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THE FLOW PROPERTIES OF BITUMINOUS MATERIALS.*

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SUMMARY.

Some results are given of the investigations now in progress on the fundamental flow properties of bitumens and bitumen-aggregate mixtures. A coni-cylindrical viscometer has been used for measuring the effect of stress and temperature on the viscosity and elastic recovery of various types of bitumens. The relation between rate of shear (D) and shearing stress (S) for all but the most plastic bitumens may be represented by an equation of the form $D = \left(\frac{1}{\eta'}\right)S^p$, where η' and p are constants. The use of the index p as a "plastic-flow index" provides a method of expressing the degree of plasticity of a bitumen, where this is considered as the divergence from ideal viscous flow. Different bitumens having the same penetration (65) may have very different viscosities. The bitumens so far investigated have been found to differ chiefly in their plastic and elastic properties.

The effect of stress and temperature on the flow properties of roller-compacted specimens of bitumen-aggregate mixtures has been investigated by beam and tensile tests. The relation between stress (S) and minimum rate of strain (R) may be expressed by the equation $R = KS^P$, where K and P are constants. The flow properties at the minimum rate of deformation under conditions of constant tensile stress may be expressed completely by a number of constants—namely P, K_0 (the minimum rate of strain at unit stress at 0° C.), N (the rate of change of log. K with change of temperature), and the extensibility at failure, the value of these constants being determined by the nature and grading of the aggregate and by the nature of the binder. Mixtures of a particular aggregate grading containing the more plastic bitumens have greater values for P than those containing non-plastic bitumen; the value of P is affected more by the grading and proportion of the aggregate than by the nature of the bitumen.

Introduction.

Bituminous materials are used for a large variety of industrial purposes, but most extensively in road construction. Although the present paper deals with this aspect of their use, much of the information presented is of more general interest, since it is concerned with fundamental properties. The materials used must be readily adaptable to keep pace with the development of modern industrial methods, and this can be achieved only if the essential properties of the materials are fully understood. Data on the fundamental flow properties of bituminous materials are being obtained with three main objects in view: first, to enable their behaviour in service to be predicted, and thus to enable their suitability for specific purposes to be judged; second, to enable their behaviour during mixing and laying to be predicted, and so to enable the most satisfactory conditions for application to be determined; and third, to provide information on

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the nature of the internal structure of the bitumens themselves, in order to indicate the best method of preparing a binder having any required properties.

In the study of the rheological properties of mixtures of bitumen and aggregate a knowledge of the characteristics of the binders is clearly of first importance. Until recently little was known of the fundamental flow properties of bitumens, although in the testing of bitumens for industrial purposes many different empirical tests involving flow properties have long been used as aids to the selection or specification of materials. Such tests are useful for ensuring that samples of the same material conform to a standard measured under certain arbitrary conditions of flow, but as a true comparison of the behaviour in service of different materials and as a basis for improving and understanding existing techniques they are of little value. In fact, certain of these tests (such as the penetration test), when taken alone, can often be misleading. Moreover, in cases where the measurements are reproducible to a high degree of accuracy, fundamental importance may frequently be attached erroneously to small differences. In general, the tests measure complicated and variable functions of several fundamental properties operating simultaneously. For example, the " penetration " value depends on viscosity, elasticity, tensile strength, and adhesion; and the " ductility " value depends, among other properties, on the viscosity and the internal cohesion. Bingham [1] has pointed out that " the use of such empirical tests which are not based on any sort of theory of the fundamental nature of flow have more than any other thing prevented the progress of the art of rheology." It is probably true to add that it has also retarded the development of the industries using these and other plastic materials.

An investigation has therefore been started at the Road Research Laboratory to correlate the behaviour on the road of bituminous surfacings with the rheological characteristics of their binders and of mixtures prepared in the laboratory. This investigation thus involves initially an attempt to evaluate in absolute units the viscous and elastic properties of both the bituminous binders and the consolidated bitumen-aggregate mixtures.

Simple proportionality between stress and strain or rate of strain is not generally shown by these materials; therefore, the determination of the flow coefficients expressing these relations must be made under conditions of uniform stress. For the bitumens themselves the use of suitable viscometers is therefore necessary; for the bitumen-aggregate mixtures uniform stress distribution across the specimen must also be ensured, involving either the application of a constant stress or a constant rate of strain, whichever is the more convenient. Extensibility, as defined by the percentage elongation of the specimen at failure, and the elastic recovery which occurs on removal of the applied stress are further rheological properties which can be measured by either method of testing. Such concepts as the coefficient of viscosity or the moduli of elasticity and of rigidity are the results of experiment applied on the one hand to substances definitely in the liquid state, and on the other to those in the truly solid state. It is not, therefore, to be expected that the linear relationship between stress and strain or rate of strain implied by using such moduli will necessarily apply to these more complicated materials, which may exhibit both solid and liquid properties at the same time.

When the stresses are rapidly applied, as in the case of impact or vibration forces from passing vehicles, bitumen-aggregate mixtures exhibit the properties of solids. Some progress has been made in measuring the transient forces normally occurring on the road, and it is important to investigate the relation between stress and strain for bituminous materials under similar conditions of rapid stress application. The stresses applied by most impact tests are usually of a high, but indeterminate, order, making it impossible to determine the fundamental rheological properties involved, and it is open to question whether such tests reproduce practical conditions, or have any practical significance. A machine has therefore been constructed which subjects bituminous specimens to a repeated, suddenly applied, transient stress of a given value maintained approximately constant for a short predetermined time. The stress–strain relations can thus be evaluated for " impact " forces of known magnitude and duration (of the order of $\frac{1}{10}$ to $\frac{1}{50}$ second) which are repeated at intervals of one second to half a minute. Typical load–time curves given by the machine are shown in Fig. 1. Conditions of stress similar to those beneath the wheel of a

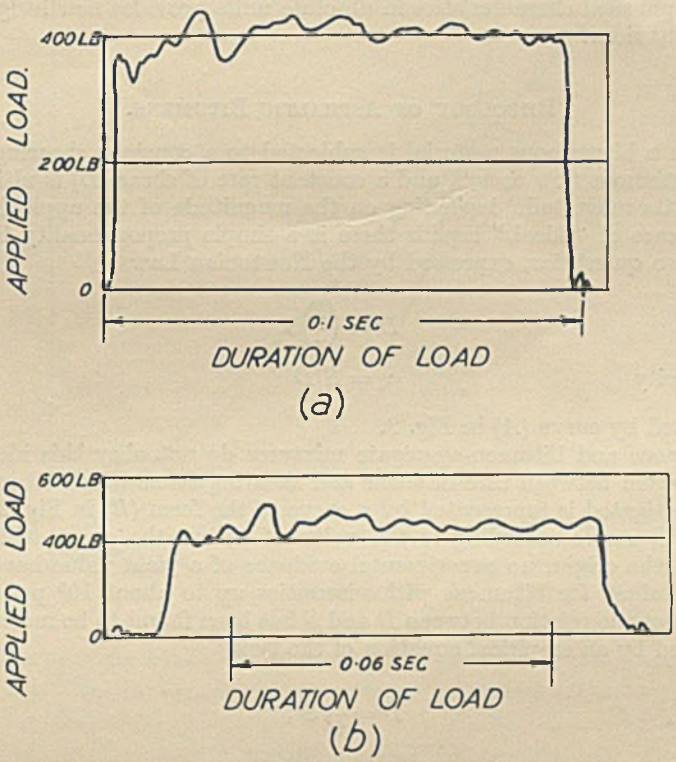

Fig. 1.

LOAD–TIME CURVES GIVEN BY REPEATED TRANSIENT LOAD TESTING MACHINE.

passing vehicle are thus obtained, but forces arising from vibration are not supplied. The extension of the measurements to the elastic properties exhibited under vibrations of audio-frequency would complete the field of investigation of the rheological characteristics of bituminous materials necessary for deducing the stress–strain–time relations met with in practice. Some measurements on these lines have already been reported.[2, 3]

Examples of the results of the investigations now in progress on bitumens and on bitumen-aggregate mixtures are given below, and serve to illustrate that, although these problems are complicated, the evaluation of the fundamental physical characteristics in absolute units provides new insight into their behaviour.

RHEOLOGY OF ASPHALTIC BITUMENS.

When a bituminous material is subjected to a constant shearing stress (S), continuous flow occurs, and a constant rate of shear (D) is ultimately set up, its magnitude depending on the magnitude of the applied stress. In the case of " ideal " liquids there is a simple proportionality between these two quantities, expressed by the Newtonian Law

$$D = \left(\frac{1}{\eta}\right)S$$

or viscosity

$$\eta = S/D$$

illustrated by curve (A) in Fig. 2.

Bitumens and bitumen-aggregate mixtures do not obey this ideal law. The relation between rate of shear and shearing stress of all bitumens so far investigated is represented by a curve of the form (B) in Fig. 2. The ratio S/D varies according to the value of S, but the curve still passes through the origin, no experimental evidence of a yield value having yet been obtained for bitumens with viscosities up to about 10^8 poises. In these cases the relation between D and S has been found to be more nearly expressed by an empirical equation of the type

$$D = \frac{1}{\eta'}S^p,$$

where η' and p are constants, η' resembling (but not in dimensions) the viscosity η in the earlier equation. As pointed out by Scott Blair,[4] this equation has been found by many investigators to apply to a great number of materials. It has as yet no theoretical significance, but provides a convenient means, at the present stage of rheological knowledge, of expressing the flow-curves in terms of certain numerical constants.

For a satisfactory evaluation of the rate of flow–stress–temperature relations, such materials must be subjected to a range of uniform shear stresses of known values at various known temperatures. Further, the rate of shear under constant stress generally varies for some time after the initial application of the stress, and the material must undergo some continuous deformation before the rate of shear becomes constant. The rotating cylinder viscometer, which gives a closer approximation to these conditions than any other viscometer, has been found most satisfactory for these investigations.

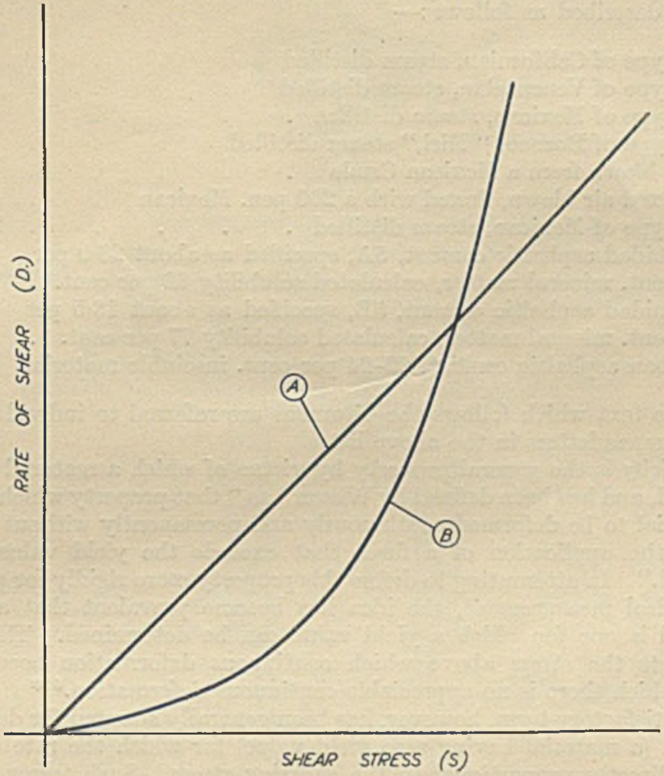

FIG. 2.

RELATION BETWEEN SHEAR STRESS AND RATE OF SHEAR. (A) IDEAL RELATION $(D = \frac{1}{\eta} S)$. (B) RELATION FOR BITUMINOUS MATERIALS $(D = \frac{1}{\eta'} S^p)$.

NOMENCLATURE.

Owing to certain difficulties that arise when considering some of the results of these investigations, attention is directed to the terminology which has been adopted.

The scientific description of naturally occurring products frequently presents some measure of difficulty. Obviously no one would regard " British coal " as a clear scientific description. Similarly, it is inaccurate and misleading to refer to " Californian bitumen," since several types of crude oils occur in the large area of California. On the other hand, a fuller description associating any particular oil with the well from which it was obtained at a particular date would not be any more helpful, since such a description would only be imperfectly understood even locally. In the circumstances the best that can be done is to refer to the products under consideration as " a type of Californian bitumen," etc., and to rely upon the chemical data to supplement the description.

The asphaltic bitumens and asphalts dealt with in this paper will therefore be described as follows :—

A.	A type of Californian, steam distilled	65	pen.
B.	A type of Venezuelan, steam distilled	65	,,
C.	A type of Mexican, steam distilled	65	,,
D.	A type of Borneo, " Miri," steam distilled	65	,,
E.	Air blown from a Mexican Crude	22	,,
F.	Fluxed air blown, fluxed with a 200 pen. Mexican	65	,,
G.	A type of Mexican, steam distilled	200	,,
H.	Trinidad asphaltic cement, 5A, specified as about 23·0 per cent. mineral matter, calculated solubility 62 per cent.	65	,,
I.	Trinidad asphaltic cement, 5B, specified as about 18·5 per cent. mineral matter, calculated solubility 77 per cent.	65	,,
J.	Cuban asphaltic cement, 22–24 per cent. insoluble material	65	,,

In the text which follows the bitumens are referred to individually by the reference letters in the above list.

Plasticity is the general property by virtue of which a material may be moulded, and has been defined by Wilson [5] as " that property which enables a material to be deformed continuously and permanently without rupture during the application of a force that exceeds the yield value of the material." In attempting to define this property more rigidly for purposes of physical measurement, the idea has become prevalent that a plastic material is one for which a yield value can be determined. This value represents the stress above which continuous deformation occurs, and below which there is no appreciable continuous deformation.[6] *

No satisfactory term, however, has been generally adopted for describing a liquid (a material having zero yield value) for which the rate of shear is not directly proportional to the shearing stress. Such terms as non-Newtonian flow, pseudo-plasticity, quasi-viscosity, and structural viscosity have been employed, but they become inconvenient when used to compare materials which differ in their degree of deviation from ideal flow. It has consequently been found desirable, in order to preserve a reasonable degree of clarity, to refer to the plastic flow of such materials even though they have a zero yield value. It is considered that if such an artificial division is necessary, the term plastic solid should be applied to materials having a definite yield value and the term plastic liquid to those which do not. With many plastic solids the yield value is indefinite and the classification depends largely on the sensitivity of the measurement or on the choice of an arbitrary minimum yield stress such as gravitational stress.

THE CONI-CYLINDRICAL VISCOMETER.

A viscometer similar to that used by Saal [7] has been used. In this instrument the difficulty of estimating the lower end effect is overcome by

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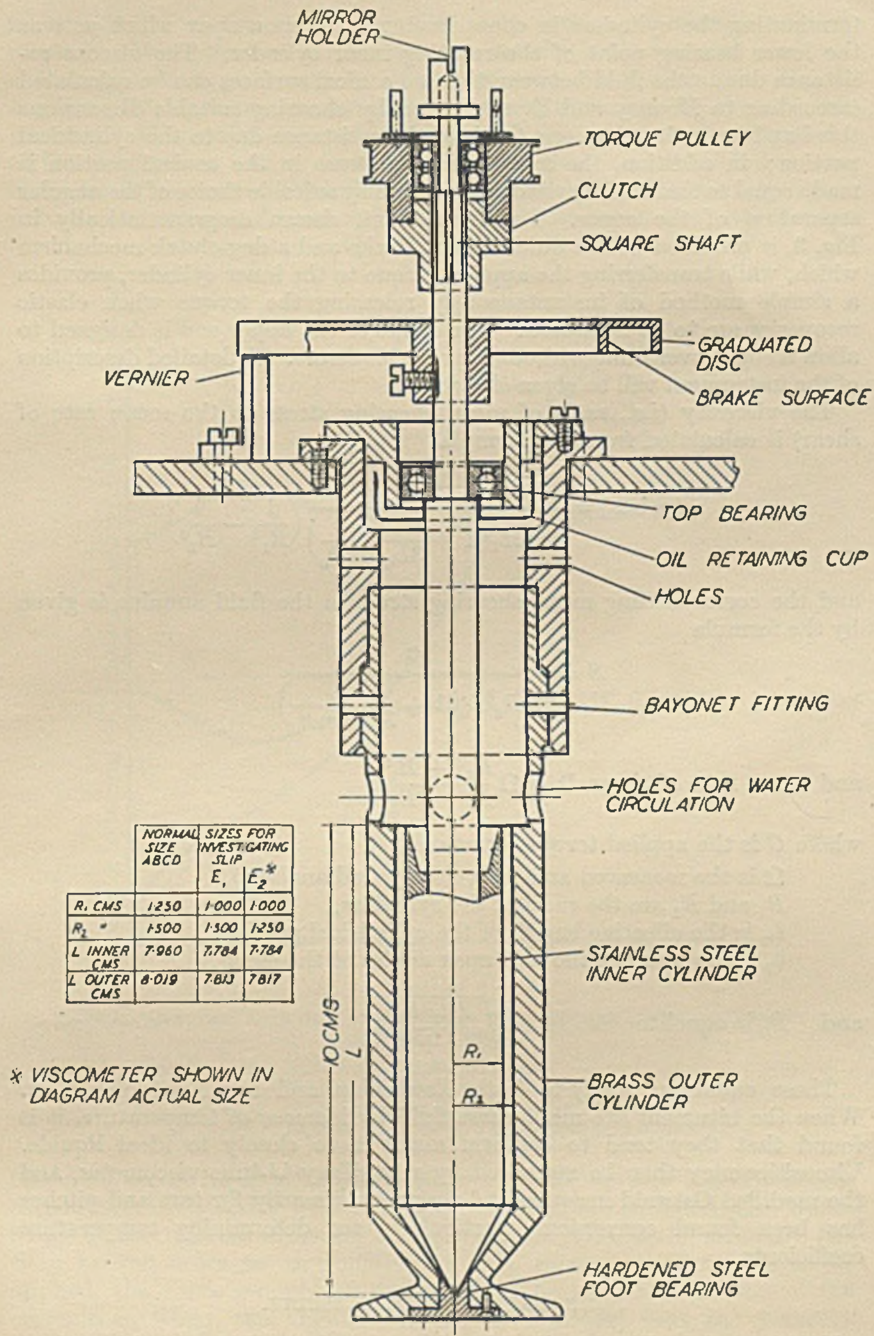
* Roller distinguishes between plasticity, which depends on the actual magnitude of the deformation, and plastic flow, which depends on the rate of deformation.



	NORMAL SIZE ABCD	SIZES FOR INVESTIGATING SLIP	
		E_1	E_2*
R_1 CMS	1·250	1·000	1·000
R_2 "	1·500	1·500	1·250
L INNER CMS	7·960	7·784	7·784
L OUTER CMS	8·019	7·813	7·817

FIG. 3.

CONI-CYLINDRICAL VISCOMETER.

terminating the cylinders in cones having a common apex which acts as the lower bearing point of the rotating inner cylinder. The viscous resistance due to the fluid between the two conical surfaces can be calculated (according to Mooney and Ewart [8]), and by choosing suitable dimensions this has been reduced to one tenth of the resistance due to the cylindrical portion; in addition, the mean shearing stress in the conical portion is made equal to that in the cylindrical portion by suitable choice of the angular separation of the cones. The instrument, shown diagrammatically in Fig. 3, is provided with a quick release brake and a dog-clutch mechanism which, while transferring the applied torque to the inner cylinder, provides a simple method of instantaneously releasing the torque when elastic recoveries are to be measured. The shape of the upper end is designed to allow a slight overfilling without appreciable errors. A detailed description of the instrument will be given elsewhere.

The viscosity (*i.e.*, ratio of mean shearing stress to the mean rate of shear) is calculated from the formula

$$\eta \text{ (poises)} = \frac{G}{4\pi\Omega L_0\left(1 + \dfrac{R_0}{3L_0 \sin\theta_0}\right)}\left(\frac{1}{R_1^2} - \frac{1}{R_2^2}\right)$$

and the corresponding mean shearing stress in the fluid annulus is given by the formula

$$S = \frac{G}{2\pi R_0^2 L_0\left(1 + \dfrac{R_0}{3L_0 \sin\theta_0}\right)}$$

and mean rate of shear $D = \Omega\dfrac{R_2^2 + R_1^2}{R_2^2 - R_1^2}$

where G is the applied torque (dyne cm.),

Ω is the measured angular velocity (radians/sec.),

R_1 and R_2 are the radii of the cylinders,

L_0 is the effective length of the cylindrical portion,

θ_0 is the mean of the half apex angles of the cones,

and R_0 is equal to $\sqrt{\dfrac{2R_1^2R_2^2}{R_1^2 + R_2^2}}$

These equations apply to both Newtonian and non-Newtonian flow. When the bitumens are made more fluid by increase of temperature, it is found that they tend to conform much more closely to ideal liquids. Viscosities may then be measured by a capillary U-tube viscometer, and the modified Ostwald instrument [9] designed primarily for tars and pitches has been found convenient, particularly for determining temperature coefficients.

Some Experimental Results.

No bitumen so far examined has been found to possess a yield value, whatever the constant shear stress applied, and after sufficient time the inner cylinder of the viscometer ultimately attains a constant angular rotation. When the load is removed the elasticity of the bitumen produces a recovery. A typical angular rotation-time curve is shown in Fig. 4, and indicates the four processes which operate during the flow of the material. The small initial curved portion *AB* arises from elastic elongation of the bitumen as well as from some viscous flow, and is related to the final elastic recovery. With fluid binders this elastic fore-effect occupies only a few seconds of time and is scarcely noticeable, but with harder binders it occurs for a rather longer time. The section *BC*, which indicates a reduction in viscosity with continued working, is associated with thixotropy or the internal structure of the material. When the structure has been broken down to an equilibrium state corresponding to the stress applied, the curve straightens out (*CD*). It is from this portion of the curve (*i.e.*, where the angular velocity is constant) that the viscosity (applied stress/rate of strain) is calculated for the particular shearing stress applied. The elastic recovery, after removal of the applied stress, is

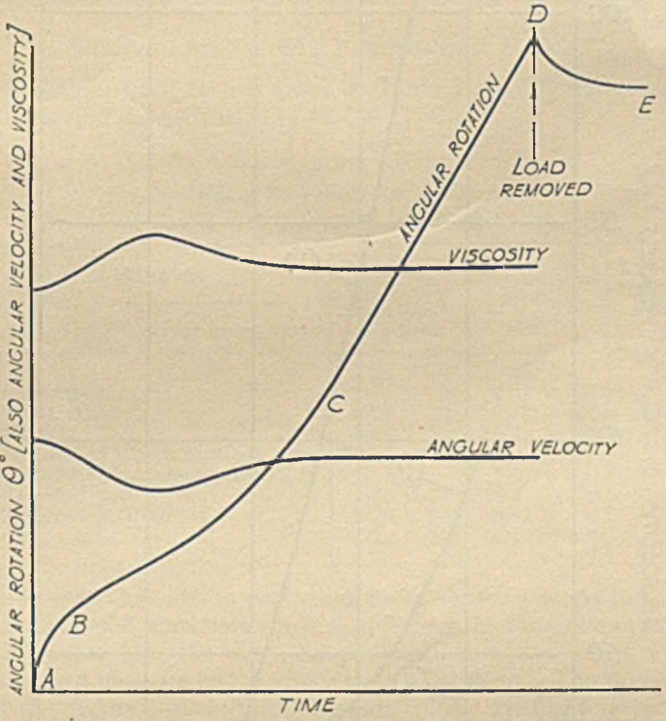


FIG. 4.

TYPICAL ANGULAR ROTATION/TIME CURVES FOR BITUMEN UNDER CONSTANT SHEARING STRESS.

Section AB. Initial Elastic Fore-Effect.
,, BC. Thixotropic Region.
,, CD. Final Constant Angular Velocity Region.
,, DE. Elastic Recovery. [Exaggerated Angle Scale.]

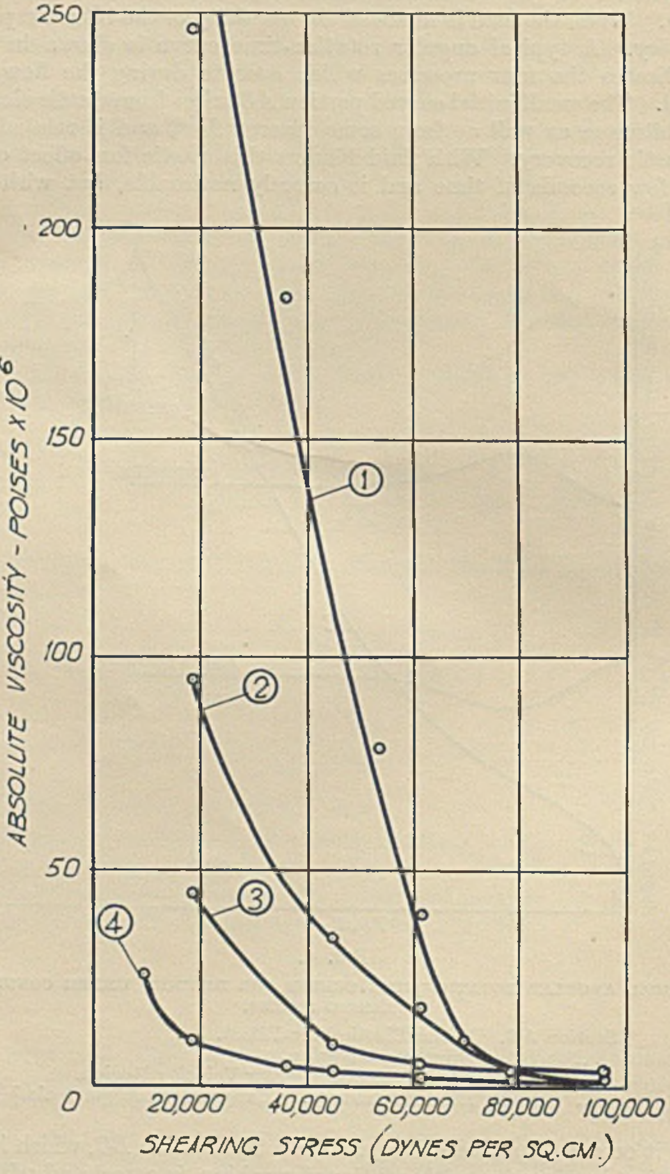


FIG. 5.

EFFECT OF SHEARING STRESS ON VISCOSITY OF E, AIR-BLOWN BITUMEN, AT DIFFERENT TEMPERATURES.

(1) Temperature 30·7° C.	(3) Temperature 44·9° C.
(2) Temperature 40·2° C.	(4) Temperature 49·2° C.

represented by DE. The corresponding angular velocities and apparent viscosities are also shown.

The viscosity of each material has been determined over a range of shearing stresses and temperatures. As previously stated, the viscosities vary with the shearing stress. An extreme case is shown in Fig. 5, in which the viscosity of the blown Mexican bitumen, E, is plotted against the corresponding shear stress at four temperatures from 30° C. to 49° C. The other bitumens have shown variations of this type, but to a less degree; the Californian bitumen, A, shows the least variation with stress.

SIGNIFICANCE OF THE PENETRATION VALUE.

The viscosities at 25° C. are given in Table I for different bituminous binders all having a penetration of 65 (at 25° C.).

TABLE I.

Viscosity of 65 *Penetration Bitumens.*

(Measured with Ostwald type Viscometers.)

