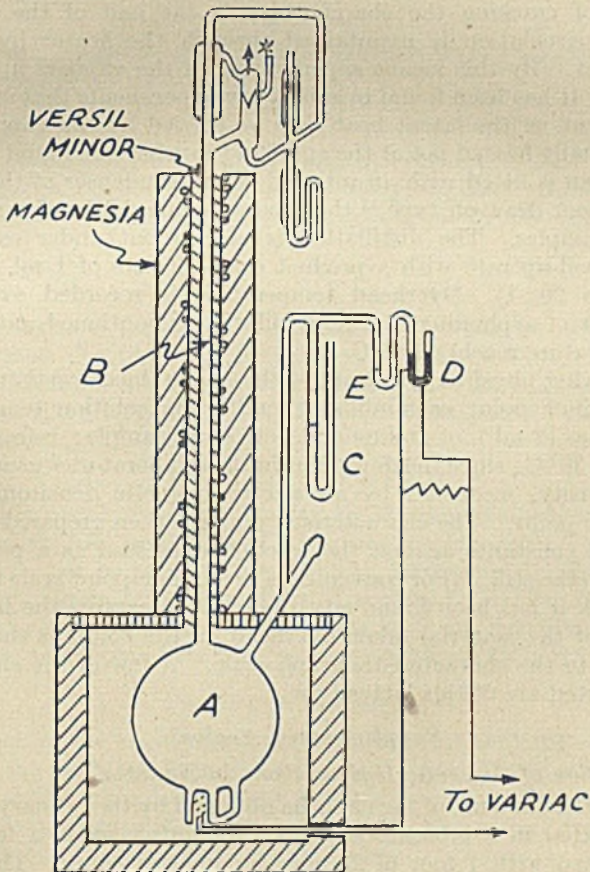


FIG. 2.
SECONDARY STILL.

to the secondary still (Fig. 2), which consists of a 3-litre stillpot fitted with an internal heater and a fractionating column packed with 4 feet of 25-mm. Stedman packing.

A mercury U-tube cut-out *D* is operated by the pressure-drop across the column, but isolated from the vapours by an intermediate glycerine-filled

U-tube *E*. This cut-out is connected in parallel with an auxiliary resistance in the stillpot heater circuit, so that a constant boil-up rate may be automatically maintained throughout the distillation. Adiabatic conditions are maintained by means of a heater wire wound round the pre-formed glass-wool lagging ("Versil Minor"), the precise current required at different top temperatures having been determined by means of calibration experiments with special columns fitted with devices for the measurement of the liquid rate above and below the packing.

In order to assist the maintenance of adiabatic conditions, the conventional hot-plate type heater has been abandoned, and an internal heater of the type shown in Fig. 2 installed. This design avoids the possibility of cracking the charge towards the end of the distillation, since rapid circulation is maintained through the heater by a thermosyphon effect. By this means superheating of the vapours in the stillpot is avoided. It has been found in subsidiary experiments that superheat up to 10 per cent. of the latent heat may be carried by the vapours leaving a conventionally heated pot at the end of a run when the liquid level is low.

The column is fitted with an internal reflux condenser of the minimum hold-up vapour draw-off type,¹² the product being delivered automatically in 10-ml. samples. The distillation is carried out under conditions of maximum boil-up rate with a product draw-off rate of 1 ml. per minute (reflux ratio 20:1). Overhead temperature is recorded every 10 ml. (at the point of syphoning). The distillation is continued until the overhead temperature reaches 200° C.

The following physical constants of the so-obtained fractions are determined: Aniline point or minimum equilibrium solution temperature of equal volumes (2 ml.), of aniline and petroleum sample; refractive index, measured at 30° C., since the dew point in these laboratories usually exceeds 23° C.; density, measured by an electro-magnetic densitometer,¹³ and mean boiling point. The characteristic graph is then prepared by plotting the physical constants against the fraction expressed as a percentage of the charge to the still. (For convenience the aniline-point scale is inverted.) In later work it has been found advantageous to express the fraction as a percentage of the material taken overhead on the columns thus resulting in a change in the characteristic graph scale. A few of the characteristic graphs reported are of this latter type.

Supplementary Analysis.

(a) Distribution of Aromatic Hydrocarbons in Naphtha.

Not more than 500 ml. of the naphtha obtained by the primary distillation are fractionated in a laboratory T.B.P. apparatus, using a fractionating column packed with 1 foot of 25-mm. Stedman packing. The following cuts are taken:—

- (a) Benzene cut, b.pt. 60–90° C.
- (b) Toluene cut, b.pt. 90–120° C.
- (c) "Xylene" cut, b.pt. 120–145° C.

Sufficient of each of these fractions is reserved for aniline-point determination and allowed to stand over anhydrous sodium sulphate. The aromatic material is removed from each of the remaining samples by

shaking with an equal volume of 98 per cent. sulphuric acid for half an hour, care being taken that the temperature of the mixture does not exceed 20° C. After standing and separating, the samples are washed with water and dried. The aniline points of both original and treated samples are then determined consecutively by the same operator using the same aniline stock. The difference in aniline points, Δ , of the two samples is then used to calculate the percentage aromatics, a , by volume by the following formulæ.

(1) For benzene and toluene

$$a = 1.13\Delta.$$

(2) For xylene

$$a = 0.39 \Delta.$$

If the percentage aromatics so determined exceeds twenty, the extraction must be repeated.

(b) *Asphaltenes.*

The asphaltene content is determined on the crude oil by the I.P.T. method,¹⁴ using a petroleum ether of slightly modified specification. By rigid adherence to standardized technique reproducible results can be obtained.

(c) *Nitrogen.*

Determinations of the nitrogen content of the crude oil have been made by the method described by Redemann.¹⁵ Unfortunately the nitrogen content of the crude oils does not provide any satisfactory basis of correlation, nor can the nitrogen content of specific fractions or residues be used for this purpose.

CRUDE OIL EVALUATION.

By suitable variation of the primary distillation, evaluation of the yield, quality, and specific properties of naphtha, kerosine, gas oil, and fuel oil residues, etc., can be made. The methods developed for this purpose in the Trinidad laboratories have been described.⁴ Recent improvements of these have resulted in methods similar to those described by Mithoff, MacPherson, and Sipos¹⁶ for the characterization of Californian crude oils.

CRUDE-OIL CORRELATION.

Correlation of the crude oils is based on the fact that the chemical composition of the naphthas from identical crude oils will be identical, and that differences in the composition of the naphthas must be related to differences in composition, history, and possibly origin of the parent crude oils.

The naphtha fraction is used for this purpose because, as is well known, the lower members of the homologous hydrocarbon series exhibit characteristic differences in physical properties to a marked degree. Extended fractionation studies of the entire crude oil indicate that the differences in the physical constants of the higher-boiling members of the main hydrocarbon series are insufficient for analytical purposes. Furthermore, the complexity of the higher-boiling crude-oil fractions is such as to render impossible, by normal fractionation procedure, the degree of separation necessary for reliable characterization. Since the physical constants of

the individual fractions isolated during the naphtha fractionation will be governed by their chemical nature, it follows that the composite graph picture so obtained will be characteristic of the naphtha examined, and therefore characteristic of the parent crude oil. This composite graph picture of the analysis we have designated the "characteristic graph" of the crude oil. Obviously the characteristic graphs should be reproducible for the same crude oil, and hence it is necessary that standard conditions

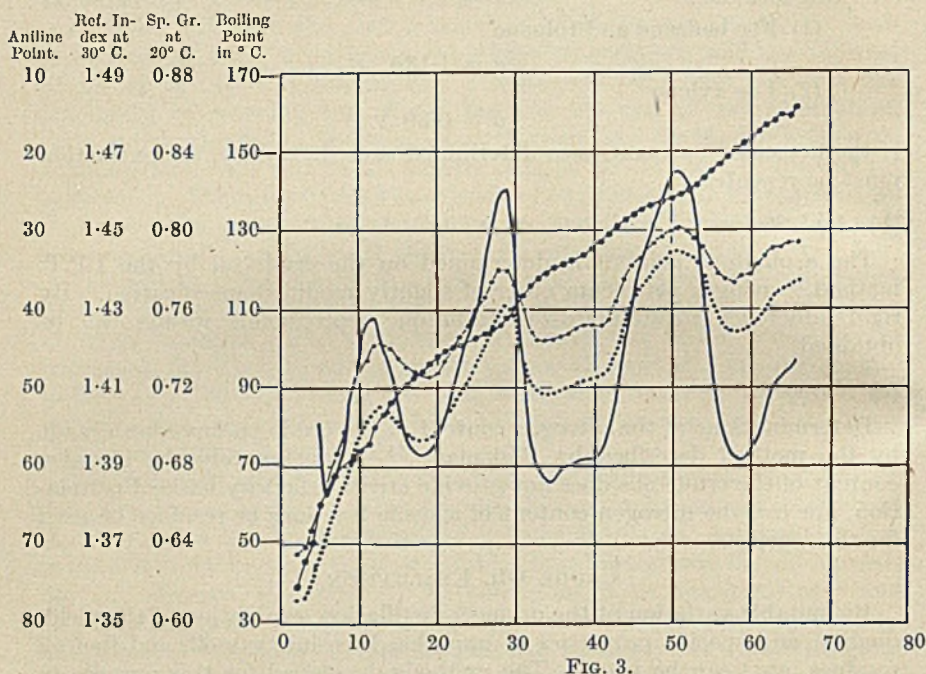


FIG. 3.

The following key applies to all characteristic graphs :

| | |
|-----------------------|-------------------|
| Aniline Points | — |
| Ref. Index at 30° C. | |
| Spec. Grav. at 20° C. | — · — · — · — · — |
| Boiling Point in ° C. | — ● — ● — ● — |

of sampling, analysis, etc., be rigidly observed. The reproducibility of the graphs is illustrated by reference to Figs. 3, 4, and 5. These represent the analysis of the naphtha from three samples of crude oil drawn from the same well, thus checking the sampling procedure as well as the laboratory analytical technique. The same procedure has been repeated in numerous other instances, thus establishing the reliability of the method to indicate identity of crude oils.

Interpretation of the graphs is assisted by the supplementary analysis. The relative amounts of benzene, toluene, and xylene appear to be a characteristic property of the various Trinidad crude oils and, together with the asphaltene content, afford a rapid means of preliminary classification.

Various ratios have been investigated, the simplest method being to express the benzene, toluene, and xylene content as a percentage of the

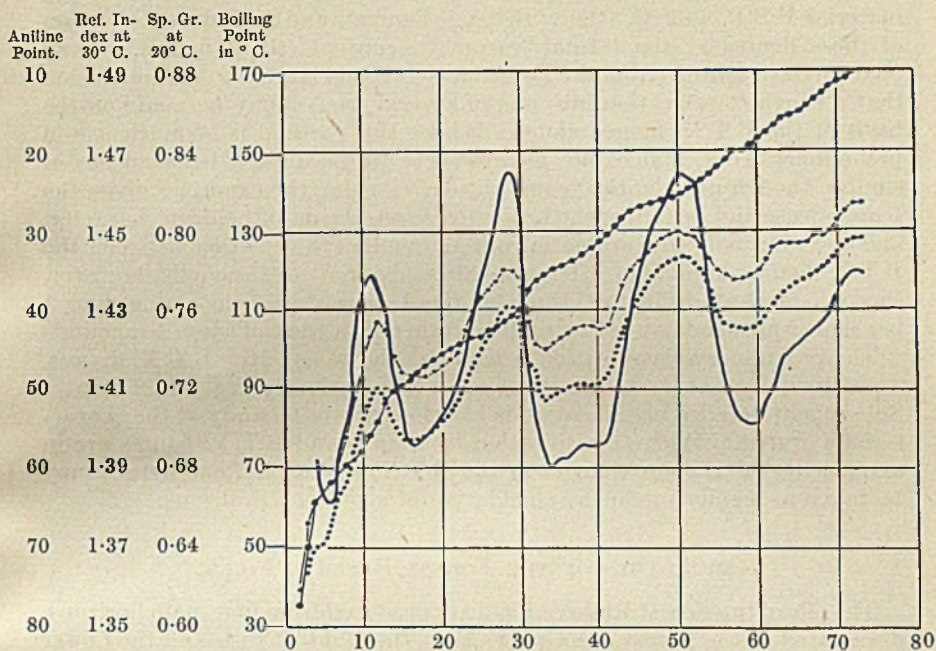


FIG. 4.

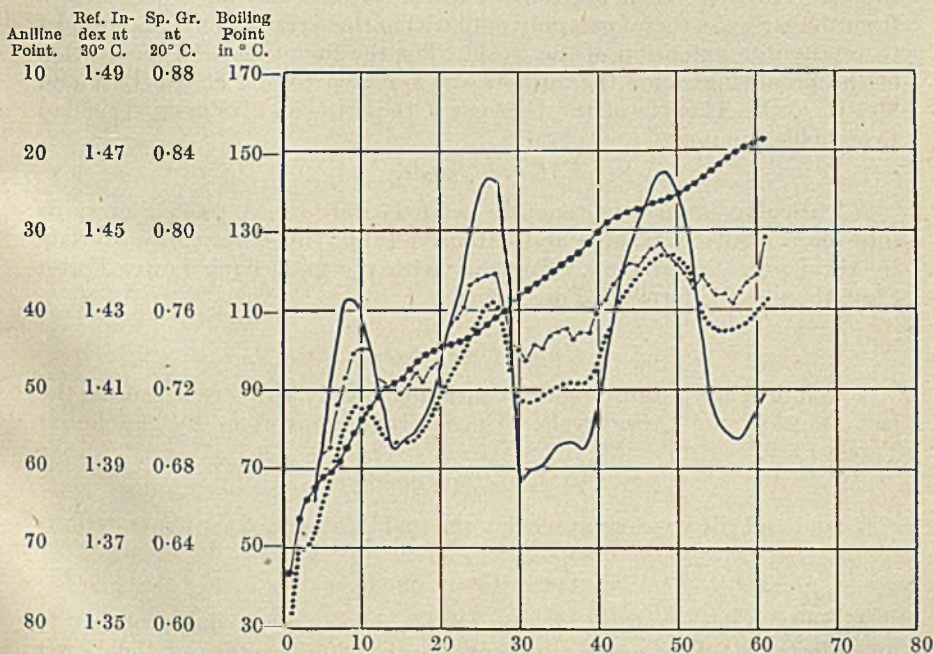


FIG. 5.

material F.B.P. 145° C. (the "B.T.X." figures), and to indicate the sum of these figures as the "total" aromatic content (the A figure). Work on over 150 crude oils from the Forest Reserve field has led to the conclusion that a rough classification into one of several groups may be made on the basis of the B.T.X. figures alone. Whilst this method is of much use in preliminary work, it does not always serve to distinguish between oils of similar, though not identical composition. Among the examples given the Upper Cruse and certain of the Lower Cruse oils are naphthenic in character, and the unusually low aromatic content renders the relation between the B.T.X. figures unreliable. The asphaltene content of these oils, however, shows a marked difference, those of the Upper Cruse containing over 1 per cent. whilst the Lower Cruse oils contain only a trace of these compounds.

The preliminary classification is made on the basis of the B.T.X. figures, asphaltene content, and, to a lesser extent, the primary evaluation figures. Subsequent detailed classification is based on a careful study of the characteristic graphs. Where classification by graphs and B.T.X. figures are in agreement, then minor changes in the B.T.X. and asphaltene figures may be taken as significant in the elucidation of geological problems.

CRUDE OILS OF THE FOREST RESERVE FIELD.

The oils of the Forest Reserve Field are produced from four main horizons, designated as the Forest, the Upper Cruse, the Middle Cruse, and the Lower Cruse Sands. The crude oils analysed from each of the producing horizons were drawn from well-defined limited areas, though not necessarily from the same area for each horizon. The conclusions and inferences drawn from these results therefore apply only within this area, and may be subject to revision on extension of the work. For the following brief description of the producing sands the authors are indebted to Mr. K. W. Barr and Mr. H. C. H. Thomas of the Geological Department of Messrs. Trinidad Leaseholds Limited.

Forest Sands.

A lenticular, often diachronously bedded sandy series, passing upwards into more regularly bedded and extensive sands, unconformably overlain by the Upper Forest Clay. Together with the underlying Lower Forest Clay, these sands form the Forest cycle.

Upper Cruse Sands.

A well-developed and laterally continuous sandy series, representing the last stage of the Cruse cycle. Unconformably overlain by the Lower Forest Clay.

Middle Cruse Sands.

A sand and silt series representing the middle stages of the Cruse cycle.

Lower Cruse Sands.

A sandy series, showing rather variable development, due probably to unconformity. This series represents the concluding stage of the Lower Cruse sub-cycle.

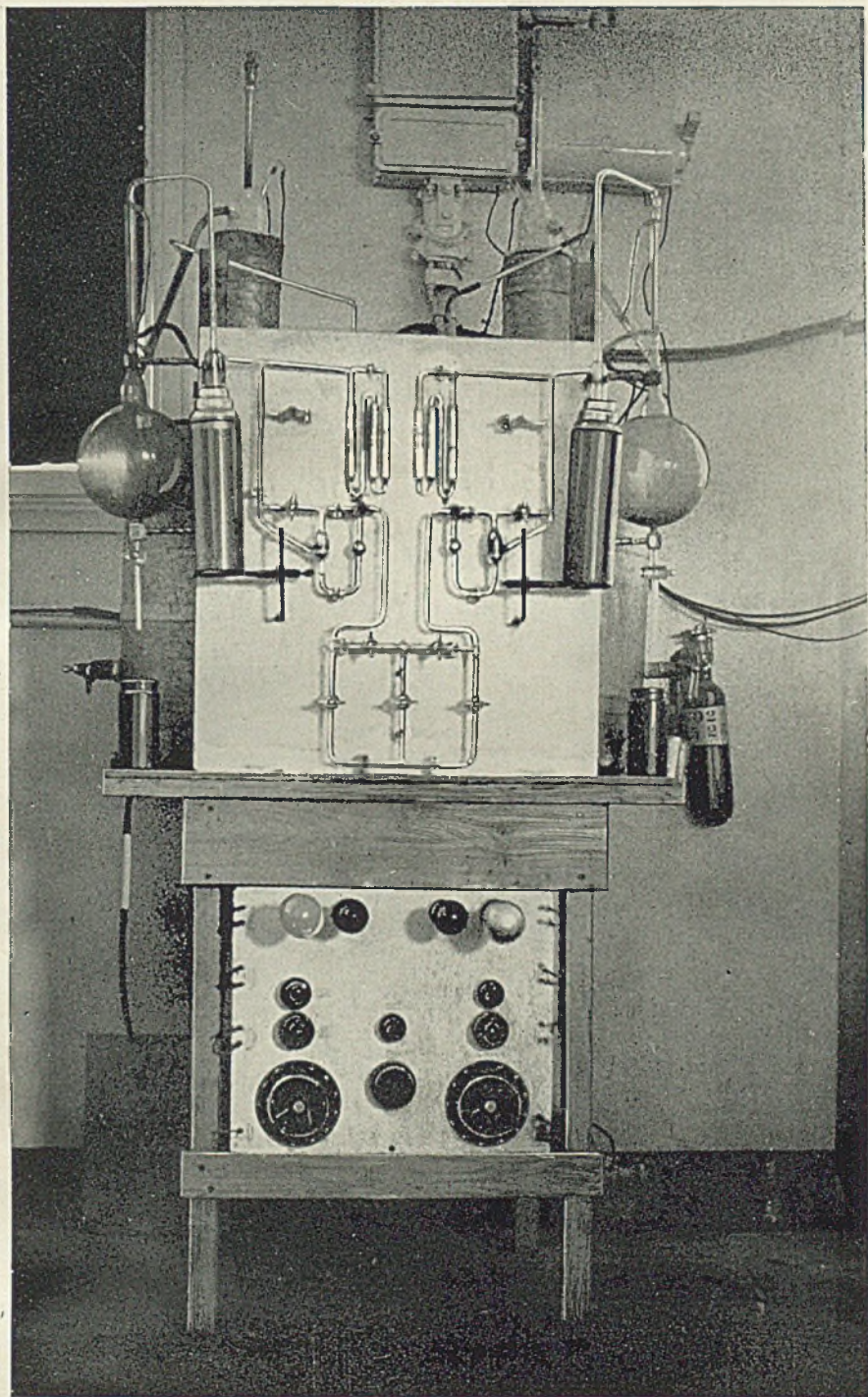


FIG. 6.

[To face p. 62.]

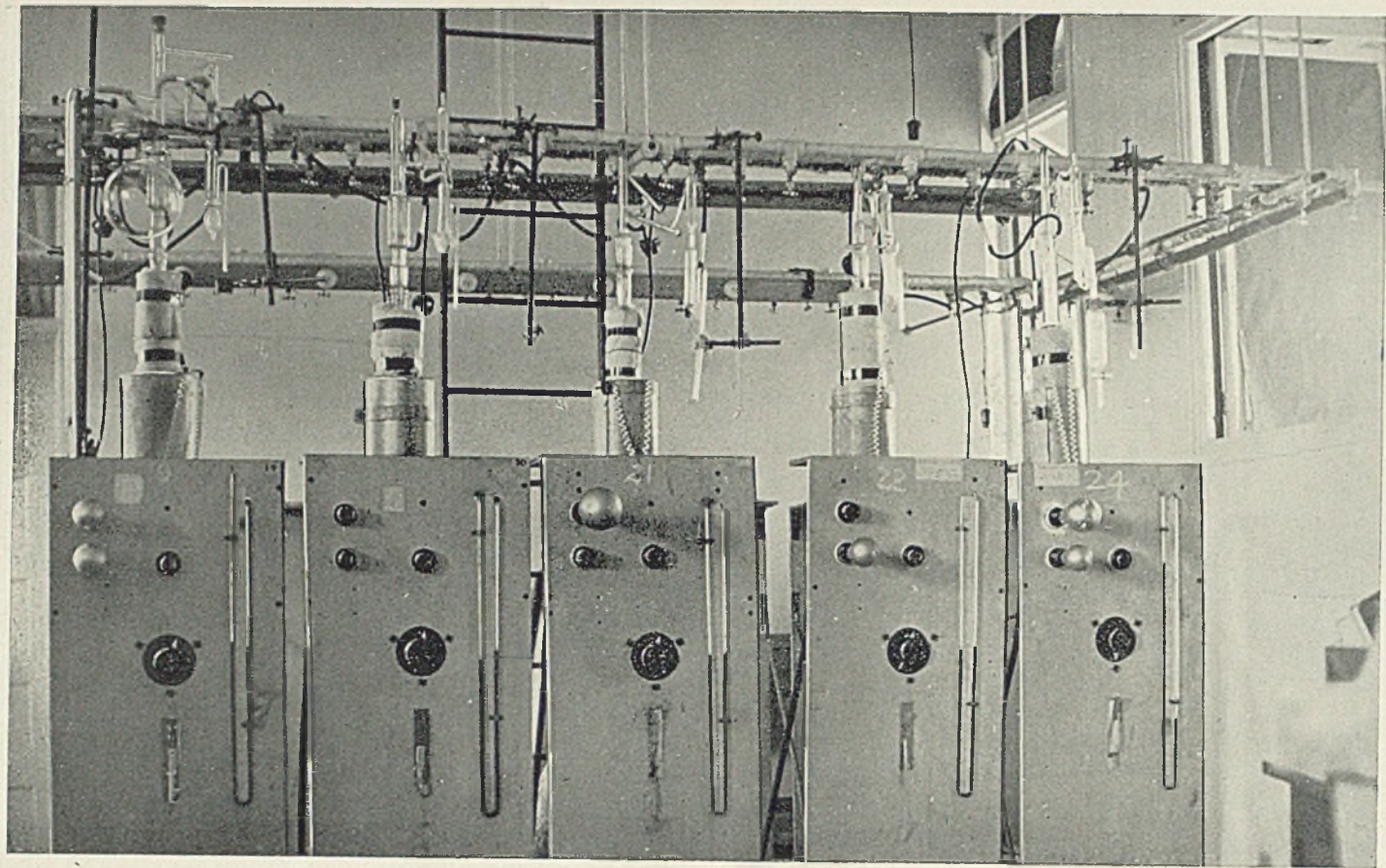


FIG. 22.

TABLE 1.

Crude Evaluation Data. Forest Reserve Wells.

| Column number | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 |
|---|---------|---------|---------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|
| Well | A | B | C | D | E | F | G | H | I | J | K | L | M | N | O |
| Horizon | F/Sands | F/Sands | F/Sands | Upper | Upper | Upper | Middle | Middle | Middle | Lower | Lower | Lower | Lower | Lower | Lower |
| Figure number | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 |
| Routine Analysis. | | | | | | | | | | | | | | | |
| Crude oil: | | | | | | | | | | | | | | | |
| Sp. gr. at 60° F. (dry oil) | 0.9593 | 0.9486 | 0.9357 | 0.9169 | 0.9148 | 0.9212 | 0.8615 | 0.8627 | — | 0.8923 | 0.8885 | 0.8822 | 0.8873 | 0.8456 | 0.8413 |
| Gravity, deg. A.P.I. (dry oil) | 16.0 | 17.6 | 19.7 | 22.8 | 23.2 | 22.1 | 32.8 | 32.6 | — | 27.1 | 27.8 | 28.9 | 28.1 | 35.9 | 36.7 |
| Visc. Say. Univ. at 100° F., sec. | 558 | 306 | 188 | 138 | — | 110 | 40 | 63 | — | 42 | 51 | 50 | 48 | 39 | 38 |
| Total sulphur, % wt. | 1.33 | 1.22 | 1.09 | 1.14 | 1.45 | 1.22 | 0.46 | — | — | 0.43 | 0.48 | 0.55 | 0.36 | 0.40 | 0.36 |
| Distillation of crude oil: | | | | | | | | | | | | | | | |
| % Light fractions (F.B.P. 200° C.) | 12.0 | 14.2 | 18.5 | 18.0 | 15.2 | 18.0 | 32.1 | 32.6 | 33.3 | 20.5 | 21.0 | 25.2 | 24.7 | 36.8 | 33.5 |
| Sp. gr. at 60° F. | 0.7914 | 0.7947 | 0.7780 | 0.7710 | 0.7685 | 0.7714 | 0.7624 | 0.7663 | 0.7649 | 0.7786 | 0.7823 | 0.7680 | 0.7709 | 0.7531 | 0.7540 |
| Gravity, deg. A.P.I. | 46.8 | 46.6 | 50.4 | 52.0 | 52.8 | 51.9 | 54.1 | 53.2 | 53.5 | 50.3 | 49.5 | 52.9 | 52.1 | 56.3 | 56.2 |
| % Distilled at 100° F. | 3.5 | Nil | 7.5 | 18.5 | 20.0 | 16.0 | 18.0 | 13.0 | 20.0 | 6.5 | 5.0 | 15.5 | 13.5 | 21.5 | 26.0 |
| % Residue (I.B.P. 200° C.) | 88.0 | 85.8 | 81.5 | 82.0 | 84.8 | 82.0 | 67.9 | 67.4 | 66.7 | 79.5 | 79.0 | 74.8 | 75.3 | 63.2 | 66.5 |
| Sp. gr. at 60° F. | 0.9662 | 0.9731 | 0.9680 | 0.9488 | 0.9496 | 0.9531 | 0.9118 | 0.9086 | 0.9149 | 0.9219 | 0.9183 | 0.9223 | 0.9245 | 0.9027 | 0.8913 |
| Gravity, deg. A.P.I. | 14.9 | 13.9 | 14.7 | 17.6 | 17.4 | 16.9 | 23.7 | 24.2 | 23.2 | 22.0 | 22.6 | 21.9 | 21.5 | 25.3 | 27.3 |
| Flash point (P.-M.), ° F. | 192 | 204 | 210 | 208 | 180 | 206 | 206 | 208 | — | 216 | 204 | 198 | 200 | 198 | 172 |
| Visc. Say. Univ. at 100° F., sec. | 700 | 1400 | 800 | 324 | 312 | 504 | 90 | — | — | 128 | 112 | — | 148 | 76 | 83 |
| Research Analysis. | | | | | | | | | | | | | | | |
| Residue (I.B.P. at 15 mm., ° C.) | 200 | 100 | 100 | 200 | 100 | 200 | 100 | 200 | 200 | 100 | 200 | 200 | 200 | 200 | 200 |
| % Asphaltenes in residue, by wt. | 3.10 | 1.54 | 1.20 | 0.610 | 1.05 | 1.43 | 0.124 | 0.389 | 0.194 | 0.194 | 0.191 | 0.325 | 0.438 | 0.123 | 0.143 |
| % Nitrogen in residue, by wt. | — | — | — | — | — | — | — | 0.2958 | — | — | 0.3075 | 0.676 | 0.2452 | — | — |
| % Asphaltenes in crude, by wt. | 2.62 | 1.29 | 1.02 | 0.500 | 0.890 | 1.15 | 0.098 | 0.262 | 0.129 | 0.154 | 0.150 | 0.243 | 0.328 | 0.078 | 0.095 |
| % Nitrogen in crude, by wt. | — | — | — | — | — | — | — | 0.1994 | — | — | 0.2429 | 0.0506 | 0.1846 | — | — |
| % Benzene, toluene, and xylene in material. | | | | | | | | | | | | | | | |
| F.B.P. 145° C.: | | | | | | | | | | | | | | | |
| B | 0.1 | 0 | 0.3 | 0.5 | 0.1 | — | 0.4 | 1.7 | — | 0.3 | 0.2 | 1.3 | 1.8 | 1.3 | 1.5 |
| T | 0.4 | 0.4 | 0.0 | 0.6 | 0.7 | — | 4.6 | 6.8 | — | 1.1 | 0.2 | 2.6 | 3.6 | 4.6 | 4.8 |
| X | 0.2 | 0.8 | 0.6 | 1.9 | 2.4 | — | 7.9 | 9.5 | — | 0.6 | 0.6 | 4.2 | 4.6 | 7.2 | 7.7 |
| % Aromatics in material F.B.P. 145° C. (A) | 0.7 | 1.2 | 0.9 | 3.0 | 3.2 | — | 12.9 | 18.0 | — | 2.0 | 1.0 | 8.1 | 10.0 | 13.1 | 14.0 |

Crude Oils of the Forest Sands.

A number of crude oils from the Forest Sands have been examined. Despite differences in physical appearance the oils examined, with few exceptions, proved to be identical throughout the area under investigation. Crude evaluation data of three typical oils are given in Columns 1, 2, and 3 of Table I, the characteristic graphs being given in Figs. 7, 8, and 9. As will be noted, the characteristic graphs are identical for each of the three naphthas. The aromatic content of the naphthas is extremely low, and throughout the entire boiling range naphthenic

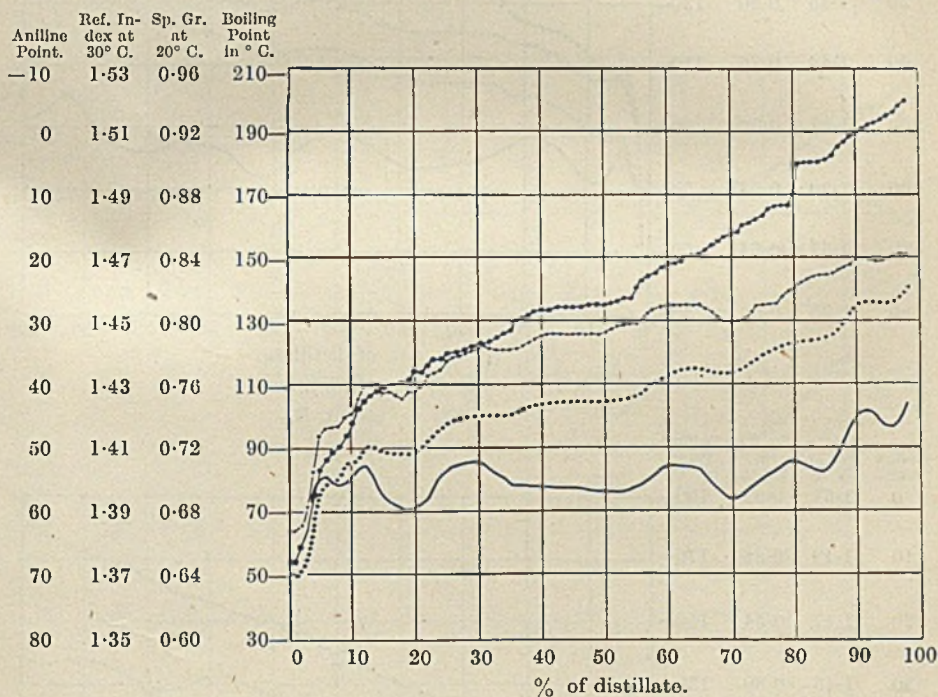


FIG. 7.

WELL A.

hydrocarbons preponderate. The presence of *cyclohexane*, *methylcyclohexane*, *dimethylcyclohexane*, and certain *trimethylcyclohexanes* can be inferred from the physical constants of the fractions isolated. In subsequent detailed examination of these naphthas¹⁹ only traces of normal paraffins could be isolated, whilst the amount of *cyclopentane* derivatives was also small. Thus the naphthas fall into group 1 of the naphthenic type as classified by Fenske, Tonberg, and Sweeny.⁷ It is interesting to note that by the Bureau of Mines Method³ the light fractions would be classified as naphthenic. The examination of certain exceptional oils from this area is continuing.