Type of Bitumen.		Viscosity at 25° C. (extrapolated) in poises.	Viscosity at 40° C. in poises.	Logarithmic temperature coefficient "n."
Code.	Source.			
D	Miri	$1·28 \times 10^6$	$3·55 \times 10^4$	12·0
A	Californian	$1·70 \times 10^6$	$4·87 \times 10^4$	11·9
B	Venezuelan	$2·64 \times 10^6$	$9·12 \times 10^4$	11·2
C	Mexican	$3·92 \times 10^6$	$14·3 \times 10^4$	11·1
F	Mixture of Blown Mexican 44% and 200 Pen. Mexican 56%	$22·1 \times 10^6$	$57·9 \times 10^4$	12·2
H	Trinidad A.C. 5A	$4·66 \times 10^6$	$15·9 \times 10^4$	11·3
I	Trinidad A.C. 5B	$2·78 \times 10^6$	$8·91 \times 10^4$	11·5
J	Cuban A.C.	$44·7 \times 10^6$	$84·1 \times 10^4$	13·3

It will be seen that at the particular mean shearing stress in the viscometers the extreme materials show a difference in viscosity of 35 times. These differences indicate that the penetration measurement has little significance as a measure of the viscosity of a bitumen. The precise depth to which the needle will sink in 5 seconds will be greatly affected by the degree of non-Newtonian flow, and will also depend on the thixotropic, elastic, and adhesive properties. With this instrument the effect of these properties is exaggerated in relation to that of the viscosity, and with some bitumens will have a predominating influence on the measurement. Further, besides the large change in stress which occurs during a measurement, a low-penetration bitumen is tested under much higher stresses than a high-penetration bitumen. The penetration test may therefore be quite misleading if it is used alone for comparing one bituminous material with another.

PLASTIC PROPERTIES.

It is found that for most bitumens the relation between D (rate of shear) and S (shearing stress) may be expressed by the empirical equation

$$D = \frac{1}{\eta'} S^p \quad . \quad . \quad . \quad . \quad . \quad (1)$$

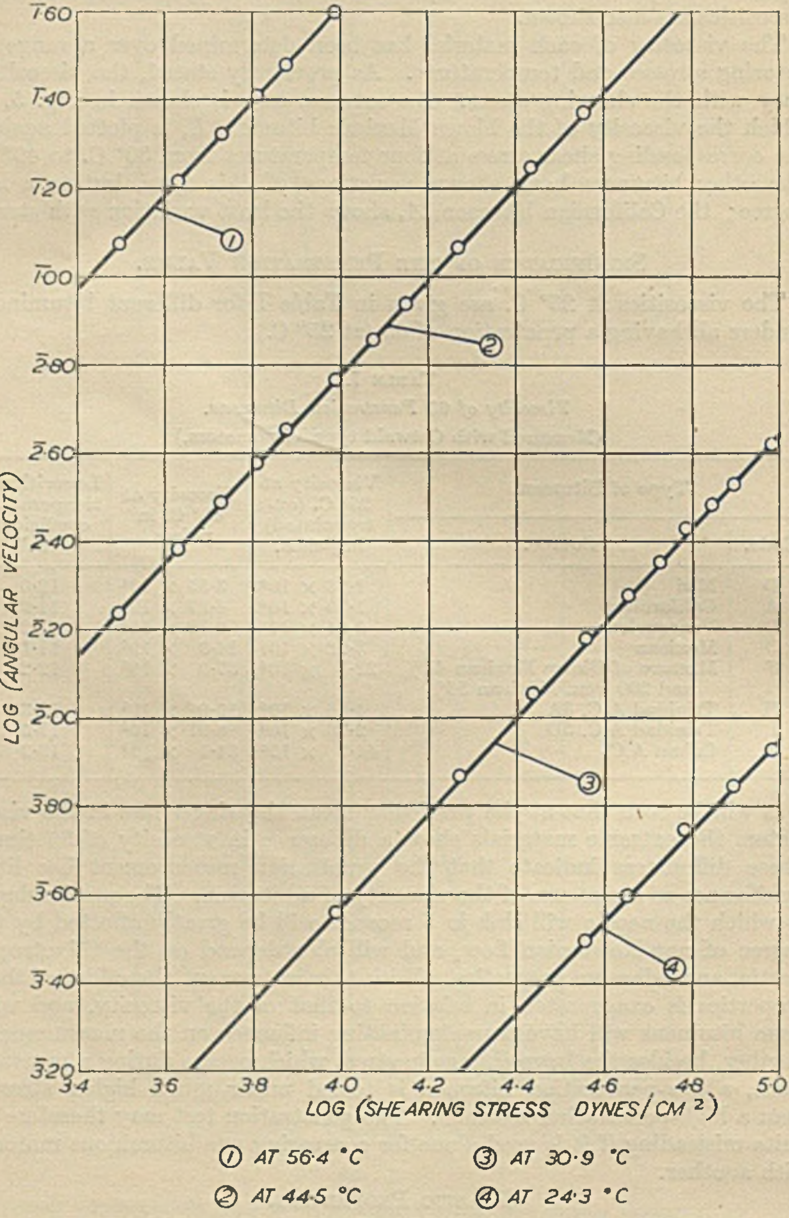


Fig. 6.

RELATION BETWEEN ANGULAR VELOCITY AND SHEARING STRESS FOR I, TRINIDAD ASPHALT 5B, AT DIFFERENT TEMPERATURES.

The results from the " plastic " air-blown bitumen, however, do not fit even this equation.

Fig. 6 shows the straight-line relation obtained on plotting log. angular velocity against log. shearing stress for the Trinidad A.C. 5B (I), at temperatures from 24° to 56° C. The slope of the lines gives the value of the index p. Other writers [10] have referred to the deviation from ideal flow exhibited by bituminous materials, but no method based on fundamental considerations has yet been proposed for defining the degree of plasticity. The " penetration index " used by Pfeiffer and Van Doormal [11] is largely determined by the plastic properties of the material. The use of the index p in the above equation as a " plastic flow index " provides for the time being a method, based on the fundamental flow properties, of expressing the degree of plasticity where this is considered as the divergence from ideal viscous flow. The values of p for the different materials are given in Table II, which contains other data on these materials.

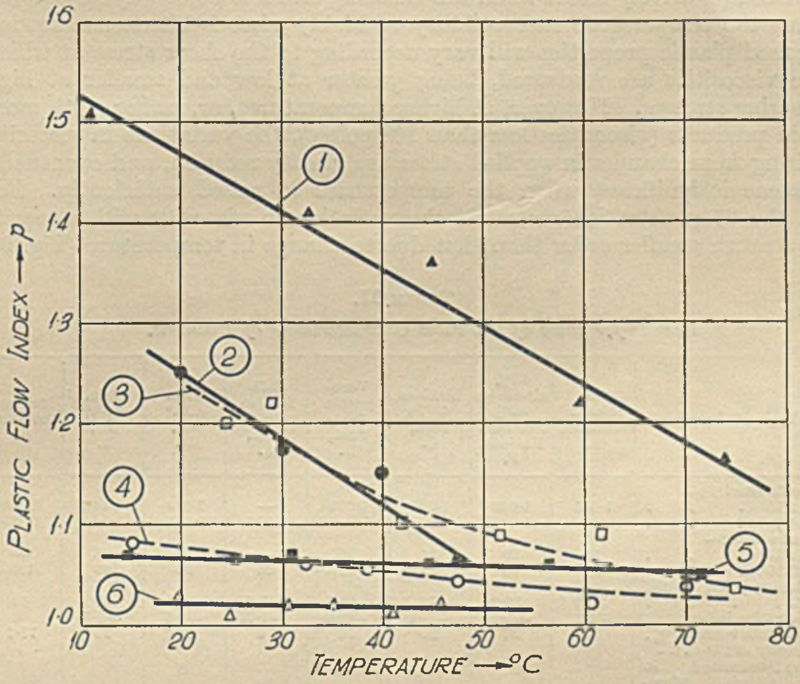


FIG. 7.

EFFECT OF TEMPERATURE ON PLASTIC FLOW INDEX OF 65 PENETRATION BITUMENS.

1. Mixture of Blown Mexican and Spramex. F.
2. Mexican. C.
3. Trinidad A.C. 5A. H.
4. Venezuelan. B.
5. Trinidad A.C. 5B. I.
6. Californian. A.

As noted by previous writers, the deviation from ideal flow decreases as the materials are made more fluid by rise of temperature. The effect of temperature on the plastic flow index of the materials is shown in Fig. 7.

EFFECT OF TEMPERATURE ON VISCOSITY.

All bituminous materials are characterized by the very large changes in viscosity produced by changes in temperature; this property is of vital importance in the use of the materials.

The curves given in Fig. 5 show values of the viscosity of *E*, the blown bitumen, obtained for a range of shearing stresses at temperatures between 30° and 49° C. The change in viscosity produced by this change in temperature is large when the shearing stress is 20,000 dynes/sq. cm., and comparatively small when the shearing stress is 80,000 dynes/sq. cm. Thus the temperature susceptibility of highly viscous bitumens showing marked plastic properties will vary according to the shear stress at which the viscosities are measured, being greater at low and smaller at high shearing stresses. However, at higher temperatures, or, rather, with more fluid products (viscosities less than 10^4 poises), the variations in viscosity arising from changes in applied stress are greatly reduced, and eventually become insignificant when the temperature is raised sufficiently. For all the 65 penetration materials the variation in viscosity with stress is of a much smaller order than that due to change in temperature (Fig. 9).

TABLE II.

Results for some of the Flow Characteristics of Bitumen.

Type of bitumen.	Air-blown Mexican, E.	44% air-blown 56% 200 Pen. Mexican, F.	Mexican 60/70 Pen., C.	Venezuelan 60/70 Pen., B.	Californian 60/70 Pen., A.	Trin. A.C.* 5A, H.	Trin. A.C.† 5B, I.	Mexican 200 Pen., G.
Specific gravity:—								
At 15° C. . .	1·051	1·042	1·045	1·025	—	1·244	1·164	1·035
At 25° C. . .	—	1·028	1·039	—	1·015	1·237	1·152	1·025
Penetrations:—								
At 15° C. . .	13	29	26	26	—	24	28	—
At 25° C. . .	22	60	63	64	66	59	66	199
Softening point, R. and B.	85·5	57·2	52	49·7	45·6	51·1	66	40
Penetration index .	+3·2	+1·2	−0·1	−0·6	−1·75	−0·5	−1·5	0
Asphaltene content, % .	37	27	20	13	4	21 ‡	15 ‡	17·7
Viscosity at 25° C.:—								
(*a*) Determined in Ostwald viscometer mean stress about 3,000 dynes/sq. cm. .	—	$22{\cdot}1 \times 10^6$	$3{\cdot}92 \times 10^6$	$2{\cdot}64 \times 10^6$	$1{\cdot}70 \times 10^6$	$4{\cdot}66 \times 10^6$	$2{\cdot}78 \times 10^6$	$2{\cdot}98 \times 10^5$
(*b*) Determined in Conicylindric viscometer mean stress 36,130 dynes/sq. cm. .	$3{\cdot}0 \times 10^8$	$5{\cdot}64 \times 10^6$	$3{\cdot}47 \times 10^6$	$2{\cdot}11 \times 10^6$	$1{\cdot}91 \times 10^6$	$3{\cdot}65 \times 10^6$	$1{\cdot}94 \times 10^6$	$2{\cdot}32 \times 10^5$
Log temperature coefficient . . .	—	11·1	11·4	11·6	11·8	11·0	10·6	9·7
Plastic flow index (*p*) at 25° C. . . .	3	1·44	1·22	1·10	1·02	1·2	1·08	1·19
Maximum elastic recovery, degrees in Couette viscometer at 25° C. . . .	8	5	4	2	0·5	1	1	3·7

* Trinidad A.C. 5A consists of 83·5% of Trinidad Epure and 16·5% of Flux Oil.

† Trinidad A.C. 5B consists of 49·5% of Trinidad Epure, 5% of Flux Oil, 45·5% 200 pen. Venezuelan Bitumen.

‡ Estimated on the extracted bitumen.

Fig. 8 shows the values of log. viscosity over a temperature range from 25° C. to 90° C. for six bitumens (each having a penetration of 65 at 25° C.)

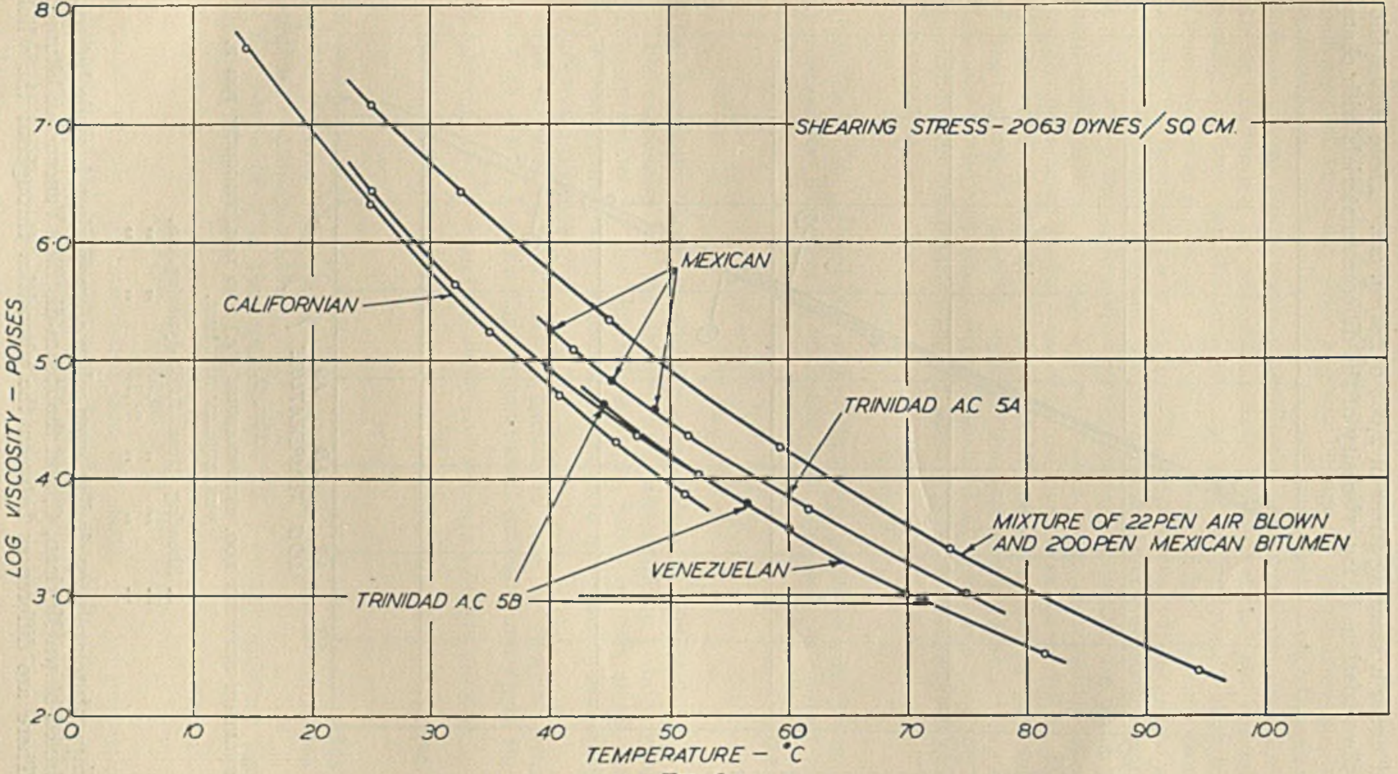


Fig. 8.

EFFECT OF TEMPERATURE ON LOG. VISCOSITY OF BITUMENS (65 PENETRATION).

tested under a shearing stress of 2,063 dynes/sq. cm. These curves show that the variations in log. viscosity of the different materials with change

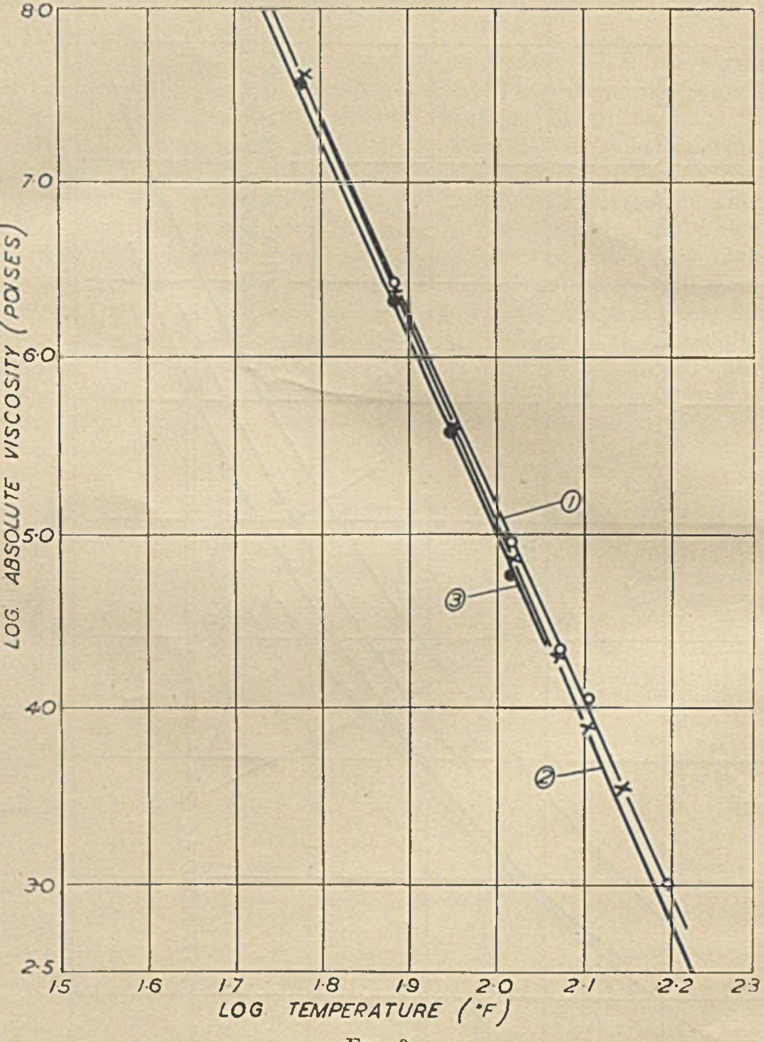


FIG. 9.

RELATION BETWEEN LOG. TEMPERATURE (°F.) AND LOG. VISCOSITY FOR B, VENEZUELAN BITUMEN.

1. Shearing stress 2,063 dynes/sq. cm.
2. ,, ,, 9,730 ,, ,,
3. ,, ,, 36,130 ,, ,,

of temperature are very similar, even when a comparison is made between the fluxed blown Mexican, C, and the steam-distilled Venezuelan bitumen, B. There are differences between the viscosities throughout the whole range, but these arise mainly from the initial differences in viscosity at 25° C. Curves of this type provide no means of defining the temperature coefficient of viscosity, since a given change in temperature produces a greater change in viscosity at low temperatures than at high temperatures. Various viscosity/temperature coefficients have been proposed for bituminous materials; for example, Traxler [12] assumes that the curved lines relating log. viscosity and temperature (° C.) are sufficiently straight over a small range to define an " Asphalt Viscosity Index " as the percentage decrease in viscosity for 1° C. rise in temperature. In order to obtain a single numerical coefficient for extrapolation and comparison purposes, it is necessary to use functions of viscosity and temperature which give a linear relation over as large a temperature range as possible. Accurate straight lines have so far been obtained over a range of 70° C. for any bituminous binders up to viscosities of 10^7 poises on plotting the logarithm of the apparent viscosity against the logarithm of the temperature Fahrenheit, the viscosities being measured at the same shearing stress throughout the temperature range; some typical curves are given in Fig. 9. The equation

$$\log. \eta = a - n \log. T,$$

which also holds for coal-tars and pitches, thus provides a simple empirical expression for variation of viscosity with temperature defined by one constant, viz. :—

$$n = \frac{\log. \eta_1 - \log. \eta_2}{\log. T_2 - \log. T_1} \quad . \quad . \quad . \quad . \quad (2)$$

n has been called the " logarithmic temperature coefficient."

This expression for the temperature susceptibility, while inaccurate for extrapolation to the high temperatures necessary for mixing, is valid for a temperature range sufficient to indicate the relative susceptibilities of different bitumens.

The equation $\eta = aT^{-n}$ is a particular case of Slottes' formula [13] $\eta = C/(b + t)^n$, where t is the temperature Centigrade, and where the value of b becomes $\frac{5 \times 32}{9}$ and the other contents are suitably chosen.

The theoretical formula of Andrade [14] and Sheppard [15]

$$\eta = Ae^{-k/\theta}$$

where θ is absolute temperature, which was derived for pure monomolecular liquids, would not be expected to hold for the complicated mixtures which constitute bitumens and tars.

The values of n in the equation $\eta = aT^{-n}$ for the different bitumens are given in Table II.

ELASTIC PROPERTIES OF BITUMENS.

It has already been mentioned that the elastic or solid properties of a bitumen are most prominent when the stress is rapidly applied or varied, but, even when a bitumen has been sheared slowly under constant stress, elastic recovery occurs on the sudden removal of the stress. The amount

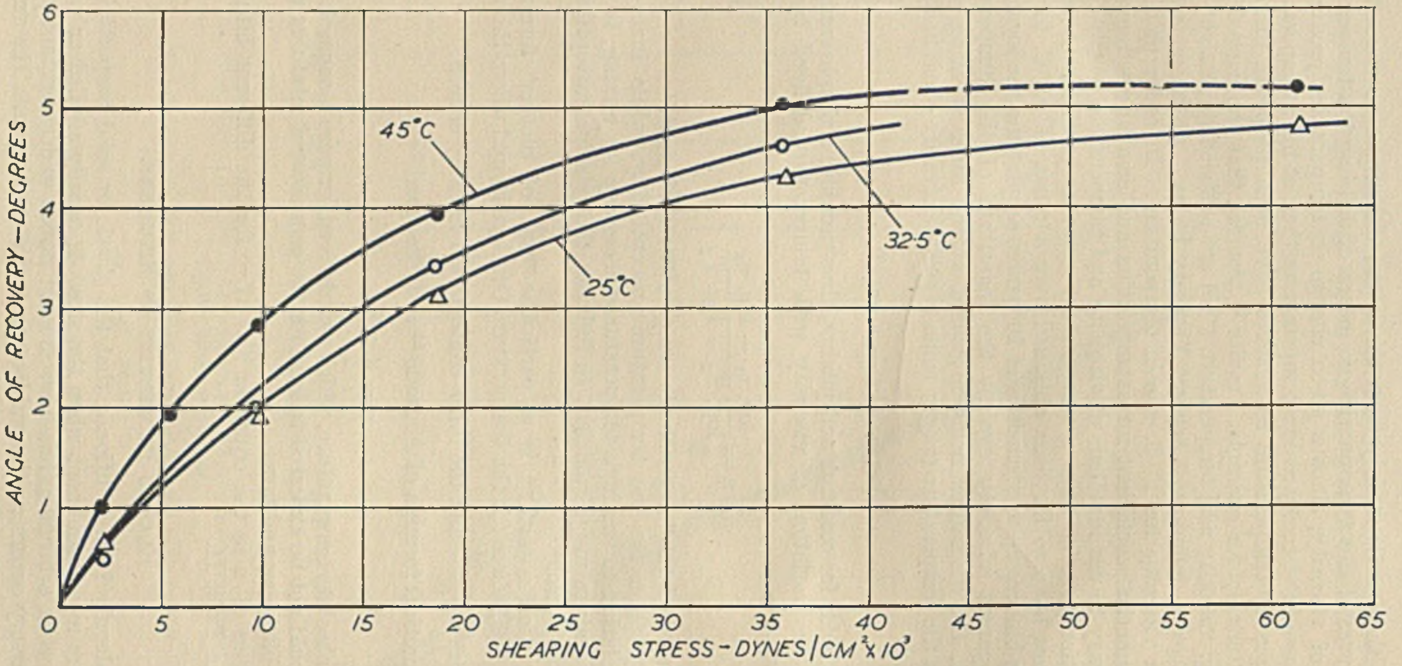


FIG. 10.

RELATION BETWEEN SHEARING STRESS AND TOTAL ELASTIC RECOVERY OF F, 65 PENETRATION MIXTURE OF BLOWN AND 200 PENETRATION MEXICAN BITUMEN.

of recovery depends on the stress applied and the degree to which the material has been previously sheared. For a given stress, the recovery increases to a definite maximum value with increase in the previous shear. Fig. 10 shows the relation between the applied stress and the maximum recovery for the fluxed blown bitumen, *F* (65 pen.).

From the angular recovery values which occur on the removal of definite applied stresses an apparent rigidity modulus, taken as the ratio of shear stress to shear recovery, has been calculated for various values of the shearing stress. Allowing for the dimensions of the viscometer and assuming that the recovery corresponds to a simple shear motion with no flow, the shear recovery is equal to five times the measured angular recovery (α) of the inner cylinder. These calculated values are tabulated in Table III.

TABLE III.

Apparent Moduli of Rigidity for Fluxed Blown Bitumen F.

Temperature.	Shearing stress (dynes/sq. cm.) S.	Angle of recovery (degrees) a.	Apparent modulus of rigidity (dynes/sq. cm.) $S/5a$.
25° C.	$1{\cdot}5 \times 10^3$	0·4	$4{\cdot}3 \times 10^4$
,,	$10{\cdot}0 \times 10^3$	2·0	$5{\cdot}7 \times 10^4$
,,	$17{\cdot}5 \times 10^3$	3·0	$6{\cdot}8 \times 10^4$
,,	$30{\cdot}0 \times 10^3$	4·0	$8{\cdot}6 \times 10^4$
,,	$47{\cdot}5 \times 10^3$	4·6	$11{\cdot}9 \times 10^4$
45° C.	$2{\cdot}5 \times 10^3$	1·15	$2{\cdot}5 \times 10^4$
,,	$5{\cdot}0 \times 10^3$	1·87	$3{\cdot}05 \times 10^4$
,,	$10{\cdot}0 \times 10^3$	2·85	$4{\cdot}0 \times 10^4$
,,	$20{\cdot}0 \times 10^3$	4·02	$5{\cdot}4 \times 10^4$
,,	$35{\cdot}0 \times 10^3$	4·96	$8{\cdot}0 \times 10^4$

Fig. 10 shows that for the 65 penetration fluxed blown bitumen, *F*, a change of temperature from 25° to 45° C. produces little change in the elastic recovery. It has been found that for the bitumens investigated there is a temperature range within which the recovery is a maximum; above and below this range the recovery diminishes, and at high temperatures, at which the materials are quite fluid, the elastic recovery eventually disappears. Over the range of temperature from 25° to 45° C. the change in the apparent rigidity modulus of the bitumen is of a much lower order than the change in viscosity. As would be expected from consideration of viscous internal damping, the rate of recovery increases as the temperature of the bitumen is raised or its viscosity reduced. The values for the apparent rigidity modulus (2 to 12×10^4 dynes/sq. cm.) are of a lower order than values of the rigidity modulus of bitumen obtained by dynamic methods (*e.g.*, Lonsdale and Wilson,[16] 10^8 dynes/sq. cm.).

COMPARISON OF BITUMENS.

The results given in Table II show that the bitumens so far investigated differ chiefly in their plastic and elastic properties, and the temperature differences found necessary in practice in the use of the materials appear to be due primarily to differences in these properties, and to the difference in initial viscosity of the bitumens arising from the adoption of a standard penetration to which the various materials must conform.

There is little difference between the logarithmic temperature coefficients of viscosity, although the Californian bitumen, *A*, has the highest coefficient, and the blown bitumen, *F*, the least. These facts are substantially in agreement with the conclusions of Pfeiffer and Van Doormal (*loc. cit.*), and the explanation put forward by these authors to account for the differences in rheological properties of different types of bitumen are so far supported by the present results.

Rheology of Asphaltic Road Mixtures.

The flow properties of a bitumen-aggregate mixture are directly influenced by the flow properties of the bituminous binder. The large amount of work on measuring the mechanical properties of such mixtures[17] done by earlier investigators is, on examination, usually found to comprise the measurement of flow properties under various arbitrary conditions of stress.