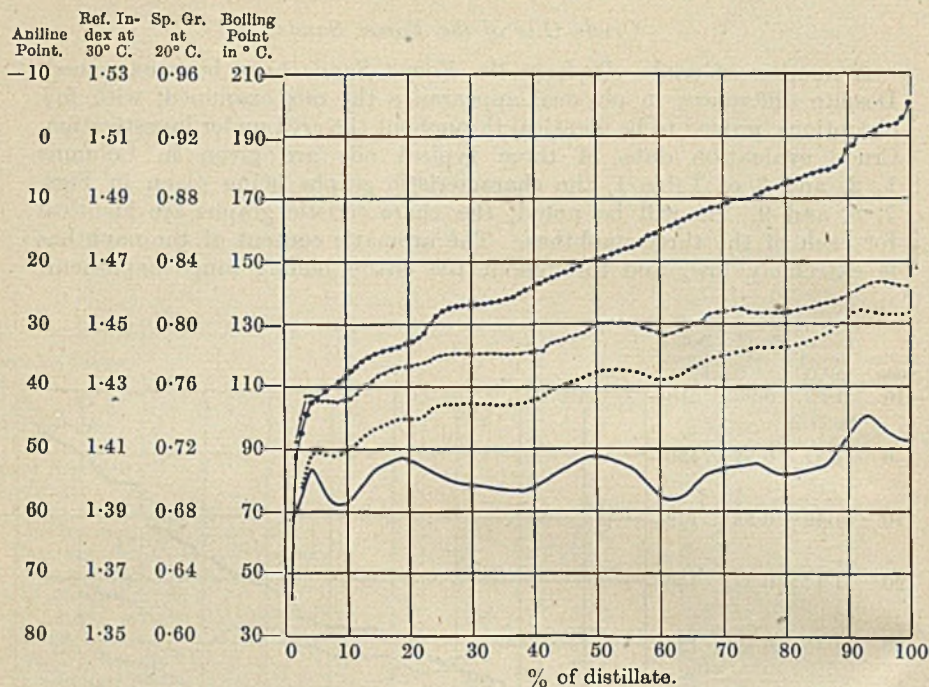


FIG. 8.
WELL B.

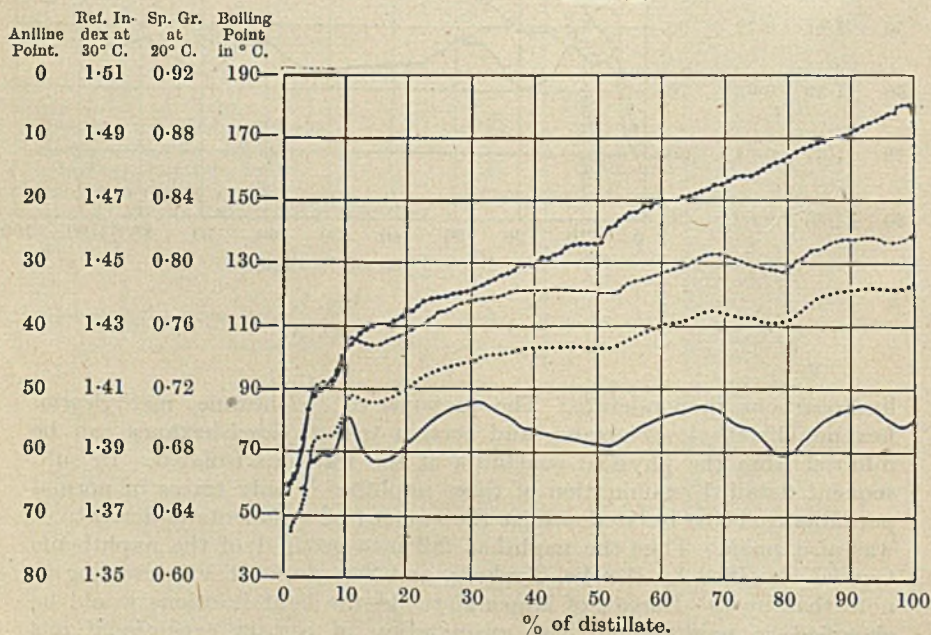


FIG. 9.
WELL C.

Crude Oils of the Upper Cruse Sands.

A number of crude oils from within a strictly limited area of the Upper Cruse Sands have been examined. The original investigation was carried out to assist in a geological examination of the area connected with a study of pressure maintenance. Despite minor differences in crude-oil properties (slight variation in crude-oil gravity, etc., the significance of which is being studied), the oils examined proved to be identical. Crude evaluation data of three oils are given in Columns 4, 5, and 6 of Table I, whilst the corresponding characteristic graphs are given in Figs. 10, 11, and 12, by reference to which it will be noted that naphthas are identical. The

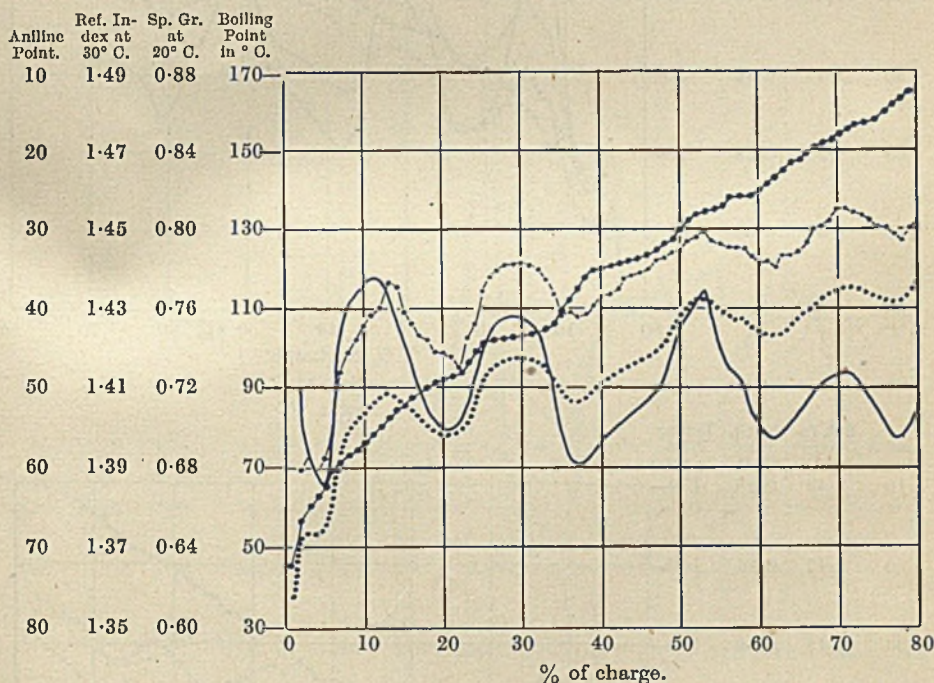


FIG. 10.

WELL D.

aromatic content of the naphthas is low (2-3 per cent.), but slightly greater than the values recorded for the crude oils of the Forest Sands. The presence of small quantities of benzene, toluene, and xylenes is indicated by the physical constants of the fractions and confirmed by the B.T.X. data. Normal paraffins are present only in small amounts, but the presence of certain branched-chain paraffins has been confirmed in the fractions boiling between 85° C. and 95° C. Naphthenic hydrocarbons, however, constitute the main portion of the fractions. The presence of *cyclopentane*, *methylcyclopentane*, *cyclohexane*, *dimethylcyclopentanes*, *methylcyclohexane*, *dimethylcyclohexanes*, and *trimethylcyclohexanes* can be inferred from a study of the characteristic graphs and has been confirmed by subsequent detailed study of the bulk naphtha from this area.¹⁹

| Aniline Point. | Ref. Index at 30° C. | Sp. Gr. at 20° C. | Boiling Point in ° C. |
|----------------|----------------------|-------------------|-----------------------|
| 10 | 1.49 | 0.88 | 170 |

| | | | |
|----|------|------|-----|
| 20 | 1.47 | 0.84 | 150 |
| 30 | 1.45 | 0.80 | 130 |
| 40 | 1.43 | 0.76 | 110 |
| 50 | 1.41 | 0.72 | 90 |
| 60 | 1.39 | 0.68 | 70 |
| 70 | 1.37 | 0.64 | 50 |
| 80 | 1.35 | 0.60 | 30 |

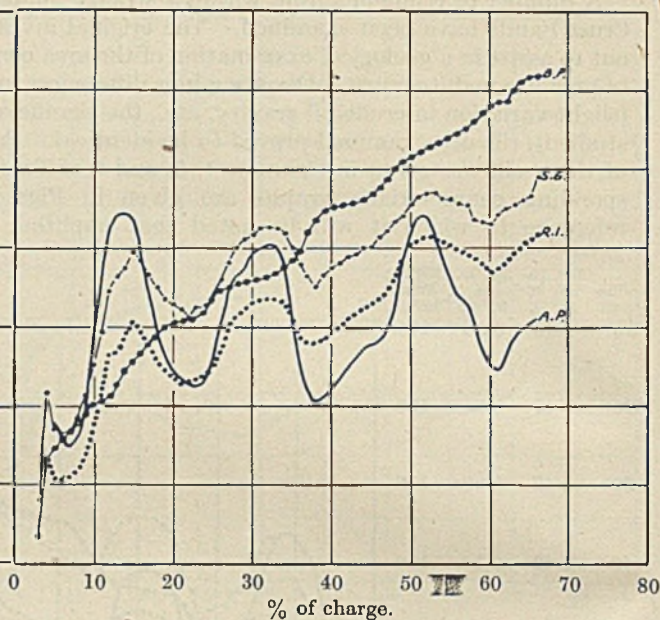


FIG. 11.

WELL E.

| Aniline Point. | Ref. Index at 30° C. | Sp. Gr. at 20° C. | Boiling Point in ° C. |
|----------------|----------------------|-------------------|-----------------------|
| 10 | 1.49 | 0.88 | 170 |

| | | | |
|----|------|------|-----|
| 20 | 1.47 | 0.84 | 150 |
| 30 | 1.45 | 0.80 | 130 |
| 40 | 1.43 | 0.76 | 110 |
| 50 | 1.41 | 0.72 | 90 |
| 60 | 1.39 | 0.68 | 70 |
| 70 | 1.37 | 0.64 | 50 |
| 80 | 1.35 | 0.60 | 30 |

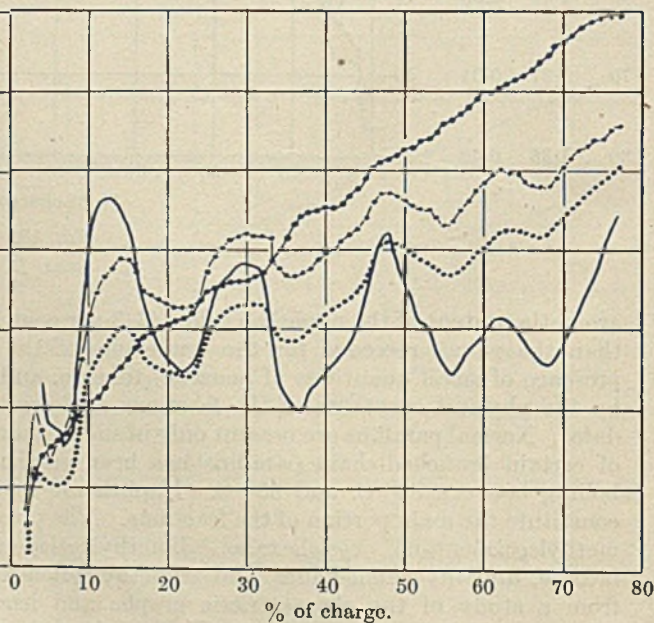


FIG. 12.

WELL F.

Crude Oils of the Middle Cruse Sands.

As might be expected from the nature of the Middle Cruse Sands, the crude oils from this horizon show some variations in physical properties. The analysis of the naphtha, however, indicates the chemical nature of the crude oils from these sands to be identical; three examples are given. The crude evaluation data are given in Columns 7, 8, and 9 of Table I, and the corresponding characteristic graphs in Figs. 13, 14, and 15. The identity of the naphthas is clearly indicated by the characteristic graphs, which further show the presence of quantities of normal paraffins and aromatic hydrocarbons. These graphs should be compared with the

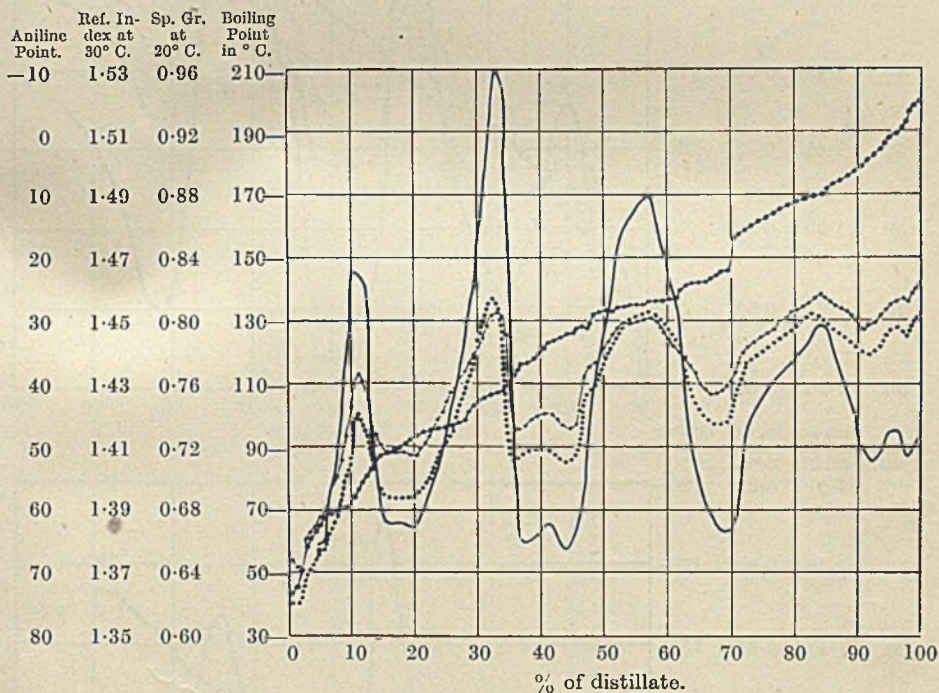


FIG. 13.

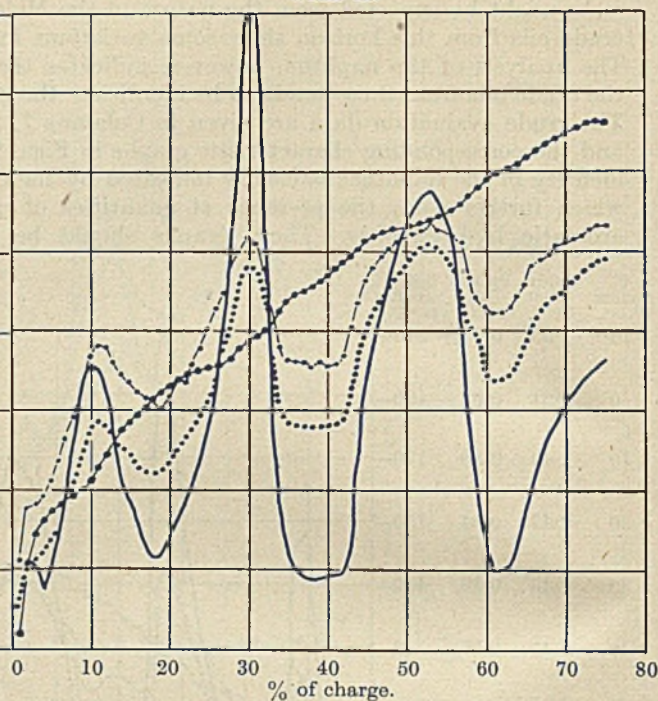
WELL G.

refractive-index data given by Fenske, Tonberg, and Sweeny¹⁷ for a Ponca City naphtha. The naphthas contain large amounts of normal paraffins, together with moderate amounts of aromatic and naphthenic hydrocarbons. Both *cyclopentane* and *cyclohexane* derivatives have been identified. By methods similar to those used by the A.P.I. Project⁶ workers,¹⁸ the presence of the following hydrocarbons has been demonstrated:¹⁹ *n*- and *iso*-pentane, *cyclopentane*, *n*-hexane, *n*-heptane, *n*-octane, 2- and 3-methylpentane, methyl*cyclopentane*, *cyclohexane*, certain dimethylhexanes, methyl*cyclohexane*, dimethyl*cyclohexanes*, benzene, toluene, xylenes, mesitylene, pseudocumene, ethyl benzene. Classified by the U.S. Bureau of Mines Method,³ the light fractions of the Middle Cruse oils are of intermediate type.

| Aniline Point. | Ref. In- dex at 30° C. | Sp. Gr. at 20° C. | Boiling Point in ° C. |
|-------------------|------------------------------|-------------------------|-----------------------------|
| 0 | 1.51 | 0.92 | 190 |

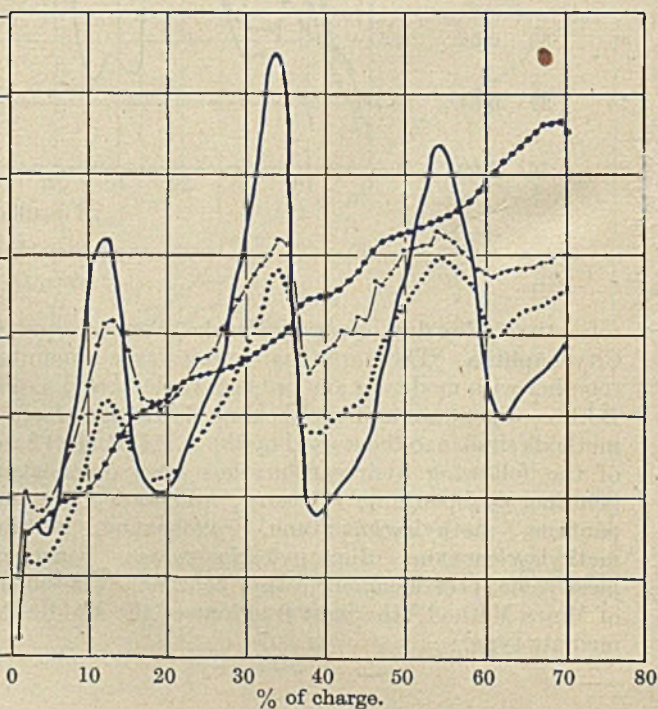
FIG. 14.
WELL H.

| | | | |
|----|------|------|-----|
| 10 | 1.49 | 0.88 | 170 |
| 20 | 1.47 | 0.84 | 150 |
| 30 | 1.45 | 0.80 | 130 |
| 40 | 1.43 | 0.76 | 110 |
| 50 | 1.41 | 0.72 | 90 |
| 60 | 1.39 | 0.68 | 70 |
| 70 | 1.37 | 0.64 | 50 |
| 80 | 1.35 | 0.60 | 30 |



| Aniline Point. | Ref. In- dex at 30° C. | Sp. Gr. at 20° C. | Boiling Point in ° C. |
|-------------------|------------------------------|-------------------------|-----------------------------|
| 0 | 1.51 | 0.92 | 190 |

| | | | |
|----|------|------|-----|
| 10 | 1.49 | 0.88 | 170 |
| 20 | 1.47 | 0.84 | 150 |
| 30 | 1.45 | 0.80 | 130 |
| 40 | 1.43 | 0.76 | 110 |
| 50 | 1.41 | 0.72 | 90 |
| 60 | 1.39 | 0.68 | 70 |
| 70 | 1.37 | 0.64 | 50 |
| 80 | 1.35 | 0.60 | 30 |

FIG. 15.
WELL I.

Crude Oils of the Lower Cruse Sands.

In order to assist geological work in a section of the Lower Cruse Horizon, a number of crude oils representing the production of the various Lower Cruse Sands have been examined. Unlike the oils of the Forest and Upper Cruse Sands, the Lower Cruse oils examined were of three distinct types, designated as Class I, II, and III. The oils of Class I are definitely naphthenic in character, crude evaluation data being given in Columns 10

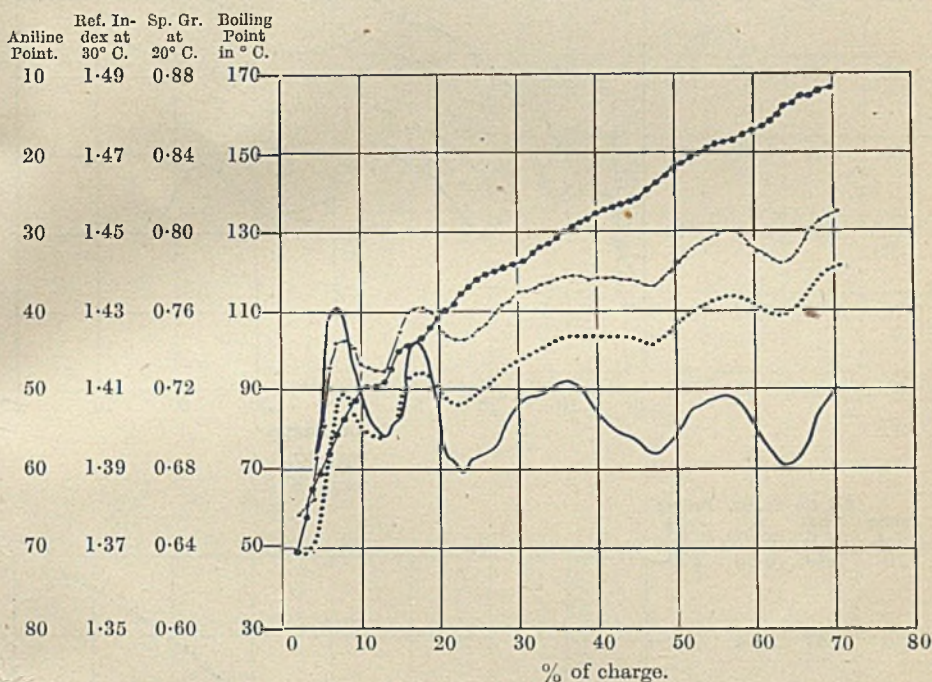


FIG. 16.

WELL J.

and 11 of Table I, whilst the characteristic graphs of these oils are given in Figs 16 and 17. The bulk of the oils examined was of the Class II type illustrated by the oils shown in Columns 12 and 13 (Table I), and Figs. 18 and 19. A small number of the oils were of the Class III type illustrated by the oils shown in Columns 14 and 15 (Table I), and Figs. 20 and 21.

Class I Oils.

The naphthas of the Class I oils are similar to the naphthas of the Forest Sand oils. They are essentially naphthenic, containing only traces of aromatic hydrocarbons, but differ from the naphthas of the Forest Sand oils in containing a greater quantity of material boiling below 100° C. The lower-boiling fractions contain branched-chain hydrocarbons (dimethylpentanes b.pt. 90–91° C.), cyclopentane derivatives, as well as relatively large amounts of cyclohexane and methylcyclohexane. The oils can be

| Aniline Point. | Ref. Index at 30° C. | Sp. Gr. at 20° C. | Boiling Point in ° C. |
|----------------|----------------------|-------------------|-----------------------|
| 10 | 1.49 | 0.88 | 170 |

20 1.47 0.84 150

30 1.45 0.80 130

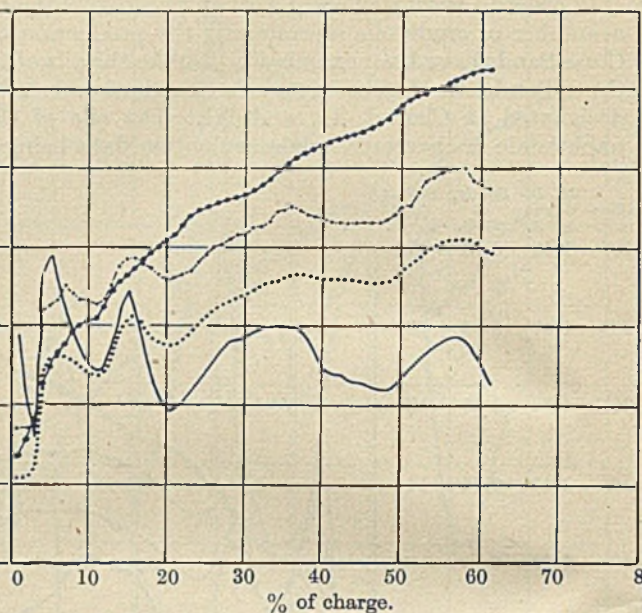
40 1.43 0.76 110

50 1.41 0.72 90

60 1.39 0.68 70

70 1.37 0.64 50

80 1.35 0.60 30



% of charge.

FIG. 17.

WELL K.

| Aniline Point. | Ref. Index at 30° C. | Sp. Gr. at 20° C. | Boiling Point in ° C. |
|----------------|----------------------|-------------------|-----------------------|
| 10 | 1.49 | 0.88 | 170 |

20 1.47 0.84 150

30 1.45 0.80 130

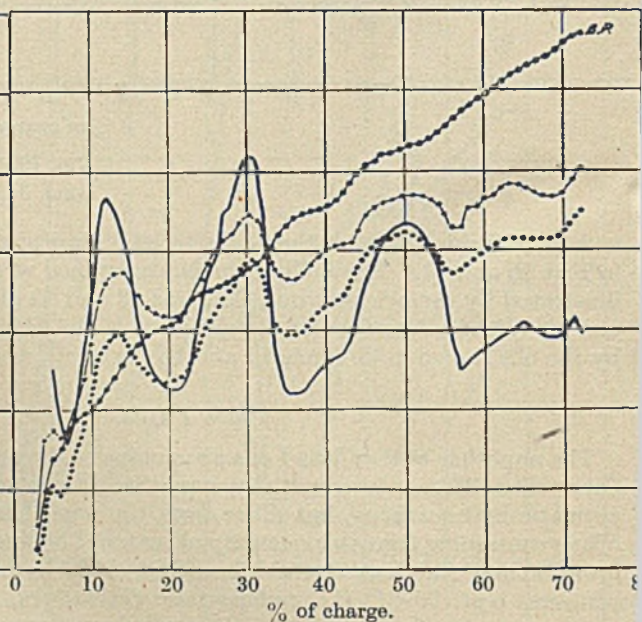
40 1.43 0.76 110

50 1.41 0.72 90

60 1.39 0.68 70

70 1.37 0.64 50

80 1.35 0.60 30



% of charge.

FIG. 18.

WELL L.

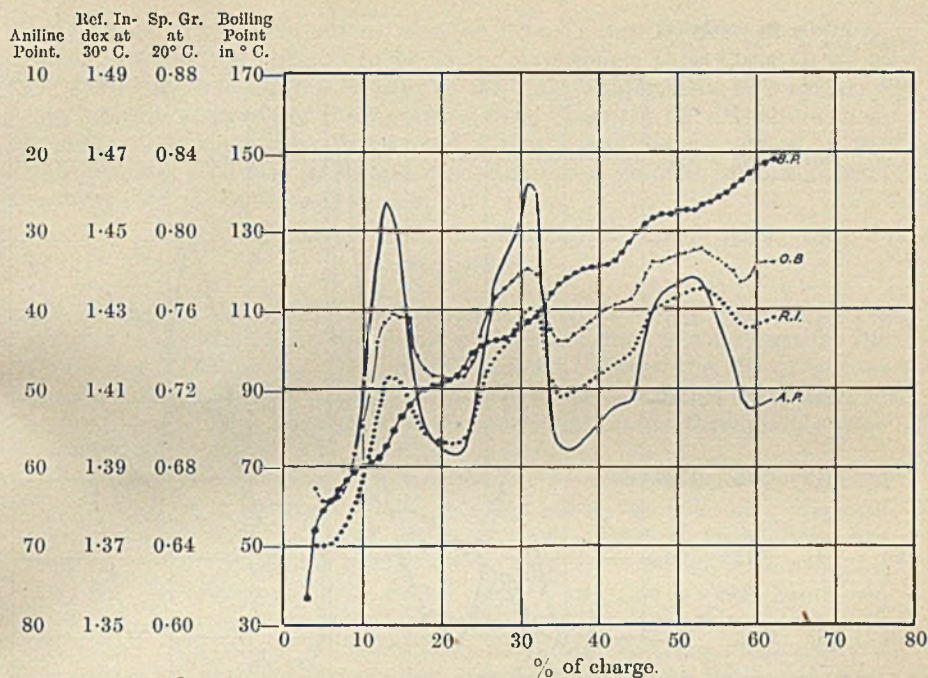


FIG. 19.

WELL M.

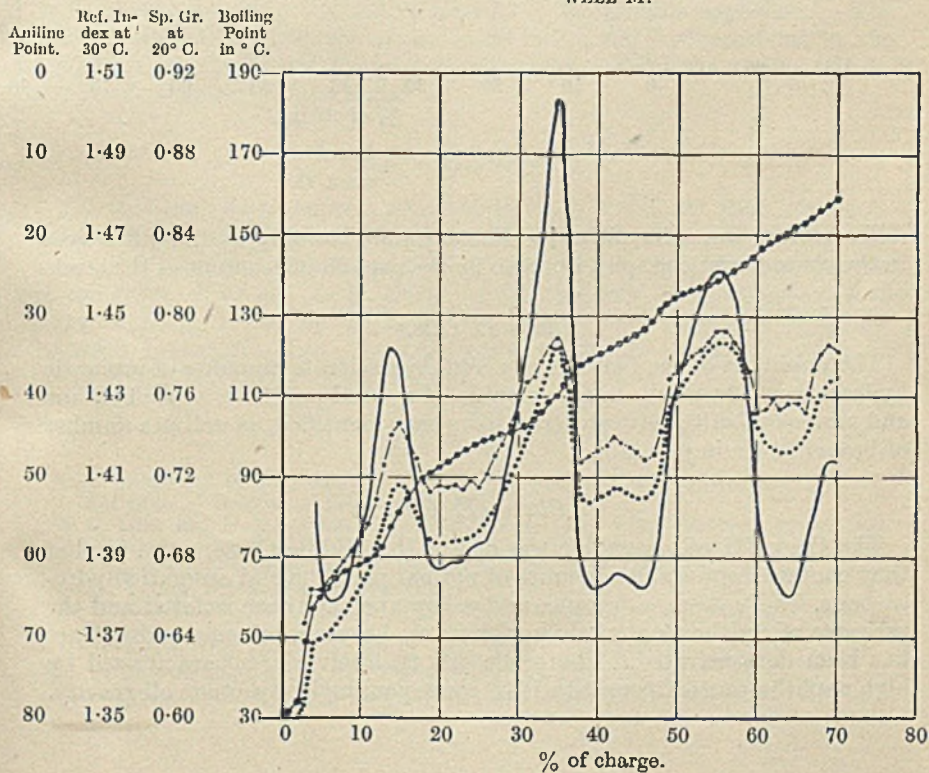


FIG. 20.

WELL N.

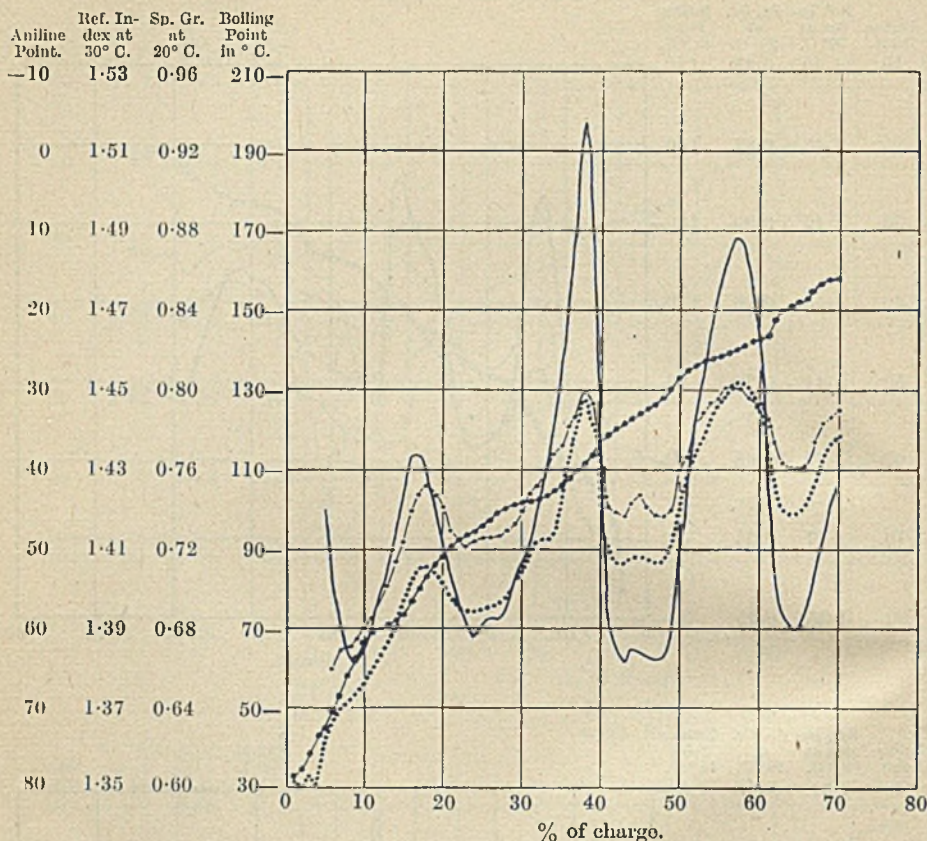


FIG. 21.

WELL O.

differentiated from the oils of the Forest Sands not only by the differences in the characteristic graphs, but also by the asphaltene content of the crude oils.

Class II Oils.

The naphthas of the Class II oils contain moderate amounts of aromatic hydrocarbons, but only small amounts of normal paraffins. *cyclo*Pentane and various substituted derivatives have been identified, as well as a number of branched-chain paraffins.

Class III Oils.

The Class III oils resemble the oils of the Middle Cruse series in that they contain appreciable amounts of normal paraffins and aromatic hydrocarbons. *n*-Pentane, *n*-hexane, and *n*-heptane have been isolated and the presence of *cyclo*hexane, methyl*cyclo*hexane, benzene, toluene, and xylenes has been demonstrated. The crude oils themselves are characterized by high naphtha content coupled with a correspondingly low crude oil gravity.

The bulk of the production from the Lower Cruse Horizon in the area under examination appears to be of the naphthenic type Class II. The oil is probably a mixture consisting of the Class I naphthenic oil with small and varying amounts of the paraffinic type Class III oil. There is some evidence that these oils are grouped within specific areas related to the fault system, and that in certain cases there is a gradual transition from the Class III to the Class II type of oil.

DISCUSSION.

The examination of a large number of crude oils from the Forest Reserve Field indicates that analysis by the methods outlined can be used for the correlation of crude oils. Differences existing between the oils of various horizons are noted. The analysis of one crude oil can be completed in approximately four days. Using duplicate apparatus throughout, from ten to fifteen crude oils can be analysed per week.

Crude-oil surveys of the type outlined are of considerable value in planning refinery operations, and can be used as the basis of a crude-oil segregation programme. The importance of crude-oil segregation has recently been emphasized by Nelson.²⁰ In the Forest Reserve area, for instance, the crude oils of the Forest, Upper, and Lower Cruse Sands can be bulked as producing naphthenic oils of similar (though not identical) character. In general, the observations of Fenske, Tonberg, and Sweeny¹⁷ concerning the composition of virgin naphthas have been confirmed, more particularly the statement that "contrary to expectations aromatic hydrocarbons are present in low concentrations in naphthenic naphthas." The observations concerning the presence of individual hydrocarbons in the naphthas examined, and the geological applications of the survey will be amplified in future publications.

ACKNOWLEDGMENT.

The authors wish to express their gratitude to Mr. K. W. Barr, Dr. H. G. Kugler, Dr. C. J. May, and Mr. H. C. H. Thomas, of the Production and Geological Departments, for assistance in planning the geological aspects of the survey; to Mr. A. E. Gerty of the Refinery Laboratory for data given in Table I; to Mr. F. L. Melvill and the Management of Messrs. Trinidad Leaseholds, Ltd., for permission to publish work carried out in the Company's Research Laboratories.

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ABSTRACTS.

| | PAGE | | PAGE |
|-----------------------------------|------|---------------------------------|------|
| Geology and Development ... | 30 A | Chemistry and Physics of Hydro- | |
| Drilling ... | 44 A | carbons ... | 60 A |
| Production ... | 47 A | Motor Fuels ... | 69 A |
| Transport and Storage ... | 52 A | Gas, Diesel, and Fuel Oils ... | 70 A |
| Gas ... | 53 A | Lubricants and Lubrication ... | 72 A |
| Polymerization and Alkylation ... | 53 A | Asphalt and Bitumen ... | 74 A |
| Synthetic Products ... | 54 A | Special Products ... | 74 A |
| Refining and Refinery Plant ... | 57 A | Detonation and Engines ... | 75 A |
| Fire Prevention ... | 60 A | Coal and Shale ... | 76 A |
| | | Economics and Statistics ... | 77 A |

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.

- Agruss, M. S., 237,
 Albright, J. C., 117
 Alexander, C. W., 102
 Allen, H., 127
 Anthony, R. L., 154
 Appalachian Geological
 Society, 85
 Armentrout, A. L., 119
 Arsdell, P. M. van., 252
 Ayers, G. W., 237
 Ayers, L. K., 119
 Bachman, G. B., 184
 Bailey, J. R., 189
 Bailey, T. D., 125
 Baker, W. L., 121
 Baldwin, F. P., 146
 Ballantyne, R. S., 115
 Baruch Committee, 137
 Beatty, H. A., 220
 Bekkedahl, N., 143
 Bell, H. W., 124
 Berger, L. B., 248
 Bimmerman, H. G., 155
 Binnie, A. M., 134
 Blanpied, B. W., 94
 Bogin, C., 244
 Bonnet, C. F., 223
 Borden, J. L., 81
 Bossler, R. B., 126
 Botkin, D. F., 211
 Bowen, G. W., 127
 Boynton, A., 119
 Bradley, W. E., 203
 Bragg, L. B., 218
 Brill, K. G., 97
 Brooks, B. T., 165, 251
 Brown, H. C., 178, 179
 Brown, K. M., 136
 Bruce, W. E., 226
 Buckley, D. J., 142
 Budenholzer, R. A., 211
 Burk, R. E., 165, 194
 Bynum, P. T., 119
 Byrns, A. C., 203
 Campbell, J. G., 119
 Campbell, W. B., 119
 Campbell, W. P., 182
 Carney, S. C., 165
 Case, E. N., 187
 Cattell, A. R., 245
 Cheney, M. G., 112
 Chenicek, J. A., 136
 Cheyney, L. V. E., 151
 Church, W. L., 127
 Claggett, E. E., 130
 Clark, J. B., 127
 Clayton, E. E., 127
 Clowes, G. H. A., 171
 Cole, T., 98
 Collins, A. J., 127
 Collins, F. C., 212
 Conner, R. E., 119
 Corner, J. C., 170
 Coroniti, S. C., 164
 Crawford, J. G., 96
 Croneis, C., 93
 Crow, R. H., 119
 Crowell, A. M., 125
 Dana, F. E., 127
 Davis, D. S., 133, 197, 204
 Davis, W. W., 171
 Davison, J. A., 214
 Dennison, E. R., 231
 Diamond, H., 234
 Dickey, P. A., 126
 Dietzmann, S. J., 127
 Dons, E. M., 165
 Dorrance, J. R., 86
 Dougherty, G., 177
 Dow, W., 139
 Drennan, H. E., 165
 Dumoulin, F. E., 201
 Eastman, Du B., 246
 Ebberts, A. R., 238
 Egloff, G., 252
 Elder, A. L., 138
 Elliot, M. A., 248
 Ennis, G. H., 119
 Evans, C. L., 127
 Farkas, A., 135
 Farkas, L., 135
 Fieser, L. F., 185
 Fisher, H. L., 159
 Flory, P. J., 172
 Fragen, N., 136
 Fraser, D. F., 145, 241
 Fraser, J. A., 141
 Freese, J. A., 147
 Frey, F. E., 225
 Friend, L., 206
 von Fuchs, G. H., 234
 Fuenning, P., 103
 Fuoss, R. M., 176
 Gardner, R. I., 119
 Garvey, B. S., 141, 147,
 148, 149, 150
 Gerlicher, R. A., 245
 Gillbergh, J. R., 127
 Goebel, C. B., 184
 Gohlke, 247
 de Golyer, E., 92
 Grant, R. P., 84
 Griffen, G. L., 166
 Griswold, J., 205
 Grosse, A. V., 168
 Grummitt, O., 187
 Gurd, G. W., 165
 Guth, E., 154, 157
 Hall, J. D., 119, 127
 Hamilton, L. A., 245
 Hanna, W. S., 191
 Hanson, A. C., 152
 Hass, H. B., 240
 Hawk, C. O., 174
 Haworth, J. P., 146
 Hazzard, R. T., 94
 Henne, A. L., 186
 Hill, M. L., 87
 Horeczy, J., 181
 Horne, G. H., 216
 Howard, W. V., 113
 Howe, H. M., 89
 Howe, J. P., 167
 Howell, L. G., 119
 Howlett, R. M., 142
 Hudson, E. J., 127
 Huggett, J. L., 225
 Hughes, E. C., 165
 Humphrey, D. E., 127
 Hunt, H., 242
 Hunter, T. G., 213
 Ipatieff, V. N., 168
 Irons, C. R., 119
 James, H. M., 157
 Johnson, J. M., 119
 Johnston, L., 119
 Justis, D. W., 127
 Juve, A. E., 149
 Kane, S. S., 179
 Karnofsky, 207
 Kasch, J. E., 205
 Keffer, W. F., 167
 Kelley, E. J., 151
 Kelly, B. F., 119
 Kelly, J., 127
 Kharash, M. S., 178,
 179
 Kiperash, M., 173
 Kirn, E. R., 136
 Kobe, K. A., 193
 Koch, F. C., 225
 Koester, E. A., 82
 Kothney, G. L., 119
 Krah, M. E., 171
 Krase, N. W., 222
 Krymova, L. G., 192
 Kurtz, S. S., 214, 233
 Lacey, W. N., 202, 211,
 215, 219
 Lamberger, E. H., 119
 Landsberg, W., 224
 Langer, B. F., 119
 Lankelma, H. P., 194
 Larian, M. G., 221
 Larsen, R. G., 209
 Laudermilk, J. J., 120
 Lawson, W. E., 127
 Leifer, E., 190
 Levorsen, A. I., 111
 Lipkin, M. R., 214
 Lobo, W. E., 206
 Lochte, H. L., 181
 Lowery, C., 127
 Lucas, F. F., 158
 Lyon, N. X., 108
 Mackeown, S. S., 129
 Mahan, R., 189
 Maier, A. R., 119
 Mark, H., 153
 Markham, A. E., 193
 Markley, E. A., 95
 Marvel, C. S., 170
 Matteson, R., 191
 Mauro, O. G., 165
 Maxwell, J. B., 165
 Mayfield, F. D., 208
 Mead, D. J., 176
 Melaven, R. M., 225
 Miller, E. E., 119
 Miller, J. C., 101
 Moll, R. A., 142
 Moore, T. V., 127
 Moren, R. C., 245
 Mowrey, L. D., 127
 Mudd, O. C., 128
 Muller, J. A., 119
 Musatov, K. A., 192
 McArdle, E. H., 243
 McBee, E. T., 240
 McClain, H. M., 127
 McClaughry, R. A., 165
 McDuffie, Jr. H. F., 177

- McShane, P., 119
- Naragon, E. A., 194
- Neal, A. M., 155
- Neher, C. M., 240
- Nelson, W. L., 228
- Neufeld, J., 119
- Noble, W. B., 119
- Novello, F. C., 185.
- Ocon, E. A., 225
- Olds, R. H., 215, 219
- O'Leary, C. M., 119
- O'Neill, W. E., 174
- Ospina-Racines, E., 107
- Ostrom, E. W., 127
- Othmer, D. F., 198, 199, 200, 217
- Owen, E. W., 88
- Parks, G. S., 173
- Paulus, G. L., 123
- Peacock, H. B., 90
- Peterson, L. E., 154
- Piemister, J., 250
- Pines, H., 168
- Polly, O. L., 203
- Poole, J. W., 236
- Pratt, W. E., 91
- Prettyman, I. B., 144
- Proell, W. A., 165, 237
- Reamer, H. H., 219
- Richard, Z. B., 119
- Richards, A. R., 218
- Riddle, E. H., 170
- Riemann, K. F., 127
- Rifenberick, W. L., 161
- Roberts, S. M., 189
- Robertson, A. E., 243
- von Rosenberg, H. J., 119
- Roth, F. L., 143
- Roth, R., 99
- Ryan, J. G., 162
- Sage, B. H., 202, 211, 215, 219
- Sarbach, D. V., 148
- Schindler, H., 237
- Schulze, W. A., 165
- Schumacher, F. W., 165
- Schumacher, J. E., 242
- Scott, G. L., 119
- Seager, O. A., 100
- Shankland, R. A., 225
- Shaw, E. N., 180
- Shive, B., 181, 189
- Shop Transport of Supplies, 229
- Short, G. H., 165
- Showalter, J. C., 245
- Silverman, A., 196, 210
- Smallwood, J. C., 219
- Smoker, E. H., 195
- Smyth, C. P., 183
- Soffer, M. D., 182
- Stambaugh, R. B., 156
- Steadman, T. R., 182
- Sterrett, E., 122
- Still, A. C., 127
- Stinson, T. K., 119
- Stone, A. L., 127
- Stone, F., 127
- Storch, H. H., 174
- Stratford, R. K., 165
- Strickland, H., 240
- Sun, K. H., 196, 210
- Thayer, S. 131
- Thompson, A. F., Jr. 180
- Thomson, G. W., 220
- Thorpe, K. E., 165
- Thorpe, R. E., 209
- Tobias, P. E., 198, 199, 200
- Treybal, R. E., 201
- Turk, A., 186
- Turkevich, A., 183
- Twelvetrees, W. N., 230
- Urey, H. C., 190
- Valerius, C. N., 95
- Vaughan, W. E., 212
- Vila, G. R., 140
- Vincent, J. R., 155
- Wakeman, R. L., 160
- Wall, F. T., 175
- Wamprier, H. L., 244
- Wash, G., 181
- Washburn, 165
- Weeks, W. B., 102
- Weil, B. H., 160
- Wheland, G. W., 188
- Whitlock, M. H., 147
- Wiggen, M., 245
- Williams, G. H., 127
- Williams, N., 118
- Willis, R., 115
- Wilson, G. M., 116
- Wood, L. A., 143
- Woodbury, C. A., 127
- Woodward, R. B., 169
- Wouk, V., 129
- Yerzley, F. L., 241
- Ziegenhain, W. T., 239

Geology and Development.

81.* Development in Oklahoma during 1941. J. L. Borden. *Bull. Amer. Ass. Petrol. Geol.*, June 1942, 26 (6), 1058.—After declining since 1937, Oklahoma's total production rose in 1941 by 2½ million bbl. to 152 million bbl., or 10·9% of the total for the U.S.A. Estimated reserves have also increased to 1036 million bbl. The chief areas of new oil and augmented production are in the south and south-west. In the northern part of the State increases have been chiefly obtained by reconditioning wells and by deeper drilling. As a whole the central countries have declined.

Discoveries of forty-one new pools were made, of which Apache, in Caddo County, is the most important. A 3433-ft. well was completed in September 1941 in Simpson sand (Middle Ordovician), which flowed 1466 bbl. of oil—39·2° gravity corrected—in twenty-four hours, and about 3 million cu. ft. gas. Gas is also encountered in higher formations—viz., Sylvan dolomite and Viola limestone (Ordovician)—and its control presents problems, but it will be valuable in repressuring and in gas-recycling when the Simpson gas falls off. A seismographical survey discovered this trap, which is in the form of an asymmetrical fold, probably overturned.

The 40-acre spacing rule may somewhat curtail Oklahoma production. A. L.

82.* Developments in North Mid-Continent in 1941. E. A. Koester. *Bull. Amer. Ass. Petrol. Geol.*, June 1942, 26 (6), 1073.—Kansas produced 83,229,159 bbl. crude oil in 1941, compared with 64,824,721 bbl. in 1940—an increase of 28%. Output was speeded up with ease as pipeline facilities were made available.

Heightened activity in wildcats caused an increase in the percentage of dry holes from 20·3 in 1940 to 26·9 in 1941, in which year 1253 oil-wells, 75 gas-wells, and 490 dry holes were completed.

The chief discovery was commercial production from a sand in the Cherokee (Lower Pennsylvanian) at a depth of 4740–4752 ft. in the Patterson pool, Kearny County, Kansas. Initial output was 3000 bbl./day. This opens up hopes of similar productive areas in western Kansas and in eastern Colorado.

An important group of pools has been found in the Viola limestone (Ordovician), along the Peace Creek trend in south-west Reno County. Eighteen wells completed in 1941 had a potential of 48,879 bbl. These pools are north-east of the Zenith pool, which they resemble. New pools on the Central Kansas uplift are relatively unimportant. In north-west Kansas the Ray pool is successful. Development of the McLouth pool, Forest City basin, continued.

A "pay" was found at depth in the Hunton dolomite (Siluro-Devonian) of Falls City pool, Richardson County, Nebraska. In the same county the Barada pool has

been drilled in an equivalent dolomite which was topped at 2432 ft. Productive capacity is the same in both, but the Barada producing area may be small.

Six dry holes each, in Missouri and Iowa, showed small promise. No wells were drilled in South Dakota, but exploration goes on. Low crude-oil prices discouraged wildcatting in these three States. A. L.

83.* Developments in Eastern Interior Basin in 1941. A. H. Bell. *Bull. Amer. Ass. Petrol. Geol.*, June 1942, **26** (6), 1086.—In 1941, 3838 wells were drilled in Illinois, more than in any year except 1907. In spite of a rise in south-western Indiana from 450 (1940) to 463 wells, the decrease in drilling in western Kentucky left the total of 4651 completed wells in the Eastern Interior Basin somewhat lower than the figure of 4680 for 1940.

In the deep basin of the lower Wabash River forty-four new pools and forty-three extensions were discovered. None of these is of major importance, however, and the production of the whole Basin was 145,603,000 brl., showing a decline of 6% since 1940. The percentage of the U.S.A. total was 10.3%.

In Illinois most of the new discoveries were in Chester sands (Upper Mississippian) and in the Iowa Series (Lower Mississippian). 91.5% of the year's yield was from Mississippian. Many deep tests were sunk to Devonian—one discovery—and "Trenton" (Ordovician)—no discovery. Production from Devonian limestone has fallen from 26% of the Illinois total in 1940 to 6% in 1941. Ordovician production stands at 0.9%. Pennsylvanian—three discoveries—yields 1.7%.

The "Niagara" or Lower Silurian of eastern Indiana has produced some gas in Pulaski County.

In western Kentucky the shallow depths at which Chester occurs are attractive to "small business". At no great depth Devonian and Silurian also offer an enticing speculation. But as the Knox dolomite (Ordovician) has yielded no showings of oil or gas, little interest is being taken in deeper drilling. A. L.

84.* Oil and Gas Developments in Michigan during 1941. R. P. Grant. *Bull. Amer. Ass. Petrol. Geol.*, June 1942, **26** (6), 1097.—The number of wells completed decreased from 1181 in 1940 to 951 in 1941, and the number of feet drilled from 2,304,855 to 2,002,341. The reduction is due to shift of interest from the shallow district of south-west Michigan to the deeper part of the Basin area. The total production was 16,358,717 brl., approximately 17% below 1940. Sixteen oil and gas discoveries and major extensions were made.

In the Basin, development is notable in the Reed City field, western Osceola County. This field taps the Detroit River pay (Devonian), which gave an initial flow, under natural conditions, of 1900 brl./day. By December 1941 the field was yielding 18,610 brl./day from 3000 acres. The structure trends from north-west to south-east, and has steep dips on either flank. Other pays are in the Traverse and Dundee formations. In the same area "Michigan Stray" (Mississippian) gas fields are also expanding.

In south-western Michigan the most important find was the West Hopkins field, Allegan County, producing oil from the Traverse limestone (Devonian). By the end of 1941, from about 500 acres, nineteen wells were giving 1435 brl./day. A. L.

85.* Developments in the Appalachian Area during 1941. Appalachian Geological Society. *Bull. Amer. Ass. Petrol. Geol.*, June 1942, **26** (6), 1110. *New York*.—Of forty-one wells completed in the Oriskany (Devonian) sand area of southern New York, twenty-one were dry and twenty have a combined open flow of 98,508,000 cu. ft. No new areas were found, and production is on the downgrade. Wildcats to Oriskany, in Allegheny County, found dry sand, or salt water, or missed the sand.

Pennsylvania.—More than at any time during the past decade, attention was focused on the gas territory with shallow sands in western Pennsylvania. Old pools have been extended and new pools have been located, including the Armbrust pool, Westmoreland County, producing from Fifth Sand (Upper Devonian) over an area of more than 600 acres. Open flows up to 5 million cu. ft./day have been obtained in the Big Injun sand (Mississippian), in Fayette and Greene Counties. Successful deep drilling was practically confined to the Summit gas pool (Devonian), Fayette County. Production in Pennsylvania fell 3.5% from 1940.

Ohio.—333, 21% out of 1561 holes drilled, produced oil, 701 or 45% produced gas, and 527 or 34% were abortive. The total production was 3,547,534 brl. from 24,801 oil-wells. This represents an increase over the 1940 figure of $\frac{1}{2}$ million brl., practically all of Pennsylvania grade, and principally due to new flowing wells in the Clinton sand (Silurian) in Perry County. Natural gas yield for 1940 (hitherto unpublished) was 40,369 million cu. ft. from about 7000 wells—viz., half of the maximum reached in 1915. New Clinton gas wells have proved of importance. Good results have been obtained by flooding the Berea (basal Mississippian) in Medina County, where the sand lies at an average depth of 475 ft.

West Virginia.—182 wells were drilled to or through the Oriskany; 166 gave a combined open flow of 764 $\frac{1}{2}$ million cu. ft. and sixteen were uneconomic. Tests of the Silurian in the Elk-Poca field and in Boone County were fruitless.

East Kentucky.—Of 422 wells sunk in 1941, sixty were dry, 259 gave gas with open flow of roughly 117 million cu. ft./day, and 103 had an initial production of 903 brl. Producing horizons range from the Salt sand (Pennsylvanian) down to the Knox dolomite (Cambro-Ordovician).

East Tennessee.—Nine wells, totalling 13,705 ft., east of the Cincinnati arch, had possibly significant showings.

Maryland.—One well in western Panhandle, at 8096 ft., showed gas and salt water in the Oriskany.

Virginia.—Two wells were drilled to Devonian shale, one dry, one with some gas.
A. L.

86.* Californian Exploration and Development in 1941. J. R. Dorrance. *Bull. Amer. Ass. Petrol. Geol.*, June 1942, 26 (6), 1135.—The decline in new discoveries has been checked. Eight entirely new fields—one a gas field—have been established; and five other areas may be new, or connected with old fields. In 1941, 101 wildcat wells were drilled, as against seventy-eight in 1940. Geophysical parties at work increased from sixteen to twenty-five.

Wilmington and Coalinga were first and second as the most active fields, with the Santa Maria Valley field replacing Coles Levee in having the third largest number of holes completed in 1941.

A production of 230 million brl. was the biggest during the past ten years except for the flush period of 1937–38. Many of the new discovery wells have had an initial flow from Miocene or Pliocene horizons of up to several hundred brl./day. Unfortunately the reserves in the newly found fields are disappointing—only equal to a tenth of a year's production.

The discoveries at Raisin City, and those in the Helm and Riverdale fields, are important, since they prove the extension of oil occurrence northwards in the San Joaquin valley. The Helm well assures of productive Eocene beds beyond the bounds of the Gatchell pool, near Coalinga.

Among significant extensions are the following:—

(1) In the Paloma field, Kern County, 90–125 ft. of B-12 sand, yielding an initial flow of 575 brl./day, have been found above the Paloma producing zone. This sand seems to have the form of an open umbrella with the centre of the cover cut away.

(2) In the Inglewood field, Los Angeles County, on the northern outskirts of the old Pliocene pool, the Smith Well No. 1, produced 2000 brl. gross/day, of 31.1° gravity through a 1 $\frac{1}{2}$ -in. choke, accompanied by 2,300,000 cu. ft. gas. This came from roughly 170 ft. of sand in a 413-ft. zone of the Middle Miocene (mainly of *Valvulineria californica* horizon). Pressure may exceed usual hydrostatic pressure. Sixteen producing wells completed by December showed a total sand thickness averaging 125 ft.

(3) The Del Valle field, discovered in 1940, has been extended to produce from the Modelo series (Uppermost Miocene), 1 $\frac{1}{2}$ ml. west of the original area. Accumulation is probably owing to lenticularity and faults.

(4) New deep zones have been found in the Oak Canyon field (Lechler zone), at 6905 ft.

(5) Two sub-commercial zones, at depths of 8275–10,075 ft., with saturated sands, too tight to be profitable, have been found both in the Ventura Basin.

The larger anticlines have been well examined; and attention is now turning to study faults for closures and to reconstruct coastlines, etc., for stratigraphical traps. There is a growing need—and a more aggressive search—for gas, especially in gas regions of the central and northern valleys. A. L.

87.* Graphic Method for Some Geologic Calculations. M. L. Hill. *Bull. Amer. Ass. Petrol. Geol.*, June 1942, 26 (6), 1155.—A graph with quadrant arcs on rectangular co-ordinate paper is supplied on which, with the help of protractor, set-square, compass, and scale, solutions can be quickly arrived at in finding thickness of a bed, given depth and width of outcrop; in finding depth, given thickness and dip; in finding dip, given depth and width of outcrop; and in other problems concerning dip, depth, width of outcrop, and thickness, where two of these are given and a third must be found.

Graphical methods eliminate the gross errors which sometimes originate from hasty trigonometry.

The graph can be used in "three point" problems.

A. L.

88.* Artificial Horizon and Geological Perspective. E. W. Owen. *Bull. Amer. Ass. Petrol. Geol.*, July 1942, 26 (7), 1185.—War is the "datum plane" for immediate geological planning. The qualities of a good oil-finder are the same as those of a good army man—visualizing a countryside from maps, flexible mentality, diverse training. It is expected that up to 50% of the membership of the A.A.P.G. will enter the forces. At present a surplus of oil is available, but with the expansion of the fighting services and corresponding demand for oil, new exploration and development will become urgent within two years.

War conditions and regulations are a threat especially to the financial position of independent operators who make up one-third of the members of the A.A.P.G. These "small men" have made most of the discoveries in the past, and their independence must be defended. A. L.

89.* Neglected Gulf Coast Tertiary Microfossils. H. M. Howe. *Bull. Amer. Ass. Petrol. Geol.*, July 1942, 26 (7), 1188.—To-day, eastward from the Mississippi delta terrigenous sediments rapidly diminish, while fine clays, limestones, and chalks increase. This was also true during the Eocene and Oligocene, when the less muddy environments favoured the larger Foraminifera and other groups seldom encountered in the area west of the Mississippi.

Ophiurans—brittle stars—are very common under certain environmental conditions upon modern sea-floors; and eighty living species have been described from the Gulf region. Very few records have been made, but their armbones are important in the earlier Tertiary of the south-eastern United States.

Only a few Tertiary crinoids have been described, though A. H. Clark's great "Monograph of Existing Crinoids" (1915-41) is available to help in classifying and describing them. The unstalked "free-swimming" comatulids are not so rare in the Tertiary as Springer suggested in 1925. Howe records their ossicles from the Salt Mountain limestone and Princetown sand (Lower Eocene) and other horizons up to the Vicksburg (Oligocene).

Marginal plates, variously ornamented, with a row or rows of nodes, or a spine, serve for the identification of different starfishes at a number of horizons up to the Choctawhatchee (Miocene) at Jackson Bluff, Florida.

Holothurian—sea-cucumber—remains are also common enough.

Restricted to the Vicksburg (Oligocene), the bryozoan *Enoplostomella* appears to give rise to definite species at certain horizons, and the genus *Bactridium* can be used in much the same way in the Jackson (Eocene). "Acorn" and "goose" barnacles, occurring as separated plates, Crustacea, and marine diatoms—all abundant in many places—should all be useful in stratigraphy. A. L.

90.* How can Geophysicists best serve? H. B. Peacock. *Bull. Amer. Ass. Petrol. Geol.*, July 1942, 26 (7), 1200.—How essential are new discoveries of oil? From discussions of proration and allowables, people seem to think production can be doubled or trebled. But the fact is that such increases would greatly decrease ultimate amounts recovered and production would the more rapidly decline. Reserves in the

U.S.A. as at 1st January, 1942, have been estimated at 19,586 million brl. Output for 1941 was 1404 million brl. Possibly we have almost fourteen years' supply on hand. The optimum supply would, however, only be obtained in many cases if production could be stretched over twenty-five or more years.

The loss of the East Indies means greater demands on American oil. The Petroleum Co-ordinator expected that 3,600,000 brl./day would be needed in 1942, or almost the same production as in 1941, and the demand will increase. The Government has called for up to 5000 wildcats to be drilled in 1942. This must surely imply increasing exploration.

For the three years 1938-41, of wildcat wells sunk on geological advice, 4631 were dry and 825 productive, *i.e.*, 1 in 6.6; on geophysical advice 1535 were dry and 390 were productive, *i.e.*, 1 in 4.9; on joint geological and geophysical advice 301 were dry and 94 productive, *i.e.*, 1 in 4.2. This raises geophysical hopes, and suggests more co-operation between geology and geophysics. Of non-technical holes 3554 were dry and 199 productive, or only 1 in 18.9.

Of all geophysical methods, that of the reflection seismograph offers greatest opportunity of benefit, from detailed study of fault patterns and structural variation at depth. This provides a check on the continuity of geological observations obtained from wells. Geochemical and fluorographic methods have their appeal in locating stratigraphical accumulations, "but until more effective techniques for finding stratigraphic traps" are discovered, we must continue to seek the tectonic type.

It would be dangerous for the United Nations if the numbers of geophysical personnel suffered serious reduction.

A. L.

91.* Good Geologists make Good Neighbours. W. E. Pratt. *Bull. Amer. Ass. Petrol. Geol.*, July 1942, 26 (7), 1207.—Supporting the Good Neighbour Policy for a Commonwealth of the Western Hemisphere, W. E. Pratt, Standard Oil Co. of New Jersey, predicts the development of oil in Latin America by United States technicians and finance. What the South American republics require is a working class. "In the American method of oil-finding the scientist is a workman and the workman becomes a scientist. . . . The technique is peculiarly American, born of free enterprise and the dignity of labour."

A. L.

92.* Problem of Exploration. E. de Golyer. *Bull. Amer. Ass. Petrol. Geol.*, July 1942, 26 (7), 1214.—The American Petroleum Institute's estimate of U.S. reserves in 1938 was a little over 21 billion brl. At the beginning of 1942 it was somewhat under 20 billion. For the past three years, 1939-41, the average number of fields discovered was exactly double the average annual discovery rate for the previous five years, 1934-38. But the estimated average reserve in each field in the earlier period was 15.6 million brl., whereas in the second period it was only 1.18 million brl. The estimated reserves discovered annually have fallen from 1900 million brl. in 1937 to 400 million in 1941. This is not comforting.

The intensity of wildcatting and prospecting depends on (1) price of oil and the prosperity of the oil industry, (2) availability of land suitable for prospecting, and (3) degree of exhaustion of current prospecting techniques.

Successive exploratory methods have come in slowly, been accepted, reached a peak rapidly, and have then declined to relative unimportance. "A technique exhausts itself by being used." Pemberton says that with the discovery of the Casmalia field, California, in 1904, the technique of drilling near seepages, which had given thirty-two discoveries, was at the end of its usefulness. Subsequent discoveries up to 1936—sixty-eight in all, and seven in addition from 1936 to 1939—were due to purely geological techniques. From 1936 to 1939 there were thirteen fields discovered by geophysical exploration.

On the Gulf Coast from 1901 to 1924, the technique in vogue was to find seeps and/or topographical mounds. From then until 1932 the discoveries were mostly geophysical by means of torsion-balance or refraction seismograph. Now, as in 1924, we are faced by the exhaustion of prospecting methods as far as the Gulf Coast is concerned, since refraction surveying has now covered the area, and some parts have been examined six or seven times by competing interests.

For Oklahoma the earliest technique was clinometer surveying; about 1912 plane-table mapping of the surface geology came in, and was a derelict method by the middle

'twenties. Core-drilling was the next specific technique, supplemented about 1930 by correlation reflections.

The task is to find new exploratory methods—one is the palæogeography of coastlines—as well as new fields. A. L.

93.* Geology in War and Peace. Carey Croneis. *Bull. Amer. Ass. Petrol. Geol.*, July 1942, 26 (7), 1221.—Hugh Miller sixty years ago was a popular author. Allowing for later increase in the numbers of those who read, it may be said that at least three of his geological books had a circulation greater than that of *Gone with the Wind*! Since 1919 his name has been deleted from most of the encyclopædias. That is a true index of the decline in status of the Science of Geology. In literature, in national administration, in the effort of war, in salaries, geologists are stepchildren.

There is still a public demand for geological information, and much of geology is readily comprehensible by the lay mind. Nevertheless the more abstruse aspects of physics, chemistry, and biology command fifty times as much space in the Press. Since the passing of the elder Geikie, geologists have been much too self-effacing. The Geological Societies of America and London have adhered too closely to an exclusive professional etiquette, and have actively avoided publicity among the generality of people.

The tendency of individuals to call themselves mineralogists, geophysicists, and palæontologists, instead of plain geologists, has also been an adverse influence. One result is that the geological profession, and the advice they give, are increasingly neglected, except in the oilfields. On one aerodrome site alone in Britain, to mention no others, £500,000 was lost through the ignoring of geological advice. The same kind of thing will certainly happen in America, unless geologists, like other scientists, assert the value of their work.

An American Geological Association to include 10,000 geologists from the Western Hemisphere is suggested. This would publish and propagate geological news, would arrange for rewards to geological workers in different age groups, instead of keeping these in the main for the semi-superannuated, and would maintain public relations committees on topical subjects. It would be supremely important to try to raise the standard of the recruits to the profession, and also to work for improvement of the educational opportunities of geological students. In fourteen groups of post-graduate students, arranged according to subjects of study, the geological researchers, in tests of general education, have been found to occupy only sixth place. They were graded below the students doing research in Physics, Moral Philosophy, Mathematics, Chemistry, and Psychology!

The Japanese expansion in the East Indies was evidently planned on a basis of the geological resources required by them; and it is criminal folly for the United Nations not to be fully advised upon what must be held at all costs. A remarkable suggestion is quoted for bombing of major fault-lines in Japan to hasten the next great earthquake, "which, on a periodicity basis, is due sometime in the next few years." A. L.

94.* Developments in North Louisiana and South Arkansas in 1941. B. W. Blanpied and R. T. Hazzard. *Bull. Amer. Ass. Petrol. Geol.*, July 1942, 26 (7), 1250.—A production of about 53 million bbl. in 1941 was almost equally distributed between North Louisiana and South Arkansas. In the former, 798 wells were drilled, and in the latter 207. Of the total 564 were oil-wells, 123 obtained gas and gas-distillate, and 157 were dry.

In South Arkansas, Hosston—"Travis Peak"—oil (Lower Cretaceous) was discovered in the Smart Sand area of Stephens field, Columbia County; Cotton Valley oil (Jurassic) in East Schuler field, Union County; and Smackover Limestone oil (Jurassic) in two fields—Mount Holly, Union County, and Patton field, Lafayette County.

In La Salle Parish and Catahoula Parish, North Louisiana, six new fields were discovered. In Haynesville field Claiborne Parish, the Pettit limestone (Lower Cretaceous) at 5431–5440 ft. yielded an initial 227 bbl./day of 38.7° gravity oil after being acidized through gun perforations; the gas-oil ratio was 269 to 1. Jurassic gas-distillate pools were also found in the same Parish. Yield from Smackover limestone, in the North Lisbon field, Claiborne Parish, is so far the only oil from this horizon in North Louisiana. The gas-oil ratio is 9900 to 1. A. L.

95.* Midway Field Discovery, Lafayette County, Arkansas. E. A. Markley and C. N. Valerius. *Bull. Amer. Ass. Petrol. Geol.*, July 1942, 26 (7), 1289.—Hitherto the whole production of the Smackover limestone (Jurassic) has been from the topmost member—the Reynolds Oolitic zone. In addition to this the Bond well has found an entirely new producing zone of 118 ft. of granular, almost completely non-oolitic limestone at 65 ft. below the Reynolds zone.

The Bond well produces sweet gas with only 1.42% by weight of high-boiling point sulphur compound. This is non-corrosive, unlike the sour oil and gas from the Smackover in other parts of Arkansas, which has much sulphur of a corrosive nature.

The anticlinal axis of the Midway field trends from north-west to south-east, and is more steeply folded than most Smackover producing structures. A. L.