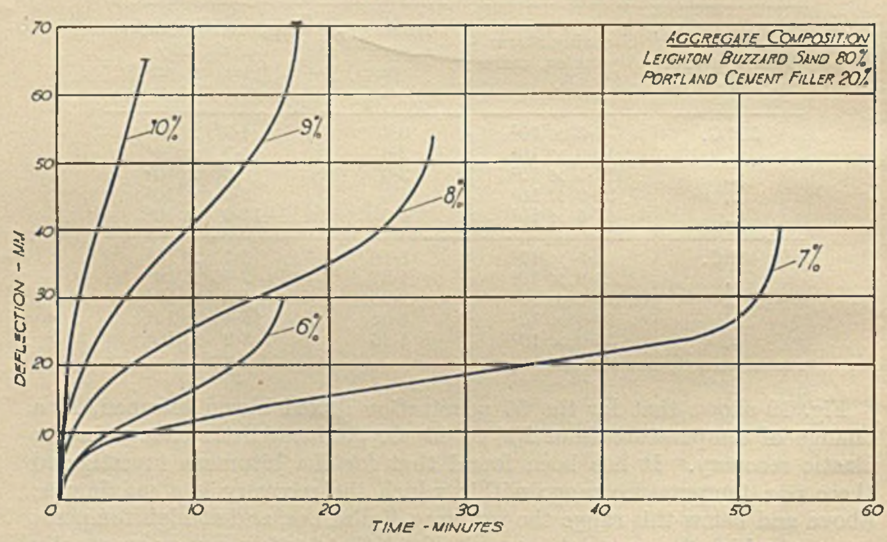


FIG. 11.

EFFECT OF BINDER CONTENT ON THE DEFLECTION OF BEAMS OF SAND ASPHALT.

Storage time 8 days. Temperature of test 25° C. Dimensions of beams 10″ × 2″ × 1″.
Binder—Trinidad Asphaltic Cement—Type 5A. Percentage of Soluble Bitumen Marked on Curves.

Among a considerable number of tests investigated those selected for the present purpose are the beam and tensile tests. The methods and technique adopted for preparing and testing specimens have been described elsewhere.[18, 19] Although for certain purposes the two tests give the same information, the tensile test has the advantage that the results may be expressed quantitatively, are independent of the dimensions of the specimen, and that the material is subjected to a constant uniform stress or rate of strain. The experimental procedure has been to obtain the deformation-time curves given by roller-compacted rectangular specimens. Two fundamental characteristics are thus obtained—namely, the rate of flow under a known stress and the extensibility or total flow before failure. Information on the flow properties of the mixtures involves a study of the variations of these quantities with stress, temperature, and age.

Some typical deformation-time curves are shown in Fig. 11. The resulting deformation of the tensile specimen may be considered as due to two shear stresses of one-third the tensile stress.[20] The rate of elongation may be shown to be equal to the rate of shear strain.

The ratio of the stress to the slope of the straight-line portion of the curves (the minimum rate of deformation) may be considered a measure of the viscosity of the material. On this basis, from the curves shown in Fig. 11, the specimen containing 7 per cent. of bitumen exhibits the maximum resistance to deformation, and from this point of view 7 per cent. may be considered the optimum binder content for the particular aggregate. This optimum binder content has been determined for each bitumen-aggregate mixture referred to below.

Effect of Stress on Rate of Strain.

In Fig. 12 some typical stress–rate of strain curves are shown for specimens of sand asphalt, each made with its optimum binder content. When, from such results, log. stress is plotted against log. minimum rate of strain, straight lines are obtained, as shown in Fig. 13. Thus these results show that the relation between stress and minimum rate of strain may be expressed by the equation

$$R = KS^{P} \quad . \quad . \quad . \quad . \quad . \quad (3)$$

where R is the minimum rate of strain,
S is the applied stress,
K and P are constants.

In Fig. 13 the slope of the straight lines is constant over the temperature range investigated. P may thus be considered to be a characteristic of the material representing the divergence of the flow from that expressed by a linear relation between stress and rate of flow. By analogy with the equation applicable to bitumens, P may therefore be termed the " plastic flow index " of the bitumen-aggregate mixture. The value of the constant K in the above equation represents the minimum rate of deformation at unit stress, and is thus a measure of the " mobility " of the material (*i.e.*, rate of flow/unit stress).

Effect of Temperature on Rate of Strain.

It has been found that a straight-line relation exists between log. K and temperature over a temperature range of about 25° C.; Fig. 14 shows

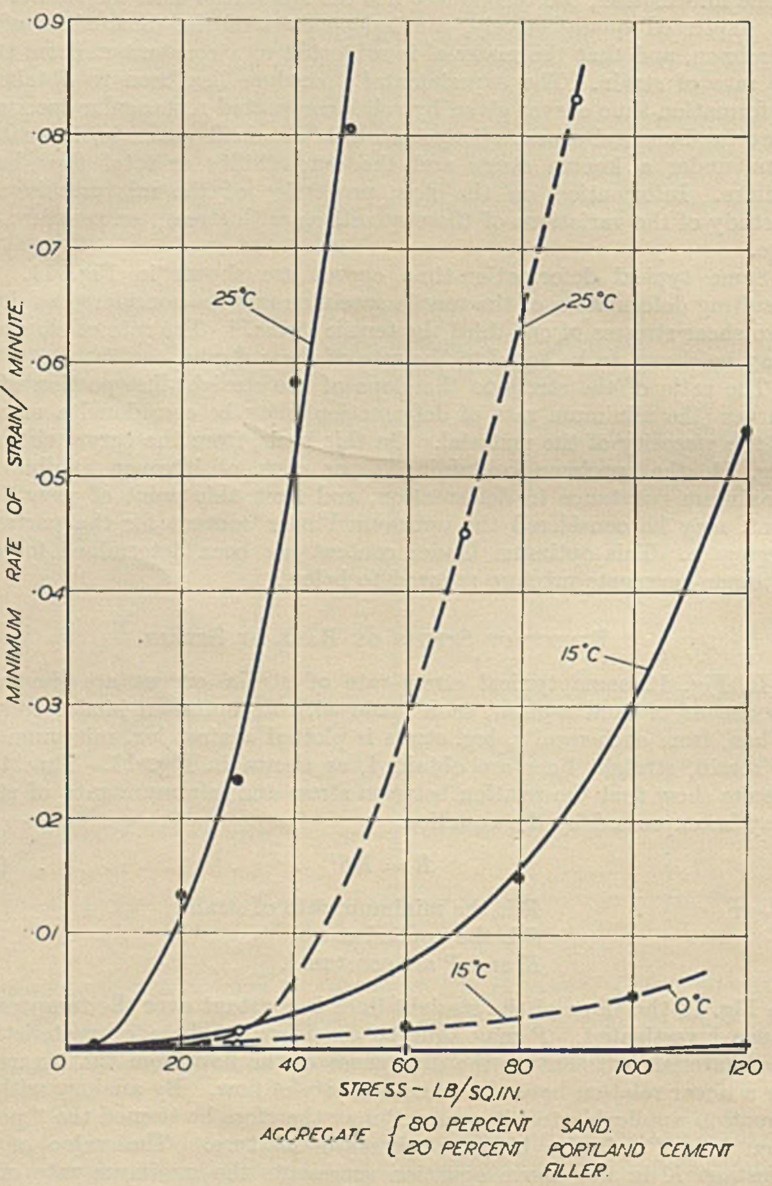


FIG. 12.

RELATION BETWEEN STRESS AND RATE OF STRAIN FOR SAND ASPHALTS AT VARIOUS TEMPERATURES.

— — — Laboratory Prepared Material containing Venezuelan Bitumen.
———— Material from Public Road.

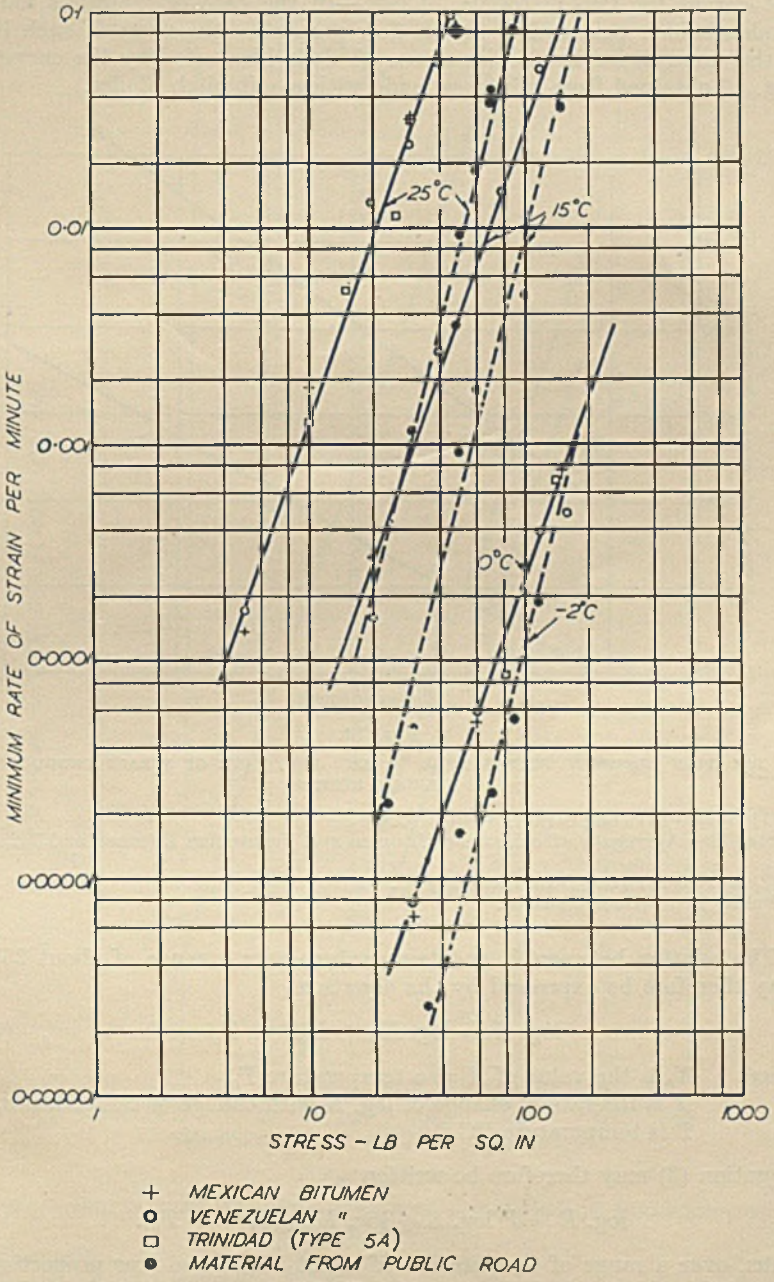


Fig. 13.

RELATION BETWEEN LOG. STRESS AND LOG. MINIMUM RATE OF STRAIN OF SAND ASPHALT AT VARIOUS TEMPERATURES.

the curves for two materials. (*Note.*—In the case of materials having binders which possess Newtonian flow properties the slope of such lines is the same as for the binder alone. This is illustrated by the curves in Fig. 15 obtained from mixtures made with a soft pitch binder.)

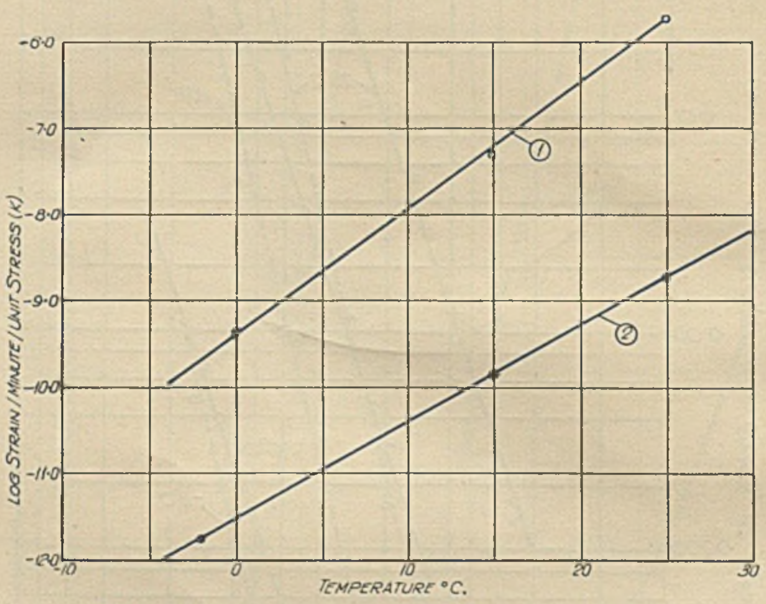


Fig. 14.

RELATION BETWEEN TEMPERATURE °C. AND LOG. RATE OF STRAIN PRODUCED BY UNIT STRESS

(1) $N = 0{\cdot}147$ (Log Strain/Minute)/°C.
Standard Aggregate with Mexican Bitumen and Venezuelan Bitumen and Trinidad 5A.
(2) $N = 0{\cdot}111$ (Log Strain/Minute)/°C.
Public Road (Good Section).

The relation between K and temperature over a range of about 25° C. may therefore be expressed by the equation

$$\log. K = \log. K_0 + N(T - T_0) \quad . \quad . \quad . \quad (4)$$

where K_0 is the value of K at a temperature T_0,
N is the rate of change of log. K with change of temperature,
T is temperature (°C.).

Equation (3) may therefore be written

$$\log. R = P \log. S + \log. K_0 + N(T - T_0).$$

Thus, over a range of temperature of about 25° C. the flow properties at the minimum rate of deformation of a bitumen-aggregate mixture under conditions of constant tensile stress may be expressed by the constants P, K_0, N, and the extensibility or percentage strain at failure.

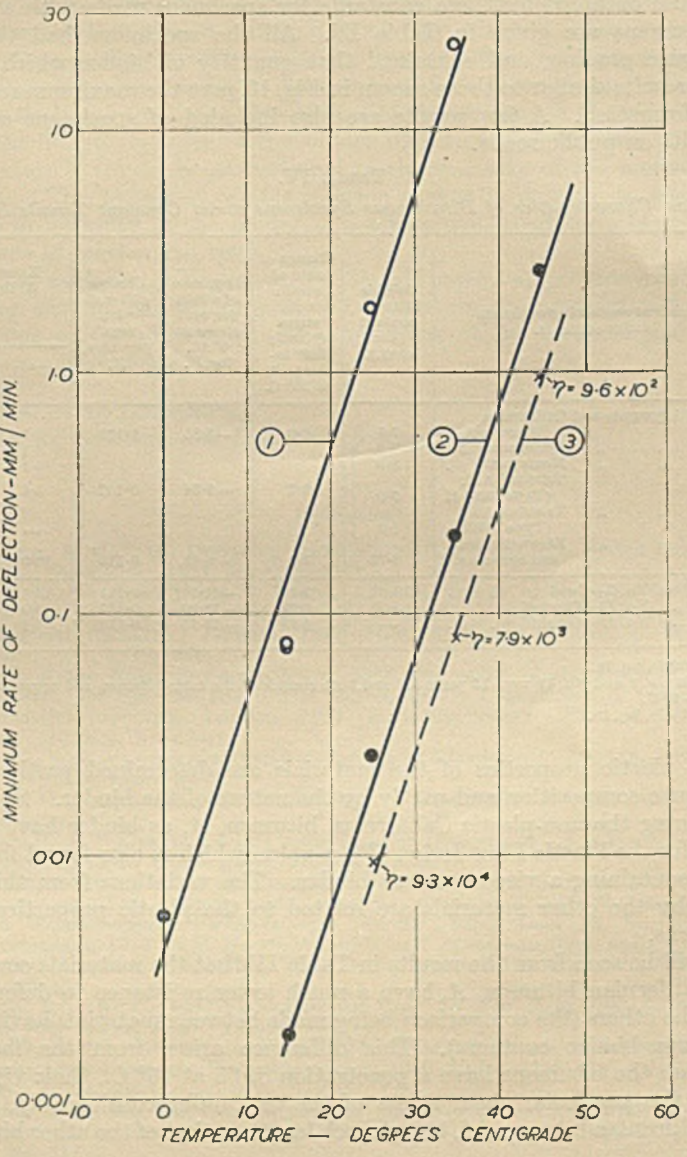


FIG. 15.

EFFECT OF TEMPERATURE ON MINIMUM RATE OF DEFLECTION OF BEAMS AND ON VISCOSITY η OF BINDER.

(1) Sand 80% / Portland Cement 20% } 10% Binder.

(2) Sand 60% / Limestone Dust 40% } 11% Binder.

(3) Temperature Fluidity Line for the 300 Pen. Pitch Binder.

Values obtained for these constants for specimens made with a variety of bitumens are given in Table IV. All the specimens had the same aggregate grading, and contained that quantity of binder which from a set of results similar to those shown in Fig. 10 gave the maximum resistance to deformation. A few results are also included of specimens cut from asphalts on public roads.

TABLE IV.

Flow Characteristics of Bituminous Specimens under Constant Tensile Stress.

Specimens containing optimum binder contents.	Soluble bitumen content (per cent.).	Change of rate of strain with stress (plastic flow index), *P*, at 25° C.	Log. rate of strain for unit stress at 0° C., log. *K*.	Change of log. *K* with temperature, *N*.	Extensibility, 50 lb./sq. in. *E*.	
					25° C.	0° C.
Standard Aggregate and Californian Bitumen A .	7·5	2·0	−8·35	0·170	8·7	7·3
" " " Venezuelan B	7·5	2·8	−9·34	0·147	6·1	6·0
" " " Mexican C .	8·0				7·1	6·2
" " " Trinidad A.C. (Type 5A) H	7·0				3·0	3·1 [*]
" " " Trinidad A.C. (Type 5B) I	7·0				—	—
" " " Blown Mexican and Spramex. F	8·75	3·2	−9·42	0·115	10·0	7·0
[†] Public Road No. 2—Good . . .	10·25	3·91	−11·78 [‡]	0·111	4·0	1·6 [‡]
[†] " " No. 12—Cracked . .	8·70	3·95	−12·95	0·137	2·0	0·5 [§]
" " No. 22—Cracked . .	—	5·28	−16·25	0·129	1·1	0·15 [§]

[*] At 100 lb./sq. in.

[†] Roads No. 2 and No. 12 were 13 years old and both contained the same bitumen and aggregate.

[‡] At −2° C.

[§] At 150 lb./sq. in.

The plastic properties of the materials are determined partly by the aggregate composition and partly by the nature of the binder. Specimens containing the non-plastic Californian bitumen, *A*, as binder have a value of 2·0 for the Plastic Flow Index (*P*), a value which is also found for specimens containing a viscous tar as binder. The variations from this value given by the other materials are related to the plastic properties of the bitumens.

It will be seen from the results in Table IV that the materials containing the Californian bitumen, *A*, have a much lower resistance to deformation than the others (the comparison being made between materials having their optimum binder contents). This difference arises from the fact that although the bitumens have a penetration of 65 at 25° C., their viscosities under the particular shear stress of the test differ considerably, that of the Californian bitumen, *A*, being much less than that of the other bitumens.

CONCLUSIONS.

The examples given in this paper of the results of the investigation of the fundamental flow properties of bituminous materials illustrate the progress made in understanding the problems.

The flow properties of a bitumen-aggregate mixture are determined by the nature and grading of the aggregate and by the quantity, the viscosity, and the nature of the binder. The more plastic the binder, the greater is the value of the plastic flow index of the mixture. The logarithmic temperature coefficient of flow of the mixture (defined as $\Delta \log. r/\Delta \log. T$) is equal to that of the binder. The fact that, for a given change in temperature, the relative change in rate of flow of the mixture is the same as that produced in the viscosity of the binder indicates that the rate of flow of the mixture is inversely proportional to the viscosity of the binder in the mixture. The existence of this relation makes it possible to follow the change in viscosity of the binder in a bituminous road-surfacing material by means of mechanical tests.

Further work on the lines described in this paper will provide information enabling the mechanical properties of mixtures to be predicted from a knowledge of the properties and proportions of the bitumen and of the aggregate constituents.

Road Research Laboratory,
Dept. of Scientific and Industrial Research.

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THE SYNTHESIS OF LUBRICATING OILS BY CONDENSATION REACTIONS.*

PART I.—THE CONDENSATION OF CHLORINATED PARAFFIN WAX WITH AROMATIC HYDROCARBONS.

By W. R. Wiggins, Ph.D., T. G. Hunter, Ph.D., M.Inst.Pet., and
A. W. Nash, M.Sc., F.Inst.Pet.

High-boiling hydrocarbons were synthesized by Friedel and Crafts in their investigations on the reaction of alkyl halides with aromatic hydrocarbons using aluminium chloride as catalyst.

This classical reaction opened a new field for the synthesis of hydrocarbons and has been used and developed extensively; but only recently has this condensation type of reaction been utilized for the production of viscous hydrocarbons of high boiling point and possessing good lubricating properties.

The Friedel–Crafts condensation has been used by Fischer [2, 3] for the production of lubricating oils from the liquid products, designated by the term "Kogasin," synthesized from water-gas by low-pressure catalysts. The fraction boiling above 220° C., essentially paraffinic in character, was chlorinated at room temperature. The chlorinated material was then mixed with aromatic hydrocarbon and anhydrous aluminium chloride, and the reaction, which commenced at room temperature, completed by heating on a water-bath. The products separated from the aluminium chloride sludge were refined with bleaching earth and vacuum distilled, the refined products varying from medium to highly viscous oils. In addition, Fischer has investigated the dechlorination of the chlorinated Kogasin in the presence of activated aluminium (aluminium mercury couple). In the preparation of the pour-point depressant "Paraflow" chlorinated paraffin wax is condensed with an aromatic hydrocarbon in the presence of aluminium chloride.

The manufacture of pour-point depressants by the condensation of chlorinated paraffin wax with cyclic hydrocarbons [5] and with hydroxy compounds [5] using an aluminium chloride catalyst has been proposed. Products, used as pour point, viscosity index, and colour improvers, have been claimed [7] by the condensation of chlorinated paraffin wax with aromatic hydrocarbons using as catalyst aluminium chloride, together with a metal chloride of the first or second groups of the periodic table. The manufacture of addition agents for improving oiliness [8] and the manufacture of lubricating oils [9] by condensing aromatics with chlorinated paraffin wax have also been suggested.

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* Paper received 6th September, 1939.

Preliminary experiments on the action of metallic aluminium on chlorinated hydrocarbons indicated that:

1. Chlorinated hydrocarbons undergo a reaction, apparently of the Friedel–Crafts type, when heated in the presence of metallic aluminium.
2. Alkyl chlorides such as amyl chloride yield viscous oils, apparently of unsaturated character.
3. Alkyl chlorides in the presence of aromatic hydrocarbons yield viscous oils.
4. Chlorinated naphthenes, such as chloro*cyclo*hexane, alone or in the presence of aromatic hydrocarbons, yield asphaltic and resinous materials.
5. Zinc also catalyses this reaction to a slight extent, but alumina and metallic tin do not induce any reaction.

From this preliminary work it was decided to investigate the synthesis of lubricating oils by the condensation of alkyl chlorides with aromatic hydrocarbons, using metallic aluminium as a catalyst.

Available data on the relationship between constitution and physical properties of hydrocarbons indicate that long paraffin chains are valuable components of lubricating oil molecules.[10, 11] For the synthesis of lubricants, therefore, it is desirable to use alkyl chlorides with long carbon chains, such compounds being conveniently prepared by the chlorination of solid paraffin hydrocarbons.

A Burmah paraffin wax, melting point 51° C., was therefore chlorinated to three chlorine contents: 10 per cent. chlorine content, corresponding analytically to monochloroparaffin; 17 per cent., corresponding analytically to dichloroparaffin, and 25 per cent., corresponding analytically to trichloroparaffin. Since chlorination does not proceed in simple and complete stages, these chlorinated waxes are probably mixtures of unchlorinated paraffins, mono-, di-, and higher chloroparaffins.

Condensation of Chlorinated Paraffin Waxes with Aromatic Hydrocarbons.

Condensation reactions with chlorinated paraffins and aromatic hydrocarbons were carried out in 5-litre, three-necked pyrex flasks fitted with reflux condenser, glass stirrer, and thermometer. The outlet tube from the top of the reflux condenser was connected to a Dreschel wash-bottle and water-pump in order to remove conveniently the hydrogen chloride fumes which were evolved in large amount during the reaction. Preliminary experiments were carried out to ascertain the proportions of chloroparaffin, aromatic hydrocarbon, and aluminium catalyst required.

Experiments with chlorinated wax (25 per cent. chlorine content) and excess benzene showed that the chloroparaffin and benzene reacted in approximately molecular proportions. Experiments with an excess of aluminium catalyst indicated that 1·4–1·5 per cent. of aluminium metal, calculated on weight of chloroparaffin, was required in the reaction. In the final procedure 500 gm. chlorinated wax, 50 gm. aromatic hydrocarbon, and 10 gm. aluminium were used.

Difficulties were encountered in the working up of the reaction product, owing to the formation of emulsions. In addition, the colour of the final product from the preliminary experiments varied from dark green to black. In the early experiments the reaction product was allowed to stand for several hours in order to settle out a lower layer of heavy sludge. The upper liquid layer was decanted, washed with water to decompose and remove aluminium chloro-complexes, then washed successively with dilute caustic soda, dilute sulphuric acid, and water. Each washing stage resulted in the formation of emulsions which were extremely persistent. In spite of repeated treatment with water, acid, and alkali, the colour of the final product was dark green or black, comparing unfavourably with refined mineral oils. This dark colour was traced to small amounts of the lower layer sludge, which remained in suspension in the upper layer. A prolonged settling period improved the colour of the final product, but centrifuging had eventually to be adopted to remove the last traces of heavy sludge. Further, it was found that percolation filtration of the water-washed product through a granular bleaching earth of the floridin type was sufficient refining treatment, replacing efficiently the alkali and acid washes, and yielding clear, light-coloured oils. The finally adopted and most satisfactory experimental procedure consisted of the following :—

In a three-necked reaction flask were placed 500 gm. chlorinated wax, 50 gm. aromatic hydrocarbon, 10 gm. aluminium metal fillings, and 500 c.c. diluent (petroleum ether or refined kerosine). The mixture was stirred vigorously and heated until the diluent was refluxing steadily. A preliminary induction period of 1–6 hr., according to the aromatic hydrocarbon used, was usual before the condensation reaction began. Evolution of large quantities of hydrogen chloride accompanied the reaction, and during its progress the liquid darkened in colour. In the initial stages of the reaction it was essential to control the temperature to prevent the reaction proceeding too vigorously. In the later stages the reaction was completed by heating gently with steady refluxing for 1–2 hr. until no further fumes of hydrogen chloride were evolved. The total time for the condensation reaction was 4–6 hr. The liquid product was then allowed to stand for some hours, during which two liquid layers were formed. The upper layer was decanted off and centrifuged to remove final traces of sludge. The liquid was then agitated vigorously with water until an emulsion was formed. This emulsion broke on standing for a short time, and complete separation of water was obtained by further centrifuging. This treatment was followed by percolation through a granular bleaching earth, which rendered the liquid light and clear in colour. Removal of petroleum-ether diluent was effected by distillation, and blowing with nitrogen to remove the last traces. The kerosine diluent, used when naphthalene was the aromatic constituent, required vacuum distillation up to 250° C./10 mm. for complete removal.

CONDENSATION OF AROMATIC HYDROCARBONS WITH CHLORINATED PARAFFIN WAX OF 10 PER CENT. CHLORINE CONTENT.

Experiment A/W 40.

A chlorinated wax with 10 per cent. chlorine content, corresponding analytically to monochloroparaffin, was condensed with benzene, by the procedure described above. The diluent used was petroleum ether, b.pt. 100–120° C., and a trace of iodine (5–10 mg.) was added as a promoter. The reaction was initiated by refluxing at 110° C. for approximately 2 hr., and was completed by heating gently for 6 hr. The product was a white, waxy solid at room temperature with a pour point of 85° F., and above this temperature a pale mobile oil.

Experiment A/W 37.

A similar procedure was employed, with toluene as the aromatic component. The reaction commenced after a short induction period of 1 hr. The product was a yellowish-white, waxy solid at room temperature with a pour point of 85° F.

Experiment A/W 38.