96.* Oilfield Waters of Montana Plains. J. G. Crawford. *Bull. Amer. Ass. Petrol. Geol.*, August 1942, 26 (8), 1317.—The identification of strata by means of their contained waters is becoming a possible procedure throughout the Rocky Mountain States. In this region, oilfield waters are much less concentrated than elsewhere, and if concentrations exceed 2000 parts per million total solids, commercial pools are possible and probable. In general the lower concentrations indicate water-movement which may have swept oil away, but in some cases dilute artesian water has been forced upwards through faults and fractures, and so has been trapped with oil. Average waters of Montana oilfields have 1500–15,000 p.p.m. of solids. Almost all contain a small amount of calcium and magnesium, but these radicles are not prominent above the "Quadrant" (Upper Mississippian and Lower Pennsylvanian). This appears to be due to the softening of action of bentonite layers which remove calcium and magnesium by base-exchange. In the "Quadrant" and below it, calcium and magnesium are prominent.

The first important oilfield waters are those of the Montana group (Upper Cretaceous), with fairly dilute solutions of sodium salts. Sodium sulphate prevails where surface waters have access to the sands, but deeper waters associated with gas are moderately concentrated, and contain sodium chloride. Where secondary characteristics are present the ratio of magnesium to calcium may be greater than unity. Sands in the Colorado shale (Upper Cretaceous) have small quantities of water, of higher salinity than waters of the Montana group. This is due to tightly packed grains retaining connate water.

Salt-and-pepper sands of the Kootenai formation (Lower Cretaceous) are important oil- and gas-producers in the Border-Red Coulee, Cutbank, and Kevin-Sunburst fields. Where associated with gas, the waters are fairly concentrated with sodium chloride and sodium bicarbonate, which are present in proportions found to be characteristic of the different sands.

The Ellis formation (Upper Jurassic) of black organic limestone and black shale with sand yields sulphur-bearing gas—not commercially produced—in the area of the northern Sweetgrass arch. Oil is obtained from the Ellis-Madison contact in the Kevin-Sunburst field. Ellis waters are moderately concentrated with sodium chloride and sodium bicarbonate; alkalinity is greater than salinity; 0–20% calcium and magnesium bicarbonates, appreciable hydrogen sulphide, and some sulphate are present.

"Quadrant" rocks comprise marine and non-marine red and black shales, cherty limestone, and sandstone. The waters contain large quantities of sulphates of calcium and magnesium. The bicarbonate content is low. The Tensleep sandstone (Pennsylvanian) of southern Montana yields similar waters. These are often hot. Flows may reach 125,000 bbl./day.

The Madison limestone (Lower Mississippian) has not been fully explored by wells. Although unproduced oil has been discovered below it in the Cedar Creek anticline, the Madison is the oldest commercial source of oil and gas in Montana. It has two types of water. The first are solutions of sodium salts, with chloride and bicarbonate as the dominant negative radicles, and with appreciable alkaline earths and sulphur. They are found in the Sweetgrass arch, and have been affected by the acidization of wells. The second type consists of solutions of calcium and magnesium sulphate, with only moderate amounts of chloride and bicarbonate radicles, as in the north-central and central fields.

The oilfield waters of Montana resemble those of Wyoming, but are less concentrated on the whole. Migration of water from one formation to another may well

be the explanation of Cosmos-Vanalta (Lower Cretaceous) water with hydrogen sulphide probably derived from the underlying Ellis. A. L.

97.* Late Palaeozoic Stratigraphy of Gore Area, Colorado. K. G. Brill. *Bull. Amer. Ass. Petrol. Geol.*, August 1942, **26** (8), 1375.—This area of 350 sq. ml. in Eagle and Summit Counties, 120 ml. west of Denver, contains an asymmetrical syncline of strata of Upper Cambrian to late Palaeozoic age. On the south-west side the dip off pre-Cambrian gneisses of the Sawatch range is at an average of 25°, and on the north-east faults bring up the pre-Cambrian of the Gore and Tenmile ranges.

The pre-Pennsylvanian systems are Sawatch quartzite (Upper Cambrian), Manitou limestone (Ordovician), Harding sandstone ((Middle Ordovician), Chaffee formation (Upper Devonian) comprising quartzite and dolomite, and Leadville limestone (Mississippian). Outcrops of these are practically confined to the south-west side of the Eagle valley; and westward thinning of the Leadville suggests that it may not have been deposited much farther west than the present outcrops.

The Pennsylvanian succeeds unconformably. The Battle Mountain formation, 4300 ft. in the north to 7900 ft. in the south, is mainly of grits and sandstones, but has some thick beds of shale and conglomerate. There are occasional limestones and dolomites ranging from a few inches to 30 ft. thick. Fossils are marine: worms, gastropods, brachiopods, corals. At the base 100–200 ft. of Belden shale—heretofore called Weber shale—rest on eroded Mississippian. Deposition took place during transgression from the south or south-east. Belden fossils in argillaceous limestone include *Orbiculoidea* cf. *capuliformis*, *Derbya* sp., *Paeckelmannia* sp. nov., *Chonetes* cf. *granulifera*, *Squamularia* sp., *Composita subtilita*, and poor lamellibranchs. Small beds of coal suggest swamp conditions and a mild climate on land. Above the Belden well-marked cycles of deposition ("cyclothems") are noticeable, consisting of: (1) massive conglomeratic grit on irregular substratum; (2) thin-bedded sandstone; and (3) thin shale. Junctions of (1) with (2), and of (2) with (3) are gradational. A 3-inch Bentonitic ash with quartz, biotite, and shards, 950 ft. above the base of the Battle Mountain formation has been found at two localities, and marks the eastward limit of Pennsylvanian volcanism in the United States. The Robinson limestone member, 15 ft., with corals, *Marginifera* cf. *lasallensis*, and *Ambocoelia* sp., is useful in Turkey Creek (type section) and in the Pando-Jacque Mountain area, for correlation of the middle beds of the Battle Mountain. Near the top of the latter, the Jacque Mountain limestone, 18 ft., with *Schizodus* sp., *Bellerophon* cf. *crassa*, *Ephippioceras* sp., and intercalated breccias, also provides a datum plane for a wide territory. Ostracods from above the Robinson are assigned by Miss Hecht to a Marinton age (Lower Pennsylvanian).

Above the Jacque Mountain member, the Battle Mountain clastics are a brilliant red, and in them macerated remains of the coniferous plant *Walchia* have been found. Still higher, *Marginifera muricatina* indicates a Des Moines age (Pennsylvanian). Evaporite beds of the Eagle gypsum basin interdigitate in the top of the Battle Mountain.

The State Bridge formation, about 500 ft., follows conformably upon the McCoy, or northern equivalent of the Battle Mountain. It is mainly of red and grey silts and shales, finer than those in the earlier formation, and presumably derived from ancestral Rockies of reduced dimensions. One calcareous sandstone, in association with algal limestone, yields the lamellibranchs *Myalina* sp., *Pleurophorus* sp., and *Aviculopecten* sp., which Newell thinks may be Middle or Upper Pennsylvanian—or even Permian.

Erosion of the State Bridge took place before deposition of the Upper Triassic. Further accumulation ensued in the Upper Jurassic and Upper Cretaceous.

In the Laramide orogeny the high-angle reversed faults along the Gore and Tenmile ranges were formed, and drag on the west sides produced the Gore syncline.

Porphyry sills were intruded in late Cretaceous (Denver) and in the early Cainozoic. In the Miocene, lavas were poured out. A. L.

8.* Subsurface Study of Ellenburger Formation in West Texas. T. Cole. *Bull. Amer. Ass. Petrol. Geol.*, August 1942, **26** (8), 1398.—The Ellenburger (Cambro-Ordovician) where penetrated in West Texas, consists of fine to coarsely crystalline dolomites and dense limestones, with secondary anhydrite, and some streaks of sand and shale. These units change laterally, so that for correlation—apart from faunal evidence from

which six zones may be distinguished corresponding with those recognized in Missouri—insoluble residues are of considerable value. The nature, rather than the actual percentage weight of the residue, is used; and the kind of chert fragments present forms the most important criterion. The four classes of chert are: smooth, granular, chalky, and drusy. The first three are diagnostic. Drusy chert may be quartz or a recrystallized form of one of the other types. Oocasts and dolocasts—spaces left after solution of oolites and dolomite crystals, respectively—are noted. By such means the 1335 ft. section of Ellenburger can be divided into five zones.

Plotting of the zones shows a truncated axis of folding parallel with the Permian folding (San Andres), which extends north-west and south-east rather than north and south. There is probable overlap of the base of the Ellenburger against the Apco Ridge, in Pecos county.

Since exploitation was begun in 1930 the Ellenburger of West Texas has yielded 30,000,000 bbl. from twenty-four wells. A. L.

99.* Upper Pennsylvanian Anhydrite, West Texas. R. Roth. *Bull. Amer. Ass. Petrol. Geol.*, August 1942, 26 (8), 1412.—Anhydrite is not restricted to sediments of Permian and younger date. It has been found in the Cisco (Pennsylvanian) of West Texas. A. L.

100.* Stratigraphy of North Dakota. O. A. Seager *et al.* *Bull. Amer. Ass. Petrol. Geol.*, August 1942, 26 (8), 1414.—The authors supplement Dr. Kline's account (*Bull. A.A.P.G.*, March, 1942) with suggestions that Oligocene and Miocene strata of the White River group are more widespread than has been believed; that Sentinel Butte is Wasatch (Eocene), and Upper Wasatch is represented north of Hebron; that the Fort Union formation (Paleocene) has three members—Tongue River, Cannonball, and Ludlow, with the latter two interdigitating; that the Hell Creek formation is Upper Cretaceous; that Jurassic should be found under much of western and northern North Dakota; that redbed Triassic and Devonian are readily confused; that some of Dr. Kline's dubitable Cambrian may be Ordovician which possibly occurs in many parts of the State.

Data from Manitoba, Montana, and South Dakota, bearing on the stratigraphy of North Dakota, are liberally adduced. A. L.

101.* Well Spacing and Production Interference in West Columbia Field, Brazoria County, Texas. J. C. Miller. *Bull. Amer. Ass. Petrol. Geol.*, September 1942, 26 (9), 1441.—From its earliest deep development in 1917 until 1937, the West Columbia piercement salt dome field produced mainly from the basal Miocene sands. There was some oil from Oligocene sands, but the first commercial Oligocene well was drilled in 1937. To January 1941, the total yield was 80½ million bbl. The basal sands of the Miocene range from 500 ft. in thickness in the vicinity of the dome to 700 ft. on the flanks. The upper "A" zone (appr. 200 ft.) is fine to medium-grained with re-worked Cretaceous and indigenous marine fauna. The lower or "B" zone, separated from "A" by a shale layer (100–150 ft.), averages 200 ft. of medium-grained, well-graded, clean sand, with permeability varying from 2000 to 15,000 millidarcys. A still lower "C" zone (50–60 ft.) is medium to coarse-grained, not so well sorted, with abundant marine fauna.

Production has been sustained by natural water drive as is seen from the northern segment, west of the East Abrams fault, where a bottom-hole pressure estimated at 1330 lb. per sq. in., in 1920, had only fallen to 1104 lb., in 1935. Over the whole period, production remained at about 450,000 bbl. of fluid/month. In flowing wells, however, where the percentage of water to oil increases, the weight of water adds to bottom-hole pressure, which, in turn, reduces the reservoir-pressure differential towards the well, and oil-flow falls.

At the reservoir temperature and pressure the normal saturation of the oil with gas would be 154 cu. ft./bbl. The actual gas-oil ratio is 60 cu. ft./bbl. This undersaturation was probably produced during regional submergence; only here and there has gas been liberated from solution owing to big withdrawals of oil. The gravity of the oil is low, 20–21° Bé. There is little shrinkage. No evidence exists of a former gas-cap.

Where wells are drilled too closely, or production is at a very rapid rate, drop in

pressure may be enough to change the type of drive from hydraulic to volumetric through liberation of gas. In the north-west segment of the field, although four times as many wells were sunk in sand "A" as in sand "B," the recovery, at a little over 1100 bbl./acre foot, was roughly the same in each case. The wider spacing of 17.5 acres per well corresponds with a drainage radius of 492 ft. Fluorescein experiments in "A" sand showed a migration of fluid up dip amounting to 800 ft. in 180 days. Differential rates of withdrawal may even produce migration in down-dip directions.

When one new well was completed about 500 ft. up dip from an older one, the percentage of water produced from the latter increased sharply. The products of the two wells, however, when added together, showed that the increase of water continued at the same rate as in the case of the older well. Lateral interference can also be illustrated from wells 500 ft. apart on the same strike. The conclusion is that the field would have been properly drained under a wider spacing programme than that of 17.5 acres per well.

A. L.

102.* Schuler Field, Union County, Arkansas. W. B. Weeks and C. W. Alexander. *Bull. Amer. Ass. Petrol. Geol.*, September 1942, **26** (9), 1467.—The Schuler field, discovered in 1937, lies west-south-west of El Dorado, Arkansas, and produces from lensing and basal sands of the Cotton Valley formation (late Jurassic to early Cretaceous?) in a domal structure elongated from west-north-west to east-south-east. Production is also obtained from the Reynolds Oolite zone of the Smackover (Jurassic). In the latter the concentration of oil is anticlinal, and there is very evident water-drive. In the Cotton Valley there is little of this, owing to sealing by petroleum residue in the basal beds and lenticularity of sands higher up.

Production from the Smackover by July 1941 had reached 2,766,280 bbl. from sixteen wells.

The Jones sand, about 65 ft., at the base of the Cotton Valley may be of sandbar origin with thickest accumulation in the Schuler area. The oil seems to be from the surrounding grey shale, but some may have migrated from the Smackover. Proved over 4000 acres, this sand between 1937 and 1941 produced 18,542,590 bbl. from 146 wells. Initially the gas-oil ratios were from 500 to 1200 cu. ft./bbl., but by June 1940 they were from 400 to 10,163/1.

The Leona sand is being developed. It had three wells at the end of 1941.

The Morgan zone, 500 ft., with lenticular sands has an upper part containing grey and maroon shales, while the lower part is more definitely redbed. Red sands and shales—apparently non-marine—predominate down to near the top of the Jones sand. They are without oil. There is some lignite in the Morgan zone, and above it 13 ft. of glauconitic shale with a few lamellibranchs. Most of the Morgan may have been deposited in off-shore shallows. To July 1941, it had yielded 2,141,040 bbl. from fifteen wells.

Time-drilling charts are a valuable adjunct to electrical logs in determining the tops of sands. There is a marked increase in drilling time after the softer Eocene, and Gulf (Upper Cretaceous), and Comanche (Lower Cretaceous) are penetrated. A. L.

103.* Thickness and Structural Study of Major Divisions of Cretaceous System in Nebraska. P. Fuenning. *Bull. Amer. Ass. Petrol. Geol.*, September 1942, **26** (9), 1517.—Isopach maps are presented of the "Dakota", Benton, Niobrara, and Pierre groups, and of the Cretaceous as a whole; also structural maps contoured on top of the Dakota sandstone, Greenhorn limestone, Fort Hayes limestone, and the Niobrara formation.

The thick development of the "Dakota group" in central Nebraska suggests a local basin of deposition, with derivation of sediment from the Sioux Falls "high" and from an elevated area in south-east Nebraska.

Absence of the Niobrara on the north-west extension of the Chadron-Cambridge axis, which runs from north-west to south-east across the north-west quarter of the State, then turning south so as to divide south-west from south-east Nebraska, would point to uplift along this line sooner in the north than in the south. Considerable movement of the axis took place towards the end of, or after, Pierre time.

A. L.

104.* Argentina's Goal is Increased Production through Expanded Drilling Activity. Anon., *World Petrol.*, September 1942, **13** (10), 33.—In 1941 Argentina consumed

5,088,000 tons of oil and produced 3,226,000 tons. The total fuel consumption was equivalent to 10,364,000 tons of petroleum. In 1937 3,061,000 tons of coal were imported, about two-thirds of it from England, whence the supply was cut off on the outbreak of war. Imports of oil have also been seriously curtailed. Consequently various measures for limiting fuel consumption have been proposed. The fuel oil shortage is more serious in some respects than the shortage of gasoline. There has been a demand for greater drilling and exploration activity, and a suggestion that some of the State reserves should be released for development by independent companies. A shortage of drilling equipment exists.

During 1941 there was a substantial rise in drilling, 364 wells being completed, 228 by the State. At the end of 1941 Comodoro Rivadavia had 3021 wells, and Mendoza had fifty-one wells in operation, Plaza Huincul 274, and Salta 157. During 1941 1,282,706 ft. were drilled. 22,013,471 bbl. of oil were produced, 7% more than in 1940. During the first five months of 1942 the output was 7% above the figures for the corresponding months of 1941.

In 1941 the El Tordillo zone was opened in the Chubut area. Argentina's deepest well (9500 ft.) is in Mendoza province. This well penetrated oil sands which have not been fully tested. The Mendoza production increased by 33% in 1941. Two substantial producers were completed in the Challaco zone of the Plaza Huincul field.

Argentina's refining capacity is over 90,000 bbl./day, sufficient to handle the domestic production, together with the normal imports of 10,000,000–12,000,000 bbl./year.

Tables give the production by companies and by fields in 1939, 1940, 1941, and part of 1942 (first five months), and the capacities of the refineries and the products.

G. D. H.

105.* Bolivian Production to be Trebled by 1944. Anon. *World Petrol.*, September 1942, 13 (10), 41.—At present Bolivia produces 114,338 bbl. of gasoline per year, 61% of the domestic requirements. It also produces 11,815 bbl. of kerosene, or 58% of the total consumption. In 1941 10,193 bbl. of diesel oil and 97,284 bbl. of fuel oil were produced, which were respectively 7% and 31% of the country's requirements. Bolivia's annual crude production is 233,630 bbl. Up to 1st April, 1942, 900,000 bbl. had come from seven wells at Sanandita, and about 800,000 bbl. from two wells at Camiri. Between these two fields three producing wells are shut in at Camatindi, while near the Argentine border is the Bermejo field.

Camiri gives 500 bbl./day, and has a proved area of 640 acres, with a potential area favourably located on structure of a further 5000 acres. Oil is obtained from the Devonian at a depth of 3200 ft. At Camatindi 1120 acres are considered to have been proved, with an additional 2000 acres favourably located on structure. Production is from a depth of 4000 ft. Sanandita gives 380 bbl./day, and it is expected that the output may rise to 1775 bbl./day in the next eighteen months. The oil is believed to come from the Triassic at a depth of 2100 ft. About 300 acres have been proved, and a further 1600 acres are favourably situated on structure. Bermejo has a proved area of about 600 acres with three separate producing zones at 2214 ft., 2870 ft. and 3600 ft. in the Jurassic. This field has been shut in for the past twelve years.

A 2000-bbl./day topping plant is planned for the Oruro mining district to supply petroleum products for the expanded mining operations. The oil will be drawn from Sanandita.

G. D. H.

106.* Brazil Continues Exploratory Drilling. Anon. *World Petrol.*, September 1942, 13 (10), 70.—After preliminary geological and geophysical surveys several districts in different parts of Brazil were considered sufficiently promising to warrant testing by drilling. The first area for testing was along the eastern coast of Bahia, and at Lobato, near Salvador, a Cretaceous oil-bearing horizon was penetrated at a depth of 702 ft. in January 1939. This well was not commercially productive, but three wells in 1940 and three more in 1941 were drilled to various depths in the Cretaceous-Tertiary belt in Bahia and Alagoas. Unofficial reports state that production has been established which is considered promising for substantial yields when the structures now being tested have been more fully explored.

Two wells are being drilled near Maceio, Alagoas, and while no commercial production has been obtained, showings of oil have been reported. In the neighbourhood of

Salvador two areas of production have been found in addition to the original Lobato showing. The latter is within the city limits of Salvador, while the new tests are to the north where small producers have been completed on each of the two structures. Shows of oil and gas and said to have been encountered in a well on an island across the bay from Salvador.

G. D. H.

107.* Colombian Exploration gives Promise of Important New Production. E. Ospina-Racines, *World Petrol.*, September 1942, 13 (10), 45.—The most promising result of the past twelve months' intensive wildcat exploration drilling is the discovery of the Casabe structure on the west bank of the Magdalena opposite the De Mares concession. Four wells have been completed at Casabe. Wildcatting on the Barco concession has been on a reduced scale. The Petrolea field was completely delimited during the first half of 1941. This field supplies the Covenas pipe-line, which has been operating at only 50% capacity on an average. Recently two new structures have been tested, Socuavo and Tres Bocas, where the first wells have given high-gravity oil.

Cimitarra 1 gave considerable gas, and a second well is to be drilled, while the McCarthy well was abandoned at 5438 ft. The Braval and Culimba tests were abandoned, although a second well is to be drilled at Culimba. The Gutierrez tract, just north of the Casabe tests, has been abandoned. Wildcatting is being carried out in the coastal area (Department of Magdalena) some 125 ml. inland.

During 1941 Colombia had an average oil production of 2,053,000 bbl./month, but since March 1942 the average figure has been about half of this. About 45% of Colombia's lubricants are imported, although 90% of Colombia's oil is exported. The Barco refinery supplied 1,320,000 gal. of last year's gasoline consumption of 51,400,000 gal.

50% of the country's prospective oil land is over 750 ml. from tidewater in the Llanos region. Experience has shown a lapse of six to ten years after the discovery of an oilfield in Colombia before its oil is sold in the world market. Some of Colombia's markets are likely to disappear after the war. In spite of the fact that Colombia produces only 1.1% of the world's oil, oil exploitation is of considerable significance in the country's economy, and in 1940 Government income from the oil industry was 14.7% of the total revenue.

G. D. H.

108. Michigan Oil Exploration More Important in Wartime. N. X. Lyon. *Oil Wkly*, 26.10.42. 107 (8), 19.—Michigan has never given more than 2% of the annual U.S. production, and its reserves have been only 0.2–0.3% of the U.S. total in the past five years. For some years 20,000–30,000 bbl./day were shipped by tanker to various eastern and southern points, but in 1937 an 8-inch pipe from Mt. Pleasant to Toledo was completed, and water transport to the south was largely discontinued. While the State exports 15,000–20,000 bbl./day, it imports 25,000–30,000 bbl./day. The Toledo call on Michigan crude has been strengthening monthly as the Illinois oil production has fallen or been diverted to the east. The eighteen independent refineries in Michigan had a raw charge capacity of 56,900 bbl./day on 1st August. Their cracked gasoline capacity is about 8000 bbl./day, excluding a refinery at Trenton, which is supplied with crude from Oklahoma and Illinois, and which has facilities for 10,000 bbl./day of charging stock for cracked gasoline.

The producing areas lie in two general provinces, the Basin and the Southwest area. The Basin has more fields and the higher recovery per acre; the structures are also larger. Geophysical work has not proved of material value in either province, and so deep drilling and coring provide the principal geological data. In Southwest Michigan the Traverse lime is the main producing horizon, being 1000–2000 ft. deep, and characterized by coral reefs and extremely erratic trends and structures. Most of the discoveries there in the last three years have been the results of wildcats drilled on "hunches".

The discovery of Reed City and Headquarters in 1941 caused attention to be concentrated on the Basin. This year the outstanding development has come from deep drilling to the Richfield-Sylvania series rather than from the uncovering of new pools in the Dundee and Traverse. The Richfield-Sylvania development zone is about 1300 ft. below the top of the Dundee lime. Several fields have been opened, but neither the fields nor the wells are large, for the horizon, an intermediate section of the Monroe, has not sufficient porosity to give large wells. The Richfield horizon has good pros-

pects, since it covers the entire basin. The Richfield-Sylvania is 3600-5100 ft. deep, and is underlain by salt, with the next potential oil horizons, the Niagara and Trenton, at depths of 8000-10,000 ft.

In Southwest Michigan small gas wells have been completed in the Monroe at Grand Rapids. Wells drilled to the St. Peter sand found no important oil-shows below the Traverse.

Considerable areas have yet to be explored fully. Drilling costs will be less in the Southwest than in the Basin, because of the shallower wells needed in the former area. The best fields have had reserves of 15 million to 25 million bbl. of oil. At present Michigan is producing about 43,000 bbl./day from prorated fields and 22,500 bbl./day from settled fields. The allowables are comparatively high, 20-acre unit wells have had a flat rate of 150 bbl./day this year, and 40-acre unit wells have had 262½ bbl./day. Regular surveys are made to check gas/oil ratios, bottom-hole and reservoir pressure changes and water conditions.

Tables give data about the leading oilfields of Michigan, and the results of wildcat and other wells during the past five years. G. D. H.

109. Peruvian Oil More Important with War. Anon. *Oil Wkly.*, 26.10.42, 107, (8), 40.—Oil production in Peru rose from 10 million bbl. in 1931 to a peak of 17,595,000 bbl. in 1937, but it fell to about 13 million bbl. in 1941, partly due to the loss of European markets. The present refining capacity of the country is 21,720 bbl./day, and it could easily be expanded.

There are indications of additional oil reserves on the eastern slopes of the Andes, in areas connected by river transport with the Upper Amazon Basin. G. D. H.

110. Taber Well Makes Largest Flow in Canada. Anon. *Oil Wkly.*, 26.10.42, 107 (8), 40.—The well at Taber, southeast of Lethbridge, is producing oil at the rate of 330 bbl./day, being the largest producer outside Turner Valley. It may indicate the existence of a new major oilfield.

Fifty wells are to be drilled at Vermillion.

G. D. H.

111.* Declining Rate of Discovery Poses Urgent Problem for Oil Industry. A. I. Levorsen. *World Petrol.*, November 1942, 13 (12), 37.—The developed or known production is that from which present production is being drawn. Of this reserve only a certain amount is recoverable, the amount depending on a number of factors. The amount of recoverable reserve in U.S.A. has increased year by year, being about 5000 million bbl. in 1920, 10,000 million bbl. in 1930, 18,000 million bbl. in 1940, and 19,800 million bbl. on 1st January 1942. These figures are estimates of the oil recoverable by methods and under the economic conditions of price and markets then prevailing. Production has risen from 442,929,000 bbl. in 1920, 898,011,000 bbl. in 1930 to 1,338,237,138 bbl. in 1940, and consumption has kept pace. In general, during recent years the reserve has been twelve to fifteen times the annual production, although only a portion of the reserve, perhaps a quarter or a fifth, is producible in the next few years, while the rest will be obtained at steadily declining rates over a period of twenty to thirty years or more. Thus unless new fields are found the existing supplies would not meet daily demands for long.

Production at an excessive rate reduces the ultimate recovery. Studies are being made to find the amount of excess producing capacity in the U.S.A.

Since 1860 about 45,000 million bbl. of oil have been discovered, and of this 25,000 million bbl. have been produced. If the same rates of expansion continue in 1952, 22,000 million bbl. more will have been found, and of this 17,000 million bbl. will have been produced; in 1962 the cumulative discoveries will have totalled 90,000 million bbl., with 60,000 million to 65,000 million bbl. of it produced. Hence to maintain the same rate of increase in supply and demand in the next twenty years, with the same ratio of reserve to annual consumption requires the discovery of a quantity of oil equal to that found in the past eighty years.

Present geological knowledge indicates with considerable assurance that much oil remains to be discovered. The undiscovered reserves are of two types: (a) Within areas of current development and production in extensions, deeper production, and new fields. This represents the bulk of current finds and the most readily available

reserve for the immediate future. (b) Reserves in partly explored regions fringing the areas of current development—e.g., the Trans-Mississippi region of Southeast U.S.A.; Trans-Pecos region of West Texas and New Mexico; Anadarko Basin; basins within the Rocky Mountain area; Plains region of North and South Dakota, Nebraska, Montana, and Wyoming (parts); northern two-thirds of San Joaquin Valley.

In the Dakota region there are over 10,000 ft. of sediments, and this is the southern end of a large province which has oil at a number of points. In the Dakotas so far only traces of oil and gas, with considerable thicknesses of porous beds, have been found in the five or six deep tests. Success would open up a large area for active exploration extending north to the Arctic.

Structural traps have been sought by many methods, but the declining discovery rate shows the decreasing effectiveness of the existing methods. Stratigraphic traps have generally been found by random drilling, and ways of locating them more readily are being sought, for some of these fields are among the country's largest.

Several writers have called for more vigorous wildcatting, the testing of new methods of locating wells, and the employment of more geologists and geophysicists. It certainly appears that means must be sought to stimulate wildcat drilling. G. D. H.

112. Advance in Oil Prices Needed to Avert Threatened Shortage. M. G. Cheney. *Oil Wkly*, 2.11.42, 107 (9), 15-17.—Besides being required in the form of ordinary and special products for war and industrial purposes, petroleum is now a raw material for the manufacture of rubber, explosives, etc. Various changes have been forced on the oil industry without adequate compensating adjustments in the price ceilings, now 40% below the 1926 figures. Early in the war it was thought that the United Nations' essential needs could be met out of known excess reserves, but that does not seem to be quite so certain now. The loss of the East Indian and Burmah production was unexpected, and the U.S.A. rate of drilling has declined 50%, while the number of producing wells completed has fallen 61% due to various factors. A further curtailment of drilling is expected.

In Texas nearly 2200 small oil wells were plugged during the first nine months of 1942, 50% more than in the whole of 1940. At least 100,000 more small oil wells are in jeopardy. Stripper production is said to be 16% of current production and 20% of present reserves. The existing adverse economic conditions must be held responsible for this physical waste by premature abandonment and the consequent necessity to produce other wells at excessive rates.

A reappraisal both of known recoverable reserves and possible additions by extensions to present fields has nearly been completed, together with a determination of the maximum efficient rates of production for the various fields. The Texas known recoverable reserves are 11,000-12,000 million barrels, 50% of the U.S.A. total, and the current output is 5000 million barrels per year, or 34% of the U.S.A. total. It is probable that few Texas fields are under-produced. Three-quarters of the reserves may be in reservoirs mainly of water-drive where production at rates greater than the rate of water movement is wasteful. Efficient rates of production in the gas-drive fields are determined partly by gas/oil ratios, and partly by considerations involved in returning gas to the reservoir.

In the period 1926-31 geological and geophysical work, and random drilling respectively discovered 5800, 800, and 4500 million barrels of oil, East Texas contributing the bulk of the reserves attributed to discoveries by random drilling. During the period 1934-38 the corresponding figures were 2000, 300, and 60 million barrels. The reflection seismograph was the most effective geophysical instrument in making discoveries in this second period.

Numerically, discoveries have been maintained since 1939, but they seem far less prolific than before. In 1941 one out of four wildcats located geophysically was successful, one out of five for wells located by geology and geophysics, one out of 5.6 for geology alone and one out of 26.7 for wells located non-technically.

Current oil prices should take into account the probable future costs of finding at least 1500 million barrels of new reserves annually. Pratt estimates that discovery costs have increased over 300% during the last few years.

It seems that the consumer would be much better off paying somewhat higher prices now rather than risk facing excessive price advances later under a condition of great scarcity.

G. D. H.

113.* Location of Oil Reserves Big Factor in Supply Deficiency. W. V. Howard. *Oil Gas J.*, 19.11.42, **41** (28), 14.—A study of the geographical relationships of the U.S.A. oilfields and refineries shows that there is a shortage of 300,000 bbl./day in the area east of the Sierras, if refinery runs are to be maintained at last year's level. The situation east of the Indiana-Ohio line remains practically unchanged. A rise in Kansas has been more than offset by a drop in Oklahoma and Nebraska, so that the amount of oil which must be transported across the Oklahoma and Kansas State boundaries is 167,000 bbl./day more than it was a year ago. The Arkansas-Louisiana-Mississippi area has maintained its production, and the Rocky Mountain region shows an increase. Texas and New Mexico now produce 99,000 bbl./day less than a year ago.

The decline in production may be merely a matter of transportation difficulties, but there is the possibility that production cannot be stepped up in any part of the country to meet the estimated demand. It is possible that 1943 will see as much or more construction of new pipe-lines or the relaying of old ones as has taken place in 1942.

Reserves of 20,000 million bbl. might be expected to furnish more than 4 million bbl./day. Assuming the existence of transportation facilities adequate to handle this production in all areas, output could probably be stepped up, but the increase in production would cause a decline in reserves equal to much more than the amount withdrawn.

The more effective the proration in a field the more nearly its years' supply approaches its productive life, although even in these areas a time comes when actual production falls below current allowables, with a resulting extension of the physical life of the field. Generally it may be considered that if a State is withdrawing oil at the rate of more than a thirteenth per year of its proven reserves, it is over-producing, and as a consequence the production may be expected to decline in the near future, unless it is augmented by discoveries of major importance. It appears that relatively few areas east of California are annually producing less than a thirteenth of their proven reserves, and these include Colorado, New Mexico and Texas, except the South and South-Central districts.

Tables show the relationship between refinery runs and production in the various major districts, and the increase in years' supply with declining production.

G. D. H.

114.* Typical Oilfield Structures : Regional High; Panhandle and Hugoton Fields, Texas, Oklahoma, and Kansas. Anon. *Oil Gas J.*, 19.11.42, **41** (28), 38.—The Panhandle-Hugoton area is the largest gas-producing area yet found. At the surface are Quaternary and Tertiary continental deposits, underlain by Permian red beds with anhydrite and gypsum, salt and anhydrite, and limestone and dolomite, which rest on the buried extension (Amarillo) of the Wichita-Arbuckle mountain system. With the subsidence of the Amarillo mountains, faulting took place, and continued for a considerable period. The oil and gas accumulations in the Panhandle sector are largely confined to the ridge and to the area to the north, although the famous Amarillo gas-field, which has much helium, is on the Bush dome to the south. Apparently the Hugoton-area is on a monocline with the Permian beds dipping east. The lowest production is from the granite wash. Above are four limestone or dolomite zones, the lowest being considered to be of Cisco age, and the rest Permian.

Oil is found along the northern margin of the Panhandle area, with gas over the top of the high and throughout the Hugoton district. The uniformity of the initial pressures throughout the area, as well as in the different pay horizons, suggests that the reservoirs were connected, although secondary cementation may later have separated large sections from one another.

Granite highs may be located geophysically, or by surface and subsurface geology combined. Structural conditions leading to the discovery of such fields as Hugoton are difficult to locate, and speculative thinking coupled with random drilling seems to be most successful at present. Detailed subsurface and geophysical work may reveal favourable structural conditions for the localization of oil and gas on the flanks and crests of buried granitic highs.

G. D. H.

Drilling.

115.* Drilling-Time Logs and their Uses. R. Willis and R. S. Ballantyne. *Bull. Amer. Ass. Petrol. Geol.*, July 1942, **26** (7), 1279-1283.—Drilling-time can easily be noted for

each foot of beds penetrated, and the time in minutes can be plotted to give a graph suitable for purposes of correlation. Such graphs are a valuable check if used in conjunction with electrical logs. They are also handy in plotting boundaries when, in contrasting sandstone and shale beds, parts of the core are lost. They also help in measurements for gun-perforating.