In a third experiment naphthalene was used as the aromatic constituent. Naphthalene reacts less readily, higher temperatures—150–200° C.—being necessary to initiate the reaction. Kerosine was therefore used as diluent. The kerosine was rendered inert by refining with several batches of concentrated sulphuric acid, followed by alkali-washing, water-washing, and distillation. There was a prolonged induction period before the condensation reaction commenced. The reaction product was settled, centrifuged, water-washed, and filtered through bleaching earth. The kerosine diluent was removed by vacuum distillation, three fractions being obtained. The first fraction, distilling up to 190° C./30 mm., consisted of kerosine, the fraction distilling between 190° C./30 mm. and 200° C./10 mm. consisted of kerosine and white wax, and the residual fraction was a viscous oil with blue fluorescence and a high pour point (85° F.).

The dark colour of the naphthalene product is probably due to slight decomposition of the chloroparaffins during the induction period.

Experiment A/W 36.

For comparison an ordinary Friedel–Crafts condensation was carried out using the 10 per cent. chlorinated wax and toluene with 10 per cent. anhydrous aluminium chloride as catalyst in place of the aluminium. With this reactive catalyst the condensation proceeds at room temperature. The product was a whitish-yellow waxy solid at room temperature with a pour point of 85° F.

PROPERTIES OF CONDENSATION OILS.

The properties of the condensation product of toluene and chlorinated wax of 10 per cent. chlorine content are compared with those of two commercial oils of similar specific gravity in Table I.

The laboratory inspection data for the condensation product compare favourably with those for the commercial oils.

The product has a low viscosity, high viscosity index, low carbon residue, and good oxidation resistance, but its pour point is too high for it to be of value as a lubricant without further treatment.

The high pour point of all these condensation products is probably due partly to the presence of unchlorinated paraffin wax in the chloroparaffin mixture and partly to the formation of solid long-chain paraffins during the reaction by the condensation of two chloroparaffin molecules. Attempts made to separate these high-melting-point components by conventional solvent dewaxing methods were only partly successful, better results being obtained by vacuum distillation.

TABLE I.

	Toluene-monochloro-paraffin product, Expt. A/W 37.	Commercial light motor oil.	Commercial hydro-genated motor oil.
Specific gravity, 60° F.	0·883	0·888	0·888
Refractive index, N_D^{20}	1·4960	—	1·4910
Viscosity at 100° F. (centistokes, cs.)	76	97·6	156
,, 200° F. (,,)	11·7	13·0	16
Viscosity index	120	110	90
Viscosity–gravity constant	0·819	0·822	0·814
Pour point, ° F.	80	20	—
Conradson carbon, per cent.	0·09	0·37	0·23
Oxidation.			
Conradson carbon after oxidation, per cent.	0·36	—	0·48
Viscosity at 100° F. after oxidation (Air-Ministry test), cs.	104	—	161
Oxidation–viscosity ratio	1·37	—	1·03
Sludge after oxidation, per cent.	nil	—	nil

Vacuum distillation effected the removal of a good deal of solid material, the residual fractions above 300° C./3 mm. being viscous oils, with a red, green, or blue fluorescence. The percentage yields calculated on the basis of the ratio of oil obtained to the maximum theoretical yield are given in Table II.

TABLE II.

	Expt. A/W 40.	Expt. A/W 37.	Expt. A/W 38.	Expt. A/W 36.
Aromatic component	Benzene	Toluene	Naph-thalene	Toluene ($AlCl_3$ catalyst)
Total yield, gm.	346	353	216	170
Waxy oil fraction below 300° C./3 mm., gm.	230	237	120	111
Viscous oil, residual fraction above 300° C./3 mm., gm.	116	116	96	59
Percentage yield of total oil	69·2	70·6	43·2	34·0
Percentage yield of waxy distillate	46·0	47·4	24·0	22·2
Percentage yield of residual oil	23·2	23·2	19·2	11·8

From the data in Table II it will be seen that, with metallic aluminium as catalyst, total yields of 70 per cent. were obtained in the condensation of monochloroparaffin with benzene and toluene. The ratio of viscous residual oil to waxy distillate was approximately 1 : 2, giving a final yield of high-molecular-weight residual oil of 23 per cent. With naphthalene the total yield was reduced to 43 per cent., but the ratio of residual oil to waxy distillate was higher, being 1 : 1·25, so that the final yield of residual oil was approximately 19 per cent. This reduced total yield may be accounted for by the higher temperature necessary to initiate the reaction, which may favour the formation of the heavy sludge. The higher residual oil ratio may be due to the formation of oil by thermal dechlorination of the chloroparaffins during the relatively long induction period.

The use of aluminium chloride as catalyst caused much greater sludge formation, although the reaction was carried out at room temperature. This resulted in the total yield of oil being reduced to 34 per cent. The ratio of residual oil to waxy distillate was the same as with the metallic catalyst—approximately 1 : 2.

PROPERTIES OF RESIDUAL FRACTIONS ABOVE 300° C./3 MM.

The properties of three residual oils prepared by the condensation of monochloroparaffin with benzene, toluene, and naphthalene using aluminium metal as catalyst, together with those of the condensation product of monochloroparaffin and toluene with aluminium chloride as catalyst, are given in Table III, and are each compared with commercial lubricating oils of similar viscosity at 100° F.

TABLE III.

	Expt. A/W 40. Residual fraction above 300° C./3 mm.	Commercial lubricating oil, A.	Commercial lubricating oil, C.	Expt. A/W 37. Residual fraction above 300° C./3 mm.	Commercial lubricating oil, B.	Expt. A/W 36. Residual fraction above 300° C./3 mm.	Commercial bright stock.	Expt. A/W 38. Residual fraction above 300° C./3 mm.
Aromatic component .	Benzene	—	—	Toluene	—	Toluene ($AlCl_3$)	—	Naphthalene
Specific gravity, 60° F..	0·897	0·926	0·910	0·900	0·905	0·898	0·945	0·952
Refractive index, N_D^{20} .	1·5020	1·5150	—	1·5075	1·5005	1·5020	1·5260	1·5230
Viscosity at 100° F., cs.	399	341	346	449	449	645	729	5185
,, 200° F., cs.	36·2	17·7	30·9	38·4	28·6	54·2	35	223
Viscosity index . .	110	70	105	110	100	115	55	—
Viscosity–gravity constant . . .	0·811	0·873	0·833	0·811	0·826	0·805	0·871	0·856
Pour point, ° F. . .	55	5	– 5	55	—	55	30	55
Conradson carbon, per cent. . . .	0·32	0·98	0·70	0·46	0·91	0·56	3·36	7·58
Oxidation.								
Conradson carbon after oxidation, per cent. .	1·49	—	—	1·27	—	1·36	4·07	8·13
Viscosity at 100° F. after oxidation, cs. .	—	—	—	590	—	850	952	6350
Oxidation–viscosity ratio . . .	—	—	—	1·31	—	1·32	1·31	1·23

The specific gravities, refractive indices, and viscosities of these synthetic oils appear to depend to a large extent on the aromatic hydrocarbon used in their preparation, these properties increasing in the order benzene, toluene, and naphthalene. The viscosity–temperature stabilities are high, the benzene and toluene derivatives having viscosity indices of 110. The viscosity–gravity constants of the benzene and toluene products are similar to the values for paraffinic base oils. The Conradson carbon residues of the benzene and toluene products are low and compare favourably with commercial lubricating oils. The naphthalene oil has a high carbon residue, but this is not excessive when its high viscosity is considered. The oxidation resistance of the synthetic oils is good, and less change in colour occurs than with the mineral oils used for comparison. Sludge determinations indicated that in all cases no sludge was formed under the oxidation conditions of the test. The low increase in carbon residue after oxidation is good for the benzene and toluene derivatives.

The use of aluminium chloride as catalyst results in the formation of an oil different from, and somewhat inferior to, that obtained with the metallic catalyst. The viscosity of the aluminium chloride product is higher than that of the corresponding oil obtained with the aluminium catalyst, the viscosity index is approximately the same, and the carbon residues, before and after oxidation, are inferior. The yield is only one half of that obtained with the aluminium catalyst.

CONDENSATION OF AROMATIC HYDROCARBONS WITH CHLORINATED PARAFFIN WAX OF 17 PER CENT. CHLORINE CONTENT.

Experiment A/W 42.

Chlorinated paraffin wax containing approximately 17 per cent. chlorine, and corresponding analytically to dichloroparaffin, was condensed with benzene using aluminium metal as catalyst. The procedure was similar to that described in detail previously, petroleum ether, b.pt. 100–120° C., being used as diluent and a minute quantity of iodine added as a promoting agent. The mixture was refluxed until reaction commenced, the reaction was then completed by gently heating until no further fumes of hydrogen chloride were evolved, and the products were allowed to settle. Sludge was separated by decanting off the upper liquid layer and centrifuging. The product was water-washed, filtered through floridin earth, and the diluent removed by distillation. The product was an oil with a pour point of 80° F. The solid hydrocarbons were removed by vacuum distillation, the residual fraction above 300° C./3 mm. being a viscous oil with green fluorescence. The distillate fractions consisted of a white wax together with a pale mobile oil.

The yields of the products are given in Table IV, and are compared with those from the condensation of monochloroparaffin and benzene.

TABLE IV.

	Expt. A/W 42.	Expt. A/W 40.
Chloroparaffin	Di-	Mono-
Aromatic hydrocarbon	Benzene	Benzene
Total yield, gm.	319	346
Yield of distillate fraction up to 300° C./3 mm., gm.	142	230
Yield of residual oil above 300° C./3 mm., gm.	177	116
Percentage yield of unfractionated oil	69	69·2
Percentage yield of waxy distillate	30·6	46·0
Percentage yield of residual oil	38·1	23·2

Experiment A/W 41.

A similar condensation was carried out with dichloroparaffin and naphthalene. The reaction was initiated by heating without diluent, petroleum ether diluent being added after the reaction had commenced. The product was a dark brown oil with a pour point of 85° F. Vacuum distillation resulted in the removal of a good deal of wax, together with a green distillate oil, and left an extremely viscous dark oil as the residual fraction.

The total yield by weight was less than that obtained with the monochloroparaffin, owing to the higher chlorine content, but the yield of unfractionated oil calculated as a percentage of the theoretical conversion was approximately the same for both mono- and di-chloroparaffin, being 70 per cent. in each case. The ratio of residual oil to waxy distillate was higher—1 : 0·8—so that the percentage yield of high-molecular-weight residual oil was appreciably higher, being 38 per cent., as compared with 23 per cent. for the monochloroparaffin oil.

The properties of the dichloroparaffin condensation products are given in Table V. The naphthalene oil was unsatisfactory and did not justify a complete analysis.

TABLE V.

	Expt. A/W 42.	Expt. A/W 41.
Aromatic component	Benzene	Naphthalene
Specific gravity, 60° F.	0·903	0·981
Refractive index, N_D^{20}	1·5050	—
Viscosity at 100° F., cs.	813	5500
,, 200° F., cs.	60	—
Viscosity index	110	—
Viscosity–gravity constant	0·809	0·907
Pour point, ° F.	55	50
Conradson carbon, per cent.	0·51	14·0
Conradson carbon after oxidation, per cent.	1·31	—

The properties of the dichloroparaffin–benzene oil are similar to those of the monochloroparaffin–benzene product, but the dichloroparaffin–naphthalene oil compared unfavourably with the corresponding monochloroparaffin derivative.

CONDENSATION OF AROMATIC HYDROCARBONS WITH CHLORINATED PARAFFIN WAX CONTAINING 25 PER CENT. CHLORINE.

Experiment A/W 29.

Chlorinated paraffin wax containing 25 per cent. chlorine, and corresponding analytically to trichloroparaffin, was condensed with benzene, using metallic aluminium as catalyst. The procedure was similar to that described for previous condensations with benzene. The product was a viscous oil, liquid at room temperature, and was therefore not subjected to vacuum distillation for removal of solid hydrocarbons. The oil had a clear amber colour.

Experiment A/W 33.

A similar experiment was performed, using toluene for the aromatic component, the product resembling that obtained with benzene. The oil was transparent and yellow in colour.

Experiment A/W 186.

Naphthalene was also condensed with the trichloroparaffin. Owing to the higher temperature required for the reaction to proceed, it was necessary to use a high-boiling diluent; for this purpose a high-grade kerosine, which had been treated with several batches of concentrated sulphuric acid, water-washed, and redistilled, was employed. The final product was a viscous oil with a blue fluorescence.

The properties of these three synthetic oils are given in Table VI and for comparison those of three commercial lubricants of similar viscosity at 100° F. are also listed.

TABLE VI.

	Expt. A/W 29.	Commercial motor oil, A.	Expt. A/W 33.	Commercial lubricating oil, B.	Expt. A/W 18b.	Commercial bright stock.
Aromatic hydrocarbon . . .	Benzene		Toluene		Naphthalene	
Specific gravity, 60° F. . .	0·907	0·926	0·914	0·905	0·917	0·945
Refractive index, N_D^{20} . . .	1·5065	1·5150	1·5100	1·5005	1·5180	1·5260
Viscosity at 100° F., cs. . . .	302	341	440	449	815	729
Viscosity at 200° F., cs. . . .	29·1	17·7	36·6	28·6	56·6	35
Viscosity index .	110	70	105	100	105	55
Viscosity–gravity constant . .	0·831	0·873	0·834	0·826	0·830	0·874
Pour point, ° F. .	55	5	55	—	50	30
Conradson carbon, per cent. . .	0·28	0·98	0·15	0·91	1·90	3·36
Oxidation.						
Conradson carbon after oxidation, per cent. . .	0·69	—	0·48	—	2·08	4·07
Viscosity at 100° F. after oxidation, cs.	416	—	616	—	1·020	952
Oxidation – viscosity ratio . . .	1·38	—	1·40	—	1·25	1·31
Total yield, gm. .	270	—	280	—	220	—
Yield, percentage of theoretical . .	63·5	—	66	—	51·8	—

The specific gravities of the synthetic oils are of the same order as those of commercial lubricants of comparable viscosity at 100° F., and increased with increasing molecular weight of the aromatic component. The viscosities increased in the order benzene, toluene, and naphthalene. The viscosity–temperature stabilities are uniformly high, the synthetic oils having viscosity indices of 105–110. The viscosity–gravity constants ranked the oils as essentially paraffinic base. The pour points are high, 50–55° F., but can be improved by vacuum distillation, the residual fractions above 300° C./3 mm. having a pour point of 25–30° F. The Conradson carbon residues of the benzene and toluene derivatives are low, the synthetic oils being superior in this respect to petroleum lubricants of similar viscosity at 100° F. Excellent oxidation resistance is shown by the synthetic oils, which exhibit comparatively little change in colour and give no sludge formation. The increase in Conradson carbon after oxidation is, in all cases, good. The increase in viscosity after oxidation is moderate, the ratios of the viscosity of the oxidized oil to that of the original oil varying from 1·25 to 1·4.

INFLUENCE OF CHLORINE CONTENT OF CHLORINATED PARAFFIN WAX ON CONDENSATION OILS.

In Table VII the properties of the oils obtained by condensing monochloroparaffin and trichloroparaffin with toluene are compared to show the effect of varying chlorine content in the chlorinated paraffin wax.

TABLE VII.

	Expt. A/W 35. Unfractionated condensation product.	Expt. A/W 33. Unfractionated condensation product.
Chlorine content of chlorinated paraffin wax, per cent.	10	25
Chloroparaffin	Mono-	Tri-
Aromatic component	Toluene	Toluene
Yield, percentage of theoretical conversion	70·6	66
Specific gravity, 60° F.	0·883	0·914
Refractive index, N_D^{20}	1·4960	1·5100
Viscosity at 100° F., cs.	76	440
,, 200° F., cs.	11·7	36·6
Viscosity index	120	105
Viscosity–gravity constant	0·819	0·834
Pour point, ° F.	80	55
Conradson carbon, per cent.	0·09	0·15
Oxidation.		
Conradson carbon after oxidation, per cent.	0·36	0·48
Viscosity at 100° F. after oxidation, cs.	104	616
Oxidation–viscosity ratio	1·37	1·40
Sludge formation, per cent.	nil	nil

The properties of residual oils above 300° C./3 mm., prepared by condensing chlorinated paraffin waxes of varying chlorine content with benzene and toluene and then subjecting the refined products to vacuum distillation, are listed in Table VIII. For comparison purposes the trichloroparaffin–toluene oil was distilled up to 300° C./3 mm. and the properties of the residual fraction determined.

It will be seen from these two tables that the specific gravity, refractive index, and viscosity of the condensation oils increased with the chlorine content of the chloroparaffin used. The viscosity index appears to decrease with increasing chlorine content of the chloroparaffin used. The pour point decreased with increasing chlorine content of the chloroparaffin component. This would be expected from the reduction in unchlorinated wax present in the higher chloroparaffins and the diminished possibility of long straight-chain paraffins being formed by the condensation of two chloroparaffin molecules. The viscosity–gravity constant increased with the chlorine content of the raw material corresponding with increased cyclisation and branching. The Conradson carbon and oxidation stability is but little affected by the chlorinated wax used.

TABLE VIII.

	Expt. A/W 40. Residual fraction above 300° C./ 3 mm.	Expt. A/W 42. Residual fraction above 300° C./ 3 mm.	Expt. A/W 37. Residual fraction above 300° C./ 3 mm.	Expt. A/W 35. Residual fraction above 300° C./ 3 mm.	Expt. A/W 33. Residual fraction above 300° C./ 3 mm.
Chlorine content of chloroparaffin component, per cent.	10	17·5	10	12·5	25
Chloroparaffin . . .	Mono-	Di-	Mono-	—	Tri-
Aromatic hydrocarbon . .	Benzene	Benzene	Toluene	Toluene	Toluene
Yield, percentage of theoretical conversion . . .	23·2	37·2	23·2	27·7	50
Specific gravity, 60° F. . .	0·897	0·903	0·900	0·908	0·933
Refractive index, N_D^{20} . .	1·5020	1·5050	1·5075	1·5080	1·5210
Viscosity at 100° F., cs. .	399	813	449	644	3270
,, 200° F., cs. .	36·2	60	38·4	47·3	144
Viscosity index . . .	110	110	110	105	—
Viscosity–gravity constant .	0·811	0·809	0·814	0·820	0·859
Pour point, ° F. . . .	55	50	55	55	30
Conradson carbon, per cent. .	0·32	0·51	0·46	0·45	0·43
Oxidation.					
Conradson carbon after oxidation, per cent. . . .	1·49	1·31	1·27	1·14	—
Viscosity at 100° F. after oxidation, cs.	—	—	590	732	—
Oxidation–viscosity ratio .	—	—	1·31	1·14	—

The increase in specific gravity, refractive index, viscosity, and viscosity–gravity constant with increase in chlorine content of the chlorinated wax agrees with accumulation of simple cyclic groups in the molecule, and supports the hypothesis that the principal reaction during the condensation is replacement of chlorine by aromatic rings.

INFLUENCE OF THE AROMATIC HYDROCARBON COMPONENT ON THE CONDENSATION OILS.

Mention has already been made of the difference in the lengths of the preliminary induction periods with benzene, toluene, and naphthalene. In the case of benzene the reflux temperature was reduced by its relatively lower boiling point, so that a slightly increased induction period would be expected, but naphthalene, even at a much higher reflux temperature than toluene or benzene, reacted less readily. The effect of the aromatic component on the properties of the condensation oils is shown in Table IX.

TABLE IX.

	Expt. A/W 40. Residual fraction above 300° C./3 mm.	Expt. A/W 37. Residual fraction above 300° C./3 mm.	Expt. A/W 38. Residual fraction above 300° C./3 mm.	Expt. A/W 42. Residual fraction above 300° C./3 mm.	Expt. A/W 41. Residual fraction above 300° C./3 mm.	Expt. A/W 29a. Unfractionated condensation product.	Expt. A/W 33. Unfractionated condensation product.	Expt. A/W 18b. Unfractionated condensation product.
Aromatic hydrocarbon .	Benzene	Toluene	Naphthalene	Benzene	Naphthalene	Benzene	Toluene	Naphthalene
Chloroparaffin . .	Mono-	Mono-	Mono-	Di-	Di-	Tri-	Tri-	Tri-
Yield, percentage of theoretical conversion	23·2	23·2	19·2	37·2	20·0	63·5	66	51·8
Specific gravity, 60° F.	0·897	0·900	0·952	0·903	0·981	0·907	0·914	0·917
Refractive index, N_D^{20} .	1·5020	1·5075	1·5230	1·5050	—	1·5065	1·5100	1·5180
Viscosity at 100° F., cs.	399	449	5185	813	5500	302	440	815
,, 200° F., cs.	36·2	38·4	223	60·0	—	29·1	36·6	56·6
Viscosity index . .	110	110	—	110	—	110	105	105
Viscosity–gravity constant . . .	0·811	0·814	0·856	0·809	0·907	0·831	0·834	0·830
Pour point, ° F. . .	55	55	—	55	—	55	55	50
Conradson carbon, per cent. . . .	0·32	0·46	7·58	0·51	14·05	0·28	0·15	1·90
Oxidation.								
Conradson carbon after oxidation, per cent. .	1·49	1·27	8·13	1·31	—	0·69	0·48	2·08
Viscosity at 100° F. after oxidation, cs. .	—	590	6350	—	—	416	616	1020
Oxidation–viscosity ratio . . .	—	1·31	1·23	—	—	1·38	1·40	1·25

The percentage yield is approximately the same for the benzene and the toluene derivatives, but the yield is greatly reduced when naphthalene is used for the aromatic component. The specific gravity increased in the order benzene, toluene, and naphthalene, and for the residual oils above 300° C./3 mm. the gravity of the naphthalene derivative is considerably higher than those of the products from the simple aromatics. The refractive index increased similarly in the normal order of the aromatic components—benzene, toluene, and naphthalene. The viscosities also followed the same order of increase, the viscosities of the residual naphthalene oils being considerably greater than those of the corresponding benzene and toluene oils. The viscosity–temperature coefficients, as evaluated by the viscosity indices, are fairly uniform, 105–110, but the viscosities of the residual naphthalene oils were completely beyond the range of viscosity index calculations. The viscosity–gravity constants of the residual benzene and toluene oils ranked them as "paraffinic," but the naphthalene residual oils have constants similar to those of "naphthenic" oils. The pour points of the synthetic oils are all of the order 50–55° F. The carbon-forming tendencies of all the benzene and toluene oils are low. The naphthalene oils have much higher carbon residues. The increase in carbon residue after oxidation is of approximately the same order for the benzene, toluene, and naphthalene oils, and is somewhat higher for the residual oils than for the undistilled oils. The increase in viscosity after oxidation is approximately the same for the benzene, toluene, and naphthalene derivatives, the oxidation–viscosity ratios being 1·23–1·40.

INFLUENCE OF THE CATALYST ON THE CONDENSATION PRODUCTS.

Condensations were carried out with anhydrous aluminium chloride as catalyst, so that comparison could be made with the metallic aluminium catalyst used in the previous experiments. It was found also that the sludge formed in condensation reactions with the metallic catalyst could be used as a condensation catalyst. Small amounts of iodine, though not essential for reaction to occur, tend to shorten the preliminary induction period. The products obtained with aluminium and aluminium chloride catalysts are compared in Table X.

TABLE X.

	Expt. A/W 37. Residual fraction above 300° C./ 3 mm.	Expt. A/W 36. Residual fraction above 300° C./ 3 mm.	Expt. A/W 18. Unfractionated condensation product.	Expt. A/W 15. Unfractionated condensation product.	Expt. A/W 16. Unfractionated condensation product.
Catalyst . . .	Aluminium	Aluminium chloride	Aluminium	Aluminium chloride	Aluminium chloride
Aromatic component .	Toluene	Toluene	Naphthalene	Naphthalene	Naphthalene
Chloroparaffin . .	Mono-	Mono-	Tri-	Tri-	Tri-
Reaction temperature (maximum), ° C. .	115	20	150	45	20
Yield, percentage of theoretical conversion.	23·2	11·8	51·8	—	—
Specific gravity, 60° F. .	0·900	0·898	0·917	Product is an asphaltic solid	Product is an asphaltic solid
Refractive index, N_D^{20} .	1·5075	1·5020	1·5180		
Viscosity at 100° F., cs. .	449	645	815		
,, 200° F., cs. .	38·4	54·2	56·6		
Viscosity index . .	110	115	105		
Viscosity–gravity constant . . .	0·814	0·805	0·830		
Pour point, ° F. . .	55	55	50		
Conradson carbon, per cent. . . .	0·46	0·56	1·90		
Oxidation.					
Conradson carbon after oxidation, per cent. .	1·27	1·36	2·08		
Viscosity at 100° F. after oxidation, cs. . .	590	850	1020		
Oxidation–viscosity ratio	1·31	1·32	1·25		

In the case of the monochloroparaffin–toluene oils, using aluminium metal or aluminium chloride as catalyst, the products have very similar properties, but the yield is much higher with the metallic catalyst. With naphthalene and trichloroparaffin very different results are obtained from the two catalysts. The condensation using metallic aluminium yields a viscous oil with good properties, but with aluminium chloride the product is a solid asphaltic or rubber-like material.

Aluminium chloride is extremely reactive, and, in addition to the condensation of alkyl chloride with aromatic hydrocarbon, it may induce dehydrogenation and polymerization reactions. Side reactions of this nature appear to have taken place in the experiments using aluminium chloride. In the case of the monochloroparaffin–toluene condensation, the amount of heavy sludge is increased and the yield of oil obtained is considerably reduced. With naphthalene and trichloroparaffin the side reactions appear to have predominated to the exclusion of the simple condensation.

The properties of the products obtained, using the sludge from a previous experiment, alone and together with fresh metallic aluminium, are compared with the normal condensation oils in Table XI.

TABLE XI.

	Expt. A/W 25. Unfractionated condensation product.	Expt. A/W 26. Unfractionated condensation product.	Expt. A/W 27. Unfractionated condensation product.
Catalyst	Al	Al plus sludge from A/W 25	Sludge from A/W 26
Aromatic component . . .	Benzene	Benzene	Benzene
Chloroparaffin	Tri-	Tri-	Tri-
Yield, per cent. of theoretical .	42·5	68	25
Reaction temperature (maximum), ° C.	110	50	50
Specific gravity, 60° F. . .	0·898	0·880	0·884
Refractive index, N_D^{20} . .	1·5025	1·4930	1·4935
Viscosity at 100° F., cs. . .	241	136	113
,, 200° F., cs. . .	25·8	18·6	16·1
Viscosity index	115	125	125
Viscosity–gravity constant . .	0·822	0·806	0·813

Sludge from a previous condensation can be used as a catalyst, although its use in this respect, as will be seen from the table, results in the formation of an oil of lower viscosity but improved viscosity index and V.G.C.

Extreme subdivision of the metallic catalyst and the removal of the oxide film protecting the metal were found to have an adverse effect on the products. An experiment was performed using trichloroparaffin and naphthalene with finely divided aluminium powder. Reaction commenced at 150° C., and the mixture was then allowed to cool slowly, but an extremely vigorous reaction commenced, and the final product was a greyish, rubber-like material closely resembling that obtained using aluminium chloride as a catalyst with naphthalene and trichloroparaffin.

In another experiment the aluminium metal was treated with sodium hydroxide solution, then washed with distilled water, absolute alcohol, and petroleum ether. Benzene and trichloroparaffin were used in this condensation, and the final product was a dark-brown viscous oil. This oil did not respond to bleaching-earth treatment, and appeared to contain undesirable resinic and asphaltic material. Preliminary removal of the alumina film or etching of the catalyst with caustic soda therefore appears to result in the formation of inferior products.

The relative efficiencies of aluminium, activated aluminium, and aluminium chloride were investigated for a simple reaction of the Friedel–Crafts type, in which *iso*propyl benzene was prepared by the condensation of *iso*propyl bromide and benzene.

The amount of catalyst used was one-tenth molar calculated on the weight of *iso*propyl bromide. With the metallic catalysts, 60 gm. *iso*propyl bromide were refluxed with excess benzene (145 c.c.) until reaction commenced. The preparation was completed by refluxing for 5–7 hr., settling, hydrolysing the upper liquid layer, and fractionally distilling the product. With aluminium chloride the reaction proceeded without preliminary heating, 60 gm. of the *iso*propyl bromide being added slowly to a mixture of the catalyst and excess benzene (145 c.c.).

The activated aluminium (*i.e.*, aluminium–mercury couple) was prepared by etching aluminium filings with dilute caustic-soda solution, washing with water, and then treating with a 0·5 per cent. mercuric chloride solution for 2 min. The catalyst was then washed with water, alcohol, and ether, and stored under benzene.

The fraction from the condensation reaction boiling at 147–157° C. was considered to consist essentially of *iso*propyl benzene, the refractive indices confirming this. The yields calculated on this assumption are given in the table below, together with the amount of unreacted benzene.

TABLE XII.

Catalyst.	Yield of *iso*propyl benzene, c.c.	Unreacted benzene recovered, c.c.
$AlCl_3$	32	65
Al	40	70
Al–Hg couple . . .	37	73

The highest yield was given by the metallic aluminium catalyst. The amount of *iso*propyl benzene and also of unreacted benzene was least in the case of the aluminium chloride catalyst, so that the use of this more reactive material resulted in the formation of a greater proportion of high-boiling compounds and sludge.

These experiments confirmed to a certain extent the results obtained with the chloroparaffin condensations using aluminium and aluminium chloride catalysts, and indicated that the activation of the aluminium did not improve the yields. The use of the more complex chlorinated waxes naturally resulted in a greater disparity between the metallic and halide catalysts, simple organic halides such as *iso*propyl bromide offering less scope for the dehydrogenation and polymerization side reactions, which occur with the aluminium chloride catalyst.

BY-PRODUCTS OF THE CONDENSATION REACTION.

It has been mentioned previously that the reaction products, on cooling and settling, separate into two layers. The upper layer is utilized for the preparation of the synthetic oils, whilst the lower layer consists of a viscous black sludge. This sludge is only slowly decomposed by water, and for complete hydrolysis hot water and agitation are required. The hydrolysis product is a dark viscous asphaltic material.

COMPOSITION OF THE SLUDGE.

The sludge is saturated with hydrochloric acid formed during the reaction, and fumes on exposure to air. Analysis of a typical sludge from

Experiment A/W 33 was carried out by dissolving a weighed amount of sludge in benzene, passing a stream of nitrogen through the solution for several hours in order to remove the hydrochloric acid, and then refluxing gently for 2 hr. with a 2 per cent. solution of sulphuric acid. The aqueous extract was separated and filtered. Chloride was determined volumetrically by the Volhard method and aluminium was estimated gravimetrically, using 8-hydroxyquinoline. The analytical results obtained were :—

Chlorine . . .	13·83 per cent.
Aluminium . . .	2·72 per cent.

These percentages correspond to a chlorine–aluminium atomic ratio of 3·86 : 1. It is probable that the hydrogen chloride was not removed quantitatively by the nitrogen blowing and that the sludge is an organic aluminium-chloride double compound of the type $AlCl_3 \cdot R$. This compound contains a high proportion of organic radical, R, corresponding to 83·45 per cent. The total molecular weight of the organic radical is at least 860, and corresponds, therefore, to approximately 60 carbon atoms.

FORMATION OF GREEN COLOURING COMPOUND.

It was observed that the heavy sludge from several of the condensation experiments, after standing for several months in corked bottles, developed in parts an intensely bright green coloration, in marked contrast to its general black appearance. This green material was extracted by washing with petroleum ether; then, after removal of the solvent, the residual oil was observed to possess a bright malachite-green fluorescence in daylight. Addition of small amounts—0·1–0·5 per cent.—of this colouring material to pale distillate oils and water-white heavy paraffin imparted to them a bright green fluorescent bloom.

Similar fluorescent materials are formed by the action of aluminium chloride on naphthalene, anthracene, and other polycyclic hydrocarbons. It is possible that in the condensation reaction the aluminium chloride–organic complex reacts to give coloured compounds, probably of condensed polycyclic structure.

SUMMARY AND CONCLUSIONS.

General.

Chlorinated paraffin waxes can be condensed with aromatic hydrocarbons, using metallic aluminium as catalyst to give viscous hydrocarbon oils. The oils have high viscosity indices, and the viscosity–gravity constants are in many cases comparable to those of paraffin base oils. The Conradson carbon residues of the benzene and toluene condensation oils are extremely low. All the condensation oils have good oxidation resistance; after oxidation the change in colour is small, no asphalt is deposited, and the increase in viscosity is similar to that of commercial motor lubricants.

Influence of Chlorine Content of the Chlorinated Paraffin Wax.

The chlorinated waxes corresponding analytically to mono- and dichloroparaffin give condensation products which are solid at room temperature. The physical properties of an unfractionated condensation oil are in accordance with its paraffin-wax content—the specific gravity, refractive index, viscosity, and viscosity index being lower than the corresponding values for the synthetic oils derived from trichloroparaffin. The yield of high-molecular-weight material, boiling above 300° C./3 mm., increases with increasing chlorine content of the chlorinated paraffin wax. The specific gravity, refractive index, viscosity, and viscosity–gravity constant also increase with increase in the chlorine content of the chloroparaffin component. The viscosity index and the pour point decrease for the higher chloroparaffin derivatives.

Influence of the Aromatic Hydrocarbon Component.

Naphthalene reacts less readily than benzene or toluene, and requires a longer preliminary induction period. The yields are approximately the same for the benzene and toluene derivatives, but the yield of the naphthalene oil is considerably less. The specific gravity, refractive index, viscosity, and viscosity–gravity constant increase in the order of the molecular weights of the aromatic components. The viscosity indices are fairly uniform—105–110—but the viscosities of the residual naphthalene oils above 300° C./3 mm. are beyond the range of viscosity-index calculations. The carbon residues of all the benzene and toluene oils are low, but the naphthalene oils have high carbon residues.

Influence of the Catalyst.

The metallic aluminium catalyst gives higher yields than aluminium chloride. The latter catalyst causes the formation of excessive quantities of sludge, and in the case of naphthalene condensed with trichloroparaffin the product is a rubber-like or asphaltic material. The heavy sludge can be used as catalyst, and produces oils similar to those obtained with aluminium as catalyst, but, unless used in conjunction with the metal, the yield decreases.

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THE MANUFACTURE AND USE OF TETRA-ETHYL-LEAD.*

By Graham Edgar.†

Gasoline containing tetraethyl-lead was first put on public sale at a single service station in Dayton, Ohio, on 1st February, 1923, under the now familiar name of " ethyl " gasoline.

Fig. 1 shows the sales in the United States of ethyl gasoline, leaded regular gasoline, leaded and total aviation gasoline, and total figures of the American Petroleum Institute for gasoline sales from 1927 through the first half of 1939. They show that the sales of ethyl gasoline reached a maximum in 1931; that the decline which followed was not affected measurably by the introduction of leaded regular gasoline in 1933, and that from 1934 on there has been a steady increase, until at present the gallonage is nearly equal to that of 1931. They show that to-day about 75 per cent. of all gasoline sold in the United States contains tetraethyl-lead. In the aviation field almost all gasoline of 80 octane number or

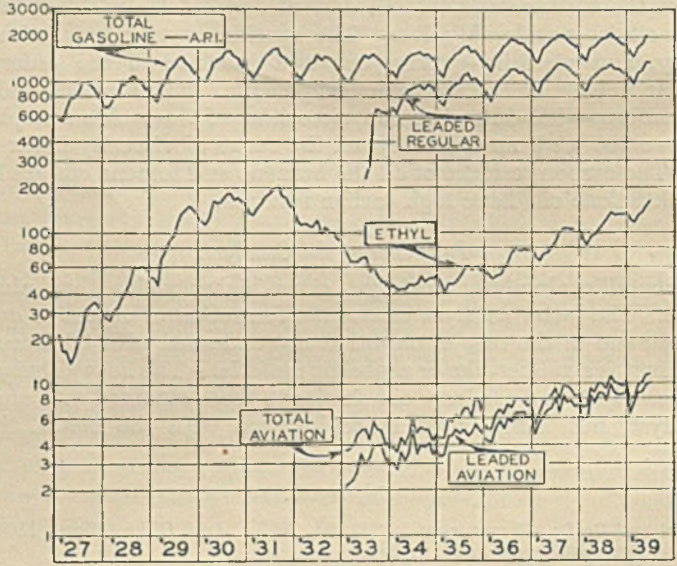

Fig. 1.

GASOLINE CONSUMED IN THE UNITED STATES (MILLIONS OF GALLONS).

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* Paper presented to the annual meeting of members of the Institute of Petroleum in U.S.A. at Chicago on 15th November, 1939. (Abridged from *Industrial and Engineering Chemistry*, 1939, **31**, 1439–1446.)

† Ethyl Gasoline Corporation, New York, N.Y.

better contains tetraethyl-lead; in fact, the performance of the modern military and transport plane is due in large part to the development of high-octane gasoline, a development in which tetraethyl-lead played an important rôle.

Outside the United States tetraethyl-lead is used in motor gasoline extensively in Canada (where the percentage of leaded gasoline is equal to that for the United States), England, France, Australia, New Zealand, and Germany, and to a smaller extent in many other countries. In the aviation field it is used in nearly every country in the world for both military and transport purposes. Manufacturing plants are in operation in Germany and France and are planned for other countries, although a share of the foreign demand is still supplied from the United States.

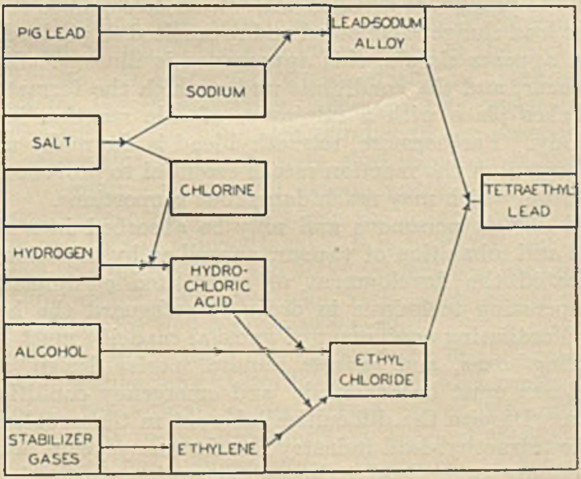

Fig. 2.

FLOW-SHEET OF TETRAETHYL-LEAD MANUFACTURE.

Tetraethyl-lead is manufactured by the reaction of ethyl chloride with an alloy of sodium and metallic lead, and the immediate raw materials are therefore ethyl chloride, sodium, and lead. With the exception of metallic lead, none of these are available commercially in the quantities required, and for this reason, as well as in the interest of manufacturing economy, it was necessary to include their manufacture at Baton Rouge.

Fig. 2 gives a flow-sheet of the manufacturing operations. Salt, obtained from the adjoining works of the Solvay Company, is electrolysed to produce sodium and chlorine. The sodium is melted with lead to form the alloy, which, after grinding, is ready for the final reaction. The chlorine formed in the electrolysis is burned with hydrogen, obtained from the adjoining refinery of the Standard Oil Company of Louisiana, to form gaseous hydrochloric acid.

Ethyl chloride is produced from hydrochloric acid by two distinct processes. The first is the familiar reaction with ethyl alcohol. The second is by reaction with ethylene. In this process, refinery stabilizer gases consisting largely of propane are cracked and the cracked gases fractionated at low temperatures to separate the ethylene formed. This is allowed to react with hydrochloric acid gas at low temperature in the presence of a catalyst to produce ethyl chloride. The Baton Rouge plant is the first commercial development of this method of manufacturing ethyl chloride. Ethyl chloride produced by either process is subjected to appropriate purification processes and is then ready for the final reaction with the lead–sodium alloy.

The reaction may be represented by the equation:

$$4PbNa + 4C_2H_5Cl = Pb(C_2H_5)_4 + 4NaCl + 3Pb$$

In the manufacturing process the alloy and ethyl chloride are allowed to react at moderate pressures and temperatures. At the completion of the reaction the product is distilled with steam to separate the tetraethyl-lead, and the lead sludge is collected and re-smelted to pig lead. Although the reaction appears simple, this appearance is illusory. Side reactions invariably occur, and the conditions under which the formation of tetraethyl-lead takes place with a minimum of side reaction have required extended study. Furthermore, tetraethyl-lead is thermally unstable, and the closest control of the reaction rate is essential to prevent the initiation of decomposition which may reach dangerous proportions.

Tetraethyl-lead is poisonous and may be absorbed into the body by skin contact and inhalation of vapour, as well as by ingestion. This fact has necessitated the development of specialized equipment and well-controlled operating technique in order to safeguard the health of the operators. Ventilating equipment of unusual capacity must be provided; valves, stuffing-boxes, and gaskets require special design, as an entire absence of leaks must be achieved; and emergency conditions must be provided for. Despite the difficulties inherent in the problem the safety record of the tetraethyl-lead industry has for many years been far better than that of any other lead industry, according to the best available figures.

In addition to tetraethyl-lead, the finished anti-knock fluid requires the addition of ethylene dibromide, ethylene dichloride, and dye. The latter two are purchased in the open market, but an adequate supply of ethylene dibromide at reasonable cost has represented a serious manufacturing problem for many years. Supplies of bromine are limited, and for this reason recourse was had a few years ago to that great reservoir of raw materials, the sea. The dramatic success, both technical and economic, of the Ethyl-Dow plant at Kure Beach, N.C., for producing ethylene dibromide from sea-water, has been described.[1]

Sea-water contains an average of only 67 parts of bromine per million of water, or about 1 lb. of bromine in 7·5 tons of water, but research has been equal to the task of extracting this minute amount. The sea-water is acidified and chlorinated; the bromine is blown out with air and concentrated by absorption, re-liberated from the concentrated solution, recovered by distillation, and finally allowed to react with ethylene to form the desired product, ethylene dibromide.

When ethyl gasoline was first put on the market, the octane-number scale was unknown, and methods of measuring anti-knock value were uncertain, to say the least. However, it may be safely stated that the anti-knock value of ethyl gasoline, as first sold, was not so high as that of regular-grade gasoline to-day. The ethyl of to-day is about 10 octane numbers better than it was fifteen years ago. An approximately equivalent increase has occurred in the anti-knock value of regular-grade gasoline.

In the past the automotive engine has taken advantage of increasing fuel quality by increasing the compression ratio, which increases both power per cubic inch of displacement and power per gallon of fuel. It is possible that in the future this trend may be the main one which will continue. This trend cannot be followed indefinitely, but it can be pursued very much farther than it has been. For example, several years ago the General Motors Corporation carried out an elaborate research project to determine the possibilities of increasing compression ratio under conditions in which the anti-knock value of the fuel was no longer the limiting factor. An automobile equipped with an overhead-valve engine was selected for the investigation. The car was operated both on the dynamometer and on the road at a number of compression ratios and a number of gear ratios, and fuels were used which in each case were just capable of avoiding knock. The octane numbers of these fuels are a little uncertain, since neither they nor the octane number requirements were determined by the conventional C.F.R. method, but approximately 69 octane fuel was required for the standard 5·25 compression ratio, about 95 octane number for 8·0 compression ratio, and something better than 100 octane number for 10·3 compression ratio.

But increase in compression ratio is only one of the methods by which the automotive engine may utilize fuels of high anti-knock value. In the development of the aircraft engine, where power per cubic inch of displacement is usually more important than thermal efficiency, it has been well demonstrated that a supercharged engine can utilize fuel of as high an anti-knock value as may be available. Already 100 octane number fuel is in wide use, and fuels above 100 octane number are under investigation. Little has been done in supercharging the automobile engine except for special purposes, but there is a good chance that the future may see this development extensively followed.

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THE TRINIDAD GEOLOGICAL CONFERENCE.

18th–27th April 1939.

This Conference was convened under the auspices of the Petroleum Association of Trinidad, and received the full co-operation of the Government, represented by the Hon. R. S. MacKilligin, O.B.E., M.C., Mr. Nelson Betancourt, and Mr. W. F. Foster, all of the Mines Department.

Other bodies and corporations which combined their efforts to make the Conference a signal success were—the Geological Service of the Venezuelan Government, the Trinidad Branch of the Institute of Petroleum, and the organizations of the many oil companies operating in the Island.

The full transactions of the Conferences are being published in the *Boletin de Geologia y Minera del Ministerio de Fomento, Caracas, E.U. de Venezuela*, and Dr. H. D. Hedburg has given a short account of the meetings in the *Bulletin of the American Association of Petroleum Geologists*, 23, 8, August 1939, accompanied by able abstracts of the papers presented.

The objects of the Conference were as follows :—

> " 1. To express to the Venezuelan Government the gratitude of the geologists of Trinidad for the generous invitations to the First and Second Venezuelan Geological Congresses; also to the oil companies operating in Venezuela for their liberal scientific contributions to these congresses.
>
> " 2. To introduce the geologists of Venezuela to stratigraphical details of the geology of Trinidad on the assumption that interchange of knowledge will be of practical value to all.
>
> " 3. To foster the good accord engendered by the Venezuelan Government in establishing closer co-operation and creating a spirit of mutual understanding between the two oil-producing countries on either side of the Gulf of Paria."

An Organizing Committee was constituted as follows :—

Chairman	Hon. R. S. MacKilligin, O.B.E., M.C.
Vice-Chairman and Secretary .	E. C. Scott.
Excursions	H. G. Kugler and A. G. Hutchinson.
Publications	C. C. Wilson.
Entertainment and Organization	N. Betancourt and A. E. Gunther.
Contact	P. E. T. O'Connor and R. G. Ffoulkes-Jones.

Between forty and fifty geologists attended, including Professor V. C. Illing of the Royal School of Mines; Dr. R. Rutsch, Natural History Museum, Basle; Dr. Buess and Dr. Kehrer of the Royal-Dutch Shell, and Dr. H. D. Hedburg of the Gulf Company.

The Venezuelan Geological, Mines Inspectorate, and Public Works Services were represented by nine members, led by Drs. G. Zuloaga and L. Herrera.

The many oil companies operating in Venezuela and Trinidad were also represented by their Geological Staffs. These included over twenty members of the Institute of Petroleum.

Overseas visitors were met at the docks and seaplane base. Proceedings were then opened by a reception given by His Excellency the Acting Governor, the Hon. John Huggins, C.M.G., M.C., at his residence.

The following morning His Excellency the Acting Governor formally opened the Conference with a short speech of welcome, and a visit was then made to the Imperial College of Tropical Agriculture.

On succeeding days six excursions were made to places of interest in the island, including type fossil localities, diagnostic type sections, etc.

These excursions were made mainly in motor buses, and entailed travelling upwards of one hundred miles a day. For the longer excursions, special trains on the Government railway were arranged by the Director of Public Works.

The itineraries and conduct of these field excursions were in the hands of Dr. H. G. Kugler, Chief Geologist to the Central Mining & Investment Corporation, and it was due to his able organization that they proved to be an outstanding success, supported, as they were, by an exact time-table, efficient guide-book and maps, and an absorbing commentary at each scheduled stop.

The weather was very propitious, and an excellent lunch and refreshment service was maintained throughout, with the aid of many local clubs and similar institutions.

The very beautiful scenery of the island was seen at its best, and perhaps the most memorable trip was that taken by launch along the small islands situated between Trinidad and Venezuela, and was made with the object of visiting the island of Patos.

On the two remaining days a series of papers was presented by members. A list of authors and papers follows. (Abstracts of these by Dr. H. D. Hedburg have been referred to previously. Abstracts will also be given in the *Journal* when the complete transactions of the Conference become available.)

1. Kugler, H. G.	"Our Present Knowledge of the Geologic History of Trinidad."
2. Schmid, K.	"The Classification of Rock Units and the Definition of Formations in Trinidad."
3. Hutchinson, A. G., and Terpstra, G. R. J.	"A Note on the Bicho Quarry Limestones."
4. Renz, H. H., and Suter, H. H.	"The Pozon and El Meno de Acosta Type Sections of the Agua Salada Formations (Falcon, Venezuela)."
5. Rutsch, R.	"Evolution of Tropical American Tertiary Faunas and Theory of Continental Drift."
6. Hutchinson, A. G.	"Note on the Jurassic in Trinidad, B.W.I."
7. Wilson, C. C.	"Los Bajos Fault of S. Trinidad."
8. Gunther, A. E., and Terpstra, G. R. J.	"A Note on some Recent Additions to the Upper Cretaceous of Trinidad, B.W.I."
9. Senn, A.	"The Paleogene of Barbados and its Bearing on the Antillean Caribbean Region."

The Chairman, the Hon. R. S. MacKilligin, declared the meeting closed with a valedictory speech. Dr. Guillermo Zuloaga, in a reply of thanks, invited members to a Third Venezuelan Geological Congress to be held in 1940.

E. C. S.

OBITUARY.

F. G. EDMED, O.B.E., B.Sc., F.I.C.

THROUGH the death, on the 22nd January, 1940, of Mr. Edmed, for many years Admiralty Chemist, the Institute has lost one of its " official " Honorary Members, who for many years gave us a great deal of valuable help in connection with Standard Methods of Testing. He was a member of the Chemical Standardization Committee and of the Fuel Oil and S.I.T. Panels.

Leaving the Royal College of Science in 1898, he entered the service of the War Office in the Chemical Inspection Department, Woolwich. After the war he transferred to the Admiralty, and took charge of the Chemical Inspection at the Royal Naval Cordite factory, later (1926) succeeding Mr. Arnold Philip as Admiralty Chemist.

His experience in analytical chemistry in these important Government offices had been very extensive, and time and again proved of great value in the work of revision of Standard Methods. Further, he was always ready to have investigations on modifications or the suggested improvement of tests carried out under his supervision.

He was associated with the closely allied work of the British Standards Institution, representing the Admiralty on the Chemical Divisional Council, besides being an active member of the Chemical Glass Ware Panel.

Mr. Edmed was for many years a keen member on the Council of the Institute of Chemistry, but had not sought re-election in the forthcoming ballot owing to increasing indisposition. He was a Vice-President of the Institute from 1933 to 1936. He retired from the position of Admiralty Chemist as recently as 1st January, 1940.

The writer enjoyed the close friendship of Edmed from the time when he left the Royal College of Science. His outlook on life was always cheery. He loved a joke and was ever ready with a witty repartee.

J. S. S. BRAME.

NICHOLAS ALEXANDER ANFILOGOFF.

MANY members of the Institute received a great shock when they learned of the sudden death of Nicholas Alexander Anfilogoff on the 27th January, 1940. Only a few hours before, many of his friends had met him in his normal exuberant health at the Institute's luncheon.

Nicholas Anfilogoff was 65, but his physical and mental activities were those of a younger man.

He was born in Riga, and in due course became an undergraduate of the Russian Imperial Technical Institute in Moscow, where he distinguished himself as a Gold Medallist.

He was attracted, as were so many Russian chemists, to the petroleum industry, which in those days was better developed in Russia than in other countries. After gaining some refinery experience with the Rilsky Petroleum Co., and some knowledge of production and storage problems by a stay in Baku, Anfilogoff decided to come to London. He arrived in 1894, being then only twenty, and obtained work with Dr. Dvorkovitz, a pioneer petroleum consultant, who up to ten or so years ago was a familiar figure in the precincts of Great St. Helen's. He then joined the European Petroleum Co., and after a few years started his long career at Thames Haven, where the Rumanian Oil Trust Refinery was operating. In those days he was much interested in the chemistry of petroleum, and carried out some investigational work himself. He has often told me of his early discovery of aromatics in East Indian petroleum, and of his many experiments in refining gasoline and kerosine by methods other than the then standard sulphuric acid and soda treatment. For some reason he seems never to have published any of his work. In the name index of the Science of Petroleum his does not appear, but nevertheless his memory will long be cherished by the many who knew him or who heard him at meetings of the Institute, discussing with vigour and emphasis points in a paper with which he did not agree.

His career at Thames Haven was marked by extensive developments in the storage installation and in the refinery, which was often called upon to work up a variety of crudes at short notice and never failed to do so. This is a striking testimony to his ability in design and management.

In 1930 he became a Director of the London & Coastal Oil Wharves, Ltd., and undertook the responsibility for the design and construction of a second great storage plant.

He was an original member of the Institute, and a regular and enthusiastic attendant at the meetings. He frequently took part in the discussions, and regularly attended the annual dinners. He was, moreover, a Fellow of the Institute of Chemistry, and a member of the Institutions of Mechanical and Chemical Engineers. Such combinations of activities are nowadays rare. But in the Institute's register he appeared as he was always known to his many friends and as he will long be remembered, simply as Anfilogoff.

J. Kewley.

Dr. J. A. L. HENDERSON.

James Alexander Leo Henderson died at his home in London in his sixty-sixth year on 4th February, 1940.

He graduated from the Royal School of Mines, Freiberg, Saxony, with first-class honours, and proceeded to the University of Leipzig. In 1898 he gained the Ph.D. at the latter University for his valuable work on " Certain Transvaal Norites, Gabbros and Pyroxenites and other South African Rocks "—a work to which references were made in the geology of South Africa, where its value was subsequently most appreciated by economic geologists.

His professional activities carried him around the world in connection with the widespread interests of his father, the late J. C. A. Henderson. In addition to the mining investigations and developments in South Africa, Australia, New Zealand, the United States, Canada and Europe, Dr. Henderson was active in the establishment of the water-works for Lorenço Marques and the Tasmanian Timber Corporation.

In 1908 Dr. Henderson became particularly interested in the development of oil within the British Empire, and was largely responsible for the organization of the Maritime Oilfields, Ltd., to undertake exploration in New Brunswick, Canada. As is so often the case, there were differences of opinion in the geological deductions, but the first results obtained by drilling in this enterprise confirmed his views, and resulted in the constant supply of natural gas to Moncton during the last 30 years and the production of high-grade oil from the wells. These natural products have made New Brunswick Gas and Oilfields, Ltd., the success he had anticipated.

Whilst, as Vice-Chairman of the Holding and Operating Companies, in addition to being their technical adviser, his life became chiefly concentrated on New Brunswick, he maintained throughout an active interest in the development of oil in other parts of the British Empire.

In 1918 he paid particular attention to Trinidad, and, although there will always be many claims to the discovery of new and important sources of oil, his work in connection with the Apex (Trinidad) Oilfields, Ltd., played a large part in, and was largely responsible for, the early success of what was later to become the largest individual producer in Trinidad. In addition to his other work, he continued as Consultant to that Company until his death.

During his career Dr. Henderson took every opportunity to visit and study the many oilfields of California, Oklahoma, and elsewhere, and he had a particularly wide knowledge and appreciation of progress in geological and technical matters relating to the petroleum industry in many countries.

He was a founder-member of the Institute and for twenty-eight years had been a member of the Council of the Institute of Mining and Metallurgy, which he joined in 1899. He was also a member of many well-known technical and other societies in England and elsewhere.

We honour him as a colleague who, throughout his career, displayed those characteristics which, in scientific men, class them as great, not for any epoch-making discoveries, but for their tolerance, willingness to learn from the experience of others, and keenness to discuss the many scientific problems on all and every occasion. His passing will be sadly felt by a large number of friends at home and abroad.

Many of his colleagues who read this will recollect with pleasure the discussions and arguments, lasting into the early hours of the morning, which, due to him, were interesting, enjoyable, and fruitful, whatever the scientific disagreement might have been.

ABSTRACTS.

AUTHOR INDEX.

The numbers refer to the Abstract Number.

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

Geology.

377.* Permian Redbeds of Kansas. G. H. Norton. *Bull. Amer. Ass. Petrol. Geol.*, **23**, 1939, 1751–1819.—An account of further detailed work on the Permian redbeds of Kansas is given with reference to Cragin's type sections and classification. With few important changes his classification is still used, after 40 years, as a satisfactory basis for the subdivisions of the Cimarron redbeds.

The present paper reports certain new facts discovered and describes in detail individual rock units of the redbed sequence. Combined surface and subsurface cross-sections show the mutual relationships of these beds and their correlations with equivalent strata in Colorado and Oklahoma.

The main conclusions reached are :—

(1) The Harper Sandstones (of Cragin), which include an important dolomite–anhydrite–salt series, has been restricted, with the exclusion of the lower formations—viz., the Ninnescah Shale and the Stone Corral dolomite–anhydrite.