A. L.

116.* Inexpensive Features Refine Cable-tool Rig. G. M. Wilson. *Oil Wkly*, 28.9.42.

107 (4), 15-19.—The field in which these unitized rigs are used is in West Texas, and cable tools are particularly suited for the conditions encountered. The cable-tool rigs are all electrically powered. One of them uses a conventional derrick, while another is equipped with an A-frame mast, but they are similar in that each employs a unitized, skid-mounted motor-house, and the power is supplied to the spudding unit through a conventional belt and band-wheel arrangement.

A definite advantage is gained—on cable-tool rigs in particular—by the use of two motors instead of a single large one. As drilling progresses and the hole becomes deeper, the rhythm or frequency of the walking-beam strokes must be continually adjusted to an optimum speed; a speed at which the greatest rate of penetration for a given number of strokes/min. is attained. The desired speed will often lie midway between two points on the controller if but a single motor is used. With the dual power-source, however, the controller of one motor may be set on the closest point and the other controller set on the next higher or lower point, depending on which direction is desired. This splitting of points tends to average the speed, thus enabling the driller to have more complete control of the spudding frequency.

An interesting item is a novel shock-absorber used in spudding. Instead of employing the usual temporary method of utilizing a spudding pole, this company obtains the spudding action directly from a take-off on the crank. A large sheave having a wide groove is placed on the crank-pin, and the drilling line is taken off the reel, run under the sheave, then over the crown block, then down to the hole. The shock-absorber device is placed under the line midway between the reel and this sheave.

The shock absorber is shop-made, and consists of a long piston working inside a cylinder, the latter being a 3-ft. length of 6-inch pipe. At the bottom of the cylinder is a heavy coil spring of the type commonly used on the front-wheel assemblies of automobiles, and on which the piston rests in a vertical position. A small half-moon-shaped sheave over which the cable runs is mounted on the top of this piston. The assembly stands approximately $4\frac{1}{2}$ ft. high, and in the operating position beneath the line, exerts a strong upward tension against the drilling line at this point during the complete revolution of the sheave turning on the crank pin. The piston is close-fitting in the cylinder, and is kept lubricated with a heavy oil for smooth acting motion. Well braced, and mounted on a broad base, the shock-absorber is lag-screwed to the derrick floor to prevent its "walking" while in operation.

The spudding sheave, in making each revolution, alternately pulls down and releases the drilling line, producing the desired spudding action of the bit. In addition to the tendency to smooth out the drilling stroke, the shock-absorber holds the cable in forceful contact with the spudding sheave to eliminate lost motion and helps to eliminate much friction and wear on the line at that point.

A number of other details are similarly described.

A. H. N.

117.* Unique Boiler Setting Carries Own Foundations. J. C. Albright. *Oil Wkly*,

5.10.42, **107** (5), 24.—An installation of drilling boilers now in use in California has been designed so that the amount of labour and time required for either setting-up or dismantling has been materially reduced, and so only the minimum amount of equipment necessary for efficient operation and convenience of the operator is used. In addition to carrying its own foundations, thereby saving foundation time and reducing the non-salvageable material remaining when moved to a new location, all fittings and connections of the battery are equipped with unions so that dismantling and erections can be accomplished quickly, with little effort, and without requiring heavy wrenches. Naturally the expense of boiler installation has been reduced by these features.

Five conventional oilfield boilers make up the battery, one of which is used as a spare. Gas is employed for fuel. The burners are grouped in a compartment attached below the boiler firebox by means of staybolts which pass through lugs welded to the outside of the side sheets and through holes made in short joint of pipe attached to

the bottom at each end of the burner attachment. These four bolts, one at each corner, have proved sufficient to retain the burner assembly in place, which means that only four nuts need be removed for disconnecting either to service or move the burner compartment to another location. The supports for the smokebox and the rear ends are described and illustrated photographically.

Pumps are set on unitized bases with all necessary piping permanently connected, so that the water supply, steam for power, and the exhaust and discharge lines can be made up by using each section in its individual place. The heat for the boiler-feed water is the exhaust from the feed-pumps, plus any required from the rig engines which can be conveniently piped to the boilers. The expense of this type boiler equipment is obviously less than many other types, and the quantity of material remaining at the setting after the boilers have been moved is almost negligible.

A. H. N.

118.* New Problems Faced in Killing Off-Shore Cratered Blowout. N. Williams. *Oil Gas J.*, 5.11.42, **41** (26), 29-32.—Directional drilling is used now in various normal routine matters, but it is in the killing of a cratered blowout well that the proficiency of directional control of drilling is demonstrated most impressively. Here, a relief well is drilled from a convenient, safe surface location to a precalculated position in close proximity to the bottom of the blowout well, and by pumping fluid and mud through it into the producing formation around the bottom of the well the flow and pressure are readily choked. The paper deals with one of the latest and most difficult of these jobs. At a depth of 8570 ft., the well was one of the deepest to which there had ever been occasion to drill a directional relief well. Bottom-hole pressure was estimated to be around 5780 lb., which was equivalent to "normal" Gulf Coast pressure at a depth of 12,280 ft. This added not only to the hazards of drilling the relief well, but also to the problems of killing the flow in the blowout well, requiring the provision of an elaborate assemblage of pumping and steam-generating capacity. After putting 210 tons of junk on the well to localize the dangers, the well cratered and these disappeared into the bay. A relief well was then drilled.

In calculating the objective of the relief well it was known from slope tests that the bottom of the cratered well was within a radius of 126 ft. of its projected vertical hole. The direction of the deviation from vertical was not known, but in drilling the well every effort had been made to maintain the hole as nearly straight as possible, and frequent check had been made of the amount of the deviation. Consequently, if the bottom of the relief well was placed within this radius of the projected vertical it could not be more than 252 ft. from the actual bottom of the crater well. The latter would be the case only if the bottoms of the two wells were on a periphery of the circle described by the 126-ft. radius at points opposite each other on a line through the centre. The chances were that the bottoms would be much closer.

Final calculations on completion of the relief well indicated its bottom was approximately 44 ft. from the projected vertical of the crater well. At this point the actual distance it could be from the actual bottom of the crater well was 170 ft. (126 ft. plus 44 ft.), but it could have been bottomed immediately adjacent to the blowout well. Measured total depth of the relief well was 8683 ft., at a point 944.65 ft. north 45° 05' west from the surface location. At that point the vertical depth was 8586.90 ft. as compared with the depth of 8570 ft. of the crater well. Details and troubles encountered in drilling the relief well are given.

A. H. N.

119. Patents on Drilling. E. E. Miller. U.S.P. 2,295,678, 15.9.42. Appl. 17.3.41. Mud-pump piston consisting of a specially constructed core and rubber on the outside.

C. M. O'Leary. U.S.P. 2,295,803, 15.9.42. Appl. 29.7.40. Cement shoe having flexible hellically inclined external surface vanes.

A. L. Armentrout. U.S.P. 2,295,822, 15.9.42. Appl. 14.9.40. Apparatus for cementing objects in well-bores.

W. B. Campbell and J. M. Johnson. U.S.P. 2,295,932, 15.9.42. Appl. 6.3.41. Cathead with spirally grooved drum.

J. D. Hall. U.S.P. 2,296,161, 15.9.42. Appl. 2.11.40. Lateral drill for wells using flexible drill-pipe to go into the walls of a well.

- J. Neufeld. U.S.P., 2,296,176, 15.9.42. Appl. 9.3.40. Well-survey method and apparatus using radioactive radiations.
- Z. B. Richard. U.S.P. 2,296,183, 15.9.42. Appl. 27.11.40. Drill-bit of the fish-tail type with parallel sides.
- H. J. von Rosenberg. U.S.P. 2,296,186, 15.9.42. Appl. 5.5.41. Portable derrick fitted with wheels.
- A. Boynton. U.S.P. 2,296,198, 15.9.42. Appl. 22.9.38. Threadless drill-pipe.
- G. H. Ennis. U.S.P. 2,297,754, 6.10.42. Appl. 28.12.36. Method of locating strata in wells and electrode apparatus therefor.
- J. G. Campbell. U.S.P. 2,297,939, 6.10.42. Appl. 9.10.40. Method of detecting the penetration of an oil-bearing horizon by testing for oil in the drilling fluid as it enters and leaves the well.
- R. I. Gardner. U.S.P. 2,298,049, 6.10.42. Appl. 26.11.40. Tool-joint for rotary well-drilling.
- C. R. Irons. U.S.P. 2,298,129, 6.10.42. Appl. 29.3.38. Treatment of wells to seal and consolidate a stratum penetrated by the bore-tool.
- E. H. Lamberger and B. F. Langer. U.S.P. 2,298,216, 6.10.42. Appl. 26.9.39. Weight indicator for rotary well-drilling.
- P. McShane. U.S.P. 2,298,222, 6.10.42. Appl. 7.3.40. Automatic feed for rotary well-drills by electrically weighing the drill-string, and thus controlling the motor.
- G. L. Kothney. U.S.P. 2,298,706, 13.10.42. Appl. 18.11.40. Method and apparatus for orienting tools in wells.
- L. G. Howell. U.S.P. 2,298,794, 13.10.42. Appl. 23.6.41. Well-logging using Geiger-Muller counters.
- T. K. Stinson and L. K. Ayers. U.S.P. 2,298,984, 13.10.42. Appl. 28.5.37. Iron oxide weighting material for drilling muds.
- P. T. Bynum. U.S.P. 2,299,076, 20.10.42. Appl. 30.1.41. Side-wall sampler for drilling wells.
- J. A. Muller. U.S.P. 2,299,171, 20.10.42. Appl. 18.1.41. Rotary hose coupling for high pressures.
- J. A. Muller. U.S.P. 2,299,172, 20.10.42. Appl. 10.12.41. Rotary hose coupling assembly for high pressures.
- R. H. Crow. U.S.P. 2,299,383, 20.10.42. Appl. 20.11.39. Portable derrick.
- R. E. Conner. U.S.P. 2,299,528, 20.10.42. Appl. 22.9.41. Casing-mill for cutting pipes in wells.
- A. R. Maier. U.S.P. 2,299,528, 20.10.42. Appl. 15.6.36. Oil-well drilling apparatus using steam-engines.
- A. R. Maier. U.S.P. 2,299,549, 20.10.42. Appl. 12.9.40. Well-drilling rotary machine with a lubricant pump.
- J. E. Hall. U.S.P. 2,299,978, 27.10.42. Appl. 25.6.38. Casing protector for drill-pipes and the like.
- G. L. Scott and W. B. Noble. U.S.P. 2,300,016, 27.10.42. Appl. 3.4.39. Directional drilling apparatus comprising a device carried in a drilling-bit.
- B. F. Kelly. U.S.P. 2,300,122, 27.10.42. Appl. 23.3.39. Cathead and spinning drum assembly on one shaft of a draw-works.
- E. L. Johnston. U.S.P. 2,300,384, 27.10.42. Appl. 29.1.40. Method of locating stuck pipe in wells.

A. H. N.

Production.

- 120.* Graphical Mechanics of Counterbalancing Individual Well-Pumping Units. J. J. Lauder milk. *Oil Wkly*, 28.9.42, 107 (4), 20-24.—The principles of finding graphically the resultant torque curve for a pumping installation fitted with counter-

balance are given in detail and illustrated by working out completely a typical example. The first step for the counterbalancing of an individual well-pumping unit by use of graphical mechanics is to secure a drawing of the individual well-pumping unit in question. This can be done very simply if the unit is in operation. By merely measuring the existing physical dimensions of the unit the engineer will be able to draw his preliminary sketch. This process will be much simpler if an existing drawing of the unit has been furnished by the manufacturer. The second step in the preparatory field-work necessary is to undertake dynamometer well-load studies and obtain the normal card under desired conditions of operation. It is also necessary to determine the type and physical characteristics of the counterbalance in use on the well.

After these two steps a line drawing is made of the mechanism. This includes (1) crank-pin, (2) crank, (3) wrist-pin, (4) circle of travel of wrist-pin, (5) circle of travel of centre of gravity of counterbalance, (6) pitman, (7) stirrup bearing, (8) arc of travel of stirrup bearing, (9) saddle-bearing, (10) sampson post, (11) arc of travel of horsehead, (12) and an arbitrary distance measured from the point of contact of the arc of travel of the horsehead and the straight-line motion of the polished rod to an arbitrarily established point on the line of action of the polished rod. The drawing must be accurate as any error introduced here is cumulative in subsequent operations. From this diagram and a dynamometer card resultant torques are calculated. A. H. N.

121.* Ten Years of Conservation Keep Conroe Wells Flowing. W. L. Baker. *Oil Wkly*, 5.10.42. **107** (5), 17.—The Conroe oilfield has produced one-fifth of its estimated ultimate recovery since it was discovered 10 years ago, yet, due to early adoption of modern conservation practices on a widespread scale, the field's reservoir pressure has been husbanded to the point that some 93% of the wells are still flowing naturally, and only nine producing wells have been abandoned. The reservoir pressure of the principal producing formation, which has produced 120 million barrels, or 90% of the field's total to date, is but 222 lb. lower than the original, a change of only 1.85 lb./million brls. of oil produced. Significantly most of this energy loss occurred in the first eighteen months, or before conservation was adopted to a material extent. A decrease of only 90 lb. while producing 113 million barrels, or 0.79 lb./million brls., has been recorded in the past nine years; and currently its pressure is identical with that existing four years and seven months ago, although over 42 million barrels of oil have been recovered from the horizon during the interval.

The field was drilled following a wide spacing pattern. This amounted to large reduction in drilling cost and conservation of reservoir energy simultaneously. The conservation of energy was further enhanced by careful completion and choking of wells and proper withdrawal rates to utilize most effectively the water-drive present. Details of these practices are presented.

The practice of gathering produced salt-water in lease-pits where it either evaporates or is turned into natural drainage channels during rainy seasons is the common disposal system at Conroe. During the past two years a number of new earthen storage pits were built or old ones enlarged due to the increase in water production. There also has been some recent activity towards use of disposal wells for the subsurface injection of salt-water. The disposal of salt-water by this means is still in its initial stages, but appears successful, and additional installations are likely. A. H. N.

122.* Ingenious System for Starting Central Power Engines. E. Sterrett. *Oil Wkly*, 5.10.42, **107** (5), 30.—An ingenious method of kicking off the two-cylinder two-cycle 100- and 150-horse-power engines used by one company for actuating its powers was developed to replace the former method of "cranking" the unit by revolving it under manual power—applied by climbing the spokes of the flywheel until a charge of fuel has been drawn into the engine, then carefully compressed to a setting in the operating cycle as close to the firing point as can be judged, after which the ignition is snapped on or the magneto breaker flipped to fire the compressed charge. Due to the limited arc of flywheel rotation in which ignition occurs with normal timing, this operation generally is unsatisfactory as well as hazardous, and requires close co-ordination between the man rocking the engine and the one manipulating the spark.

The plan as adopted involves the use of a compressor unit, but instead of a storage tank large enough to furnish several fillings of the engine cylinder, a small or garage-type compressor is used, belt-driven by a $\frac{1}{2}$ -horse-power gasoline engine. This entire

unit costs less than the storage tank sometimes provided for high-pressure air starting, occupies but a small corner of the engine-house, and can be started readily and operated by one man.

Aside from the expected elimination of accidents caused when attempting the starting of the power units, the availability of the pre-mixed charge, and consequent easy starting, helps prevent accidents formerly caused by the pumper, attempting minor adjustments to the engine while operating. This easy re-starting after shut-down means that the worker no longer chances injury—and possible dismissal—by failing to observe the company's order to shut down the engine before working on it.

A. H. N.

123.* Metering of Oil-well Production. Part 1. G. L. Paulus. *Oil Wkly*, 12.10.42, 107 (6), 17.—Advantages of metering over using gauge-tanks to measure well production are briefly discussed, savings in steel required and amount of oil stored above ground at any one time being indicated. Metering in the field is then reviewed historically from 1924, when the first oilfield meter was installed. The problems connected with metering oil wells are great, since it is possible for the meter to receive into its measuring chamber a mixture composed of the following: (1) mixture of hydrocarbons which are in the gaseous state at the temperature and pressure of metering; (2) mixture of hydrocarbons which are liquid at the temperature and pressure of metering; (3) salt-water and its accompanying water vapour; (4) hydrocarbon wax which has a consistency of cup grease at metering temperatures and pressures; (5) formation sand; (6) precipitated salt scale; (7) foreign solid materials such as stuffing-box rubber-packer rubber and canvas, waste, and rags, the last of these two being introduced by careless workmen; (8) chemicals which are corrosive, such as sulphur compounds, and (9) chemicals for dehydration purposes which are often introduced upsteam of the meter.

The production from an oil-well may consist of as few as two of the above materials, but it is not uncommon to find all present. Unfortunately, most of the meters available for production measurement have been designed to handle relatively clean liquids, and in most cases the meter which has been designed for clean liquids is tried on oil-well production without any changes, with the hope that it will happen to have been designed in such a manner as to do the job satisfactorily. Three types of meters are studied in the paper: (1) positive displacement, (2) current, and (3) weighing meters, Part 1 being devoted entirely to the first type. Accuracy, maintenance, and effects on tolerances, etc., are discussed in detail.

Most positive-displacement meters do not account for the change in volume of the oil due to a change in temperature, and record only a definite volume/cycle. However, some meters now on the market are provided with a thermostat which causes the meter to register a 60° barrel at all times. These thermostats come with the meters as extra equipment, and are expensive in relation to the cost of the meter. They correct on the basis of the expansion factor of the liquid metered. Thus, unless the meter is measuring a relatively dry oil the correction would be in error, because of the mixture of oil and water involved. To hold the thermostatic correction accurate, the coefficient of expansion for the mixture would have to be used and an adjustment made whenever a change in composition occurred. The difference in volume between 60° oil and oil at the temperature of metering generally is only about 1 or 2%, so it is believed that until such time as this type of meter can be held to closer accuracy while metering oil-well production, the thermostat is not essential. In most cases accuracies better than 1 or 2%, although desirable, are not absolutely necessary when handling well production. In places where greater accuracy is necessary, the expense of metering the well production rises rapidly. With the meters now available, this expense would be almost prohibitive if the meters were held to a registration as close as plus or minus 1/2%.

A. H. N.

124.* Conservation of Gas in Louisiana. H. W. Bell. *Oil Wkly*, 12.10.42, 107 (6), 28.—The legal and engineering aspects of natural gas production and conservation are discussed in some detail.

A. H. N.

125.* Casing Corrosion in Oilfields Producing Sour Gas. T. D. Bailey and A. M. Crowell, *Oil Gas J.*, 15.10.42, 41 (23), 31.—Operators in the sixteen sour gas-producing

oilfields of southern Arkansas have been requested by the State of Arkansas to take preventive measures to guard against corrosive action of hydrogen-sulphide-bearing gases found in these reservoirs. While damaged casing has been found only in the Magnolia field to a large extent and the Atlanta and McKamie fields to a minor extent, the imminence of corrosive action in the other fields has caused the State Commission to include them in their workover requests. A table gives relevant data about the fields and the fluids found in each. Two theories are advanced for the severe corrosion: (1) electrolysis and (2) electrochemical or galvanic action resulting from the presence of hydrogen sulphide. The latter theory seems to have the most support.

Working on the electrolysis theory, several tests were made to determine if a current of electricity was actually flowing through the gathering lines. Results of these tests showed that currents of 0.3–3 amp. were found to be present in the flow-lines. This current was found to flow towards the well in all cases. Although this current is small, considerable electrolysis could take place over a long period of time. Theoretically, a current of this size could remove 15–20 lb. of metal/year. At any rate, this theory should not be entirely overlooked. Electrochemical or galvanic action resulting from the presence of hydrogen sulphide in the gas seems to be the most prevalent theory because of the high concentration of hydrogen sulphide present in the Magnolia field. This theory is discussed on the basis of Prof. Cloud's studies in his book "Petroleum Production."

Since there are good arguments for both the theories given, precautions are being taken against both possibilities. The electrolysis possibility is being easily remedied by placing insulated connections on the flow-line at the point of connection to the well or separator. Possibility of electrochemical or galvanic action due to the presence of hydrogen sulphide is being guarded against by setting corrosion-resistant packers above the producing formation between the tubing and oil-string and by filling the annular space between these two strings with either oil-base mud or sweet oil. The annular space between the water string and surface string is also being kept filled with mud or oil. As an added measure of safety, a commercial inhibitor might be added to the mud or oil behind the packer to reduce corrosion further.

A. H. N.

126.* Effects of Well-Cleanout Work in Venango District. R. B. Bossler and P. A. Dickey. *Oil Gas J.*, 29.10.42, 41 (25), 33.—It costs nearly as much to operate a well producing a small amount of oil as it does to operate a well producing a large amount. This simple fact accounts largely for the vastly different costs of production in different parts of the country and even in different parts of the same pool. Costs of production differ widely in the Kane–Butler district of Pennsylvania, even between adjacent leases, depending on how intensely they are being repressured and their general condition and efficiency, as well as on the richness of the sand.

In September 1941 various producers submitted costs of production to a committee of the Pennsylvania Grade Crude Oil Association. These data are published in a brief submitted to the Office of Price Administration on September 26. Costs of production in the Kane–Butler area ranged from \$1.34 to \$4.62/brl. (not including interest on invested capital). The lowest cost leases are those undergoing intensive repressuring, while the highest cost leases are those in relatively poor districts where no repressuring is attempted. It should be emphasised that costs for the repressured leases are lower than the non-repressured leases even when depletion, depreciation, amortization, and overhead charges are increased by the secondary-recovery development. The weighted average cost/brl. for the non-repressure properties was \$2.91 and for the repressured properties it was \$2.36. Cleaning-out of wells in order to increase production and thereby reduce costs is discussed.

In the ordinary procedure of cleaning-out a well, the rods and tubing are removed, and the cavings and junk are fished out or drilled up with the tools. It is not considered good practice to drill out all the material at once, and "put the well on the bottom". It is considered better to "keep the tools on top" of the cavings, running a fairly slow motion and short stroke to promote a scouring action on the face of the sand by the bit and rock fragments in the hole. It is also thought that this method will induce the sand to cave, and the cavings will be drilled up as they come in and not be so likely to fall on the tools when they are below the sand. After the material has been removed and the well is clean to bottom, further caving is induced by dumping in several barrels of water and churning it around with the tools.

At this point some operators shoot the well, while others do not. If the well is shot, the charge is usually light; 1 or 2 quarts to the foot. Some operators shoot the wells themselves, using dynamite lowered or often dropped in from the surface. Less water is used for tamping than in a new well, in order to avoid plugging the pores of the sand by water under a large head. After the shot, the cleaning-out operation is repeated, and the tools are run in very much the same manner as before. A. H. N.

127. Patents on Production. L. D. Mowrey. U.S.P. 2,295,598, 15.9.42. Appl. 21.2.40. Well-flowing device with double chambers and a flow-control device.

G. W. Bowen. U.S.P. 2,295,630, 15.9.42. Appl. 18.10.40. Overshot grapple for sucker-rods.

A. J. Collins. U.S.P. 2,295,634, 15.9.42. Appl. 9.2.40. Gun for perforating well-casing within the well.

S. J. Dietzmann and K. F. Riemann. U.S.P. 2,295,720, 15.9.42. Appl. 16.4.41. Sucker-rod tool with a frame to be clamped to the tubing and a rotating gear to be fixed to the sucker-rod.

J. R. Gillbergh. U.S.P. 2,295,738, 15.9.42. Appl. 16.12.40. Method and means for determining the points of ingress of well-fluids.

A. L. Stone. U.S.P. 2,295,873, 15.9.42. Appl. 25.9.39. Well pipe collar.

F. Stone and A. L. Stone. U.S.P. 2,295,874, 5.9.42. Appl. 25.9.39. Adapter for well-pipes having external annular upset.

D. E. Humphrey. U.S.P. 2,296,164, 15.9.42. Appl. 4.10.40. Pump-rod actuator for deep well-pumping.

L. D. Mowrey. U.S.P. 2,296,220, 15.9.42. Appl. 10.6.39. Gas-lift flow device with flow-controlling means.

H. Allen. U.S.P. 2,297,678, 6.10.42. Appl. 2.7.37. Pressure-gauge for very high-pressure readings.

H. Allen. U.S.P. 2,297,679, 6.10.42. Appl. 7.6.38. Pressure-gauge.

E. J. Hudson. U.S.P. 2,297,832, 6.10.42. Appl. 5.11.40. Extraction and treatment of volatile liquid hydrocarbons to maintain the rock pressure in a subterranean reservoir.

J. E. Hall. U.S.P. 2,297,956, 6.10.42. Appl. 28.11.38. Single duct, hydro-pneumatic, well-tool actuator.

J. Kelly, E. W. Ostrom and G. H. Williams. U.S.P. 2,298,567, 13.10.42. Appl. 20.7.40. Pump anchor for wells.

T. V. Moore. U.S.P. 2,298,834, 13.10.42. Appl. 24.5.40. Means for producing oil-wells passing through a plurality of formations.

C. A. Still and A. C. Still. U.S.P. 2,298,985, 13.10.42. Appl. 5.9.40. Paraffin cleaner for oil-wells.

H. M. McClain. U.S.P. 2,299,057, 13.10.42. Appl. 19.9.40. Apparatus for gravel-packing wells.

W. L. Church. U.S.P. 2,299,304, 20.10.42. Appl. 18.10.40. Fluid lift-pump for wells.

C. L. Evans. U.S.P. 2,299,315, 20.10.42. Appl. 5.3.40. Pump.

W. E. Lawson and C. A. Woodbury. U.S.P. 2,299,907, 27.10.42. Appl. 18.8.39. Explosive charge for oil wells, the charge being in fluid form.

E. E. Clayton. U.S.P. 2,300,103, 27.10.42. Appl. 19.6.41. Process for breaking petroleum emulsion.

D. W. Justis. U.S.P. 2,300,121, 27.10.42. Appl. 30.11.40. Deep well-pump for oil.

J. B. Clark. U.S.P. 2,300,206, 27.10.42. Appl. 30.10.41. Testing wells for the location of the lowermost point of water entry into the well.

F. E. Dana. U.S.P. 2,300,348, 27.10.42. Appl. 21.4.41. Method for cleaning oil-wells.

C. Lowery. U.S.P. 2,300,370, 27.10.42. Appl. 9.7.41. Sucker-rod elevator.
A. H. N.

Transport and Storage.

128.* Use of Soil Surface Potential in Locating Pipe-line Corrosion. O. C. Mudd. *Oil Gas J.*, 14.5.42, 41 (1) 50.—Voltage is set up in a corroding pipe-line in contact with one soil electrolyte in differing concentrations, or two different types of soil electrolyte, in contact themselves, in a manner comparable to its production in a dry-cell battery by contact of two different elements with one electrolyte. The pipe is analogous to the external circuit conductor between the anode and cathode of the dry cell, and although potentials developed are lower than those of batteries, they may be detected with a millivoltmeter. The similarity is traced in detail with the aid of diagrams.

The greatest corrosion takes place at the anodic section of the pipe, and the method described for the detection of corrosion activity is dependent on measurement at regular and frequent intervals along the pipe of (a) pipe to soil potentials by observing the potential drop between a metal bar in contact with the pipe and a non-polarizing electrode over the pipe axis, and (b) soil resistance by means of suitable equipment—e.g., "Shepard Canes" or a "Soil Resistivity Megger." Corrections must be made for extraneously originating electrical influences—e.g., due to magnetic storms or to nearby cathodic protection units, etc.

Results are plotted with respect to distance along the pipe, and give a fair indication of positions of probable corrosion activity. A crew of six men have surveyed an average of 3 miles per day of 10-in. line with 100-ft. intervals between surface contact points, including four soil-resistivity measurements per 100 ft. The author considers this technique an improvement over previous methods, since anodic sections are located within closer limits, and more details of electrolytic conditions can be determined in a given time.
J. C.

129.* Electrical Charges Produced by Flowing Gasoline. S. S. Mackeown and V. Wouk. *Industr. Engng Chem.*, 1942, 34 (6), 659.—Measurements have been made of the magnitude of the electrostatic charges which can be produced when gasoline is pumped into a tank truck, and when gasoline is unloaded at a service station. It is shown that during filling, charges are formed which are capable of igniting a combustible mixture of gasoline vapour and air, but that during emptying insufficient electrostatic electricity is formed to represent a hazard.
J. W. H.

130.* Bonding Pipe-lines as Protection Against Electrolysis. E. E. Claggett. *Petrol. Engr.*, 1942, 13 (10), 128.—The more important electrical influences which may affect an underground pipe-line are (a) stray or vagrant currents, (b) galvanic electricity, (c) static electricity, (d) magnetic fields. Various types of bonds or cables may be connected to the pipe-line to harmlessly discharge currents. Descriptions, including some diagrams and dimensions, are given of jumper bonds, which provide a current path round rubber gasket couplings, tie bonds, which equalize the potential between two underground structures, drainage bonds, which carry current to a place of safe discharge, pilot wires, which are used for potential test purposes, and "deadmen" (earth electrodes). Methods of installation are discussed, and a desirable type of fibre conduit for bond and pilot wires, used by the Southern California Gas Co., is described.
J. C.

131.* When Should a Pipe-line be Coated? S. Thayer. *Petrol. Engr.*, 1942, 13 (10), 158.—A general article which emphasizes the difficulty of deciding on the basis of soil corrosiveness whether pipe-lines should be coated. Technical knowledge and practical experience are required for soil classification, but inaccuracies may still result from non-uniformity of the soil. A comparison of initial costs of coating with costs of repair for a pipe-line life of 30 years is made, and the conclusion is reached that pipe-lines should be coated not only in known corrosive areas, but also in doubtful areas.
J. C.

Gas.

132.* Liquefaction of Natural Gas for Public Supply. Anon. *Engineer*, 1942, **173** (4506), 432.—A description is given of the plant of the East Ohio Gas Co. which supplies the city of Cleveland. Liquefaction of the natural gas was resorted to in order to cope with peak requirements.

The operation of the pilot plant installed at Cornwell disclosed that it was essential to remove all CO_2 and water vapour before liquefying, and that a stainless steel of 0.09% carbon and 3.5% nickel would be satisfactory for tank construction.

Details are given of the method of construction and type of plant necessary, and of the operation under service conditions. J. G. W.

133. Calcium Chloride Nomographs. D. S. Davis. *Industr. Engng Chem.*, 1942, **34** (11), 1393.—Nomograms are given which correlate the specific gravity, freezing point, and concentration for commercial calcium chloride brines containing sodium chloride. This data is of value in gas drying and refrigeration problems. J. W. H.

Polymerization and Alkylation.

134.* The Turbulent Spreading of a Water Jet. A. M. Binnie. *Engineering*, 1942, **183** (3929), 503.—Photographic experiments on the turbulent spreading of a water-jet into a large volume of fluid at rest are described. Various observed features are discussed and compared with theory. J. G. W.

135.* Catalytic Polymerization of Olefins in the Presence of Phosphoric Acid. A. Farkas and L. Farkas. *Industr. Engng Chem.*, 1942, **34** (6), 716.—The hydrogen atoms of the phosphoric acid were replaced by deuterium atoms, and the polymerization reaction of isobutene and other olefins investigated with this catalyst. From the results of the experiments it is shown that the polymerization proceeds with an exchange of hydrogen atoms between the catalyst and the butene. The reaction mechanisms proposed by various authors are discussed, and a modification of the Ipatieff mechanism is suggested. The principle involved is the formation of the monomer in two forms, one resulting from the transfer of a hydrogen atom to the catalyst and the other by a transfer from the catalyst to the monomer. These two forms combine together to make the polymer. J. W. H.

136. Patents on Polymerization and Alkylation. E. R. Kirm and N. Fragen. U.S.P. 2,301,052, 3.11.42. Appl. 8.10.38.—An increased yield is obtained in the process of converting normally gaseous olefin hydrocarbons into distillate lubricating oil if the olefin hydrocarbons are subjected in liquid phase to the action of a polymerizing catalyst. In this way the olefins are converted into heavier hydrocarbon polymers. Unreacted gaseous hydrocarbons are separated from these polymers, and the latter are fractionated, thus producing a distillate lubricating oil and a substantially non-volatile residue. The residue is subjected to pyrolytic decomposition regulated to regenerate olefinic hydrocarbons and to produce lubricating oils of intermediate viscosity. The products of decomposition are recycled to the fractionating zone and the polymerization process is modified by recycling at least a portion of the products of decomposition from the fractionating zone to the polymerizing process.

J. A. Chenicek and K. M. Brown. U.S.P. 2,301,615, 10.11.42. Appl. 15.10.41. Saturated branched-chain hydrocarbons are produced from normal paraffins and normal or branched-chain olefins by passing a normal paraffin charge and a lesser portion of recycled hydrocarbons, together with a small amount of hydrogen chloride, through an isomerization zone. A greater portion of the recycled hydrocarbons is passed through an aluminium chloride catalyst pick-up zone. Products from the isomerization and catalyst pick-up zone are combined with a separate stream of olefins in a proportion designed to maintain an excess of isoparaffin. The combined stream is passed through an alkylation zone, and the products are separated into alkylated hydrocarbons and unreacted hydrocarbons. At least a portion of the unreacted hydrocarbons are returned to the isomerization and catalyst pick-up zones.

H. B. M.

Synthetic Products.

Progress in Rubber Chemistry. *Industr. Engng Chem.*, 1942, **34** (11), 1255-1371.—This issue contains a symposium on rubber which consists of twenty-six articles by different authors. Individual abstracts of the articles on synthetic rubber are given below. J. W. H.

137.* The Synthetic Programme.—*Résumé* of the Report of the Baruch Committee. *Industr. Engng Chem.*, 1942, **34** (11), 1256.—The production capacity of the various plants visualized in the present programme are given and compared with the estimated requirements for 1943 and 1944. Recommendations for the construction of further plants are made. The committee conclude that there is no serious conflict between the rubber and aviation fuel-production programmes. J. W. H.

138.* Progress of Butadiene Production. A. L. Elder. *Industr. Engng Chem.*, 1942, **34** (11), 1260.—At the moment the bottle-neck of the synthetic rubber programme is the production of butadiene, which is used in conjunction with styrene to produce Buna S, the synthetic rubber forming the largest portion of the production programme.

A review is given of a very large number of chemical syntheses which are available for the production of butadiene, and methods for its separation from associated substances are discussed. The following proved methods for the production of butadiene are described: (1) thermal cracking plants operating on light oils; (2) catalytic cracking plants to convert butane into butylene and thence to butadiene; (3) ethyl alcohol plants; (4) butylene glycol plants; (5) butyl alcohol plants. The butadiene requirements are 667,800 tons per annum, of which 107,800 tons will be obtained by thermal cracking, 340,000 tons from catalytic cracking and 220,000 tons from alcohol. J. W. H.

139.* Progress of Styrene Production. W. Dow. *Industr. Engng Chem.*, 1942, **34** (11), 1267.—A brief non-technical review is given of the Dow process for the conversion of ethylene to ethylbenzene which is dehydrogenated to yield monomeric styrene. J. W. H.

140.* Action of Organic Accelerators in Buna S. G. R. Vila. *Industr. Engng Chem.*, 1942, **34** (11), 1269.—Data are given on the effect of different rubber accelerators on the curing time, tensile strength, elasticity, elongation, hysteresis, and brittleness of vulcanized Buna S. It is concluded that the dithiocarbamates are the most suitable accelerators. Low sulphur contents give resistance to ageing, but slightly higher values are required for minimum hysteresis and brittleness. J. W. H.

141.* Effect of Carbon Blacks in Synthetic Tyre Compounds. B. S. Garvey and J. A. Fraser. *Industr. Engng Chem.*, 1942, **34** (11), 1277.—Twenty-four samples of carbon black, from various sources, representing ten distinct types have been blended in various proportions with a single synthetic rubber mix. After curing, the elongation, hardness, hysteresis, brittleness, and milling time were determined, and the data have been correlated for each individual black in terms of concentration. The data have also been arranged so that the effect of changing the type of black on the properties of a given tensile strength rubber can be appreciated. J. W. H.

142.* Perbunan Properties and Compounding. R. A. Moll, R. M. Howlett, and D. J. Buckley. *Industr. Engng Chem.*, 1942, **34** (11), 1284.—Data on the effect of different accelerators, softeners, and carbon blacks on the physical properties of vulcanized Perbunan rubber are given. It is shown that most of the common rubber accelerators are suitable for use with Perbunan, and that major changes in the physical properties can be made by varying the pigment loading and softener. Data are also given on the effect of oils and gasoline on various compounded Perbunan rubbers. J. W. H.

143.* Density Measurements of Synthetic Rubbers. L. A. Wood, N. Bekkedahl, and F. L. Roth. *Industr. Engng Chem.*, 1942, **34** (11), 1291.—A technique for the preparation of samples has been developed which enables consistent values of the densities of synthetic rubbers to be determined to an accuracy of 0.05%. Density

determinations on eighteen synthetic rubbers range from 0.93 to 1.6, compared with a value of 0.91 for natural rubber.

J. W. H.

144.* Thermal Decomposition of Natural and Synthetic Rubber Stocks. I. B. Prettyman. *Industr. Engng Chem.*, 1942, **34** (11), 1294.—A method is described of measuring the chemical decomposition temperature of rubbers. It consists essentially of heating the sample below the surface of molten metal, and observing the samples, after 1 hour's heating, for the presence of blow-holes and cracks. Using this method, a comparison is made between natural rubber, hevea, reclaim, guayule, Buna, and Neoprene rubbers containing various accelerators, sulphur, and carbon-black contents. Buna and Neoprene rubbers had a much higher decomposition temperature than natural rubbers. Sulphur decreased the decomposition temperature, and certain types of black and accelerators increased the decomposition temperature.

J. W. H.

145.* Effect of Petroleum Products on Neoprene Vulcanizates. D. F. Fraser. *Industr. Engng Chem.*, 1942, **34** (11), 1298.—Data obtained on the swelling of a sample of Neoprene G immersed in thirteen kerosenes of different types have been correlated by means of the diesel index ($\text{A.P.I. gravity} \times \text{aniline point } ^\circ\text{F./100}$). It is found that the lower the diesel index the greater the degree of swelling which results. In the past it has been customary to test synthetic rubbers in a 15% benzene-kerosene blend at 60° C., and it is now proposed that these tests should be carried out in an oil of definite diesel index.

J. W. H.

146.* Butyl Rubber Properties and Compounding. J. P. Haworth and F. P. Baldwin. *Industr. Engng Chem.*, 1942, **34** (11), 1301.—Butyl rubber, the elastic copolymer between isobutylene and small amounts of diolefin, is unique in the synthetic rubbers by virtue of the small amount of unsaturation present. This results in the vulcanizates being very resistant to oxidation. The rebound characteristics of butyl rubber are low at room temperature, but resemble natural rubber at 212° F. The low value at room temperature may be improved by slightly increasing the saturation. Butyl rubber can be readily handled in rubber factory equipment, the most important compounding factor being that sulphur vulcanization requires active accelerators of the thiuram type. Data on the effect of compounding on the physical properties are given, and measurements of the chemical resistance and swelling tendency have been made.

J. W. H.

147.* The Processing Characteristics of Synthetic Tyre Rubber. B. S. Garvey, M. H. Whitlock, and J. A. Freese. *Industr. Engng Chem.*, 1942, **34** (11), 1309. Laboratory tests for evaluating the properties of crude and compounded rubbers are given, the relationships between laboratory and factory processing are discussed, and the processing characteristics of synthetic tyre rubber such as is being made under the U.S. Government programme are reviewed.

J. W. H.

148.* Ebonite from Hycar OR-15. B. S. Garvey and D. V. Sarbach. *Industr. Engng Chem.*, 1942, **34** (11), 1312.—Ebonites made from Hycar OR-15 have physical properties equal to those of natural rubber and, in addition, have higher softening temperatures. This paper correlates changes in compounding composition with the physical properties of the ebonite produced.

J. W. H.

149.* Volume Change of Hycar OR-15 Compounds on Immersion. A. E. Juve and B. S. Garvey. *Industr. Engng Chem.*, 1942, **34** (11), 1316.—The effect of immersion temperature, softeners, and size and shape of specimens on the swelling of Hycar OR-15 compounds in oil has been investigated. These are all shown to be important variables.

J. W. H.

150.* Evaluation of Small Amounts of Synthetic Rubber. B. S. Garvey. *Industr. Engng Chem.*, 1942, **34** (11), 1320.—The design of a mill and the development of a testing technique are described, which enable a laboratory evaluation on 9 g. of a synthetic rubber to be made. The completed tests enable judgement to be made on

the milling behaviour at three temperatures, curing time, plasticity, tack, stress-strain, hardness, rebound, compression set, flexibility at low temperatures, brittle temperature, rapid flex hysteresis, and change in volume in five solvents. A number of comparisons have shown that conclusions based on these small-scale tests are in agreement with the data obtained on the ordinary laboratory experimental mill and testing technique which requires 200–500 g. of rubber.

J. W. H.

151.* Unsaturation of Synthetic Rubberlike Materials. L. V. E. Cheyney and E. J. Kelley. *Industr. Engng Chem.*, 1942, **34** (11), 1323.—The unsaturation of three synthetic butadiene polymers has been determined by means of a modification of the Kamp-Wijs method. The reaction proceeds more slowly than with natural rubber, requiring 24 hrs. at 30° C. compared with 15 min. or less required for natural product. The iodine values obtained vary slightly with the solvent employed, but in general are within 85–90% of the theoretical values for straight-chain polymers. The difference is attributed to cross linkages.

J. W. H.

152.* Effect of Aniline Point on the Swelling of Synthetic Rubbers. A. C. Hanson. *Industr. Engng Chem.*, 1942, **34** (11), 1326.—The investigation has been conducted with the object of determining the changes in volume to be expected with certain compounded materials in various oils of the hydraulic type used in recoil mechanisms. The increase in volume has been measured of three synthetic rubber compounds, containing Neoprene, Butyl, and Buna rubbers on immersion in eleven different oils at room temperature for periods up to 120 days. The Buna N compound gave the lowest values for swelling, and was the only rubber to show shrinkage.

A straight line is not obtained by plotting the log of the percentage increase in volume against aniline point of oils when a wide range of aniline points is covered. The inverse relation between the log% volume increase and aniline point only holds for volume increases up to 100%.

J. W. H.

153.* Intermolecular Forces and Mechanical Behaviour of High Polymers. H. Mark. *Industr. Engng Chem.*, 1942, **34** (11), 1343.—The mechanical behaviour and intermolecular forces are correlated for three typical classes of high polymers—namely, rubbers, plastics, and fibres. A general conclusion is reached that there is no fundamental difference in structure between these types of compounds. It is shown that in order to possess any mechanical strength, the average degree of polymerization must have a minimum value of between 40 and 80, and that the proportionality between mechanical strength and chain length holds until a polymerization degree of 250 is reached. At this value the mechanical strength slowly increases until a polymer value of 700 is reached, when the ultimate strength is independent of the chain length. The shape of the polymer distribution curve (the mean value of which represents the degree of polymerization) does not appear to have any definite effect on the ultimate strength, except that constituents having a polymerization degree below 150 are definitely detrimental. The chemical nature of the monomer and the manner in which the individual chains are linked together have an important influence on the mechanical behaviour. High polymers possess a two-phase structure in which certain areas of a sample exhibit a high degree of internal organization (crystallites or micelles) and other areas which consist of disordered and randomly entangled chains (amorphous fractions). The internal structure of rubber is that of chains fitting badly into the lattice. Fine and well-fitting chains represent a fibrous structure, and intermediate structures are represented by plastics. These structures are considered from a thermodynamical point of view, and it is concluded that rubber-like properties can be obtained with all types of straight flexible chain polymers, provided that the intermolecular forces are balanced by a sufficient bulky construction so that the entropy of fusion exceeds a value of 0.9.

J. W. H.

154.* Equation of State of Some Synthetic Rubbers. L. E. Peterson, R. L. Anthony, and E. Guth. *Industr. Engng Chem.*, 1942, **34** (11), 1349.—Stress-relative length data are given for two neoprene and one hycar rubber. From this data the thermodynamic equations of state for these rubbers have been calculated. The same equation of state

which characterizes natural rubber also describes in terms of relative length and temperature the retractive force exerted by those synthetic rubbers. J. W. H.

155.* Effect of Temperature and Pressure on Oxygen Pressure Ageing. A. M. Neal, H. G. Bimmerman, and J. R. Vincent. *Industr. Engng Chem.*, 1942, **34** (11), 1352.—The present ageing test for rubber vulcanizates is heating with oxygen at 70° C. and 300 lb. sq. in. and measuring the loss of tensile strength. Any attempt to shorten the time taken for this test by increasing the temperature or pressure will necessitate a revision of all ageing specification. This will involve an individual study of each stock and every cure, since no correlation exists between rate of ageing and change of temperature or pressure. These conclusions are supported by data for six stocks, which include two synthetics, at 70° and 80° C. and at $\frac{1}{2}$, 50, 150, and 300 lb. p.s.i. J. W. H.

156.* Vibration Properties of Rubberlike Materials. R. B. Stambaugh. *Industr. Engng Chem.*, 1942, **34** (11), 1358.—An electrical vibrator for determining the dynamic properties of rubbers is described. Measurements are made of the dynamic modulus, internal friction, and dynamic resilience over the temperature range - 30° to + 120° C. at frequencies of 30-100 cycles/sec. of natural and several synthetic rubbers. From this data it is concluded that: (1) the vibration modulus and resilience are independent of the frequency; (2) the internal friction is inversely proportional to the frequency; (3) the modulus decreases as the temperature rises, and curves for synthetic stocks at high temperatures are not very different to natural rubber at low temperatures; (4) resilience rises linearly with temperature. Natural rubber shows a sharp transition at 25° C.; (5) the internal friction-temperature relationship follows the same exponential law as the viscosity of liquids; (6) the amplitude of the vibration has a large inverse effect on the modulus and friction. J. W. H.

157.* Theory of Rubber Elasticity for Development of Synthetic Rubbers. H. M. James and E. Guth. *Industr. Engng Chem.*, 1942, **34** (11), 1365.—An elasticity theory is developed from thermodynamical considerations. The theory shows that for high extensions only the contracting force changes its dependency upon extension. The internal pressure remains practically the same. These effects result in the characteristic S-shaped stress-strain curve which is typical of rubbers. It has been shown that this S-shaped curve is independent of crystallization. J. W. H.

158.* Motion Picture Study of Rubber Lattices. F. F. Lucas. *Industr. Engng Chem.*, 1942, **34** (11), 1371.—An ultra-violet microscope technique has been developed for the examination of colloidal rubber dispersions. Micrographs and time study photographs are given for Balata and Hevea lattices. It is shown that a common element of any rubber structure is a primary particle with one or more satellites gyrating round it. Chains form and break up, and others form in constantly changing pattern. In the case of Buna and neoprene lattices the particles are small and uniform, and the motions are faster than natural rubber. Some lattices appear light-sensitive when much diluted and the particles gradually disappear. J. W. H.

159.* Coal in the Manufacture of Synthetic Rubber. H. L. Fisher. *Industr. Engng Chem.*, 1942, **34** (11), 1382.—The manufacture of the chief synthetic rubbers by the method of emulsifying the ingredients is described, and the substances from coal used in the processing and compounding of synthetic rubbers are discussed. Flow-sheets for the manufacture of several synthetic rubbers are given. J. W. H.

160.* Coal as a Source Material for the Plastics Industry. R. L. Wakeman and B. H. Weil. *Industr. Engng Chem.*, 1942, **34** (11), 1387.—The competition which the petroleum industry will offer to the coal industry in the production of plastics and synthetic rubber is discussed. J. W. H.

Refining and Refinery Plant.

161.* Conversion of Gasoline Plants to Increase *iso*Butane Extraction. W. L. Rifenberick. *Petrol. Engr.*, 1942, **13** (10), 150.—Among possible methods suggested for

modifying gasoline plant operation to increase the extraction of isobutane and propane are :—

- (1) Increased oil circulation.
- (2) Reduced oil temperature.
- (3) Increased absorption pressure.

(1) is an inexpensive method for plants having excess capacity in absorbers, coolers, etc.

(2) can be accomplished in several ways—for example, by reducing the load on the cooling towers, or by some form of refrigeration. A flow-sheet of a " vacuum refrigeration " unit is shown. In the case of high-pressure absorption plant it is essential to cool the wet gas as well as the lean oil.

(3) is applicable in the case of a few low pressure plants.

These methods, or any others used, must be considered in relation to the rest of the plant, so that the overall effect is beneficial.

Methods of handling, after additional extraction has been made, are briefly described and simplified flow diagrams given. J. C.

162. Influence of Sulphur Compounds on Octane Number and Lead Susceptibility of Gasoline. J. G. Ryan. *Industr. Engng Chem.*, 1942, **34** (7), 824.—The effect has been studied of some eighteen different sulphur compounds, representing eight different types, on the octane number and lead response of a reformed gasoline. The effect of these compounds on the octane number varies with the size and structure of the hydrocarbon portion of the molecule as well as the sulphur type. These data have been correlated in the form of a general equation for sulphur types which enables the effect of desulphurization on the octane number and lead response to be estimated from the group sulphur analyses. J. W. H.

163. How Refiners Conserve Critical Materials. Anon. *Chem. Met. Eng.*, October 1942, **49** (10), 93–94.—The paper summarizes several booklets on " War-time Plant Design " issued by the Office of the Petroleum Co-ordinator for War, on the saving of strategic construction materials through substitution in petroleum refineries. The suggestions deal with steel plates, boilers, elimination of explosion-proof motors by using outdoor installation, substituting concrete or wood for steel and glass for metal windows, or one type of steel for another less easily procurable, etc. In building construction, permanent trolley systems for handling heavy equipment are being omitted and, instead, space is being provided for the access of crawler planes or for temporary rigging. Some convenience platforms are being eliminated and others reduced in size. Reinforced concrete and wood are being employed wherever practicable instead of steel. For example, wood is being used as far as possible for stringers and treads of stairways, for ladders, railings, platform floorings, and some framing. Massive concrete without reinforcement is being used where possible as in foundations and slabs on the ground, or with minimum reinforcement. As far as possible, buildings are being constructed with brick walls, with wood-roof beams or trusses, with plank roofs and built-up roofing. Wood is being used for door-frames, doors, and sashes. An interesting idea for two-storey structures is to use reinforced concrete for the lower storey and heavy timber-mill construction for the upper storey.

A variety of other metal-saving suggestions has also been incorporated in the specifications, including the use of cement-asbestos sheet material instead of galvanized and coated iron, the elimination of galvanized nails, and metal lath, and the use of coated ferrous materials so far as possible without galvanizing for screening, flashing, and for down-spouts. Terra-cotta and concrete are being substituted whenever possible for metal pipes for sewer lines, and non-metallic coated materials for conduits. Instead of conduits, non-metallic sheathed cables are being employed where practicable, together with electric-light fixtures eliminating as much metal as possible. Cast iron, rather than copper, is being used for heating coils and convectors for enclosed areas.

The use of enamelled bubble caps instead of cast iron caps is advocated. Instead of large stress relieving furnaces being used, it is suggested that equipment should be stress-relieved by the manufacturer in small components and shipped ready for erection. Change in designs is suggested. A. H. N.

164. Electronic Liquid Level Indicator. S. C. Coroniti. *Rev. Sci. Instrum.*, 1942, **13** (11), 484.—Data for the design of, and a description of a liquid level indicator are given. This instrument is suitable for use with conducting and non-conducting liquids. The principle on which this piece of apparatus depends is the variation of capacitance caused by the liquid which detunes a resonance circuit resulting in a change of plate current in an oscillator tube.
J. W. H.

165. Patents on Refining and Refinery Plant. H. E. Drennan. U.S.P. 2,300,877, 3.11.42. Appl. 12.8.40. A hydrocarbon fraction containing mercaptan sulphur and colour- and gum-forming constituents is rendered sweet by desulphurizing it by contact with a metal oxide capable of reacting with the mercaptan sulphur to form the corresponding sulphide. The reaction is carried out at a temperature between 500° and 850° F., and afterwards the hot effluent is mixed with hydrogen and the mixture is passed over a hydrogen sulphide-poisonable hydrogenation catalyst to hydrogenate the unstable constituents, which are responsible for colour- and gum-instability.

B. T. Brooks and F. W. Schumacher. U.S.P. 2,301,246, 10.11.42. Appl. 24.8.40. Waxy constituents are removed from a feed-oil by mixing with it a quantity of an olefin oxide having four to six carbon atoms in the molecule. The mixture is chilled to a temperature at which the waxy constituents precipitate. These are removed from the dewaxed oil, and so is the olefin oxide.

J. B. Maxwell and K. E. Thorp. U.S.P. 2,301,304, 10.11.42. Appl. 30.11.40. Process for the removal of hydrocarbon constituents having three and less carbon atoms in the molecule from petroleum feed-oils boiling below 250° F. The feed-oil is introduced in liquid state into the top of a stabilization zone and passed down through the zone under conditions in which the temperature increases in the direction of flow of the feed-oil. Reflux is provided in the stabilization zone by withdrawing at least one intermediate stream, cooling it, and returning it to the stabilization zone. Hydrocarbon constituents containing three or less carbon atoms in the molecule are removed overhead, and heat is provided to the stabilization zone by withdrawing a bottoms stream, heating it and returning it.

S. C. Carney. U.S.P. 2,301,520, 10.11.42. Appl. 11.6.40. High-pressure well distillates are contacted with a desorbing vapour to remove essentially only methane and retain the other volatile materials heavier than methane. The liquid effluent from the desorption zone is fractionated to obtain a stabilized well distillate and a vaporious overhead. The latter is fractionated to obtain natural gasoline and a second vaporious overhead. The second vaporious overhead is cooled to obtain as a condensate a polymerization feed stock. Unpolymerized vapour is passed back to the methane desorption zone as a desorbing vapour.

W. A. Schulze and G. H. Short. U.S.P. 2,301,588, 10.11.42. Appl. 31.8.40. Carbonyl sulphide can be removed from hydrocarbon fluids subsequent to treatment for removal of hydrogen sulphide and mercaptans by contacting them with a reagent consisting of an adsorbent carrier impregnated with a solution of a lead salt and monoethanolamine.

P. Washburn. U.S.P. 2,301,595, 10.11.42. Appl. 2.9.39. Bitumens and/or crude petroleum are treated in such a way that all the raw material is converted into a mist. The diffusing moisture in the form of mist is combined with the petroleum mist, and all the mist particles are afterwards frozen. The frozen particles are broken up and subsequently subjected to melting temperatures.

W. A. Proell and R. S. McClaughry. U.S.P. 2,301,794, 10.11.42. Appl. 6.3.40. The stability to oxidation of a viscous petroleum oil is increased by treating the oil with a gas containing free oxygen. The oxidized oil is neutralized by treatment with an alkali metal hydroxide, and afterwards chemically reduced by treatment with at least one reducing agent.

R. E. Burk and E. C. Hughes. U.S.P. 2,301,802, 10.11.42. Appl. 9.9.39. Hydrocarbons are desulphurized by contacting them without the addition of free hydrogen with a 20 : 80 mol. % gel precipitated chromium and aluminium oxide catalyst at a temperature of about 575° F.

R. K. Stratford and G. W. Gurd. U.S.P. 2,302,383, 17.11.42. Appl. 7.12.38. Separation of a hydrocarbon fraction of the class of naphtha, kerosene, and light gas oil into its relatively more paraffinic and relatively more aromatic constituents. The hydrocarbon fraction is extracted with a solvent consisting essentially of a substance selected from the class of dihydric alcohols characterized by having at least two ether groups.

E. M. Dons and O. G. Mauro. U.S.P. 2,302,430, 17.11.42. Appl. 2.1.42. Continuous process for dewaxing oil and selectively de-oiling the wax. The wax is first precipitated in a liquid solution of the oil and a selective dewaxing solvent in a precipitating zone. In this way clusters of coalesced wax crystals are formed with portions of the oil solution trapped in the wax. A stream of the liquid solution and wax is passed into a settling zone, thus causing the wax to separate from free portions of the liquid oil solution, while allowing the wax to coalesce and trap portions of the oil solution. A stream of dewaxed oil solution is discharged from the settling zone and passed to a countercurrent de-oiling zone, through which is transmitted a continuous stream of selective de-oiling solvent. In this way the counterflowing de-oiling solution is caused to remove and dissolve portions of the solution carried by the wax. Afterwards the wax is discharged from the stream of selective de-oiling solvent and the coalesced wax subjected to forcible disintegrating operations while it is in transit from the precipitating zone to the de-oiling zone to liberate trapped oil solution. H. B. M.

Fire Prevention.

166. Guarding against the Flammable Liquid Fire Hazard. G. L. Griffin. *Industr. Engng Chem.*, 1942, **34** (6), 664.—The use of CO₂ in the suppression of fires depends on the rapid reduction of the O₂ content of the air from 21 to 14%. Descriptions are given of typical installations employing CO₂ for fire-fighting, including the use of automatic equipment. J. W. H.

Chemistry and Physics of Hydrocarbons.

167. Photochemistry of *iso*Butane. I. W. F. Keffer and J. P. Howe. *J. Amer. Chem. Soc.*, 1942, **64**, 1-7.—This work is an attempt to determine the mechanism of the gas-phase photochemical polymerization of *isobutane*, while observing generally the direct action of light on the molecule. Approximately monochromatic radiation from the aluminium spark was used, and both decomposition and polymerization occurred. From the analyses of the products, quantum yields were calculated. The effects of light intensity and the presence of nitrogen or oxygen are also reported. Absence of methyl-acetylene showed that the reaction was not analogous to the effect of light on ethylene.

From their results the authors discuss the mechanism of the reaction. A free radical mechanism is required for some of the processes, and, in addition, is capable of accounting for all the observed processes. E. H. W.

168. Alkylation of Paraffins at Low Temperatures in the Presence of Aluminium Chloride. H. Pines, A. V. Grosse, and V. N. Ipatieff. *J. Amer. chem. Soc.*, 1942, **64**, 33-36.—A description is given of the reactions between *isobutane* and (a) *n*-butene, (b) propene at low temperatures.

Reaction (a) was carried out at -35° C. and 1 atm. pressure, the liquid products contained more than 60% octanes and 12% dodecanes. In the octane fraction, 2:2:4-, 2:2:3-, and 2:3:4-trimethylpentane, together with 2:5-dimethylhexane, were identified.

In reaction (b), carried out at -30° C. and 1 atm. pressure, 42% of heptanes and 20% of decanes were produced. The heptane fraction consisted mainly of 2:3-dimethylpentane, together with 2:4-dimethylpentane.

The reaction products in these experiments were identified by their Raman spectra. E. H. W.

169. Structure and Absorption Spectra. III. Normal Conjugated Dienes. R. B. Woodward. *J. Amer. chem. Soc.*, 1942, **64**, 72-75.—The band maxima in the absorp-

tion spectra of normal conjugated dienes are calculated by these authors with the use of simple substitutive and positional shifts. Examples are given of these generalizations and analogies between the diene chromophore and α - β -unsaturated ketone chromophore are pointed out. E. H. W.

170. Structure of Vinyl Polymers. XII. The Polymer of Methyl Isopropenyl Ketone. C. S. Marvel, E. H. Riddle and J. O. Corner. *J. Amer. chem. Soc.*, 1942, **64**, 92-94.—The structure of the polymer of methyl isopropenyl ketone is shown to be of the "head-to-tail" type. E. H. W.

171. Solubility of Carcenogenic and Related Hydrocarbons in Water. W. W. Davis, M. E. Krahle, and G. H. A. Clowes. *J. Amer. chem. Soc.*, 1942, **64**, 108-110.—The approximate solubility in water at 27° C. for thirty-one hydrocarbons has been determined by the nephelometric method (Davis and Parker, *J. Amer. chem. Soc.*, 1942, **64**, 101-107). Thirteen of the hydrocarbons are carcenogenic, two of doubtful activity, fourteen non-carcenogenic (two of the hydrocarbons not being classified). E. H. W.

172. Statistics of Intramolecular Aldol Condensations in Unsaturated Ketone Polymers. Note by P. J. Flory. *J. Amer. chem. Soc.*, 1942, **64**, 177-179.—The author gives a correction to a previous paper (*J. Amer. chem. Soc.*, 1939, **61**, 1518), when he erroneously included as an example the intramolecular aldol condensation of the polymer of methyl vinyl ketone. He now gives a revised statistical treatment for this case. E. H. W.

173. Some Heat Capacity Data for Gaseous 2 : 2 : 4-Trimethylpentane. Note by M. Kiperash and G. S. Parks. *J. Amer. chem. Soc.*, 1942, **64**, 179.—Five determinations of the heat capacity of gaseous 2 : 2 : 4-trimethylpentane are reported and compared with a value given by Pitzer (*J. Amer. chem. Soc.*, 1940, **62**, 1224). Calculated results using Pitzer's empirical equation, and two series of C_p° values for the gas at zero pressure are also given. E. H. W.

174. Kinetics of Hydrogen Consumption, Oxygen Elimination, and Liquefaction in Coal Hydrogenation. Nature of the Catalytic Reactions. H. H. Storch, C. O. Hawk, and W. E. O'Neill. *J. Amer. chem. Soc.*, 1942, **64**, 230-236.—The paper reports on a series of experiments carried out on a bituminous coal at various temperatures and contact times in the presence and absence of a catalyst. The results are tabulated and there is a discussion on their interpretation. Oxygen elimination and liquefaction in the presence of tetrahydronaphthalene were shown to be non-catalytic, but hydrogen absorption increased with increasing amounts of catalyst. It was also shown that the nature of the rate-determining step varied with the temperature. E. H. W.

175. Intramolecular Condensations in Polymers. F. T. Wall. *J. Amer. chem. Soc.*, 1942, **64**, 269-273.—The amount of oxygen remaining in a polymer after condensation on heating has been calculated statistically. The cases considered are infinitely long "head-to-tail," random, and "head-to-head-tail-to-tail" polymers. The results for pure polymers are then extended to co-polymers. E. H. W.

176. Viscosities of Solutions of Polyvinyl Chloride. D. J. Mead and R. M. Fuoss. *J. Amer. chem. Soc.*, 1942, **64**, 277-282.—In this study, vinyl chloride polymers prepared in different ways were used, and results are given on both fractionated and unfractionated samples, dissolved in various solvents. The absolute viscosity of the solutions decreased with increasing pressure and this effect was eliminated by extrapolating to zero pressure, or more quickly by the use of an empirical correction formula.

In general, the viscosities of solvents and solutions remained essentially constant with time, but the use of cyclohexanone is recommended for these polymers.

The equivalent viscosity (λ) is a linear function of concentration, and with the solvents used it varied only slightly. With either increasing time or temperature λ showed only small increases.

An empirical formula is derived which permits determination of the limiting equivalent viscosity (λ_0) for zero concentrations from a single viscosity measurement.

From determinations of the sedimentation and diffusion constants of a given sample of polymer, the authors calculate an absolute molecular weight, and hence derive a preliminary value for the Staudinger constant for polyvinyl polymers. E. H. W.

177. The Effect of Structure on Reactivity: Nuclear Substitution of Benzene Derivatives. H. F. McDuffie, Jr., and G. Dougherty. *J. Amer. chem. Soc.*, 1942, **64**, 297-299.—To obtain further information on the effect of structure on the rates of nuclear substitution, the Friedel-Crafts reaction of acetyl chloride with benzene derivatives in the presence of anhydrous aluminium chloride has been used. By this means the relative reactivities of various mono-, di-, and tri-substituted benzene derivatives have been obtained. With mono-substituted benzene derivatives the results obtained correlate well with the available results for nitration, the substituent constants presented by Hammett, and the rates calculated from the dipole moments of the mono-substituted benzenes.

E. H. W.

178. Carboxylation. I. The Photochemical and Peroxide-catalysed Reactions of Oxalyl Chloride with Paraffin Hydrocarbons. M. S. Kharash and H. C. Brown. *J. Amer. chem. Soc.*, 1942, **64**, 329-333.—In the presence of light, oxalyl chloride was found to react with paraffin hydrocarbons forming acid chlorides; thus there is a direct substitution of hydrogen by the $-\text{COCl}$ group. The following hydrocarbons underwent this photolysis: cyclohexane, methylcyclohexane, chlorocyclohexane, methylcyclopentane, *n*-pentane, *n*-heptane, and *iso*-octane. Organic peroxides catalyse a similar dark reaction between paraffin hydrocarbons and oxalyl chloride. The authors postulate a chain mechanism for the reaction, and this is supported by the failure to detect keto-acid chlorides from the action of oxalyl chloride on pyruvic acid, benzoyl formic acid, and benzoyl peroxide.

E. H. W.

179. Carboxylation. II. The Reactions of Oxalyl Chloride with Unsaturated Hydrocarbons. M. S. Kharash, S. S. Kane, and H. C. Brown. *J. Amer. chem. Soc.*, 1942, **64**, 333-334.—This work continues that reported in the preceding abstract. Neither light nor peroxides had any apparent effect on the action of oxalyl chloride with unsaturated compounds. Gentle refluxing of the mixture was sufficient to bring about a reaction with certain olefinic derivatives.

With 1:1-diphenylethylene, styrene, α -methylstyrene, and 1-methylcyclohexane, the chloroformyl group replaced a hydrogen atom attached to one of the doubly-bonded carbon atoms. Phenyl acetylene, the only member of the acetylene series tested, reacted somewhat differently. Under the given conditions, cyclohexane, stilbene, trimethylethylene, cetene-1, octene-1, and 1:2-dichloroethylene did not react with oxalyl chloride. The factors influencing the rate of the reactions and the yields were taken as an indication of a polar mechanism for the reactions.

E. H. W.

180. The Partial Reduction of Acetylenes to Olefins using an Iron Catalyst. II. Enyne and Dienyne Reduction. A. F. Thompson, Jr., and E. N. Shaw. *J. Amer. chem. Soc.*, 1942, **64**, 363-366.—Continuing work on Paul and Hilly's iron hydrogenation catalyst, it is now stated that it is not completely specific for the carbon-carbon triple bond, but that, from the evidence available, there is a marked decrease in the rate of reduction of the olefin as compared with the acetylene.

The hydrogenation of acetylenes $\text{RC} \equiv \text{CH}$ and $\text{RC} \equiv \text{CR}$, enynes $\text{RC} \equiv \text{C}-\text{CR} = \text{CHR}$ and dienyne $\text{RCH} = \text{C(R)}-\text{C} \equiv \text{C(R)} = \text{CHR}$, using this catalyst, are reported. It is proposed to study the mechanism of the reduction of enyne and dienyne systems using this catalyst.

E. H. W.

181. Trans. 2:2:6-Trimethylcyclohexane Carboxylic Acid. A Second Solid Naphthenic Acid from Californian Petroleum. B. Shive, J. Horeczy, G. Wash, and H. L. Lochte. *J. Amer. chem. Soc.*, 1942, **64**, 385-391.—The isolation of a new acid $\text{C}_{16}\text{H}_{18}\text{O}_2$ from the unesterifiable naphthenic acids in Californian petroleum has been previously reported (*J. Amer. chem. Soc.*, 1939, **61**, 2448). The deduction of the structure of this acid as trans 2:2:6-trimethylcyclohexane carboxylic acid, together with a synthesis and preparation of derivatives, is now described.

This secondary acid, its methyl ester, and amide, behave as highly hindered com-

pounds; the Whitmore method for distinguishing types of aliphatic acids failed with this acid.
E. H. W.

182. Some Observations on the Oxidation and Determination of the Molecular Weight of Polynuclear Aromatic Compounds. W. P. Campbell, M. D. Soffer, and T. R. Steadman. *J. Amer. chem. Soc.*, 1942, **64**, 425-428.—The nitric acid oxidation of some aromatic hydrocarbons and derivatives is described. The titration of several hydrocarbon picrates is reported and the advantages of this method of analysis are pointed out.
E. H. W.