(2) The most important and definitely recognizable units of the Cimarron redbeds (1732 ft.) are the three dolomite–anhydrite formations, Stone Corral, Blaine-Dog Creek, and the Day Creek. Regional correlations can be made confidently on these. Intervening and variable red sandstones and shales occur between the Stone Corral and the Blaine, and for these the name Nippewalla has been introduced.

(3) There is but little evidence of a major unconformity in the Kansas redbeds. Local unconformity may be present just above and below the dolomite–anhydrite formations, but most of the irregularities result from lateral gradation or slumpage.

(4) The Blaine-Dog Creek may be considered one formation in Kansas, each varying in thickness and dependent on the presence or absence of soluble gypsum deposits. The gypsum bed in Cragin's Jenkins clay, formally uncorrelated and unnamed, receives the name Nescatunga.

(5) The Marlow and Relay Creek dolomite members of the Whitehorse are thought to be present in Kansas. Cloud Chief gypsums are unknown, and thus the upper Whitehorse may be equivalent to the Rush Springs member.

In addition to sections the paper contains many photographs. G. S. S.

378.* Development of the Geological Studies Undertaken in the Gulf of San Jorge. A. Rossbach. *Bol. Inform. Petroleras,* November 1939, XVI (183), 27–42.—This account is the story of Comodoro Rivadavia. Oil was discovered here in 1907, as a result of borings which had been undertaken along the coast, with the object of finding water for the growing Patagonian villages. The search for water failed, but in exchange an important oilfield was located. The article is well illustrated with plans and sections. H. I. L.

379.* Control of Albanian Oilfields Ensures 4% of Italy's Crude Requirements. Anon. *World Petrol.,* May 1939, **10** (5), 26–27.—In 1938 Albania's oil output was 72,166 tons.

Although concessions have been granted to various interests, the Italians alone have carried out much work. They hold concessions in the coastal zone, Vojussa or intermediate zone and the interior or Devoli zone. In 1925 wells were drilled to 1500 m. in the coastal zone without finding anything of commercial significance, and the same was true in the Vojussa zone. In 1927 drilling was undertaken in the Devoli zone and an oil-impregnated sand was found. Further geological and geophysical work ensued, and in 1935 commercial production was established.

Some 290,000 m. have now been drilled in Albania, using modern methods. A 74-km. pipe-line has been built to the sea. The oil is asphalt base, giving 13% of gasoline on distillation and 80% on hydrogenation. G. D. H.

380.* Early Exploration Methods. H. B. Goodrich. *World Petrol.,* May 1939, **10** (5), 32–37.—The early drilling was not intentionally for oil, but for brine, and prior to the commencement of oil exploration, wells had been drilled to over 2000 ft. One of the earliest well logs was prepared by Hildreth for a salt well. Lesley fostered the use of well logs.

The anticlinal theory of oil accumulation was probably initiated about 1840, for Hildreth indirectly associated oil accumulation with structure. Before oil wells were drilled albertite was mined and shipped from New Brunswick for retorting, and in a law case discussions devolved on whether it was a bedded deposit, had been injected into a fissure or was on an anticline.

For a long time uses for petroleum in one form or another had been known, but the small requirements had limited development to seepages or accidental discoveries.

In 1811 Aikin put forward ideas on oil origin. G. D. H.

381.* Near East Discoveries have Led to Vast Increase in Activities. Anon. *World Petrol.,* June 1939, **10** (6), 44–51.—The Kirkuk structure which yields 30,000,000 brl./year is now a settled field. The wells are 1000–3500 ft. deep, and penetrate sandstones, silts, salt, gypsum, anhydrite and limestone. Oil is obtained from a limestone horizon. The drilling practice is described. In recent years drilling in has been carried out with crude oil circulation.

Drilling has been begun in the Qatar principality.

In Iran the Masjid-i-Sulaiman and Haft Kel fields are now stabilized with an output of 10,000,000 metric tons/year. At Haft Kel productive conditions have been proved in the Eocene below the Asmari. In the north-west in the White Oil Springs area is a separate structure with important possibilities. A new field has been developed at Gach Saran. This is under very high pressure, and the zone proved is 20 ml. long and 5 ml. broad. At Agha Jari, 55 ml. south-east of Haft Kel, producing conditions have been found, and at Pazanum, to the south-east, gas has been found in two wells, with high hopes of finding oil. On the Lali structure, north-west of Masjid-i-Sulaiman, a well has obtained a small production. In 1938 a successful well was drilled in Kuwait. The discovery well on Bahrein Island came in at 2008 ft., and an elongated anticline running north-east to south-west was proved with oil in a Cretaceous limestone and sandstone. At 4700 ft. even greater production was found, and altogether there are four producing horizons down to 4700 ft. Fifty-six wells produce from about 2250 ft. The present production is over 20,000 brl./day.

In 1936 oil was found on the Dammam structure of Saudi Arabia, some 50 ml. from Bahrein. The yields from about 2175 ft. were small, but in 1938 prolific production was found at 4200 ft. The daily production is about 8000 brl., and a pipe-line has been constructed to Ras Tanura. At Abu Hadriya, to the north, a wildcat is being drilled.

Developments at Dhulian, in India, are satisfactory, and four wells have been drilled to the producing horizon at 7700 ft.; the last one giving 3000 brl./day. Little oil is being obtained at Khaur, but a deep test is under way at Jhatla. A further test is being made at Ganda Kas, north-west of Khaur.

Extensive geophysical work has been carried out in Western India and Assam, in addition to geological work and aerial photography. Geophysical work is in progress in the state of Bahawalpur in the Punjab. G. D. H.

382.* Ras Gharib Discovery Brings Rush of Prospecting Activity to Egypt. Anon. *World Petrol.*, June 1939, **10** (6), 52–53.—The Gemsah field was opened in 1912, but closed in 1927. In the meantime the Hurghada field, 50 ml. to the south, was discovered, and reached its peak in 1931. This field is difficult to operate, due to the production of an emulsion. Under the new mining law of 1937 geological and geophysical work was undertaken which led to the discovery of the Ras Gharib structure, midway between Suez and Hurghada. The first well gave 150 tons of oil/day from 2560 ft. Seven wells have been completed, which gave 80,000 tons in 1938. This oil is not emulsified.

Exploration has been carried out elsewhere, and tests are to be drilled 8 ml. inland from Ras Gharib, and also in Sinai. A well at Dishet el Dhaba was abandoned at 2000 ft. in granite in 1938, and a second well on Giftun–Saghir Island, 15 ml. to the north-east, was stopped at 2970 ft.

In the coastal regions of French Equatorial Africa, between Pointe Noir and Port Gentil, are surface indications of oil. Three wells have been drilled to 1315, 2300 and 2960 ft. without finding commercial oil. In Nigeria there are extensive bituminous deposits, which are being re-tested. A deep test is under way on the Waki dome near Butiaba in Uganda, and shallow borings are to be made at Kibero. Several shallow holes have been drilled in the Belgian Congo, on the other side of Lake Albert. In Ethiopia and Italian Somaliland the work has not yet revealed anything justifying drilling. G. D. H.

383.* Petroleum Search Broadened in Far East. Anon. *World Petrol.*, June 1939, **10** (6), 54–61.—Exploration is concentrated chiefly on the islands of Sumatra, Borneo, Java, and New Guinea. Production is obtained in North and South Sumatra and Djambi, East Java, the Tarakan and Samarinda regions of East Borneo, and Ceram.

Access is difficult in Central Sumatra, but geological and geophysical work has been carried out and two wells have been drilled. The first did not find production, and the second was at 1386 ft. in May.

Renewed attention is being given to Sarawak and Brunei. Oil was discovered in Brunei in 1927, and the present potential is 1950 tons/day of heavy oil and 600 tons/day of light. Some of the sands run under the sea.

In 1938 drilling was started in the Gisborne area of the North Island of New Zealand. Five different sites are under consideration in the Philippines: in parts of the province of Leyte; the Bondoc peninsula in Tayabas; the provinces of Cagaya and Isabela in North Luzon; Cebu province and Cotabato in Mindanao. G. D. H.

384.* Alaska—Farthest North. J. Collins. *World Petrol.*, June 1939, **10** (6), 62–63.—Oil has been found in small quantities in shallow wells in Alaska, and two wildcats are now being drilled. In 1938 drilling was started on Bear Creek dome near Kanatak, and in May this year was at 3000 ft.

On the Iniskin–Chinitna peninsula work began in 1936. By the end of 1937 a well was drilled to 5051 ft., and gas and oil had been encountered. At 6150 ft. several feet of oil sand were found. Drilling was difficult. The Iniskin structure is an anticline 12 ml. long on which Jurassic beds have been drilled in the hope of finding heavy production in the underlying Trias. G. D. H.

385.* Intensive Exploration Awaits New Oil Law in Rumania. Anon. *World Petrol.*, June 1939, **10** (6), 64.—The Rumanian production declined again in 1938, for the mining laws did not encourage exploratory work. 45% of the oil was from Moreni–Gura Ocnitei, with Boldesti providing 15% and Ceptura 10%.

The Tzintea–Liliesti field, some 7 km. long, is being rationally developed with unit operation on the south flank. Many of the wells are over 9000 ft. deep.

Sixteen wildcats were drilled in 1938. At Manesti an important high-pressure gas dome was found, and one well found commercial oil. The Draganeasa well obtained 50 tons/day; but none of the others found commercial oil. G. D. H.

386.* Decade of Exploration Fails to Reveal Additional Italian Reserves. Anon. *World Petrol.*, June 1939, **10** (6), 66–69.—It was not until 1891, and after many attempts, that oil in commercial quantities was proved in Emilia in the Velleia field. By 1918 there were also the South Giovanni and Vallezza fields, but the total production, which reached its peak in 1911, was small. In 1926 the Government took up the search, and a second and bigger maximum was attained in 1933. The Fontevivo fold was proved productive and the Apennine margin of Emilia was shown to be rich in natural gas. From 1933 to 1938 deeper drilling was tried in areas revealed as favourable by geological and geophysical work. However, the prospective oil horizons proved to be much deeper, especially in the Po valley, than was at first supposed.

Work was also carried out in Italian East Africa. On Great Dalaac Island a salt dome was found at 300 m., and there are reports of oil shows. Shallow drilling in East Libya has not shown oil in commercial amounts.

In Albania there are three zones: in the north, near Scutari; in the centre, between Durazzo and Tirana; and in the south, between Valona and the Semeri river. There are indications of good oil possibilities between Pechini and Elbassan, and between Berat and Lushnia, but the greatest activity is in the Devoli fields.

Deeper drilling is to be undertaken in Emilia, and ten wells are to be sunk in Sicily. The 1927–36 gravity survey of the Po valley and geo-electric surveys were followed by drilling in various parts of Italy. All the indications pointed to the oil being very deep.

The drilling methods are described. G. D. H.

387.* Europe Scene of Active Oil Search. Anon. *World Petrol.*, June 1939, **10** (6), 70–74.—The Hardstoft well in England was re-conditioned and gave 15 brl./day. In 1938 a small production was obtained near Dalkeith in Scotland, and other wells are being drilled there. There are two gas horizons. At Cousland there were five gas horizons, and a gas show was found at Eskdale. The Carboniferous limestone was barren at Gun Hill.

In 1938 Pechelbronn gave 500,000 brl. of oil, and wells are to be drilled at Sundhouse and in Haute Savoie in France. Wells have been drilled in Herault without success, but in the Gabian district fourteen wells were brought in during 1938, making a total output of 156,000 brl. in the year. At Pezenas an impregnated layer was found at 2400 ft.

Drilling was intensified in Germany in 1938, and there was a rise in production during the early part of 1939. Production rose at Nienhagen, but fell at Oberg and Wietze. There was a great increase at Reitbrook.

A production test was completed at Sank-Ulrich.

The Gbely wells are relatively shallow, and there are small fields at Bohuslavice, Turzova and Mikova. At Hodonin in Morovia much of the oil is from 460 ft., although the deeper wells go to 2950 ft. Gas production has been developed at Vacenovice, and there are good prospects at Watzinowitz, Zborowitz and Sokolnitz.

In 1938 work extended the fields in Poland and production rose slightly. A test was started near Rzepienniki, and a rich oil deposit is said to have been found at 220 ft. about 3 ml. north of Jaroslaw.

Although there has been favourable exploratory work at Buk-Kszek in Hungary, the main developments are at Lispe and Buda. A wildcat, at Magyar St. Miklos, east of Buda, has reached 8333 ft. At Buda the wells range 787–8104 ft. in depth.

Geological and geophysical work has been carried out in Portugal, and a well is to be drilled 30 ml. north of Lisbon. In Epirus, North-west Greece, there is a large outcrop of asphaltic sand which is being explored. At Cuarny in Switzerland a well went to 6580 ft. without finding satisfactory oil or gas indications. In South Sweden promising oil strata are reported at Soderslatt, and a concession has been granted on the island of Gotland. Geophysical work is in progress in Denmark. In Greenland oil has been located on the peninsula of Nugssuak. G. D. H.

388.* Important Peruvian Area Opened by Aguas Calientes No. 1-A. J. E. Brantly. *World Petrol.*, June 1939, **10** (6), 77–81.—The Aguas Calientes structure is about 400 ml. N. 35° E. of Lima. Access is via the Ucayali and Pachitea rivers, and the concession is in the geosyncline which runs from Trinidad to Colombia, and thence south to Bolivia and the Argentine. The sediments range from Lower Palæozoic to Upper Tertiary, but in the immediate vicinity of Aguas Calientes only Mesozoic and possibly Permian is involved. The beds consist of red sandstones and shales, limestones and marls; sandstones, grits, conglomerates, volcanic ashes and a lower limestone horizon. The slightly asymmetric structure runs north-west to south-east, with dips not over 25°. It is about 15 ml. long with 3500 ft. of closure, and is the last basinward fold of the Andean Cordillera. The Chonta anticline at the south-east end of the concession is much smaller, and probably separated by a fault. The Lower Limestone (Jurassic ?) may be the source-rock. There are numerous seeps in the mountains south and west of Aguas Calientes.

The history of the concession is described. The first well, begun in 1938, found various oil horizons, including a zone from 1021 to 1261 ft. The second was drilled in February, and gives 2500 brl./day through tubing. A pipe-line will have to be built to Pucallpa on the Ucayali. G. D. H.

389.* Development Along the South American Oil Belt. Anon. *World Petrol.*, June 1939, **10** (6), 90–95.—In 1938 Trinidad gave 17,736,176 brl. of oil. The established fields were extended and tests located in the central part of the island after geophysical work. Wells were drilled which showed the Palo Seco and Coora areas to be connected. A well on the flank of the old Point Fortin field found good production. At Point Ligoure production was obtained at 7000 ft.

Venezuela's 1938 production was 173,506,497 brl., 70% being from the Lake Maracaibo fields. In Eastern Venezuela the Oficina and Santa·Ana fields have recently been developed. The Infantas, La Cira, Petrolea, and Rio de Oro structures are productive in Colombia. Tests are being made in the Magdalena valley.

Commercial production in Ecuador is confined to the Santa Elena peninsula. In Argentina oil has been developed in the provinces of Chubut, Salta, Mendoza and Neuquen. Work has been resumed in British Guiana, and there has been geological and geophysical work in Guatemala.

Small amounts of oil have long been known in Cuba, and there is a natural gasoline field at Motembo and an oil and gas-field at Bacuranao. Tests have been made elsewhere. G. D. H.

390.* High Rate of Production Indicated for Illinois Fields. A. H. Bell and W. H. Voskuil. *World Petrol.*, Aug. 1939, **10** (8), 30–36.—Between 1936 and 1938 Illinois production rose from 4,500,000 to 24,000,000 brl./year. Illinois development began in 1904, and the first production peak was in 1908. Development fell off, due to its basinal character and the difficulties introduced by surface drift, but the introduction of geophysics was of great assistance, and in 1937 the Patoka pool was discovered. This was followed by the discovery of the Cisne pool. The Louden and Salem fields lie on the west side of the Illinois basin and produce from a sandstone in the Chester (Upper Mississippian).

The accumulation of oil in the new Illinois fields seems to be controlled mainly by large closed structures. Stratigraphical tables and maps are included.

The questions of refinery capacity and crude disposal are discussed. G. D. H.

391.* New Guinea Oil Search to be Intensified. Anon. *World Petrol.*, Sept. 1939, **10** (9), 23–25.—The N.N.G.P.M. has sunk eighty shallow wells after preliminary aerial and geological work. A deep test has been started in the South Vogelkop area.

In Papua three bores have been sunk on the Aiapu structure, and the underlying mudstone has been shown to be petroliferous. There were evidences of shore-line conditions, but the wells were not deep enough to prove or disprove the existence of suitable reservoir rocks. G. D. H.

392.* What of Canadian Oil? H. G. Cochrane. *World Petrol.*, Sept. 1939, **10** (9), 31–36.—The discovery of heavy oil at Turner Valley in 1936 sent up Canadian production rapidly, and in 1938 Alberta gave 97·54% of Canada's oil output. The Turner Valley field seems to extend for 18 ml., and there are possibilities of an even greater extension. A potential of 55,000 brl./acre is estimated for it.

Oil has been found in the Blackfoot-Ribstone well 30 ml. south-east of Wainwright, whilst one 30 ml. east of Lethbridge is attracting attention. Tests are being made near Lundbreck, Clearwater River, Brazeau, Highwood, Moose dome, Milk River and Del Bonita. A test has been started on the Grease Creek structure 45 ml. north-west of Calgary.

In 1938 proration was introduced in Alberta, and this was followed by gas conservation.

In Alberta 85·5% of the crude is from the Turner Valley limestone, there is 10% of naphtha from the Turner Valley limestone, and 1·5% of crude from shallow horizons and other fields.

Markets, transport, pipe-lines, drilling, and royalties are all discussed. G. D. H.

393.* Maracaibo Geology. Anon. *World Petrol.*, Dec. 1939, **10** (13), 84–85.—The Maracaibo basin was separated from a larger Venezuelan geosyncline in Tertiary times. The northern third has a thin covering of younger beds over folded older Tertiary, with most of the Middle and Upper Tertiary absent. The southern two-thirds may have been subsiding from Miocene to Recent times, for there are thick shallow-water deposits, and in the Middle Tertiary there were open-sea conditions for a time.

Generally the oil pools are on domes or anticlines in Cretaceous to Middle Miocene beds, on monoclines with reservoirs wedging out up-dip, or in combinations of these two sets of conditions. Shore-line accumulations now give most oil.

There is often a marked angular unconformity between the Miocene and Pliocene. G. D. H.

394.* Oil Geology of Quiriquire. Anon. *World Petrol.*, Dec. 1939, **10** (13), 112.—Quiriquire lies in the Maturin basin. Wells penetrate Pliocene, Miocene, and mid-Oligocene formations separated by unconformities. Cretaceous beds outcrop 3 km. north of the field.

The Quiriquire formation (Pliocene) contains an upper heavy oil zone, a zone of light oil, and a lower heavy oil zone. The oil is in lenses about 25 ft. thick and averaging 20 acres in extent. The oil is apparently migrant from an unknown source, but by analogy with Trinidad, the Upper Cretaceous has been suggested as an important possible source. G. D. H.

395.* Recent Discoveries Keep Illinois Busy. H. F. Simons. *Oil Gas. J.*, 28.12.39, **38** (33), 59–60.—The development of Devonian lime production in fields producing from the Ste. Genevieve or Chester formations is now holding attention in Illinois, and four fields producing from the upper horizons have found Devonian oil; two have had Devonian showings, and at Louden the discovery well was a small Devonian producer. In the Salem field the Devonian pay seems to be thicker than at Sandoval to the north, where it is 6 ft.

Electrical logs of Devonian wells have shown in most cases that the lower part of the pay horizon contains water, and heavy water production has been noted in the Sandoval field. Estimates of total recovery from the Devonian range from 3500 to 10,000 brl./acre, and there are several old Devonian fields in Illinois on which to base such an estimate.

The Prairie Creek field, one of the newer fields in the region, has a productive area of about 600 acres. G. D. H.

396.* All Operations Gain in Venezuela. L. H. Figueredo. *Oil Gas J.*, 28.12.39, **38** (33), 171–172.—Venezuela's 1939 production will be about 208,000,000 brl., an increase of nearly 20,000,000 brl. over 1938. In addition to wildcats near more or less proven territory, there were tests in North and South Guarico testing Central Venezuela; the Alquitrana well in South-west San Cristobal in the folded zones of the Andes and No. 1 Cubagua, on the small island of Cubagua, 55 km. due north of Cumana.

In 1939 Oficina and Jusepin joined the list of producing fields. In the former, which may become the largest field in Eastern Venezuela, the thirty-one wells average about 2000 brl./day each. 25 km. north-west of Santa Ana is a possible new field, whilst north-east of Santa Ana in San Joaquin, four wells have found oil. In the El Roble area the first wildcat gave 800 brl. of paraffin base oil daily.

There are nine wells at Jusepin, and a 10-in. pipe-line connects this field with Caripito, a distance of 43 ml. The 96-ml. 16-in. line from Oficina to Guanta is now in use. This will also be available for El Roble, Santa Ana, and San Joaquin.

A new refinery was opened at Caripito, and at La Salina and San Lorenzo the capacity has been increased. G. D. H.

397.* Brazil's Search for Oil. E. de Carvalho. *Oil Gas J.*, 28.12.39, **38** (33), 68.—The Algoas basin is one of the many basins in the coastal belt, and contains Cretaceous, Eocene, and Pliocene beds resting on pre-Cambrian. The Eocene has good oil and gas shows at relatively small depths. The structures are complicated and much broken by faulting. By geophysical methods at least one anticlinal fold with several domes has been located. G. D. H.

398.* Persian Gulf Area Extends Oil Activities. H. S. Norman. *Oil Gas J.*, 28.12.39, **38** (33), 70.—Five producing wells were completed in 1939 on the Dammam structure of Saudi Arabia, with the result that the 1939 production was 4,300,000 brl. A well is under way at Abu Hadriya, 100 ml. north of Dammam, but, like the well at Ma'agala, it has not shown oil. Eight wells are producing from the lower pay at Dammam. Further concessions have been granted in Saudi Arabia.

In Kuwait three wells have been completed on the Burgan structure, which is said to be 30 ml. long.

In Iran a 165-ml. 12-in. pipe-line has been constructed from Gach Saran to Abadan, but the field is not yet in commercial production. The productive Naft-i-Safid structure has been shown to be comparatively small, complex and somewhat inferior to the other Iranian fields. On the Agha Jari-Pazanum structure north of Gach Saran, oil has been discovered at 8810 ft.

The Iraq production fell in 1939 by about 12%. The Bahrein production also fell. Bahrein has now sixty-two wells giving oil from zones at 2000, 2250, 4000 and 4600 ft. G. D. H.

399.* Marked Expansion in Argentina. E. P. Canera. *Oil Gas J.*, 28.12.39, **38** (33), 72.—In 1939 three wells were completed in the Tupungato region, all being good producers. A rise in production took place at Comodoro Rivadavia and at Plaza Huincul, but there was a decline in the Salta province. The total production for 1939 is estimated at 2,930,000 cu. m., where 1 cu. m. is 6·29 U.S. barrels. G. D. H.

400.* Alaskan Wildcat Nearing Critical Point in Depth. L. P. Stockman. *Oil Gas J.*, 28.12.39, **38** (33), 83.—A wildcat on the eastern side of the Alaskan peninsula across the Shelikof Strait from Kodiak Island has reached 6390 ft. It has shown gas at times, but no satisfactory oil sand has been logged. The operations are in the Kanatak district, where a well-defined anticline was found in the Salmon Creek valley.

The operating problems are described.

In 1922 two wells were drilled on the Pearl Creek structure 25 ml. north-west of Salmon Creek. The first well was stopped at 5003 ft. in 1926 without reaching the Trias. The present well is to test the Jurassic–Triassic contact, and has shown several tight sand bodies.

The occurrence of oil in sediments on the Alaskan peninsula has been known for over 60 years, for there are numerous seeps in the Cold Bay area, around Aniakchak Bay and Chignik. At Cold Bay they are on two lines of folding. These seeps are in sandstones of the Shelikof (Up. Jur.) formation. There are also gas seeps on the eastern fork of the Kejulik river. At Cold Bay the strike is north-east to south-west, and the north-westerly dip is interrupted by at least two lines of folds and faults which parallel the coast. The Bear Creek–Salmon Creek anticline has dips of 4° to the south-east and 16° to the north-west. In the core sandy lower Shelikof shales are exposed with Naknek beds on the north-west flank. It is faulted in the north-east.

The Pearl Creek dome is asymmetrical with the south-east flank dipping up to 30° and the north-west flank up to 69°. Naknek beds are at the surface on this very promising structure.

The Mesozoic and Tertiary beds of Alaska have many unconformities, but the Jurassic appears to be over 6200 ft. thick. The Lower Jurassic and Upper Triassic appear conformable, and the former contains limestones and calcareous sandstones and shales, and an upper zone of conglomerate and sandstone. G. D. H.

401.* Present Status of Mexican Oil. Anon. *Oil Gas J.*, 28.12.39, **38** (33), 94.—The first nine months of 1939 yielded 30,313,561 brl., as compared with 26,291,848 brl. in 1938. In the Tampico area two 1600-brl. wells were completed, and five were completed at Poza Rica with a capacity of 35,000 brl./day. In the El Plan field of the Isthmus of Tehuantepec six wells were successful, their total output being 6400 brl./day.

Geological and geophysical work has been undertaken, and various pipe-lines are projected or under construction. The waste gas of the Poza Rica field is to be utilized. G. D. H.

402.* Fyzabad Structure Continues Trinidad's Largest Producer. Anon. *Oil Gas J.*, 28.12.39, **38** (33), 117.—Fyzabad gave 40–45% of Trinidad's production in 1939. Activity was concentrated between the Forest Reserve, Los Bajos, and Palo Seco areas where a continuous productive zone seems to have been established. Two deep wildcats are being drilled north of the Central Range. G. D. H.

403.* No New German Fields ; Production Mounting. C. H. Ehlers. *Oil Gas J.*, 28.12.39, **38** (33), 117.—Although no new field appears to have been discovered in Germany in 1939, the output of the old Reich oil-fields will be 4,803,000 brl., as against 4,125,000 brl. in 1938. The Austrian production is also thought to have risen.

The Reitbrook field is said to have 25 wells with an initial production of about 1000 brl./day/well, and the Zistersdorf–St. Ulrich field has probably been extended. The Nienhagen field is the chief producer, yielding 2,700,000 brl./year.

The possibility of drilling south of Wietze is reported and a big gas-well has blown in near Bentheim. G. D. H.

404.* Bolivia Outlines Program for Coming Year. Anon. *Oil Gas J.*, 28.12.39, **38** (33), 120.—Two of the tests started in the Sanandita field have been completed as producers at about 2000 ft. with a combined initial production of 1258 brl./day. This field lies in the sub-Andean zone which has fifteen fields or prospective producing areas: Bermejo, San Telmo, Sanandita, Caigua, Camatindi, Machareti, Buena Vista, Camiri, Saipuru, Guariri, Tatarenda, Espejos, Isiboro, Chapare and Caupolican. Tests have been made at Bermejo, Camatindi, Machareti, Buena Vista, and Saipuru. Drilling is scheduled in the Rio Ichilo and Caupolican areas.

Sanandita is an asymmetric dome 2 ml. long and ½ ml. wide, with a red sandstone, conglomerate, and shale core, and marked by seeps. The Devonian shales are the most important producers. Oil zones have been found at 1440, 1624, and 2017 ft.

The Camiri structure showed productive oil zones at 3133 and 3274 ft. In one test very high gas pressures were encountered at 1365–1555 ft. A small output has been obtained at Buena Vista, Camatindi and Saipuru.

Pipe-lines and refineries are to be expanded. G. D. H.

405.* Intensive Exploration Due in West Indies. Anon. *Oil Gas J.*, 28.12.39, **38** (33), 122.—Two producing wells have been completed on the Maleno structure in Dominica at about 475 ft., and one gives 90 brl./day. The first well blew out at 1100 ft. and was completed in the shallow zone. The second was taken to 1200 ft. and encountered cavernous limestone. It was plugged back to the shallow zone. 12 ml. to the west at Quita Coraza a wildcat has reached the " big lime " at 3290 ft. There are other structures which will be tested. G. D. H.

406.* Rumania Production Slightly Under 1938. Anon. *Oil Gas J.*, 28.12.39, 38 (33), 122.—Political considerations have not encouraged work in Rumania, although in 1939 drilling was maintained at the 1938 rate in the proven fields. Two or three fairly large wells were completed in the old Baicoi field, but they did not offset the normal decline. Tzintea has a daily production of nearly 25,000 brl., and wells in the south Meotic unit yield oil from about 8800 ft. The Gura–Ocnitei field gives 25,640 brl. daily from 323 wells 5400–5900 ft. deep. At the end of the year Rumania was reported to have 128,196 brl. of oil/day from 2261 wells. G. D. H.

407.* Spectacular Rise Reported in Egypt this Year. Anon. *Oil Gas J.*, 28.12.39, 38 (33), 124.—The Egyptian output of 5,100,000 brl. was 207% above the 1938 yield. This increase was exclusively from the Ras Gharib field. Oil is obtained at depths of 2500–3500 ft. in this field.

A wildcat was drilled at Dishet el Dhaba, a few miles south of Hurghada, and entered granite at 2000 ft. On the Giftun–Saghir island, 15 ml. to the north-east, a test was abandoned at 2970 ft. owing to mechanical difficulties. A third test was drilled north-west of Hurghada.

Shallow tests are being made on the south side of Lake Albert in the Belgian Congo, and a deep test is being made on the Waki dome near Butiaba. G. D. H.

408.* Limited Exploitation in Ecuador during Year. Anon. *Oil Gas J.*, 28.12.39, 38 (33), 124.—Exploitation and production in 1939 were confined to the Santa Elena peninsula. In the new Tigre field, north-east of Ancon, four wells were completed at about 3800 ft., giving 150 brl./day each. At Cautivo drilling was continued to the Socorro sand, which there yields oil to eighty-five wells. The Socorro sand is also productive at El Tambo.

In the Carolina area some thirty-five wells obtain oil at depths down to 1000 ft. Its output is about 200 brl./day. The eastern and north-eastern boundaries of the Ancon field are as yet undefined.

Two wildcats have been drilled on the San Gabriel grant east of Ancon.

G. D. H.

409.* Japan is Ill Prepared to Weather Potential U.S. Embargo. H. Leopold. *Oil Gas J.*, 28.12.39, 38 (33), 160.—During 1939 Japan's production fell. Drilling was undertaken in the Akita, Tsuchisaki, and Nagaura districts, and there was great activity in the Kotaki field, where several relatively shallow wells were completed. Oil was struck at several places in the Omono River district at less than 300 ft., and altogether 1896 wells were in operation in the Akita prefecture in 1939.

Several deep wells have been begun in the Kinsui field in Formosa, and deep wells are projected in the old fields of Niigata.

The political aspects of the oil situation, the production of synthetic fuels, etc., are all discussed. G. D. H.

410.* South Louisiana Reserves are Increasing Steadily. C. Leyendecker. *Oil Wkly*, 1.1.40, 96 (4), 21–24.—During eleven months in 1939 the completions were 734, as compared with 520 in the corresponding period of 1938, and although allowables were reduced in several fields, production was up by 2%. In 1939 fourteen new fields were discovered in South Louisiana, about one field being found for every five wildcats. This high success ratio is due to geophysics.

Nearly half a million barrels of oil have been produced in South Louisiana.

Four of the new fields are 10,000–11,000 ft. deep and seven between 8000 and 9000 ft. Fifty-two new sands have been found in the old fields. Thirty-two wells have been drilled to more than 11,000 ft. Paradis and Eola are believed to be the most important discoveries. The latter produces from the Wilcox. The other new fields are : North Elton, Perkins, Grand Lake, Vermilion Bay, Lafourche Crossing, Potash, Kennilworth, LaPice, LaPlace, Happytown and Henderson.

At Ville Platte, which gave Sparta production, Wilcox oil has now been found. Seven new oil-sands were discovered at Golden Meadows.

A map shows the positions of the fields. G. D. H.

411.* Mississippi Looms as Nation's Major 1940 Geophysical Play. J. H. Todd. *Oil Wkly*, 15.1.40, **96** (6), 15–20; 22.1.40, **96** (7), 20–26.—When the Jackson field was declining rapidly, the Tinsley structure was drilled in search of gas, and oil was found. This led to a rapid increase in geophysical work in Mississippi. Mississippi is on the eastern side of the geosyncline of the Mississippi embayment, and there are associated smaller basins. Their prospects are deemed good, for prospecting has shown that oil does occur in structural basins.

The magnetometer shows highs on the basement, and 600 gamma closure highs are avoided because of the proximity of igneous rocks to the surface. Magnetic closures of 15–25 gamma are preferred for drilling here. Faults can also be traced by the magnetometer.

Many gravity meters are being used in Mississippi, and whilst they eliminate useless areas, every gravity anomaly is by no means a structure. Some crews can cover 1000 gravity-meter stations/month, at costs of 1–2 cents/acre in Mississippi. Seismic work is restricted to favourable areas for detail work in advance of the drill.

G. D. H.

412.* Paluxy, Pettit Discoveries Intensify Deep Search in East Texas. J. A. Kornfeld. *Oil Wkly*, 22.1.40, **96** (7), 12–14.—Recently high-pressure gas has been found in the Paluxy sand member and the Pettit oolitic lime zone of the Trinity. At Chapel Hill the Paluxy is 5533 ft. deep and on a short test gauged 15,000,000 c. ft./day of gas at 350 lb./in.^{2}. This sand has potentialities on fault structures, deep-seated domes and stratigraphic traps. The fault structures include Sulphur Bluff, Talco, and the Garland City fields. Chapel Hill may be a deep dome, whilst lenticularity is said to be effective at Garland City.

In November gas production was developed in the Groesbeck segment of the Mexia fault zone in the Pettit oolitic zone of the Lower Glen Rose. This was at 5591 ft., and 5,575,000 c. ft./day were gauged with 5 brl. of water-white distillate/1,000,000 c. ft. of gas.

The Pettit zone gives oil and gas at Sligo, Lisbon, Longview, and Waskom.

G. D. H.

413. Reservoir Characteristics of the Eunice Oil-Field, Lea County, New Mexico. C. C. Anderson, H. H. Hinson, and H. J. Schroeder. U.S. Bureau of Mines, Report of Investigations, No. 3456, July 1939.—The Eunice oil-field is situated in South-east New Mexico and produces from dolomitic limestone. Oil-wells in this type of rock are prone to exhibit striking differences in their individual productive capacities even within small distances from one another, and these conditions prevail in this case. Erratic variations in porosity, permeability, and in the vertical distribution of productive zones have provided difficult problems, and no direct relation was known between the areal structure and the manner of oil accumulation within the reservoir. A detailed study was consequently made of the position and characteristics of the oil- and gas-producing zones, which included analysis of "top-oil-pay" data, comparison of initial well potentials, study of water encroachment, and interpretation of porosity and permeability data obtained from examination of core-samples. Co-ordination of the facts thus obtained resulted in the establishment of three major porous and permeable zones in this field which are independent of lithological units and may not be directly related to geological structure. The methods applied satisfactorily here are thought to be applicable to other limestone-type reservoirs where similarly difficult subsurface conditions may exist. H. B. M.

414. Oil In Uganda. Anon. *Bull. Imp. Inst.*, 1939, **37** (4), 639.—In a report received by the Imperial Institute from the Director of the Geological Survey of Uganda it is stated that a site for a deep oil well has been selected near Kibero, Lake Albert, in the vicinity of hot salt springs, and drilling will soon be started. H. B. M.

415.* Geology of Bahrein Island. O. Kühn. *Oel u. Kohle*, 5.10.39, 35 (37), 702–704. —In spite of the reticence of the oil companies, it is possible to get a fair picture of the geology of Bahrein from the data published by Pilgrim and Heim and from a knowledge of the surrounding areas. Heim's identification of Cretaceous rocks was incorrect, a close study of Pilgrim's data showing the oldest exposures to be Eocene. This error was probably due to a badly drawn section of the Jebel Dukhan. If the dips had been correctly drawn it would have showed the rocks in the centre of the area to be the youngest, instead of the oldest, as had been assumed.

Bahrein lies at the edge of the Arabian Foreland, towards the Iranian Orogen. The horizontal bedding of the Miocene above the gently domed older rocks is suggestive of Stille's Savic phase of movement. In other parts of the Persian Gulf the same phase, domes with discordant Fars on Palæogene, is seen. These domes, however, have partly an Iranian orientation, with their shorter axis at right angles to that direction. At Bahrein, on the other hand, it is the short axis which has the Iranian orientation, whilst the longer is orientated north to south. It appears probable, therefore, that Savic folding in the Iranian direction was superimposed on an original north to south folding. S. E. C.

416.* Gravity Map of Poland, with Observations on the Southerly Continuation of the Tempelburg Axis. H. Closs and R. v. Zwerger. *Oel u. Kohle*, 1.1.40, 36 (1), 2–6.— A north-west to south-east gravity high to the south-west of Thorn and Bromberg represents the continuation of the Tempelburg axis. The low-gravity values to the south of Bromberg and the Lodsch gravity low indicate, however, that in this area the uplift has been displaced. There is thus no straight connection between the Tempelburg axis and the Polish Mittelgebirge (Kielce to Sandomir). The axis, after the break in the Hohensalza district, continues south-east, and there is probably a connection between it and the Upper Silesian–Polish massif. The salt-stocks of the Bromberg basin reach the zone of regionally low-gravity values, and lie partly on the edge and partly on the break of the Tempelburg axis. The occurrence of natural gas at the edges of the Hohensalza salt-stock makes the Bromberg structures interesting to the oil geologist and raises the question whether the oil indications in the neighbourhood of the south-east continuation of the Tempelburg axis are associated with salt masses or with faults. S. E. C.

417.* Occurrence of Bituminous Shales in the Lika, Yugoslavia. G. Potunnikov. *Oel u. Kohle*, 1.1.40, 36 (1), 6–9.—Bituminous shales are found in the southern corner of the Lika, a district in the west part of Yugoslavia. These shales have been placed between the White Dolomite of the Upper Jurassic and the *Cladocoropsis* limestone, but as they are also found in a position where the Lias–Trias contact is said to occur, further investigation seems to be necessary. Shallow shafts have shown that they extend over a considerable area. The thickness of the shale series appears to be of the order of 120–200 ft., and it consists of a large number of thin marl beds which are more or less impregnated with oil. Part of this series weathers to a light colour, whilst the rest remains brown. The shales yield 5–6% of oil on solvent extraction with CS_2 and 20–25% on destructive distillation. The oil obtained is of good quality, and is much better than that yielded by the Esthonian shales. S. E. C.

418.* Southern Part of the Benthe-Gehrden Salt-stock. L. Riedel. *Oel u. Kohle*, 15.1.40, 36 (3), 27–33.—This paper is concerned with the uplift of the Hannoverian salt-stocks, and the southern part of the Benthe-Gehrden salt-stock is considered in detail in order to throw light on the subject. The stratigraphy and structure of the area are described, and it is concluded that the uplift of the salt took place in a zone previously defined by faulting. In consequence of earlier consolidation, the effect of the salt uplift on the surrounding rocks was small and was limited to the dragging up of a fault block of Cretaceous rocks and the tearing off and squeezing into a crush zone of softer rocks from below. Further evidence that the uplift took place in a zone previously defined by faulting is its position in the lattice-work formed by Rhenish and Hercynian disturbances. This salt-stock is therefore an example of the fact that in many cases the structure of an area has not been determined by the salt, but by earlier fault tectonics. S. E. C.

Geophysics.

419.* Geophysical Work in Prospective Polish Oil Regions. R. v. Zwerger. *Oel u. Kohle*, 5.10.39, **35** (37), 697–701.—There are two principal areas in Poland where geophysical prospecting for oil has been carried out: the Carpathian foreland with, to a limited extent, the north margin of the Flysch zone of the true Carpathians, and the region on the Lower Weichsel (Prov. Posen). A third area around Vilna was to have been surveyed, but it is doubtful whether any measurements have been made. The gravimetric, seismic, and magnetic work done in these areas is summarized. This work was marked by a certain lack of co-ordination between the various surveys, and in order to obtain a solid basis for future exploration and production programmes the extensive gravimetric and reflection surveys must be in part expanded and in part condensed and supplemented. S. E. C.

420.* State Oil and Geophysical Survey in Greater Germany. A. Bentz and H. Closs. *Oel u. Kohle*, 1.11.39, **35** (41), 731–740.—A summary of the work done by the survey up to September, 1939, and a discussion of the principles on which the survey is based. Its value may be judged by the fact that the eight oilfields of 1932 have now grown to twenty-five, which are divided amongst five petroleum provinces, North German, Thuringian, Upper Rhine Graben, sub-Alpine Basin, and the Vienna Basin. The type of work carried out by the survey is illustrated by the example of the Tempelburg axis and the structural investigations in the region of the Aller. S. E. C.

421.* Travel-Time Maps and Geology in E. Pommerania and in the Alpine Foreland. H. Reich. *Oel u. Kohle*, 1.11.39, **35** (41), 740–743.—Where geological conditions are favourable, travel-time maps reflect the geological structure, a seismic high, for instance, corresponding to a geological high. It is pointed out, however, that the velocity of elastic waves is not dependent on the age of the rock, but on its physical properties, and although in general the velocity in any given rock type tends to increase with age, in a series of formations the velocity may well vary widely instead of showing a steady increase. Two examples, one from East Pommerania and the other from the Alpine foreland in the neighbourhood of Kremsmünster, are dealt with in some detail in order to illustrate the care which is needed in the interpretation of these travel-time maps. It is shown that in order to get the most out of the method, travel-times should be measured for different distances. In this manner trouble due to the effect of surface beds can be eliminated and various geological structures can be isolated one from another and investigated. S. E. C.

422.* Gravimetrical Investigation of the Schleswig-Holstein Salt Uplifts. R. v. Zwerger. *Oel u. Kohle*, 1.11.39, **35** (41), 744–749.—The regional gravimeter survey of Schleswig-Holstein began in May 1935, and the two first torsion balance parties commenced work at Heide in June 1935. Seismic refraction surveys began in 1936. The results of these surveys are given on a map which shows the zones of uplift as defined by the gravimetrical work and confirmed by the seismic. Regional measurements show that the form of the uplifts, which are a Saxon–Rhenish type with a mainly Rhenish strike, is governed by the Friedrichsstädt massif in the west and the Kiel massif in the east. The Husum massif closes the area to the north. The intensity of the salt tectonics, a maximum in the younger Kimmeridgian Phase, increases with approach to the Friedrichsstädt massif. The form of the gravity anomalies differs somewhat from those typical of the Hannoverian salt-stocks. This is due to a different density distribution. In Schleswig-Holstein the core of the structure is composed of Rotliegendes salt-clay, of higher density than rock-salt. This is followed by Middle Zechstein conglomerates with Upper Zechstein rock-salt on the flanks. S. E. C.

423.* Torsion Balance Measurements over the Gifhorn Salt-stock. W. Wolff. *Oel u. Kohle*, 1.11.39, **35** (41), 750–756.—The gradient map shows a well-defined, closed gravity minimum which strikes north-east to south-west and has its centre to the north-west of Gifhorn. The gradient values are not symmetrically disposed, those in the east and south-east being of the order of 80–100 E., whereas those in the north, north-west, and west are almost all less than 50 E. This is not so much due to asymmetry of the salt mass as to the strong regional increase in gravity to the south-east. General tectonic conditions in the Gifhorn area are discussed. S. E. C.

424.* Gravitational Effects of Salt-stocks. J. Schander. *Oel u. Kohle*, 1.11.39, **35** (41), 756–759.—The normal effect of the North German salt-stocks is to give gravity minima of the order of 3–10 m.gals. Long, narrow salt-structures, such as are to be found to the north-east of Gifhorn, give much smaller anomalies—2 m.gals. or less. In between these two types all variations are to be found, but all are characterized by gravity minima. An important factor controlling the magnitude of the anomaly is the nature of the surrounding and overlying rocks. When these are compact and dense, the anomaly will be greater than in the case of loose, unconsolidated sediments. Although gravity minima are indicative of salt in Germany, in the Gulf Coast States of America the reverse is the case. This is because of the presence there of very dense caprock above the salt. It is now being recognized, however, that small gravity minima in the Gulf Coast may be due to deep-seated salt masses. A different type of anomaly is given by the Lüneberg type of salt-stock, its characteristic being a strong, well-developed ring of maximum values around a central core where the values are of the same order as the regional gradient. This more complicated pattern is due to steeply tilted older rocks surrounding the salt and its caprock and being surrounded in their turn by younger rocks. The main gravitational effect is given by the dense older rocks. S. E. C.

425.* Geophysical Laboratory of the Reichsstelle für Bodenforschung. H. J. Schoene. *Oel u. Kohle*, 1.11.39, **35** (41), 759–761.—A short description of the apparatus and the type of work done in the geophysical laboratory. S. E. C.

426.* Relationship between Elastic Properties and Temperature in Zechstein Rock-salt. St. v. Thyssen-Bornemisza. *Oel u. Kohle*, 1.12.39, **35** (45), 767.—By means of his new apparatus for determining the velocity of elastic waves in cores (see Abs. 1084, 1939) the author has determined the longitudinal velocity of waves in a core of rock-salt taken from the Meissendorf salt-stock at a depth of 400 m. The temperature of the core was varied from 20° to 320° C. The curve relating velocity with temperature shows a sharp fall between 20° and 60° C., then a gradual decline until 120° C. is reached. After this there is a rise in velocity, which falls off at about 220° C., and finally becomes a fall again at 300–310° C. Measurements made with increasing and decreasing temperatures show good agreement. S. E. C.

427.* Geophysical Methods. Anon. *World Petrol.*, December 1939, **10** (13), 74–75.—Three-quarters of the possible producing area of Venezuela is covered by young deposits which either mask or reflect only weakly the underlying structure. Most of the geophysical work has been carried out in Eastern Venezuela.

In general the torsion balance and magnetometer have given satisfactory results. Little electrical work has been done, but continuous profiling has been widely applied. During 1939 eight gravity meter, six torsion balance, twelve seismic, two magnetometer, and four soil-analysis parties were at work in Venezuela. G. D. H.

428.* The Engineer's Part in the Search for Petroleum in the Argentine Republic. E. P. Canepa. *Bol. Inform. Petroleras*, November 1939, XVI (183), 3–26.—This paper contains an interesting study of the development of exploration work in the search for petroleum in the Argentine. It is well illustrated with geological maps, but the author directs attention, as have others before him, to the great lack of reliable geological surveys of the Argentine. In Fig. 1 it will be seen that 67·5% of the total area of the Republic has not yet been surveyed. Description is given of the stages undertaken to ascertain the probable presence of oil in the strata, before actual trial borings are made. The author then discusses the two most important methods of prospecting when for various reasons the strata are abnormal or faulty—namely, the gravimetric and the seismographic methods. In connection with the gravity measurements, the use of the Ascania torsion balance is described, and in respect to the second method named, the use of a recording seismograph is illustrated. H. I. L.

Drilling.

429.* Present Year may Approach 1937 in Drilling Activity. H. F. Simons. *Oil Gas J.*, 4.1.40, **38** (34), 15–16.—Detailed statistics are given for drilling tests completed in 1938 and 1939 as well as generalized data for the years 1919–39 inclusive. The latter chart shows repeated cycles in drilling activity with peaks occurring about every four years.

Analyses are made of past experience, and the future activity for 1940 is generally outlined, based on predictions made by the author. A. H. N.

430.* Difficulties in Offshore Drilling. N. Williams. *Oil Gas J.*, 11.1.40, **38** (35), 14–15.—A description is given of a test being started approximately 300 ft. offshore, where one of the most complete assemblies of drilling equipment on the Gulf Coast is being provided. All equipment and facilities, including mud-pits, tanks for water, fuel, and reserve mud, and various auxiliary units, are being set up at the location. A major handicap in carrying out the drilling is the marshy shore, unusually treacherous, consisting of boggy and shifting soil. No marine transport can be utilized, as the Gulf is too shallow for long distances off the shore—maximum depth at ½ mile being only 4½ ft.

The methods used in overcoming unusual difficulties in this unusual drilling site are described.

The history and prospects of this potential pool are given at the end of the paper. A. H. N.

431.* Safety—Proper Handling of Cathead. Anon. *Oil Gas J.*, 18.1.40, **38** (36), 39.—This is a short discussion on the safety precautions to be observed in handling the cathead line. The cathead man is advised to watch other men on the rig rather than the cathead itself. A. H. N.

432.* Metals in Drilling—Rotary Drilling Bits. W. L. Nelson. *Oil Gas J.*, 18.1.40, **38** (36), 45.—Recommendations are given for metal used in rotary drilling-bits, these recommendations being collected from prominent metal manufacturers, steel companies, and oil-company field men. The table gives the approximate composition in terms of per cent. C, Mn, Cr, Ni, Mo, Va, and Si, the approximate physical properties in terms of yield point, elongation, and Brinell hardness, and recommended heat treatment for metals used in bodies, cutters, pins, bits, reamers, fishing-tools, core-bits, etc.

These properties are also briefly discussed, and the paper ends with a list of references to literature on metals. A. H. N.

433.* New Casing Practice Cuts Equipment Cost. P. Reed. *Oil Gas J.*, 18.1.40, **38** (36), 53.—In casing certain wells in Texas fields several operators have been following a practice which achieves substantial savings in the investment in pipe. In one case the saving has been as much as $700 per well. Essentially this practice consists of setting light-weight pipe at greater depths than have been generally customary for pipe of this type.

Specific examples are quoted, with details of dimensions and depths. Joints were welded electrically, in one case, in 8½ hr., at a total cost of $34 or 1·1 cents/ft. lineally. Other details are given. A. H. N.

434.* Complex Phosphates for Deflocculation of Drilling Mud. C. F. Bonnet. *Oil Gas J.*, 1.2.40, **38** (38), 39.—Examination of the known chemical data on commercial sodium phosphate shows that only those classed as " complex " phosphates formed by dehydrating normal phosphates are effective for deflocculating drilling muds.

From the data given in the paper it is apparent, that while these complex phosphates are good, as a class, for lowering the viscosity of drilling muds by deflocculation, there are definite chemical differences between members of this class corresponding to the different effects they have on drilling muds. It is concluded that tetrasodium pyrophosphate, (1) has a very sharp deflocculating effect on fresh mud ; (2) is quite stable in solution, but has low solubility ; (3) has a higher pH value than other " complex " phosphates; and (4) its accumulations in drilling mud will tend to increase viscosity, and this effect will retard sand settling before the increasing viscosity is apparent.

Similarly, it is concluded that sodium tetraphosphate (1) has a deflocculating effect equally as sharp, but has been observed to aid sand settling to a greater degree than the pyrophosphate; (2) is quite stable in solution; (3) has a pH value about the neutral point; and (4) its accumulation in high concentrations has little tendency to increase viscosity, or, in other words, over-treatment is not apt to occur.

A. H. N.

435.* Drilling Technique (in Venezuela). Anon. *World Petrol.*, December 1939, **10** (13), 86.—The entire issue for December is devoted to Venezuela, and in this paper the technique followed in Lake Maracaibo fields, where 1669 out of a total of 2986 wells have been drilled in the lake, is described and illustrated. A review is made of the evolution of water operations from the original crude shore-line adaptations of conventional land structures to modern special marine foundations, in 60 ft. of water and located as far as 8 miles from the shore.

Since the cost of all Lake foundations varies directly with the depth of water, the cost of erecting required pipe-racks, slush-tanks, and boiler-stations would become prohibitive in the more lakeward operations. To meet this condition, drilling-barges were developed to take the place of additional foundations. The barges, 48 ft. × 110 ft. × 8 ft. in size, are equipped with necessary boilers and pumps, ditches, pipe-racks, etc. Engine, draw-works, rotary, and blocks are erected on the well foundations. The barges are held in positions by four anchors and are not tied to the foundations. Under normal conditions wells are completed at an average depth of 3000 ft. in 10–15 days.

Producing operations are basically similar to corresponding operations on land. In many of the fields pumping and gas-lifting operations are required.

Details are given of the derricks, rigs, and power required, of the various formations drilled and specific problems encountered, of casing and of completion programmes.

A. H. N.

436.* Drilling in Eastern Venezuela. Anon. *World Petrol.*, December 1939, **10** (13), 94.—Drilling methods and equipment in use in Eastern Venezuela are described, and are found to be similar, basically, to those used in the Mid-Continent and Gulf Coast fields. Steam is the most popular form of power.

Complete unitization of rigs is adopted wherever possible. Drilling engines are unitized with the sub-structures; draw-works are made into compact units; mud-pumps are permanently mounted on wheeled wagons; feed-water pumps and generators, with all their piping, are made into skid units; engine-sheds have been designed for transportability and ease of assembling; piping connections are so made as to be transportable in sections. Where the terrain permits, derricks are skidded between locations or moved on specially designed wheeled units, whilst boilers are permanently mounted on skids.

Drilling mud control is becoming an ever-increasing problem, on account of the declining reservoir pressure in some fields. Pressure drilling is being considered as a possible solution of the problem.

Pressure-maintenance projects have been adopted wherever possible; remarkable success having been already met in some fields, as decline in pressure has been very small since these projects were put into operation. A. H. N.

437.* Drilling Equipment Selection. J. E. Brantly. *World Petrol.*, December 1939, **10** (13), 96.—Exploration for and exploitation of petroleum deposits of Venezuela require the employment of drilling equipment of varying character and capacity. Between two extremes of aridity and relatively simple transportation problems in so far as equipment is concerned and the regions of heavy rainfall where machinery and tools can only be moved at considerable expense and roads are costly, there are the various intermediate types of terrain and natural conditions.

The choice of equipment will be governed by these conditions and by the size and depth of the hole to be drilled.

In arid regions the logical source of power is the I.C. engine, and, unless fuel considerations make gasoline or butane engines preferable, the diesel type is more popular in view of the substantially lower cost of the fuel as compared with gasoline, and also because of the fact that the power characteristics of the diesel engines are more satisfactory on drilling operations than are those of the gasoline or butane engines. Relative cost of diesel fuel per brake horse-power hour appears to be approximately one-fifth that of gasoline. Diesel engines, on the other hand, require more skilful and costly attention than do the spark-plug engines.

Relative costing is made and individual advantages are studied for steam prime movers, pumps, hoisting equipment, and rotating units in a similar manner to the above. Actual examples of problems to be solved in the choice of equipment are given by assuming certain conditions to exist. A. H. N.

438.* Mechanical Practicability of Electrical Logging While Drilling. D. G. Hawthorn and J. E. Owen. *Petrol. Engr*, January 1940, **11** (4), 71.—The basic plan behind the development of electrical logging while drilling was the use of the drilling-bit as the exploring electrode from which electrical readings might be obtained and recorded at the surface. To accomplish this it has been necessary to incorporate, as an integral part of the drill-stem, an electric circuit, and to insulate by suitable means the bit from the pipe. It was further necessary to provide recording apparatus and means for connecting this apparatus to the drill-stem circuit.

The electrical record taken while drilling is similar to any conventional electrical log, except that potentials and resistances are continuously measured and recorded on a meter while drilling is in progress. The chart is in plain view of the observer at all times. Formation resistance is recorded on the right and formation potential on the left. Both measurements are recorded against the well depth as the other co-ordinate.

The paper describes in detail the electric circuit and its testing, the constructional and mechanical features of the drill-stem, insulated electric terminals, insulated drill-collar, kelly and kelly sub, and miscellaneous equipment. Records are given of the behaviour of the equipment and the advantages accruing from its use. Drilling time is now affected to an almost negligible degree.