183. The Dielectric Behaviour, Supercooling and Vitrification of certain Chlorobutanes and Chloropentanes. A. Turkevich and C. P. Smyth. *J. Amer. chem. Soc.*, 1942, **64**, 737-745.—The measurements of the dielectric constants and specific conductances at frequencies of 50, 5, and 0.5 kilocycles on *i*-butyl chloride, *i*-amyl-chloride, *t*-amyl chloride, and 1:2-dichloroisobutane are reported. Examination was made visually and with the polarizing microscope down to liquid air temperatures, and also by temperature time curves. A detailed description of the low-temperature behaviour of each of the substances examined is given. 1:2-Dichloroisobutane showed only a very slight tendency to crystallize, an explanation being put forward to explain this. The tendencies for the compounds considered to crystallize or vitrify are compared with other hydrocarbons, and reasons are suggested for their behaviour.
E. H. W.

184. The Preparation and Isolation of 4-Methyl-1:3-Pentadiene. G. B. Bachman and C. B. Goebel. *J. Amer. chem. Soc.*, 1942, **64**, 787-790.—Dehydration of 4-methyl-2:4-pentanediol gives a mixture of 4-methyl- and 2-methyl-1:3-pentadienes, the latter predominating. Separation of the two had not been previously achieved by physical means. The isolation of the desired hydrocarbon in 23% yields is now described, being accomplished by choice of conditions of temperature, solvents, and catalyst. The boiling point, density, and refractive index of the diene have been carefully determined.
E. H. W.

185. A Synthesis of 4:10-Ace-1:2-Benzanthrazene Utilizing Δ^4 -Tetrahydrophthalic Anhydride. L. F. Fieser and F. C. Novello. *J. Amer. chem. Soc.*, 1942, **64**, 802-809.—The use of Δ^4 -tetrahydrophthalic anhydride for various syntheses is described. Carcinogenic derivatives of 1:2-benzanthrazene are considered, and in particular a synthesis of 4:10-ace-1:2-benzanthrazene is described.

The hydrocarbon obtained appeared to be somewhat purer by its higher melting point than two products from earlier preparations.

The previous samples had shown a high carcinogenic activity. The new preparation is being assayed.
E. H. W.

186. Conjugated Diolefins by Double Bond Displacement. A. L. Henne and A. Turk. *J. Amer. chem. Soc.*, 1942, **64**, 826-828.—In a preparation of dimethylallyl it was observed that 10% of the conjugated di-*isooctyl* was produced. Experiments were conducted to find the most favourable conditions for the production of the conjugated isomer. From the results, seven 1:5-dienes were passed through a long column of heated activated alumina. Conclusions reached were: (a) terminal positions of the double bond rearranged most easily; there is some difficulty when one of the double bonds is in the body of the molecule and the rearrangement is most difficult to accomplish when both of the double bonds are so "buried." (b) The presence in the 2-position of a side methyl radicle facilitates the shift. (c) The direction of shift with symmetrical carbon skeletons is towards the centre of the molecule. (d) The tendency to shift past a side methyl radicle predominates over the tendency to shift towards the centre of the molecule. (e) Lastly, some pyrolysis or shift of carbon structure was observed in all cases of hot alumina treatment.
E. H. W.

187. The Study of the Action of an Aluminium-Aluminium Chloride Catalyst in Friedel-Crafts Reactions. Benzoylation. O. Grummitt and E. N. Case. *J. Amer. chem. Soc.*, 1942, **64**, 878-880.—Hall and Nash (*J. Inst. Petrol.*, 1939, **23**, 679) found that the

presence of aluminium retarded the activity of an aluminium chloride catalyst in the polymerization of ethylene.

The benzoylation of benzene by benzoyl chloride to form benzophenone in the presence of an aluminium-aluminium chloride catalyst is described in this paper, as a beginning of a study of typical Friedel-Crafts reactions using this catalyst.

Some reduction reactions occurred, being caused by hydrogen from the action of the aluminium on the hydrogen chloride, the latter being produced in the benzoylation. Evidence is produced to support this suggested reaction, which the authors say may partly explain Hall and Nash's observation. E. H. W.

188. A Quantum Mechanical Investigation of the Orientation of Substituents in Aromatic Molecules. G. W. Wheland. *J. Amer. chem. Soc.*, 1942, **64**, 900-908.—A new treatment based on the molecular orbital method is given, which differs from previous ones which gave attention to the charge distributions on the isolated molecules. Substitutions by electrophilic, nucleophilic, and radical reagents are treated from a unified point of view.

The calculated effects are of the correct order of magnitude for both the rates of substitution and the values of resonance moments. E. H. W.

189. The Nitrogen Compounds in Petroleum Distillates. XXIII. The Structure of a $C_{16}H_{25}N$ base from California Petroleum. B. Shive, S. M. Roberts, R. I. Mahan, and J. R. Bailey. *J. Amer. chem. Soc.*, 1942, **64**, 909-912.—The structure of the $C_{16}H_{25}N$ base isolated from Californian Petroleum by Bailey and Thompson (*J. Amer. chem. Soc.*, 1931, **53**, 1002) has now been shown to be 2-(2:2:6-trimethylcyclohexyl)-4:6-dimethylpyridine. For the first time a structural correlation between a naphthenic acid and naphthene base from petroleum has been established. E. H. W.

190. Kinetics of Caseous Reactions by Means of the Mass Spectrometer. The Thermal Decomposition of Dimethyl Ether and Acetaldehyde. E. Leifer and H. C. Urey. *J. Amer. chem. Soc.*, 1942, **64**, 994-1001.—A new use for the mass spectrometer is given by which the course of kinetic reactions may be followed. Advantages claimed for the method are: direct identification and concentration measurements of all stable substances involved, including intermediates. An investigation by this method was made on the thermal decompositions of acetaldehyde and dimethyl ether; in the latter case ethane was detected and a chain mechanism suggested for the reaction. E. H. W.

191.* Physical Constants of Low Boiling-Point Hydrocarbons. R. Matteson and W. S. Hanna. *Oil Gas J.*, 12.5.42, **41** (2), 33.—A valuable compilation in compact, tabular form of the physical constants of the lower paraffins, olefines, aromatics, and miscellaneous compounds. Constants included are molecular weight, carbon-hydrogen ratio, melting point, boiling point, critical constants, liquid density, A.P.I. gravity and pounds per gallon, gas density, gas-law deviation factor, specific heat and ratio of specific heats, heats of combustion, vaporization and fusion, air required for combustion, inflammable limits, refractive index, aniline point, and octane number.

A bibliography is given of the literature from which the figures are quoted. J. C.

192.* Desulphurizing Properties of Zinc Hydroxide. K. A. Musatov and L. G. Krymova. *Oil Gas J.*, 21.5.42, **41** (2), 40.—Translated and edited from the original in the *Journal of Applied Chemistry, U.S.S.R.*, this article is of interest in view of the present necessity for obtaining the highest possible lead response in motor and aviation gasoline.

Zinc hydroxide was shown to be an effective reagent in removing sulphur from light distillates. Batch experiments were carried out by shaking the distillate with ground hydroxide and continuous experiments by passing the vapour through a glass tube packed with granular hydroxide and heated in an electric furnace. The temperature ranged from 20° to 500° C., and maximum desulphurization was obtained at 350° to 370° C.

It was shown that zinc hydroxide adsorbs resins, whilst its desulphurization activity decreases with increase of sulphur content in the original distillate. J. C.

193. The Solubility of Gases in Liquids. A. E. Markham and K. A. Kobe. *Chem. Rev.*, 1941 (3), 519.—An extensive review of the subject is given, which includes methods of measurement and solubility relationships in addition to extensive references to sources of solubility data for fifty-four different gases in various solvents, including many hydrocarbons. J. W. H.

194. Thermal Reaction of Ethylene with Acetylene. E. A. Naragon, R. E. Burk, and H. P. Lankelma. *Industr. Engng Chem.*, 1942, **34**, 355.—The synthesis of butadiene by the interaction of ethylene and acetylene at 610° C. at atmospheric pressure has been studied. It is concluded that, in addition to the direct combination which occurs to form butadiene, the side reactions involved are the dimerization of ethylene and acetylene to form primary products from which gaseous and liquid secondary products result. In these liquid products diolefins and aromatics are prominent. J. W. H.

195. Nomographs for Minimum Reflux Ratio and Theoretical Plates for Separation of Binary Mixtures. E. H. Smoker. *Industr. Engng Chem.*, 1942, **34**, 509.—The equations for the calculation of minimum reflux ratio and number of theoretical plates are frequently used in distillation problems, and the nomographs presented enable their immediate solution to be obtained. J. W. H.

196.* Interconversions of Binary Compositions by Simple Graphical Methods. K. H. Sun and A. Silverman. *Industr. Engng Chem.*, 1942, **34** (6), 682.—Graphical methods are given for the interconversion of mol. weight, and volume fractions for binary mixtures which enable the conversion to be made rapidly when these become routine operations. J. W. H.

197.* Molecular Refraction—Critical Temperature Nomograph. D. S. Davis. *Industr. Engng Chem.*, 1942, **34** (6), 689.—A nomograph is given which enables the critical temperature to be estimated from the molecular refraction. The chart given is applicable to hydrocarbons, acids, alcohols, esters, ethers, and nitriles. J. W. H.

198.* Liquid-liquid Extraction Data. D. F. Othmer and P. E. Tobias. *Industr. Engng Chem.*, 1942, **34** (6), 690.—Data are given for the systems toluene-*n*-heptane-acetic acid-water, and for ternary systems of acetaldehyde and water with the solvents benzene, toluene, furfural, and *n*-amyl alcohol. The data on the toluene systems are given with the object of extracting toluene from its associated paraffinic hydrocarbons. The application of the synthetic method for the determination of tie lines is discussed, and a graphical method is given for the application of the lever rule to these data. J. W. H.

199.* Tie Line Correlation. D. F. Othmer and P. E. Tobias. *Industr. Engng Chem.*, 1942, **34** (6), 693.—From theoretical considerations a general equation for the correlation of tie-line data has been derived which results in a straight line plot of $\log \log (1 - a_1)/a_1$ against $\log (1 - b_2)/b_2$, when *a* and *b* are the solvent composition of the solvent and diluent phases. Employing this method of plotting the data, a number of ternary systems have been correlated. J. W. H.

200.* Partial Pressures of Ternary Liquid Systems and the Prediction of Tie Lines. D. F. Othmer and P. E. Tobias. *Industr. Engng Chem.*, 1942, **34** (6), 696.—An equation is given relating the partial pressure of the solute in a ternary system to the composition. By the use of this equation the tie lines for a ternary system may be predicted from partial-pressure data of the two binary systems forming the ternary system. The value of the method is illustrated by comparison of the determined and calculated determined phase distribution data for the following third components in benzene-water systems: acetic acid, acetaldehyde, ethanol, and for the systems cyclohexane-ethanol-water and chloroform-acetone-water. J. W. H.

201.* Liquid-Liquid Extraction in a Perforated Plate Tower. R. E. Treybal and F. E. Dumoulin. *Industr. Engng Chem.*, 1942, **34** (6), 709.—A 3.56-diameter tower has been

operated for the extraction of benzoic acid from toluene by water, the toluene being in the disperse phase, with the object of examining the effect of plate spacing on extraction tower performance. Data has been obtained for 3, 6, and 9-inch plate spacings. The H.T.U. are shown to be almost identical for 6- and 9-inch spacing, but are halved for 3-inch spacing. The permissible throughput for a given extraction coefficient (lb. moles acid transferred/hr./cu. ft. per log mean conc. gradient) is almost identical for 6- and 9-inch spacings, but is halved for 3-inch spacing. It is therefore concluded that the most useful plate spacing is 6 inches.

J. W. H.

202.* Thermodynamic Properties of *n*-Pentane. B. H. Sage and W. N. Lacey. *Industr. Engng Chem.*, 1942, **34** (6), 731.—The specific volume of *n*-pentane has been determined over the temperature range 100–460° F. and at pressures up to 10,000 lb. sq. in. The vapour pressure was also determined over this temperature range and the enthalpy–pressure coefficients, isothermal enthalpy changes, and fugacity calculated. The results are presented in graphical and tabular form.

J. W. H.

203.* Isolation of Sulphur Compounds from California Straight-Run Gasoline. O. L. Polly, A. C. Byrns, and W. E. Bradley. *Industr. Engng Chem.*, 1942, **34** (6), 755.—The distribution of sulphur with boiling point is given for a sample of Californian gasoline, and it is shown that each of the regions of high sulphur content corresponds to the boiling point of a thiophane. These thiophanes have been isolated by extraction with aluminium chloride and resolved with mercuric chloride.

J. W. H.

204.* Molecular Volume Nomograph for Liquid Alkanes. D. S. Davis. *Industr. Engng Chem.*, 1942, **34**, 797.—A nomograph is given which enables the reduced temperature and molecular volume to be read off directly over the temperature range –170° to +70° C. for the alkanes from ethane to octane with an accuracy of 0.4%.

J. W. H.

205.* Hydrocarbon–Water Solubilities at Elevated Temperatures and Pressures. J. Griswold and J. E. Kasch. *Industr. Engng Chem.*, 1942, **34** (7), 804.—The solubility of water in three petroleum fractions has been determined up to 280° C. and 940 lb. sq. in. At this temperature and pressure the water solubility has a value of 45 mol%. The solubility is independent of the molecular weight for straight-run fractions, but aromatic hydrocarbons show a higher solubility. Similar data from the literature is given for the solubility of hydrocarbons in water, and this solubility is shown to be a function of molecular weight and hydrocarbon type.

J. W. H.

206.* Pressure Drop in the Flow of Compressible Fluids. W. E. Lobo, L. Friend, and G. T. Skaperdas. *Industr. Engng Chem.*, 1942, **34** (7), 821.—Considerable error can arise in the calculation of the pressure drop for compressible fluids if the kinetic energy term of the Bernoulli equation is neglected. A chart is presented which enables the pressure drop to be corrected for kinetic energy change. An example is given in which it is shown that the pressure drop may be in error to as much as 25% if the kinetic energy term is neglected.

J. W. H.

207.* Rapid Solution of Multicomponent Distillation Problems. G. Karnofsky. *Industr. Engng Chem.*, 1942, **34** (7), 839.—The method proposed by Hibsham (*ibid.*, **32**, 988) for estimating the number of theoretical plates required for a given separation has been modified so as to dispense with the construction of a transparent Cox's vapour-pressure chart. This chart is replaced by a vapour-pressure nomogram which is used in conjunction with the operating line data to determine the plate-to-plate composition by a simple graphical construction.

J. W. H.

208.* Critical States of Two-Component Paraffin Systems. F. D. Mayfield. *Industr. Engng Chem.*, 1942, **34** (6), 843.—Empirical correlations are given between the composition and the critical temperature and the critical pressure for two-component paraffin systems, and it is shown that the results can be calculated to within 13 lb. sq. in. and 6.4° F. for eight of the systems for which published data are available. The

critical temperature is directly proportional to the weight per cent. composition. The critical pressure does not follow any such simple rule, but a chart is given which enables the deviation from an additive rule to be estimated from the calculated value of the critical temperature.
J. W. H.

209.* Specific Dispersion of Pure Hydrocarbons. R. E. Thorpe and R. G. Larsen. *Industr. Engng Chem.*, 1942, **34** (7), 853.—The specific dispersions are given for some 250 different hydrocarbons comprising conjugated and non-conjugated olefins, alkyl aromatic, complex benzene hydrocarbons and aromatic-naphthenic complexes. From an analysis of these data it is shown that it is possible to calculate the specific dispersion from the molecular structure to an accuracy of five units in 75% of the examples given.
J. W. H.

210.* Graphical Methods for Interconversion of Ternary Compositions. K. H. Sun and A. Silverman. *Industr. Engng Chem.*, 1942, **34** (7), 872.—Graphical methods are given for the interconversion of mol. weight, and volume fractions for ternary mixtures, which enable the conversion to be made rapidly when these become routine operations.
J. W. H.

211. Joule-Thomson Coefficients in the Methane-Propane System. R. A. Budenholzer, D. F. Botkin, B. H. Sage, and W. N. Lacey. *Industr. Engng Chem.*, 1942, **34** (7), 878.—Determinations of the Joule-Thomson coefficients have been made at pressures up to 1500 lb. sq. in. and over the temperature range 70–310° F. for three mixtures of methane and propane. From these experimental data the isothermal enthalpy-pressure coefficients have been calculated and the partial enthalpy of the individual hydrocarbons in the mixture has been established.
J. W. H.

212. P-V-T-x Relations of the System Propane-Isopentane. W. E. Vaughn and F. C. Collins. *Industr. Engng Chem.*, 1942, **34** (7), 885.—Experimental data are given for the P-V-T-x relations of five mixtures of propane and isopentane over the temperature range 0–300° C. and in the pressure range 2–80 atmospheres. These data include the two-phase and critical regions. From these data the liquid vapour equilibrium constants have been calculated, and their relationship with pressure is shown graphically.
J. W. H.

213. *Mixed Solvent Extraction. T. G. Hunter. *Industr. Engng Chem.*, 1942, **34** (8), 963.—The minimum number of experiments required to establish the phase equilibrium relationship for a ternary system is shown to be three, and ten for a quaternary system containing one pair of partly miscible components. The tetrahedron method of plotting the results of a quaternary system are discussed, and it is shown that the orthogonal projection of the tetrahedron is the most convenient manner of illustrating the results. The geometrical construction of this orthogonal projection is given, and an actual example worked out and shown in detail.
J. W. H.

214.* Viscosity of Propane, Butane, and isoButane. M. R. Lipkin, J. A. Davison, and S. S. Kurtz. *Industr. Engng Chem.*, 1942, **34** (8), 976.—The viscosities of propane, n-butane, and isobutane have been determined over the temperature range –75° to +40° C. These data extend considerably the range over which viscosity data are known. Within the ranges of previous determinations excellent agreement is shown with the results of other workers. A linear plot is obtained for the normal paraffins when the viscosity at 25° C. is plotted against the number of carbon atoms.
J. W. H.

215.* Methane-Isobutane System. R. H. Olds, B. H. Sage, and W. N. Lacey. *Industr. Engng Chem.*, 1942, **34** (8), 1008.—The phase behaviour of the system methane-isobutane has been examined over the temperature range 100–460° F. and up to a pressure of 5000 lb./sq. in. Experimental determinations of the specific volume and dew-point have been made and the compressibility and equilibrium constants calculated.
J. W. H.

216. Concentration Change. G. H. Horne. *Industr. Engng Chem.*, 1942, **34** (9), 1042.—A graphical solution relationship is given showing the number of times a system must be flushed to ensure any desired purity of exit product. Perfect mixing is assumed, and any tendency to deviate from this assumption in actual practice will result in a smaller number of flushes being required. J. W. H.

217.* Correlating Vapor Pressure and Latent Heat Data. D. F. Othmer. *Industr. Engng Chem.*, 1942, **34** (9), 1072.—It is shown that $\log P_R / \log P'_R = L_R / L'_R$, in which P_R is the reduced pressure and L_R the reduced latent heat (latent heat/critical temperature). By the use of this equation the latent heat of any substance may be estimated by comparison with some standard substance such as water. This relationship has the greatest accuracy in the critical region. Nomograms are given which enable the reduced temperature and pressure to be estimated, and the ratio of the values to those of water to be determined readily. J. W. H.

218.* Binary Mixtures for Testing Fractionating Columns at Atmospheric and Reduced Pressures. L. B. Bragg and A. R. Richards. *Industr. Engng Chem.*, 1942, **34** (9), 1088.—From the determination of the efficiency of Stedman packing under vacuum conditions, the relative volatility and composition of the binary mixture benzene-ethylene dichloride have been determined at 100, 200, 400, and 760 mm. pressure.

The data demonstrate that this mixture is not ideal, and that at 760 mm., on comparison with other workers, a considerable divergence of results is shown.

Data are also given for the relative volatility and composition for the binary mixture o-dichlorobenzene and diethylbenzene at pressures of 10 and 50 mm. J. W. H.

219.* Phase Equilibria in the System Methane-*n*-Pentane. B. H. Sage, H. H. Reamer, R. H. Olds, and W. N. Lacey. *Industr. Engng Chem.*, 1942, **34** (9), 1108.—The specific volume of six mixtures of methane and *n*-pentane have been determined over the temperature range 110–460° F. and at pressures up to 5000 p.s.i. At a number of temperatures the bubble-point and dew-point pressures have been determined and the composition of the dew-point gas established. From these data the enthalpy and fugacity pressure and temperature relationships have been calculated. J. W. H.

220.* Simplified Calculation of Theoretical Plates. G. W. Thomson and H. A. Beatty. *Industr. Engng Chem.*, 1942, **34** (9), 1124.—Based on the assumptions that the operating lines and equilibrium curve are linear near the ends of an *x-y* diagram, equations are derived for the calculation of the number of theoretical plates required for the separation of a binary mixture containing less than 5 mol. % of one component. The results calculated by this method do not differ appreciably from the values calculated from the more complex Smoker equation. The use of the method is illustrated by examples. J. W. H.

221.* Heat Balance Equations for Multiple-Effect Evaporators. M. G. Larian. *Chem. Met. Eng.*, October 1942, **49** (10), 90–91.—In multiple-effect evaporator design calculations, the most important quantity to be calculated is the heat-transfer area. The heat-transfer area is calculated by the simultaneous solution of three equations: (1) The heat-balance equation, (2) the heat-transfer rate equation, and (3) the capacity equation. The heat-balance equation to be used depends on the method of feeding the evaporator, and on the temperature of the dilute feed. There are four different methods of feeding, and the dilute feed may enter the evaporator at a temperature which may or may not require preheating in the effect which it enters. In the latter case the feed may or may not flash. There are therefore several combinations of conditions possible. These are discussed.

Evaporators may be fed in the direction of decreasing pressure drop, with the new feed entering the first effect and passing thence to the second, third, and later effects, if any. This is known as forward feeding. Or the feed may first enter the last effect, in which the pressure is lowest, and flow forward through each earlier effect to the first, which is known as backward feeding. Mixed feeding is the procedure where the new feed enters some other effect than the first or last. There are various methods of mixed feed, depending on the requirements, a common method in the case of a

quadruple-effect evaporator being to introduce the new feed in the second effect, from which it flows in turn to the third, fourth, and finally to the first.

The equations for all four methods are given and two cases are discussed in detail.

A. H. N.

222.* Recent Advances of Catalysis in Chemical Process Industries. N. W. Krase. *Chem. Met. Eng.*, October 1942, **49** (10), 104.—A large portion of this paper is cut out by the censor, and thus no adequate abstract is possible. The remaining portions deal with fluid catalysts, catalysts in hydroforming, the production of toluol and aviation fuels by catalytic processes, and a little on catalytic isomerization. The treatment is a brief review of plants, giving, where possible, pertinent data and general figures on capacity.

A. H. N.

223. Patent on Chemistry and Physics of Hydrocarbons. C. F. Bonnet. U.S.P. 2,301,609, 10.11.42. Appl. 30.1.41. Petroleum emulsions of the water-in-oil type are broken by subjecting them to the action of a demulsifying agent containing an acidic nitro-aromatic compound selected from the group consisting of nitrophenols and acidic nitro-aromatic carboxylic acids.

H. B. M.

Motor Fuels.

224. The Use of Substitute Motor Fuels on the Continent. W. Landsberg. *Engineering*, 1942, **153** (3969), 114–115.—The substitute fuels available may be classified under the following groups: producer gas, highly compressed gases, and liquefied gases.

Despite the technical deficiencies of the producer-gas system, the ample availability and variety of relatively cheap fuels have resulted in its becoming the most popular substitute. In Germany in particular efforts in this direction have been most strenuous, some 150,000 units being in service in 1941, with a large expansion programme in view. In Italy, methane has been used extensively, but it appears that natural-gas supplies are already falling short of requirements.

One of the biggest problems of the producer-gas system is the protection of the generator and engine from corrosion. Standardization of plant has been impossible on account of the varying qualities of fuel available in the countries under Nazi control.

In spite of the efforts made, the author considers that the saving in liquid fuel is only of the order of 5–10% of the civilian demand of Hitler's Europe.

J. G. W.

225. Patents on Motor Fuels. E. A. Ocon. U.S.P. 2,300,691, 3.11.42. Appl. 17.4.39. In the production of a high anti-knock motor fuel a crude petroleum is fractionated and distilled to form a naphtha distillate fraction, a higher-boiling cracking stock distillate, and a residue. The residue is partly vaporized, and the vapours are passed through an adsorbent contact mass and partly condensed. The condensate obtained in this manner is mixed with the distillates of the crude petroleum, and the cracking stock distillate is cracked. The naphtha distillate is reformed and partly oxidized to produce oxygen-containing aliphatic compounds boiling within the gasoline range. The partly oxidized reformed naphtha is cooled and then reacted with a reducing gas containing principally hydrogen and carbon in the presence of a basic dehydrating metal oxide catalyst. The gasoline boiling-range products are finally combined with gasoline products from the cracking process.

J. L. Huggett. U.S.P. 2,301,281, 10.11.42. Appl. 16.1.40. Production of high-quality motor fuels of increased stability from petroleum oil fractions boiling below 420° F. The petroleum oil fractions have a relatively low sulphur content, and are of such a character that they would not be subjected to treatment with sulphuric acid for the reduction of sulphur. Initially the petroleum oil is separated into a relatively high-boiling fraction and a relatively low-boiling fraction. The former fraction is treated with sodium carbonate solution, and the latter is treated with a stronger solution of sodium hydroxide. The oils are separated from the respective treating agents and blended to produce high-quality motor fuel.

F. E. Frey. U.S.P. 2,301,391, 10.11.42. Appl. 24.3.36. Method of converting a normally gaseous hydrocarbon mixture containing both saturated and unsaturated

hydrocarbons into normally liquid hydrocarbons of the gasoline boiling range. The original mixture is subjected in a first zone to conditions of pressure and temperature adequate to convert a substantial portion of the unsaturated hydrocarbons to normally liquid products. From the effluent from this zone are separated a fraction boiling within the gasoline range and a fraction boiling above this range. These two fractions are subjected in a second zone to a higher temperature than that obtaining in the first zone. Conditions are so adjusted that a substantial portion of aromatic products boiling within the gasoline range is produced. Finally the normally liquid hydrocarbons are separated from the effluent from the second zone.

E. C. Koch. U.S.P. 2,301,548, 10.11.42. Appl. 5.2.40. A process of conversion of hydrocarbons into motor fuels which involves absorbing gases, predominantly ethane, in the oil to be cracked to produce a mixture which can be separated into the following four fractions: (1) a mixture of hydrogen and hydrocarbons having 1-4 carbon atoms per molecule; (2) hydrocarbons within the gasoline boiling range; (3) a recycle stock within the gas-oil boiling range, and (4) tar. Fraction (3) is returned to the cracking zone; (2) is withdrawn; (1) is cooled and compressed to liquefy some of the C_3 and C_4 hydrocarbons. The C_3 and C_4 hydrocarbons are heated to convert them to olefins, and these are introduced into the converted oil. A C_2 - C_3 fraction is at least partly separated from (1) by absorption in gas-oil. A gas, predominantly hydrogen and methane, is bled from the process, and finally the C_2 - C_3 gas-enriched gas-oil is passed to the cracking zone.

R. M. Melaven and R. V. Shankland. U.S.P. 2,301,734, 10.11.42. Appl. 30.12.38. Heavy hydrocarbon oils are converted into gasoline by subjecting them at a temperature between 700° and 1050° F. to the action of a catalyst consisting essentially of a silica gel treated with a cerium compound in an acid solution. H. B. M.

Gas, Diesel, and Fuel Oils.

226. Rotary Oil Burners for Low Pressure Steam Boilers. W. E. Bruce. *Industr. Pwr and Fuel Econ.*, May 1942, 40-41.—It is reported that rotary burners were first employed in the Western States of America. Initially it was deemed possible to operate these only with a light grade oil of low flash point and viscosity which did not require preheating. Subsequently it was found that the high latent heat of low-pressure steam enabled oil temperatures of 100° F. to be maintained in ordinary heaters, and that in these circumstances good atomization and combustion were achieved with the heaviest grade of oil. In other words, the rotary burner could burn the same class of fuel as the standard type, though it suffered from serious disadvantages where high pressures were concerned.

Every rotary burner required an electric motor, the failure of which put it out of action until a spare could be installed. They had to be made in different sizes for varying capacities and with one-, two-, and three-phase and D.C. motors to suit electric current supply. This made the system expensive.

Advantages of the rotary burner were that extensive variation of fire at each individual burner was possible with no tip to change or clean; better air distribution; and simpler operation.

In the early days of the burner, oil was not graded as it is now. Heavy fuel oil was usually specified at 15 Beaumé, but in actual fact it was frequently 12, 10, or even 8. Difficulties of burning the heavy type of Bunker fuel oil remained great, and operation of the rotary burner with the lighter types of oil, which did not require preheating, proved most satisfactory. To-day, however, it is claimed that the rotary burner remains a simple, efficient medium for burning any kind of oil without the elaborate installation and skilled attention necessary with the high-pressure type. H. B. M.

227. Engine Efficiency Research Equipment. *Industr. Pwr and Production*, July 1942, 72-75.—The Research Department of the National Gas and Oil Engine Co., Ltd., reports that the war has greatly curtailed the work of the Department. It is maintained, however, that vast quantities of fuel oil can be saved each year as a direct result of carefully organized research.

For powers over 20 h.p. the company employs for testing purposes Heenan and

Fronde hydraulic dynamo-meters, in which the output is measured by the torque reaction of a swirling mass of water set in motion by an impeller driven by the engine.

Special measuring devices are employed to test fuel-oil consumption of all experimental engines. By means of these the engineer can obtain results with a tolerance of only 0.26%, or about 0.001 lb. per b.h.p. hour. For larger engines a refined direct weighing method is employed.

Measurement of exhaust temperature is made by an "Elliott" multi-point pyrometer, great care being taken to see that the sheaths of thermo-couples project the same depth into the exhaust pipe of all engines. Only in this way can true comparisons be made.

Other apparatus employed by the company includes a "Sigma" calorific value indicator for measuring the gross value of gas corrected for atmospheric pressure and temperature; a Kent orifice and curved tube manometer by means of which rates of flow from 30 to 30,000 cu. ft. per hour can be measured; a Junkers gas calorimeter for checking the "Sigma" indicator and two gas analysis apparatus, one of which can be used for the analysis of coal or Mond gas. For engine indicating either the cathode-ray oscillograph with camera attachment or the Farnborough electric indicator is used.

H. B. M.

228.* Performance Characteristics and Specifications of Diesel Fuel Oils. W. L. Nelson. *Oil Gas J.*, 17.9.42, **41** (19), 47.—Fuels for use in diesel engines powering trucks, tractors, and tanks are becoming of increasing importance. Specifications for such fuels are becoming standardized, and tables presented show: (1) typical specifications and average properties of some diesel fuels, (2) cetane number, diesel index, pour point, boiling range, and viscosity of typical straight run diesel fuels from crude stocks of various types, and similar properties of typical light and heavy cracked oils. High-ignition-quality oils are generally of higher boiling range than the low-ignition-quality oils, due to normal production of kerosine from such crudes, and the pour points are also considerably higher. Difficulty in the production of diesel fuels of satisfactory ignition quality arises mainly because of the difficulty of obtaining a low pour point. This may be accomplished (a) by blending high-ignition-quality, high-pour-point oils with cracked, low-pour-point oils; but tends to production of poorer ignition quality and somewhat unstable oils, (b) producing a low-boiling-range straight-run stock, which interferes with kerosine manufacture, (c) use of wax crystallization inhibitors or dewaxing the oil, which methods are too costly relative to the usual value of the distillates.

Likewise solvent extraction of low-ignition-quality oils is usually uneconomic. In other words, the claim of the diesel-engine manufacturers of low fuel cost is not a fact if large quantities of high-quality fuel are demanded.

Fuel tests applied and specified can, generally speaking, be grouped under five performance-characteristic headings.

(1) Ignition quality, at present usually evaluated by determination of diesel index and cetane number, or indirectly by the octane blending number. The harmful effects on engines due to the use of fuels of inferior ignition quality are described. The range of suitable cetane numbers indicated are: for diesel electric motors 52, high-speed engines 47, medium-speed engines 43, low-speed engines 38, and corresponding diesel indexes are 50, 46, 44, and 40.

(2) Cleanliness is determined by sediment and water, ash content, and modified gum content tests. General complaints which involve cleanliness are probably more prevalent than any other criticism, but the presence of adventitious matter must arise primarily during handling and storage. Freedom from abrasive matter and water is of the greatest importance in view of the nature of the fuel-injection pumps and fabric filters employed on engines. Suitable specification limits are suggested for various types of fuel.

(3) Flow and atomization. Viscosity and pour point are related to these performance characteristics. Viscosity at the injection nozzle must be controlled within close limits, particularly the viscosity must not be too low, or decrease in power output may result. Viscosities of fuels used in 1939 for various types of engines are listed.

(4) Volatility may be evaluated by A.S.T.M. distillation curve, Conradson carbon value, particularly when applied to 10% fuel bottoms, and indirectly by gravity.

Relationships between these properties and production of smoke, engine deposits, etc., are discussed.

(5) Corrosion. Control tests employed are sulphur content, free acidity, and copper-strip test. Literature references on performance characteristics of diesel fuels are appended. R. A. E.

Lubricants and Lubrication.

229. Oil Purifying Auxiliary Equipment. Shop Transport of Supplies. *Industr. Pur and Fuel Econ.*, February 1942, **23**.—A portable compartment tank, divided equally for holding clean and dirty oils, and with a capacity of 75 gals., is described and illustrated. The essential function of this unit is to carry dirty oils from various points in industrial works to a central oil-reclaiming plant. All types of used oils can be transferred into the dirty-oil compartment by means of a semi-rotary hand-pump fixed to the top of the tank. The oil can then be replaced from the clean-oil compartment. Flexible hoses are supplied with the equipment to facilitate operation. The actual model illustrated is 3 ft. long, 2 ft. wide, and 2 ft. deep, but larger or smaller units could be constructed to meet specific works requirements. H. B. M.

230. Inspection of Bearing Surfaces. W. N. Twelvetrees. *Aircraft Eng.*, 1942, **14** (160), 173.—The paper is subdivided into the following sections: (1) White Metal, Phosphor Bronze, and Iron; (2) Steel; (3) Lead Bronze; (4) Lead; (5) Later Developments with White Metal and Bronzes. In each section the properties and peculiarities of the bearings are discussed, together with the requirements for satisfactory operation. J. G. W.

231. Graphical Solution of Fluid Friction Problems. E. S. Dennison. *Engineering*, 1942, **153** (3972), 179–180.—A graphical method is described for the solution of fluid friction problems in which a knowledge of Reynold's number is required and which would normally be solved by trial-and-error methods.

The principle is applied to the determination of terminal velocities of falling bodies, the diameters of pipe-lines, and flow velocities. J. G. W.

232. Wear Inhibiting Agents in Lubricating Oils. Anon. *Engineering*, 1942, **154** (3999), 195.—A summary is given of the paper "Some Aspects of Industrial Lubrication," by W. J. Hund, R. G. Larsen, O. Beeck, and H. G. Vesper.

A characteristic of boundary lubrication is that the coefficient of friction is practically independent of viscosity and sliding velocity.

The effect of chemical polishing agents on wear is discussed. Reduction of boundary friction did not necessarily result in reduction of wear. The best-known example was tricresyl phosphate, which apparently acted in a corrosive, rather than a protective, manner.

In addition to polishing the surface, an anti-welding film must be formed, and the surface should contain minute oil crevices between areas of unbroken level.

J. G. W.

233.* Viscosity Pole and Pole Height of Ubbelohde. S. S. Kurtz. *Industr. Engng Chem.*, 1942, **34** (6), 770.—A short note is given on the method of calculating the viscosity pole and pole height. These properties correspond to viscosity index and viscosity gravity constant, but there is no correlation between the two factors.

J. W. H.

234.* Oxidation Characteristics of Lubricating Oils. G. H. von Fuchs and H. Diamond. *Industr. Engng Chem.*, 1942, **34** (8), 927.—An apparatus is described for automatically measuring the oxygen absorption of lubricating oil. In this apparatus the oxygen is continuously pumped through the heated oil, the volatile oxidation products removed, and the decrease in volume of the oxygen measured. In addition to the measurement of oxygen absorption, it is shown that the saponification number is of importance in determining the types of oxidation products formed. It is shown that saturated hydrocarbons exhibit autocatalytic oxidation effects and aromatic hydrocarbons act as anti-oxidants by a mechanism of auto-retardation. The balance between these

two opposing effects is governed by the reaction temperature. It is shown that, under specified conditions, an increase in the aromaticity increased the stability until a maximum stability is reached, and that at a certain value of the aromaticity any further increase results in a decrease in the stability.

J. W. H.

235. Movement, De-oiling, and Disposal of Swarf. Anon. *Industr. Pwr and Production*. October 1942, 112-113.—In this article is described a plant capable of recovering up to 30 gals. of cleaned oil per ton of swarf handled, with an estimated saving of nineteen man-shifts per day. It has already been in use for two years at a B.S.A. Group works, and reports on its performance are favourable.

Throughout the process of de-oiling the swarf is moved on a conveyor of the plate-belt type, the top portion of which passes along the bottom of a tank with a curved base, giving the swarf its first washing. The swarf which emerges on the conveyor belt is passed beneath several hot-water sprayers for its second cleansing. The water washings, mixed with oil from the swarf, drain into a collecting tank, which is divided into two sections to avoid eddy currents. A temperature of 180° F. is maintained in the tank. The oil forms a surface layer on the tank, which is fitted with a floating pipe through which the oil is withdrawn. The "dirty oil" is pumped to an overhead tank, also maintained at a temperature of 180° F., whence it is fed to a centrifuge, and afterwards to another tank. It is then ready for re-use in the shops. The quality of the reclaimed oil is reported to be excellent, averaging only about 0.2% of water, containing no harmful bacteria, and being acid-free.

H. B. M.

236.* Evaluating Petroleum Lubricants. J. W. Poole. *Petrol. Engr*, 1942, 13 (10), 175.—The two most important obstacles facing the chemist in the field of lubrication are considered to be the highly complex nature of petroleum lubricants and the extreme variability of the conditions under which they perform. Lubricating oils have been divided into semi-arbitrary chemical groupings, paraffinic, olefinic, naphthenic, aromatic, and resinous, which, although inclusive of all oil constituents, are not rigidly distinctive. Moreover the terms "naphthenic" and "aromatic" have been confused, each having been used to signify that the nature of the material is antithetical to "paraffinic." In this article "paraffinic" and "naphthenic" ("aromatic") oils respectively refer to oils with a viscosity index of 90 or over and 20 or under.

In general, paraffinic oils appear to be stable in service and resistant to chemical action, but they do form "lacquer," which eventually leads to serious engine deposits of hard and tenacious character, causing piston-crown scuffing with aluminium pistons. General Motors Research Labs. have discovered that the stability of paraffinic oils is more apparent than real, since they produce resinous material, which remains dissolved in the parent medium, but is precipitated as a gummy mass when fresh paraffinic oil is added, and causes sticking of vital engine parts. On the other hand, the high V.-I. oil helps easy starting in cold weather, is less prone to cold driving "moisture sludge," and seems to be the best compromise for winter crankcase problems.

Non-paraffinic low V.-I. oils are, in general, sludge formers; at low temperature they form "moisture sludge" and at high temperature "high-temperature sludge." They cause difficult starting in cold weather. They are, however, as good lubricants as paraffinic oils, and their deposits are not so likely to include "lacquer." They give soft "carbon," are less likely to cause scuffing, and are rarely corrosive to high-duty alloy bearings.

Intermediate oils, between the two extremes, are not necessarily intermediate in properties, and are just as likely to have the deficiencies of both types as the desirable attributes.

The reactions of crankcase chemistry are so multivariant (variations include temperature, time, chemical nature of materials of construction and of chance invaders of the system, mechanical type and condition of the equipment, etc.), and so complexly interdependent as to be practically unpredictable at present. For example, oxidation may lead to auto-accelerators or to auto-retardants of the oxidation reaction, and these products may be useful or detrimental from other aspects. In general, conventional criteria consisting of rapidly determinable laboratory characteristics are not reliable guides to lubricating-oil performance. Tests in engines under actual conditions, or controlled conditions simulating service, are time-consuming and expensive, but are by far the best standards of quality at present available.

J. C.

237. Patents on Lubricants and Lubrication. M. S. Agruss, H. Schindler, and G. W. Ayers. U.S.P. 2,300,391, 3.11.42. Appl. 21.6.40. A small proportion of a petroleum resin-halogenated hydrocarbon condensation product is added to a lubricating oil normally deficient in green fluorescence to produce the desired fluorescence.

W. A. Proell. U.S.P. 2,301,795, 10.11.42. Appl. 16.6.41. The formation of sediment in a liquid-mineral-oil composition is greatly reduced by the addition of a small amount of an oil-soluble metal soap and a small amount of an aromatic hydroxy-aldehyde.
H. B. M.

Asphalt and Bitumen.

238.* Oxidation of Asphalt in Thin Films. A. R. Ebberts. *Industr. Engng Chem.*, 1942, **34** (9), 1048.—The oxygen absorption of a thin film of asphalt is measured by means of potassium permanganate. The results of a number of tests on asphalts from different sources are given. It is concluded that if good service is to be obtained from a pavement asphalt the oxygen absorption must be low.
J. W. H.

Special Products.

239.* Make Butadiene by Catalytic Dehydrogenation of Butane. W. T. Ziegenhain. *Oil Gas J.*, 20.8.42, **41** (15), 30.—A description with flow-sheet is given of a plant designed to produce 15,000 tons per annum of butadiene by the Houdry process. The plant consists essentially of six reactors, heaters for the first and second stage reactions, a vapour-recovery system, and a butadiene purification system. Each reactor works on a 90-min. cycle, during which it operates for one 15-min. period on first-stage reaction, and two periods of 15 min. each on the second-stage reaction. Thus one reactor is always on stage one, two are on stage two, whilst in the remaining three purging or revivifying of catalyst is taking place. In stage one butane is heated to 1050° F. and passed to one of the reactors, where it is partly dehydrogenated under a pressure of 5–10 mm. Hg absolute. The evolved gases pass to the vapour-recovery system, where the butane/butene portion is concentrated, and after butadiene removal, pass to the second stage heater, where the mixed gases are heated to 1100° F. for delivery to the second-stage reactors. The products of the second-stage dehydrogenation are mixed with those from the first and compressed to 115 lb. per sq. in. before entering the vapour-recovery system. Gas analyses and material balances are tabulated and a 17% concentration of butadiene in the effluent from the second stage is expected. The reactors are 12 ft. in diameter and 12 ft. long, 1 in. thick and fire-brick lined, thus permitting use of carbon steel for the shell. Each reactor contains a 3-ft. bed of catalyst, the estimated life of which is six months.

The butane/butene fraction from the vapour-recovery system passes to the butadiene extraction and purification system; in the extractor the ascending vapours meet a descending flow of solvent which extracts the butadiene. The spent butane fractions pass from the top of the extractor to a scrubber for removal of entrained solvent by means of a water-wash. The overhead product is condensed and delivered to the second-stage heater, whilst the solvent is recovered from the water solution in a stripper. The purity of the butadiene in solvent is improved to the desired standard by recycling butadiene vapour from the desorber, which gives the desired butene stripping effect. Rich solvent from the extractor passes to the desorber, where butadiene is vaporized, and the lean solvent is subsequently cooled and passed back to the extractor. Butadiene from the desorber enters a washer for removal of solvent by water and is then condensed, inhibited and sent to storage under a pressure of 70/75 lbs. per sq. in.

Estimates are given of utility requirements of the plant and of the costs of operation. With butane available at 6 c. per gal. butadiene is expected to cost 6.77 c. per lb.

R. A. E.

240.* Chlorination of Methane. E. T. McBee, H. B. Hass, C. M. Neher, and H. Strickland. *Industr. Engng Chem.*, 1942, **34**, 296.—The process described enables the direct chlorination of methane to be controlled to produce the four chloromethanes, the individual ratio of which in the products can be controlled from nearly 100% CH_3Cl

to CCl_4 . This reaction is carried out by the controlled addition of chlorine to methane at a number of points in a continuous reactor. Data are given on the design and spacing of the chlorine jets, the effect of the number of jets and the effect of mol. ratio and temperature.
J. W. H.

241.* Effect of Low Temperatures on Neoprene Vulcanizates. F. L. Yerzley and D. F. Fraser. *Industr. Engng Chem.*, 1942, **34**, 332.—Several tests are described for investigating the ability of synthetic rubbers to resist low temperatures. Data are given on the resistance to freezing of several synthetic rubbers, including data on the effect of various softeners.
J. W. H.

242.* Nitromethane-isoPropyl Alcohol-Water System. J. E. Schumacher and H. Hunt. *Industr. Engng Chem.*, 1942, **34** (6), 701.—The vapour-liquid equilibria for the binary and ternary systems of nitromethane, isopropyl alcohol, and water are given. The binary and ternary systems form minimum boiling azeotropes. Data on the mutual solubility of nitromethane and water are given, and a method for the separation of nitromethane from the ternary system is discussed.
J. W. H.

243.* Solvent Properties of the Isomeric Paraffins. E. H. McArdle and A. E. Robertson. *Industr. Engng Chem.*, 1942, **34** (8), 1005.—Data are given for the solvent properties of the two isomeric pentanes, four isomeric hexanes, *n*-heptane, and triptane with respect to low-molecular-weight polybutenes and alkyd resins. Although the solvent power of these paraffins is shown to be similar, the viscosity of the solutions are greatest for the highly branched paraffins, even when these viscosities are adjusted to a reduced temperature basis.
J. W. H.

244.* Nitroparaffins as Solvents in the Coating Industry. C. Bogin and H. L. Wampner. *Industr. Engng Chem.*, 1942, **34** (9), 1091.—The solvent power and applications of the nitroparaffins are discussed, with particular reference to their use in the coating industry.
J. W. H.

245. Patents on Special Products. R. A. Gerlicher. U.S.P. 2,301,270, 10.11.42. Appl. 9.11.40. High-quality phenols are produced from crude phenol fractions segregated from mineral oils by distilling the original material in the presence of added high-molecular-weight petroleum asphalt under conditions designed to remove overhead the refined phenols and to remove as a fluid-bottom products the added hydrocarbon and impurities present in the feed phenol fraction.

J. C. Showalter and M. Wigen. U.S.P. 2,301,335, 10.11.42. App. 1.9.39. Process of preparing derivatives of petroleum hydrocarbon acid sludge. The sulphuric acid sludge, obtained by treating cracked hydrocarbon naphthas with sulphuric acid, is treated with water, and an acid-water solution is separated from the sludge. The residual material is treated with water, and an acid-water solution is separated from the sludge. The residual material is treated with propane and allowed to settle. A layer of the carbonaceous material which settles out is removed and the residual material is distilled to remove propane. The residual material is treated with sulphuric acid which is afterwards removed. After clay treatment the residual material is separated into an oil fraction and a fraction which is solid at ordinary temperatures.

L. A. Hamilton, R. C. Moran, and A. R. Cattell. U.S.P. 2,301,806, 10.11.42. Appl. 9.3.40. A white refined paraffin wax product is inhibited against the formation of deleterious colour upon prolonged exposure to light by the addition of a small amount of an ester of an alkyl monohydric alcohol and an oxygen containing acid selected from the group consisting of aliphatic hydroxy-acids, phthalic acid, and oxygen acids of phosphorus.
H. B. M.

Detonation and Engines

246.* Prediction of Octane Numbers and Lead Susceptibilities of Gasoline Blends. D. Eastman. *Industr. Engng Chem.*, 1941, **33** (12), 1555.—A method of predicting the octane numbers of blended gasolines is given which is based on a knowledge of the Motor Method and Research Method ratings of the components. A blending co-

efficient is determined from the difference in octane sensitivities of the stocks blended, from which the Motor Method octane number of the mixture can be predicted.

A modification of the Hebl, Rendel, and Garton chart is presented for the evaluation of lead response, and correlations for the prediction of this factor from sulphur content and octane sensitivity are given. Methods for the prediction of the lead response of blends are described. J. G. W.

247. Thermal Air-Jet Propulsion. Gohlke. *Aircraft Engineering*, 1942, **14** (156), 32.—A comprehensive summary is given of the patents dealing with air-jet propulsion. These have in common: the air compressor, the combustion chamber, and the expansion tunnel (diffuser). The essential difference between them lies in the method of compression. J. G. W.

248.* Combustion in Diesel Engines—Effect of Adding Gaseous Combustibles to the Intake Air. M. A. Elliot and L. B. Berger. *Industr. Engng Chem.*, Industrial Edition, 1942, **34** (9), 1065.—Experiments on the effect of adding natural gas to the air intake of two commercial diesel engines are described. These studies were initiated as part of a programme to evaluate the hazards that might attend the use of diesel engines in mines or other underground operations, but information was gained incidentally on combustion phenomena in this type of engine.

The composition of the exhaust products indicated an effect analogous to the lower limit of inflammability. The existence of overlean regions in which the flame does not propagate is discussed, and evidence is offered indicating that such regions are the source of carbon monoxide and aldehydes in the exhaust gas at mixtures less than chemically correct. J. G. W.

249.* Equations for the Specific Heats of Gases. J. C. Smallwood. *Industr. Engng Chem.*, 1942, **34** (7), 863.—Condensed equations and constants are given for calculating the specific heats of O_2 , N_2 , CO , H_2O , CO_2 , and air, for combustion purposes. J. W. H.

Coal and Shale.

250. Fused Spent Shale from a Retort at Pumpherston, Midlothian [Scotland]. J. Phemister. *Trans. Geol. Soc., Glasgow*, September 1942, **20** (2), 238–247.—Fragments of fused spent shale in slag are surrounded by two shells, the inner almost opaque retaining some of the structure of the shale, and the outer finely recrystallized as cordierite ($2MgO \cdot 2Al_2O_3 \cdot 5SiO_2$) in a glassy or opaque grey matrix. In the slag one finds ferromagnesian silicates and spinel in an irregularly fluxional aggregate of cryptocrystalline and microcrystalline material. Cordierite forms prisms up to 0.1 mm. in length. Bytownite-anorthite gives microlites, laths, and prisms up to 0.5 mm. Olivine—ferrohortonolite—appears as spongy grains reaching 1 mm. across. Pyroxene occurs as grains and prisms, and, if non-aluminous, is identified as a diopside-hedenbergite.

Cordierite may be produced (1) in the unfused shale, as in contact altered argillaceous rocks, (2) in the corona around the fragments, (3) in practically holocrystalline parts of the slag, (4) in glass as idiomorphic crystals. It may either grow in heated solid rock or be precipitated from fusion.

The high concentration of cordierite in certain positions is attributed to selective diffusion of the fluxing oxides CaO and FeO to places where fusion is initiated, leaving the MgO and Al_2O_3 behind to crystallize as a sinter of cordierite crystals.

The temperature at the bottom of retorts is, according to E. B. Bailey (1927), only 705° , while temperatures of fusion of the system $MgO-Al_2O_3-SiO_2$, which quench to cordierite and glass, are given by Rankin and Mervin (1918) as from about 1350° to $1450^\circ C$.

Phemister quotes comparisons of the fused shale with naturally occurring buchites, or basalt-jasper, and refers to the aluminous xenoliths in the tholeiites of Mull, the vitrified phyllites of Argyll, and the Tertiary sediments of south-west Persia, which have been metamorphosed by combustion of hydrocarbons.

The fused shale, mixed with about 10% of lime, is used for brick-making. A. L.

Economics and Statistics.

251.* Petroleum Research and Wars. B. T. Brooks. *Industr. Engng Chem.*, 1942, **34** (7), 798.—A general review is given of the part which research has played in the development of the oil industry with particular reference to processes of value in time of war. The future of research in oil industry progress is also considered. J. W. H.

252. Axis Draws on many Sources for Petroleum Supplies. G. Egloff and P. M. Arsdell. *Oil Gas J.*, 20.8.42, **41** (15), 32.—It is estimated that the maximum production of petroleum products in European countries under Axis control amounts to 53,501,000 brl. per annum, and the maximum production of synthetic and substitute fuels amounts to the equivalent of 81,720,630 brl. of petroleum products, a total of 135,221,630 brl. per annum. This is estimated to be 120 million brl. short of the estimated military and civil requirements of these countries on the basis of a full year of military operations on all fronts. Tables show the known Hydrogenation and Fischer-Tropsch plants operating in Germany and the location and capacity of known and projected synthetic fuel plants in Italy and France. Estimates are also given for each country of the maximum and minimum production, in terms of oil equivalents, of compressed gases, shale oils, benzol, alcohols, wood and coal-gas generators. Indications of the increasing use made of substitute fuels are given, and the practical limitations in production and utilization of some of these fuels are described. Details of Japanese production of petroleum and substitute fuels prior to her entry into the War are given, together with details of pre-war imports from foreign sources. R. A. E.

BOOK REVIEW.

Oil Well Drainage. By Stanley C. Herold. Pp. xv + 407, and 36 figures. Stanford University Press, Stanford University, California; London, Humphrey Milford, Oxford University Press, 1942. Price 30s.

In 1928 "Analytical Principles of the Production of Oil, Gas and Water from Wells" was published. While it was in the press one of Herold's colleagues at Stanford University suggested that when he had had an opportunity of verifying the mathematical theory presented therein, he should write another book without any mathematics, and make it easier to read by telling the story in simple language. The present volume has been written with the total exclusion of mathematical proofs of the propositions (apart from three geometrical proofs in the appendix), and with the inclusion of field examples of the circumstances described, the two ideas which met with the approval of all who were consulted during its preparation. It has been written for the particular attention of operators and owners of producing-oil and gas properties, and with the realization that it is impossible "to satisfy all types of individuals concerned directly with the oil and gas industry."

In addition to the complete avoidance of mathematical theory, Herold imposed upon himself the further restriction of a somewhat unusual lay-out for the book, which involves such features as confining the illustrations to diagrams forming the chapter headings, and the alternate discussion of each of the two types of drainage as the successive factors or groups of factors are dealt with, just as though the other type of drainage did not exist. The rigid adherence to this form, while giving uniformity and a very definite character to the book, makes it a little difficult to read, and in places causes the discussion to be longer and harder to follow than might otherwise have been the case.

The two types of drainage which are discussed are termed "Cenozoic" and "Palæozoic" after the eras in which each type is said to be most characteristically, though not exclusively, exhibited. The author realized that "there may be a question respecting the wisdom of applying the names of two geological eras to these types, particularly in view of outstanding exceptions to the classification." This, and some of the other terminology, is not entirely free from any possibility of causing confusion, although no succinct and entirely satisfactory alternatives readily present themselves. Gas drive and water drive are not respectively synonymous with Palæozoic and Cenozoic production since Herold considers that both drives—first one and then the other—occur within reservoirs of Cenozoic drainage, although gas drive alone exists in reservoirs of Palæozoic drainage.

The principal characteristics of the two types of drainage are as follows: (1) **Cenozoic:** The oil-producing formation outcrops in the foothills adjacent to the basin in which the field lies, and edgewater encroaches progressively in the field, wells being abandoned only because of edgewater trouble. A well may have an initial output of over 10,000 bbl./day, and may produce naturally from year to year without decline, sometimes ultimately producing more oil than could possibly be present in the reservoir space underground in the area allotted to the well. The gas/oil ratio of a well reaches a peak within a year or so of the well's completion. Artificial gas or water drive is unsuccessful when the field is approaching exhaustion, and when gas is pumped back into the field the pressure at the input well falls, on standing, to the value obtaining before injection began. Screens may be necessary to keep sand out of wells. On plotting closed-in pressures and rates of production against time, with an early pair of simultaneous readings used as 100% for each set of data on the same scale, the rate curve lies above the pressure curve. (2) **Palæozoic:** There is no progressive encroachment of edgewater up structure, and wells may be abandoned in the middle of the field on account of exhaustion, without having had edgewater trouble. They may also be abandoned because of exhaustion while surrounding wells continue to produce from the same formation at profitable rates. The rate of production declines with the age of a well, and less oil is recovered than would fill the pores in the reservoir rock within the area allotted to a well. Artificial water or gas drive increases recoveries in old fields nearing exhaustion in

terms of primary recovery methods, and when gas is pumped back into the producing formation, on standing the pressure at the input well remains above the value prior to injection. Wells, old or new, may have high pressures at depth, while the surrounding wells, completed in the same formation, have low pressures. The pressure-time curve lies above the production rate-time curve when an early pair of simultaneous readings of pressure and rate of production are both plotted as 100% on their respective scales. Shooting may be needed to bring in a well, and its gas/oil ratio does not swing up to a peak in the first year or so of its life.

Each chapter except the first and last is divided into two parts, Cenozoic production being discussed in one part and Palaeozoic production in the other. The main topics examined are as follows: typical artificial reservoirs; natural reservoirs; reservoir energy; the function of gas; the radius and area of drainage; regional drainage and water encroachment; drainage across property lines; the effects on drainage of stratigraphy and structure, reservoir penetration, multiple zones, rates of production and field development; drainage of wells of all or no gas; injection of gas, water or oil; reservoir content; ultimate recovery and reserves; abandoned oil and gas; curtailment, proration and conservation.

"Oil Well Drainage" is not a text-book on oil production, but a detailed discussion of the movement of oil to wells on the basis of two distinct mechanisms. Before reading the main body of the book it seems preferable that the preface and also the appendix (omitting the geometrical proofs) should be studied, for there are some points where the absence of appreciation of the author's intentions and of his realization of the existence of certain difficulties may engender an unsympathetic attitude.

In the examination of the various aspects of production and drainage according to the two mechanisms, attention has rightly been directed to many features which are apt to be overlooked or to be incorrectly assumed to occur in all fields. Frequently the examination is made from a new angle, and altogether the treatment is thought-provoking; but there are many instances where the presentation of the original field data and measurements, or at least where they have been published, the citation of the source, would have been more satisfying to readers, some of whom will probably want to ascertain how far data of their own agree with Herold's ideas.

G. D. HOBSON.

BOOKS RECEIVED.

The Institution of Mechanical Engineers. Proceedings. Vol. CXLVII (January-June 1942). 11 $\frac{1}{4}$ in. \times 8 $\frac{3}{4}$ in. 246 pages.

Comptes Rendus (Doklady) de l'Academie des Sciences de l'U.S.S.R. Vol. XXXV, No. 9.

Journal of Physics. Academy of Science of the U.S.S.R. Vol. VI, No. 1-2.



INSTITUTE NOTES.

FEBRUARY, 1943.

STAFF.

Mr. F. H. Coe, who was appointed Acting Secretary of the Institute in July last, has now been confirmed in his appointment as Secretary.

CANDIDATES FOR ADMISSION.

The following have applied for admission to the Institute. In accordance with the By-laws, the proposals will not be considered until the lapse of at least one month after the publication of this *Journal*, during which time any Fellow, Member, or Associate Member may communicate by letter to the Secretary, for the confidential information of the Council, any particulars he may possess respecting the qualifications or suitability of the candidate.

The object of this information is to assist the Council in grading the candidate according to the class of membership.

The names of candidates' proposers and seconders are given in parentheses.

BASS, Ernest Leon, Mechanical Engineer, Asiatic Petroleum Co., Ltd. (*John A. Oriel ; R. I. Lewis.*)

CHARLESWORTH, Percy Allan, Research Chemist, Moore & Barrett. (*James Barrett ; Harold Moore.*)

COE, Frederick Henry, Secretary, Baku Consolidated Oilfields. (*A. Frank Dabell ; Richard R. Tweed.*)

CROSS, David Thomas, Patent Agent, Standard Oil Development Co. (*Hugh C. Tett ; Prof. F. H. Garner.*)

FRANKEL, Paul Herzberg, Managing Director, Raven Oil Co., Ltd. (*Cecil W. Wood ; Dr. F. Kind.*)

OSTLER, Frank Allan, Research Chemist, Arthur Brown & Co., Ltd. (*C. B. Wingfield ; J. F. M. Webb.*)

CONTRIBUTIONS TO THE JOURNAL.

In view of the fact that the orbit of the Institute has now been widely extended, it was decided at a recent meeting of the Publication Committee to invite contributions to the *Journal* from members, not only on purely scientific and technical topics, but on those matters that might be of general interest. The Publication Committee will be pleased to accept such contributions from members.

STUDENTS' SECTION, BIRMINGHAM UNIVERSITY.

A meeting was held in the Oil Department, Birmingham University, on 1st December, 1942. Fourth-Year Students presented papers based on their Theses, half an hour being allowed for reading and quarter of an hour for discussion.

The following papers were read in the morning :—

"The Design of High Pressure Reactors," by J. Tadayon.

"Disease and its Relation to the Oil Industry," by M. L. Fellowes.

The following papers were read in the afternoon :—

"The Hydrodynamics of Jets," by A. W. Pearce.

"Modern Well Completion," by A. G. T. Weaver.

"Prime Movers in Rotary Drilling and Mechanical Pumping," by D. A. Hartley.

Voting by secret ballot resulted in A. W. Pearce winning the First Prize of £2, and M. L. Fellowes winning the Second Prize of £1. A. W. Winward won the prize for the best contribution to the discussion.

New Officers were elected as follows :—

| | | | | | |
|-------------------------|-----|-----|-----|-----|-----------------|
| Chairman | ... | ... | ... | ... | G. K. Ashforth. |
| 3rd-Year representative | ... | ... | ... | ... | A. W. Winward. |
| 2nd-Year representative | ... | ... | ... | ... | B. A. Faulkner. |

The meeting concluded with tea in the Museum of the Oil Department.

NOTE.

It will be of interest to the many members of the Institute who for various reasons are unable to visit the premises or attend meetings, to know of the many activities being carried on to an even greater extent than formerly.

Regular monthly meetings are being held during the current session, attendances at which are beyond expectations, and the discussions give proof of the keen interest taken in submitted papers.

There are now no less than thirty-seven active committees and panels, with a total membership of upwards of one hundred and thirty, meeting frequently, and much valuable work is being carried out.

ARTHUR W. EASTLAKE,
ASHLEY CARTER,

Joint Honorary Secretaries.

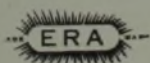
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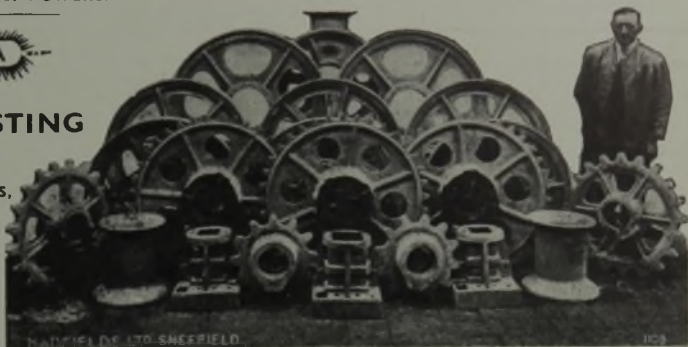
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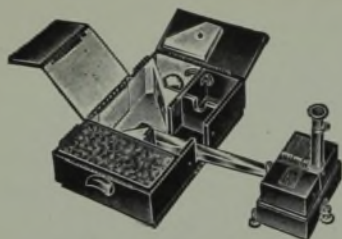
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| OIL WELL SUPPLY CO. | Back cover |
| OXLEY ENGINEERING CO., LTD. | xiii |
| JOHN G. STEIN & CO., LTD. | x |
| STEWARTS AND LLOYDS, LTD. | — |
| TINTOMETER, LTD. | iv |
| TYLORS, LTD. | v |
| WHESSOE FOUNDRY AND ENGINEERING CO., LTD. | xi |
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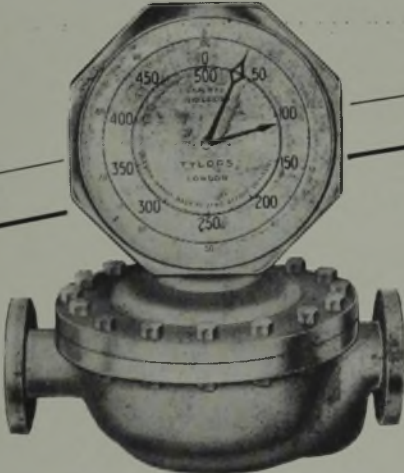
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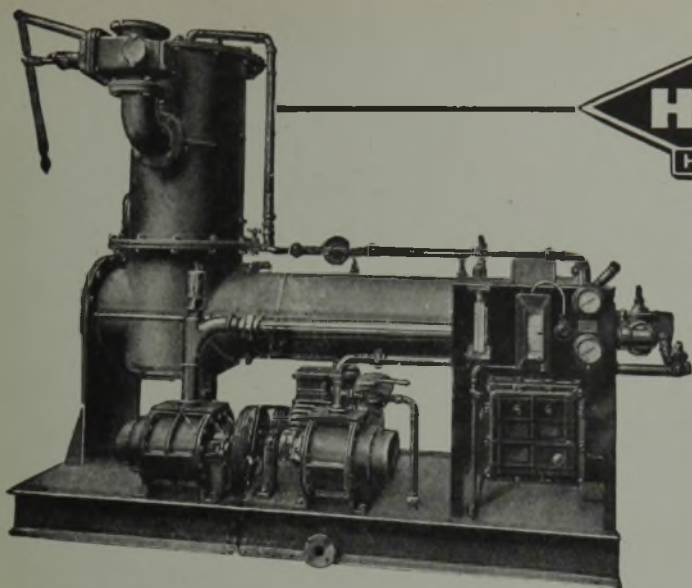
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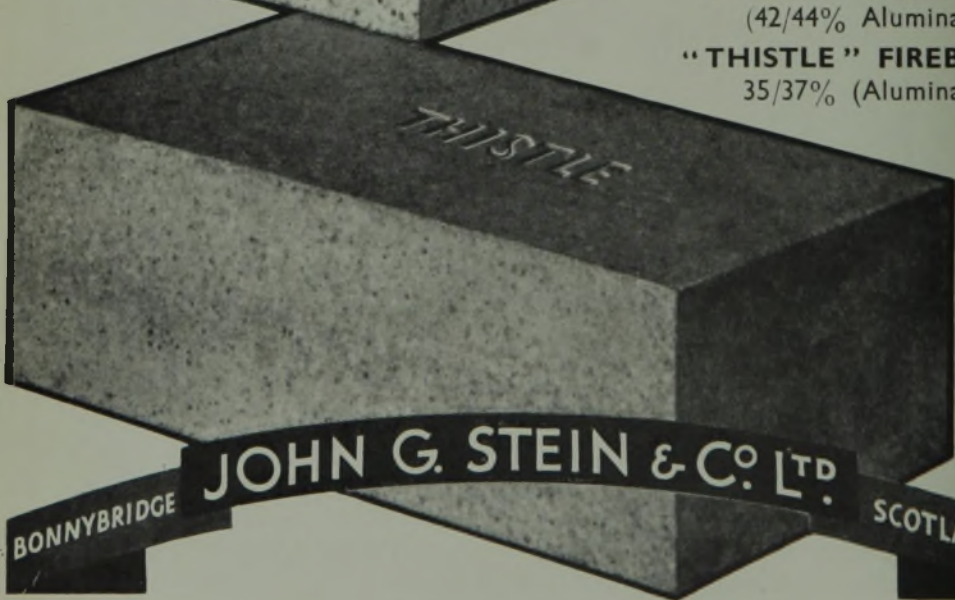
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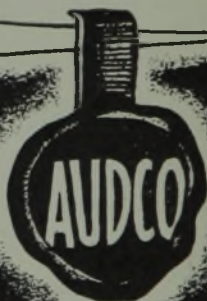
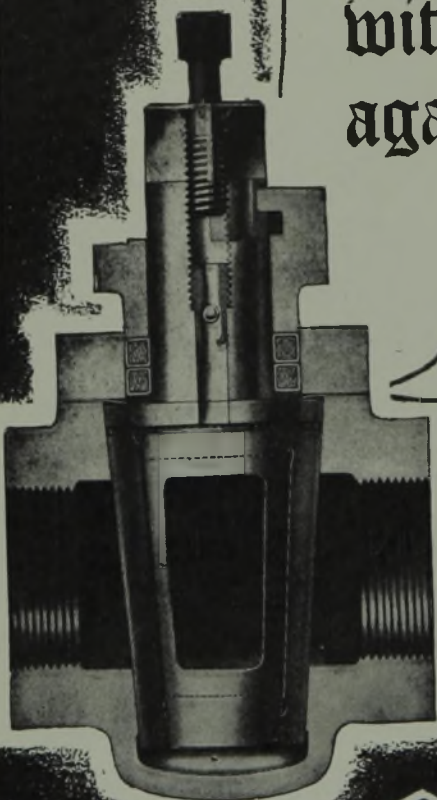
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