All advantages of using this method of electrical logging apply more or less to the drilling of wildcat wells and also to the drilling of proven structures that are unusually difficult to explore. The most important advantages of continuous electrical logging appear to be—

(1) it is an invaluable aid in conducting an intelligent coring programme;

(2) contact points and breaks in the formation can be instantly detected as the bit drills by;

(3) data that indicate the nature and characteristics of the formation being drilled are continuously and instantly available for subsurface correlation while drilling is in progress.

The availability of this information should be of great assistance in answering the many difficult questions arising in present-day deep exploratory well drilling (*cf.* abstract No. 246, 1940, for similar paper). A. H. N.

439.* December Spurt Brings Year's Drilling Near 1938 Level. L. J. Logan. *Oil Wkly*, 15.1.40, **96** (6), 12–14.—Statistics for drilling and completion activities in the U.S.A. are given for December 1939. Whereas drilling normally declines seasonably in December, it increased materially in the final month of 1939, further reflecting the brisk general business activity and the improved markets for refined products and crude oil.

Having expanded about 12% from the November proportions, field development in December was the greatest for the year. Well completions were the most numerous since November 1937, and thus were near all-time record level.

Records are given for average number of wells completed daily in U.S.A., by months from January 1933 to December 1939. A. H. N.

440.* More Drilling in U.S. Forecast for 1940. W. H. Strang. *Oil Wkly*, 29.1.40, **96** (8), 54–56.—The circumstances surrounding the industry as the year opens should

react to bring about the drilling in 1940 of 6·5% more wells than in 1939. Detailed studies of these circumstances show that 29,346 wells will be drilled during 1940.
A. H. N.

441.* Rapid Expansion of Deep Drilling Continues. Anon. *Oil Wkly*, 29.1.40, **96** (8), 68.—A study is made of deep-well drilling over the past years, and data are shown both in tabulated and graphical forms. The number of tests carried to 10,000 ft. or more during 1939 is double the total of all preceding years. Indications are that 250 such operations will be drilled during 1940. A. H. N.

442.* Drilling Expenditures in 1940 to be Larger. B. Mills. *Oil Wkly*, 29.1.40, **96** (8), 84.—Cost analysis is made in various states and interesting figures are presented. Depreciation in the form of wear-and-tear is much greater than most operators realize. It is pointed out that the charge of only the amount of equipment used on and left at the well is incorrect, since depreciation of all equipment should be included. Many small equipment items will not drill more than one well, but others may drill a dozen wells.

Forecast for drilling expenditures for 1940 is made for various States of America.
A. H. N.

443.* Average Well Depth Decreases in 1939. W. H. Strang. *Oil Wkly*, 29.1.40, **96** (8), 92.—A slight decrease in the average drilling depth in the U.S.A. is a significant feature of 1939 operations. Data are presented for average depths from 1925 onwards, and a comparative study is made of these figures. A. H. N.

444.* U.S. Drilling Above Average Level in 1939 Despite Drop. Z. H. Mischka. *Oil Wkly*, 29.1.40, **96** (8), 124.—Tables are given for drilling activities in the U.S.A. and a study of the trend of events is made. The completion of 28,274 tests in 1939 represents a decrease of 2·5% as compared with 1938; but this figure is still 28% larger than the average annual rate for drilling for the past decade. A. H. N.

445.* Increased Wildcat Drilling has Comparable Success. Anon. *Oil Wkly*, 29.1.40, **96** (8), 160.—A study is presented of wildcat activity and its results in the U.S.A. for the years 1938 and 1939. A. H. N.

446.* Rotary and Cable Tool Rigs Fulfil Divergent Needs. Anon. *Oil Wkly*, 29.1.40, **96** (8), 178–180.—A survey is presented of the rotary and cable-tool rigs in use in the U.S.A. Rotary rigs are in use in about 60% of drilling operations on January 1, 1940; cable-tool rigs constitute the remaining 40% of the total. A. H. N.

447. Drilling Patents. F. W. Hild. U.S.P. 2,186,139, 9.1.40. Appl. 9.1.37. Safety casing-head for permanently holding an outer casing and an inner casing in suspension and adapted to receive a temporarily superimposed drilling control column.

J. D. Hughes. U.S.P. 2,186,725, 9.1.40. Appl. 22.4.38. Straight-hole bit with blades on a body, one of the blades extending radially a greater distance than the others to create a greater unit area pressure on the low side of the bore being drilled when the bit is inclined from the vertical, thus reaming the low side of the bore and correcting the inclination.

D. C. Matthews. U.S.P. 2,186,875, 9.1.40. Appl. 27.6.38. Well-bore treatment during drilling consisting of forming a body of plastic setting material *in situ* in a well-bore above an uncased portion into which such material would normally dissipate while in plastic state.

A. L. Stone and A. E. Rice. U.S.P. 2,186,999, 16.1.40. Appl. 22.12.37. Oil-field power-plant.

C. H. Barnes. U.S.P. 2,187,007, 16.1.40. Appl. 29.3.38. Releasable cable-head, adapted to connect a cable with a well-tool, consisting of a case in which an enlargement at the end of a cable is held. The cable and case can be separated by exerting a predetermined tension.

R. E. Hendrickson. U.S.P. 2,187,028, 16.1.40. Appl. 24.10.38. Well-survey instrument casing consisting of double-walled member, the space between the double walls being evacuated to avoid ill effects of high or "destructive temperatures" encountered in deep wells.

L. H. Kirkpatrick. U.S.P. 2,187,037, 16.1.40. Appl. 9.6.39. Well tool.

W. A. Larson. U.S.P. 2,187,042, 16.1.40. Appl. 4.8.39. Bailer or sand-pump consisting of plunger, valves, and means for operating the plunger.

G. A. Smith. U.S.P. 2,187,367, 16.1.40. Appl. 4.5.39. Method and apparatus for orienting drill-stems.

G. J. Maier. U.S.P. 2,187,384, 16.1.40. Appl. 14.3.39. Diamond drill-bit.

J. F. Chappell. U.S.P. 2,187,392, 16.1.40. Appl. 11.1.37. A small derrick with laterally movable crown block.

L. J. Hopkins. U.S.P. 2,187,399, 16.1.40. Appl. 13.1.39. A device for making drill-pipe connections.

R. C. Baker. U.S.P. 2,187,480, 16.1.40. Appl. 12.12.38. Well-cementing apparatus.

R. C. Baker. U.S.P. 2,187,481, 16.1.40. Appl. 12.12.38. Well-packer.

R. C. Baker. U.S.P. 2,187,482, 16.1.40. Appl. 12.12.38. Cement retainer.

R. C. Baker. U.S.P. 2,187,483, 16.1.40. Appl. 21.4.39. Well-cementing apparatus.

C. E. Burt. U.S.P. 2,187,487, 16.1.40. Appl. 14.1.39. Bridge plug of the Baker cement retainer type.

A. R. Maier. U.S.P. 2,187,623, 16.1.40. Appl. 28.5.37. Draw-works for rotary-drilling apparatus of the three-shaft, two-post type.

G. F. Stamps. U.S.P. 2,187,635, 16.1.40. Appl. 23.5.38. Well-packer utilizing high-pressure fluid.

L. L. Smith. U.S.P. 2,187,668, 16.1.40. Appl. 23.5.38. Waterproof quick-setting adhesive Portland cement and process of making same.

J. B. Picard. U.S.P. 2,187,693, 16.1.40. Appl. 3.7.37. Band-wheel construction.

V. Voorkees. U.S.P. 2,187,871, 23.1.40. Appl. 9.8.37. Apparatus for drilling sub-aqueous wells.

H. A. Wood. U.S.P. 2,187,960, 23.1.40. Appl. 29.1.37. Dead-line fastener and clamp for derrick lines and the like.

H. E. Grau and J. D. Chesnut. U.S.P. 2,187,969, 23.1.40. Appl. 21.3.38. A rotary drilling system in which the table is driven by a hydraulic prime mover deriving its energy from a fluid under pressure and from a common source as the mud-pump. The speed of rotation of table and the pressure of the mud-flush system are interdependent.

W. T. Caldwell and J. P. Lang. U.S.P. 2,188,107, 23.1.40. Appl. 6.4.38. Rotary drilling-rig.

E. K. Lane. U.S.P. 2,188,409, 30.1.40. Appl. 18.2.37. Wire-line pipe-cutter fitted with slips which engage on giving the wire an upward jerk. Pulling the line farther upwards results in cutters moving outward from the body of the apparatus and piercing the pipe.

H. W. Cardwell. U.S.P. 2,188,455, 30.1.40. Appl. 25.6.37. Well-spudding apparatus.

W. C. Trout and E. M. Tollefson. U.S.P. 2,188,583, 30.1.40. Appl. 11.1.37. Walking-beam bearing and hanger arranged to transmit power and accommodate misalignment of the various parts.

A. L. Armentrout. U.S.P. 2,188,589, 30.1.40. Appl. 22.5.39. Method for landing well-casings by putting it under tension, and then welding it at the head and removing the tensioning means.

G. E. Cannon and J. L. Foster. U.S.P. 2,188,767, 30.1.40. Appl. 25.7.36. Cement and cementing operation using Portland-type cement to which has been added a solution of caustic alkali and a material of the class consisting of humic, gallic, tannic, quercitannic, and lignic acids. A. H. N.

Production.

448.* Mixing Gases in Porous Media. R. Ducker and R. L. Huntington. *Oil Gas J.*, 4.1.40, **38** (34), 37.—Gas-recycling in distillate fields is necessary for three main reasons :—

(1) conservation of gas as fuel ;
(2) maintenance of a single-phase fluid within the reservoir ;
(3) driving the distillate-bearing fluid toward the producing wells.

The ideal situation would be one in which the dry gas would push the distillate-bearing fluid forward as a piston to the producing wells without mixing taking place in the pore spaces. Mixing actually does occur.

To determine the rate of mixing in porous media under static and flow conditions, small-scale tests were undertaken both for one- and three-dimensional flow, in which air and gas were allowed to diffuse in opposite directions through sand-packed tubes. The apparatus used is illustrated and the procedure followed described. Graphs are given of the results obtained, followed by a discussion and analysis of the data.

The authors' conclusions are that although the theory points out the likelihood of much slower diffusion between gases at higher reservoir pressures, it appears that the dilution of rich distillate gas with dry recycled gases will present a problem which must be solved lest the economic production life of a field be shortened due to high and prohibitive recycling ratios. Until a mass of data can be accumulated showing the effects of such variables as injection rate, well spacing, gas densities, permeabilities, porosity, etc., the empirical method of attacking the problem seems to be the logical approach. A. H. N.

449.* Improved Repressuring Plant in Titusville Field. J. P. O'Donnell. *Oil Gas J.*, 18.1.40, **38** (36), 36.—Core analysis revealed the fact that the saturation value was high enough to warrant the installation of a modern production equipment on an old lease near Titusville, Pa.

The paper describes a compact repressuring plant which has been installed and which has been progressively improved. Purchased electric power is used on this property. A. H. N.

450.* Repair Long String of Tubing under High-flowing Pressure. Anon. *Oil Gas J.*, 25.1.40, **38** (37), 201.—Indications of trouble in the world's deepest flush-producing well were given by the fact that the pressure on the oil string had continued to build up gradually, although in completion of the well two tubing-packers had been set at 11,200 ft. to seal off the extremely high bottom-hole pressure. The conclusion was that either the packers were not holding or that the tubing collars were leaking.

An attempt was first made to kill the well by pumping heavy mud through the tubing, and pressures up to 6000 lb./sq. in. were used. When the pumps were stopped, the well pressure would build up quickly to 4950. Other preliminary operations are described.

The trouble arose, it was found, from a hole which had been cut by well pressure in the tubing at a point between 4000 and 5000 ft., the mud being returned to the surface because of the jetting action caused by the hole.

Detailed description is given of the operations carried out in repairing the tubing. Ordinarily, in cases of tubing leaks, it might be possible to run a string of small pipe inside the $2\frac{3}{8}$-in. tubing and kill the well, but in this case the tubing was found to be so crooked as a result of high pressure that it would have been impossible to get another string down. The operations were carried out with a drilling barge. A. H. N.

451.* Gas Condensate Well Important to Lisbon. G. Weber. *Oil Gas J.*, 1.2.40, **38** (38), 31–33.—Discovery of deep high-pressure gas-condensate production in Lisbon field of North Louisiana is of considerable engineering interest because of the thoroughness of its drilling record through the employment of advanced engineering principles.

Careful drilling was necessary due to the slim hole carried. Rotary speeds, choice of bits and fluid volumes were controlled to give a hole which never varied 1° off vertical. With $\frac{7}{16}$-in. clearance through the 7-in. casing and total depth of 8900 ft., the test is believed to have required the deepest cementing job with the smallest clearance of any test to date.

A concise record of the well is given with drilling-time studies, electric logs, sample, gas-detector record, etc. The prospects of the pool are discussed. A. H. N.

452.* Bottom-hole Well Regulators. K. C. Sclater. *Petrol. Engr*, January 1940, **11** (4), 25–26.—One method of preventing or mitigating freezing in high-pressure gas wells on reduction of pressure is the use of removable bottom-hole chokes. This practice has been followed for years. The basis for its success is that the cooled gas draws heat from the walls of the well on its way to the surface. The method has its limitations, the chief one being that it is dependable only in gas wells, the rate of production of which is constant. A change in the rate of production means a change of choke, and consequently a pulling-up operation, with interruption in the flow of the well.

A bottom-hole regulator has been designed which works on the principle that a variable opening allows gas to flow at a constant pressure drop between its two sides. A spring-controlled valve automatically regulates the flow of the gas, so that the pressure on the exit side plus that due to the spring equals the pressure on the inlet side. A decrease in the inlet pressure-formation pressure means a decrease in flow, so that the pressure drop still remains the same. An adjusting ring adjusts the force exerted by the spring so that various limits of pressure variation may be dealt with effectively.

A diagram giving a detailed and clear section of the regulator both in the open and closed positions of the valve is included in the paper. While data are still inconclusive, it is believed that this regulator has a wide application, particularly in distillate production fields. A. H. N.

453.* Gas-lift Practice in West Texas Fields. H. L. Flood. *Petrol. Engr*, January 1940, **11** (4), 27–30.—West Texas, considered as a whole, embraces as great a variety of production phases as does any area comprised of old and new fields. This paper, however, deals mainly with gas-lift practice in fields where production has declined to 5 or 10 brl./day and where water/oil ratio may be as high as 1000 to 1.

The predominant characteristics of large fluid-volume wells in the Hendrick field is the high static level of the fluid, usually 200–250 ft. from the well-head. The working fluid level, however, is from 1200 to 1400 ft. from the well-head. Consequently an essential feature of any gas-lift installation must be the ability to kick-off the high fluid column and then produce efficiently the large volume of fluid. Flow-valves of the differential-, and velocity-control types have, therefore, been used extensively in this service.

Gas-lift in these fields is being practised extensively with installations ranging from conventional types to new applications, some incorporating new principles, others reverting to the earliest and simplest arrangements known. The methods selected in the paper represent the more interesting and representative methods in use.

Detailed diagrams and discussions are made of various intermittent operations and arrangements and types of packers. In certain instances throughout the West Texas area operators have been able, by suitably packing-off overlying gas sands, to use the energy of the gas to lift oil from the well either in continuous or intermittent flow—an operation termed " Braden-heading." A. H. N.

454.* Efficiency and Load Tests on Well-pumping Unit. B. Hopper. *Petrol. Engr*, January 1940, **11** (4), 38.—The object of these tests was to determine the relative merits of pumping unit of a conventional type, but designed

(1) with the tail-bearing below walking-beam on a centre line with the centre bearing;
(2) with the tail-bearing above the beam; and
(3) with the tail-bearing above the beam and the gear-box set back from its usual position.

Descriptions of the equipment and the testing procedure are given, with diagrams and photographs illustrating the different cases. The test results are tabulated. Typical polished-rod cards are reproduced.

The results of the tests indicate that the centre-line type pitman tail-bearing is the most desirable. It is found that the centre-line beam produced 12% more fluid than the unit having the tail-bearing above the beam at the same pumping speed, and almost exactly the same polished-rod stroke. This fluid was produced at about ½% more power/day; so that the cost in kw./brl. was 11·6% more for the bearing above the beam.

Comparing the centre-line type pitman tail-bearing assembly with the tail-bearing above the beam and the unit set back 8½ in., it is found that the centre-line bearing produced 21% more fluid at about 3% longer polished-rod stroke and the same speed. This fluid was produced at 6% more power/day; so that the fluid was produced with the bearing above the beam at more than 14% greater costs in kw./brl.

Other comparisons are made and advantages discussed. A. H. N.

455.* Proper Installation of Pumping Unit Essential to Satisfactory Service. K. N. Mills. *Petrol. Engr*, January 1940, **11** (4), 67–69.—The selection of a pumping unit of the proper size for a given well does not give complete assurance that the unit will render satisfactory service, because the service obtained from the unit will depend to a considerable extent on how the unit is installed and serviced. If the unit is properly installed, all loads imposed on it will be applied in the most favourable manner, and none of its members or bearings will be subjected to unnecessary loads incident to some installation errors. Similarly, the foundation bolts will not suffer unnecessary loads and possible failure.

One of the most common errors involving pumping-unit foundations is misalignment of the pumping unit relative to the well-head. Methods of avoiding such errors are detailed. Correct alignment of unit or foundation may be obtained by the use of bolt-templates and grout-sleeves. Diagrams illustrate a typical template, various faults in grout-pipes and aligning double- and single-crank installations.

The rules advocated here to obtain the proper installation of a pumping unit are all simple, and the cost of conforming to them is small when compared with the return received. This return will manifest itself in the form of lower maintenance cost and less loss of production due to shut-downs. A. H. N.

456.* Alignment Chart for Determining Pump Displacements as Related to Plunger Diameters. F. E. Hangs. *Petrol. Engr*, January 1940, **11** (4), 80.—Examples are given to illustrate the use of this simple chart. Pump speed, stroke, and number of plungers are assumed constant. A. H. N.

457.* Maintenance of High A.P.I. Gravities in the Production of Crude Oil. R. L. Huntington. *Oil Wkly*, 8.1.40, **96** (5), 10–13.—It is becoming increasingly appreciated by production engineers that conservation of the lighter fractions in crudes is important. In the first place, there is often a price differential between low- and high-gravity crude oils amounting to as much as several cents/brl. between one price-bracket and the other. Secondly, the loss of 1° A.P.I. gravity in most Mid-Continent crude oils results in a shrinkage of approximately 2½% by volume.

Such losses in gravity can often be prevented by (1) treating crude-oil emulsions at lower temperatures through the use of more chemicals or soap solutions, and (2) by proper separation and storage of crude oils.

An understanding of the principles governing vaporization and condensation is essential.

A case is cited whereby treating a crude oil at 130° F. instead of 110° F. the chemical treating cost was reduced from 0·2 to 0·1 cents/brl. ; the gravity of the crude, however, dropped from 40 to 38° A.P.I., with a consequent loss of 5 cents/brl. on account of the 5% shrinkage and 2 cents/brl. due to the drop in gravity.

If the oil producer is compelled to use high-temperature demulsification, the loss of the lighter fractions can be prevented by using storage-tanks which will withstand several lb./sq. in. pressure.

The author then details certain of the more general principles of vaporization, solubility of lighter fractions in crude oils, and breathing losses of tanks. Raoult's Law is given, and a simple example on equilibrium flash vaporization is worked out for a gasoline fraction consisting of 40 mol.-% *n*-butane and 60 mol.-% *n*-pentane.

A. H. N.

458.* Paraffin Formation and Removal by Mechanical Methods in Pumping Wells. B. Mills. *Oil Wkly*, 8.1.40, 96 (5), 14–18.—The current study of paraffin in pumping wells involves several influences not recognized during earlier production periods: low formation pressures necessarily present in pumping wells, slow movement of oil in tubing, water, motion of the fluid, loss of temperature and mechanics as factors affecting pumping operations in typical paraffin-producing areas. Chemists are not in full agreement on the reasons for paraffin formation in tubing and surface equipment, since loss of temperature and loss of vapour from the oil each have a different importance to two schools of thought.

Experiments were conducted some time ago in East Texas to determine the relative importance of those two factors in light crudes. The results indicated that vaporization was a greater contributing factor than was originally thought. The author describes the experiments, but concludes that the experiments were not conclusive, as they did not represent accurately conditions existing in a pumping well.

Agitation tends to accelerate the accumulation of paraffin by causing small crystals to unite. Vicinity of a water-sand helps materially to accentuate paraffin deposition at certain points in the tubing. An oil–water emulsion sometimes increases the accumulation of paraffin. Free water often minimizes the formation of paraffin, particularly where it has a temperature above 90° F.; if it is allowed to remain and cool in the upper part of the tubing, water, however, often accelerates formation of paraffin. Loss of gas from the crude, on reduction of formation pressure, is a major cause of paraffin deposition at low points in the tubing. Presence of foreign matter in the crude has increased paraffin trouble in several fields. The action of paraffin in oil indicates that it will not ordinarily go back into solution when the temperature at which it precipitated is reached. The principles of the mechanisms of all these facts are explained in the paper.

Mechanical removal of deposited paraffins is next described. Cutting, scraping, drilling out, and swabbing methods are being used extensively where the accumulation of paraffin has seriously retarded normal pumping production. Use of steam has declined, but many operators are still trying to find a way of forcing steam to the seat of the trouble.

Detailed drawings give the use of a simple go-devil scraper; but various other methods are also fully described. A. H. N.

459.* Disposal of Oil-Field Brines. M. J. Leahy. *Oil Wkly*, 8.1.40, 96 (5), 19–24.—Many oil producers are attempting to dispose of their salt water as it accumulates on the surface by pumping it into a water stratum lying below the oil-producing horizon. There are two general methods in use. The first consists of gathering all brine into one central reservoir and then pumping it into a specially drilled brine-input well at the edge of the reservoir. The second method is to pump the brines from smaller areas into an abandoned well incapable of producing its allowable. Both methods are extremely costly; the first for drilling and maintenance expenses, the second for the cost of a complicated aerating system necessary to avoid plugging the formations by precipitates.

The author puts forward five methods for the utilization of oil-field waters which show some possibilities.

The first method utilizes a special waste-gas burner which burns under water, and thus, by submerging the burner in a vat, the water is evaporated, leaving a black, vitreous mass of high strength both in compression and tension, and which is very difficult to fracture or to grind. It is suggested that if a market be found for this new fused material the process will yield a dividend.

The second method is a modification of the first where woven glass blankets are used in the flues of an oven using these burners and suspended over the brine. Rapid evaporation results in accumulation of sodium chloride and complete loss of water.

The third method is a chemical double decomposition one, and consists, in principle, of forming the two insoluble salts, sodium bisulphite and lead chloride. Lead sulphite is dissolved in strong hydrochloric acid and the solution is added to the cold brine, the insoluble salts precipitated quickly—without excess of hydrochloric acid. The advantages and practical difficulties of the process are discussed.

The fourth method is simply the reverse of the base-exchange method commonly used for softening hard water. In the final form the method was elaborated into passing oil-field brine through a column of artificial sodium–copper zeolite, and the liquid leaving the tower was essentially a cupric chloride solution. This liquid was treated with sponge copper, which quantitatively precipitated all the cupric chloride as cuprous chloride, leaving the water in a very pure state.

The fifth method is a complicated arrangement of methods 4 and 3.

In the summary a study is made of the economics of salt recovery and brine disposal. A. H. N.

460.* Electrified Lease. W. C. Lane. *Oil Wkly*, 8.1.40, **96** (5), 26.—The case of a lease which gave a remarkable record of 10 years' service after it was electrified mostly by salvaged material is described. The record shows very little trouble in all respects and negligible time lost due to shut-downs. It is believed that the feature most responsible for the successful operation of the wells is the use of high-slip motors to provide the power for the seventeen pumping wells. The only cases of motor trouble experienced were due to lightning and a broken gear-shaft. When a 5-h.p. high-slip motor was replaced by a 7½-h.p. motor of the industrial type for temporary use, the higher-rated motor burned out before the great difference in the load characteristics of the two types of motors when subjected to pumping loads could be realized. As an instance of the better adaptability of the high-slip motor for work of this type a case was cited in which it required 8 min. for a motor to bring a well up to speed. It is believed that no industrial-type motor could stand such abuse and remain in service for 10 years. A. H. N.

461.* Repressuring Successfully Retards Water Encroachment. J. C. Albright. *Oil Wkly*, 8.1.40, **96** (5), 32–33.—Repressuring projects are usually initiated to accelerate the production recovery of a sand which has already produced a considerable quantity of oil, but the application of this process for the purpose of retarding or controlling water encroachment is being used successfully in at least one instance.

Detailed production record is given of this particular instance where not only have the repressuring operations increased the oil yield, but the water output has at the same time been materially reduced. The effect of repressuring on water encroachment was all the more remarkable as, according to the author, it was almost instantaneous. A. H. N.

462.* Chemical Removal of Paraffin from Pumping Wells. G. F. Williams and F. N. Alquist. *Oil Wkly*, 15.1.40, **96** (6), 22.—Chemical removal of paraffin is definitely a method past the experimental stage. The first attempts were confined to the use of natural derivatives of oil and to oil itself to dissolve the paraffin. These methods are now abandoned, chiefly because the solvents are of low specific gravity, which fact prohibits proper contact with the deposited paraffin. More successful methods utilize a mixture of a heavy commercial solvent with a light carrying agent, so that the specific gravity of the mixture is from 0·9 to 1·1.

The major advantage of using solvents is the ability to apply them to pumping wells without pulling-rods or tubing.

In the first of two types of wells in which solvent is used considerable gas is pumped with the oil. On releasing the back pressure in shutting down such wells, a quantity of oil is pushed up out of the tubing. In such a case the most effective method of applying solvents has been found in removing the stuffing-box and pouring a heavier-than-oil solvent down the tubing.

In the second type of pumping wells there is insufficient gas produced with the oil to unload the tubing. Three methods may be used in such a well.

The first method aims at lowering the head in the tubing by letting the oil out at the lower end. The standing valve is lifted, the oil seeks its own level, and the solvent is introduced into the tubing; the solvent, being heavier than the oil, sinks to the bottom.

The second method utilizes 25 ft. of copper tubing, the lower end of which is closed and perforated, run down the well inside the tubing beside the rods. The solvent is poured down a funnel, displaces the oil at the top of the tubing, and on sinking dissolves the paraffin. The solvent should be heavy—of 1·25 specific gravity.

The third is a circulation method in which the solvent is introduced into the well by a lubricator through the casing at the casing-head. The well is not shut down, and paraffin is removed from the sand-face, as well as from the tubing, as the solvent is pumped out. The method is used regularly—say, weekly or monthly. The solvent used in the circulation method should be only slightly heavier than the crude, so that it sinks to the bottom of the well and yet does not stay there indefinitely, but rises through the tubing with the inflow of oil.

Variants of this method and details of application are given in the paper. Diagrams and photographs illustrate the connections at the well-head and procedure to be followed. A. H. N.

463.* Repressuring Showing Quick Profit. Anon. *Oil Wkly*, 15.1.40, **96** (6), 28.—The advantages of intelligent application of repressuring are demonstrated in one pool where a $100,000 repressuring plant is sustaining itself while returning the investment at a rate greater than $120 per month. In addition to these measurable advantages, it is estimated that the plant will eventually bring to market 30–50% more oil.

The pool produces through fifty-seven wells from two sands at 2400 and 3000 ft., respectively. Because of the diversity of ownership in the pool, the first step was the formulation of a unitization plan. This was completely successful.

The key, or input, wells were selected from the original producers and cleaned of all sand and sediment to the bottom of the hole. Two types of control-heads, both illustrated, were designed. The first was for use where the gas was injected into only one sand through the annulus; the second was used where gas was introduced to both sands through tubing and annulus. Injection into the upper sand required a gas pressure of 310 lb./sq. in.; injection into the lower sand 325 lb./sq. in.

The pumping wells were all connected to centralized lease batteries equipped with separators to recover all the gas at these points, obviating the expensive network of lines necessary to connect each casing-head.

Illustrations are given for producing well connections, compressors, intake pipings, etc. Details of plant layout are outlined. A. H. N.

464.* Influence of Submergence and Fluid Level on Pumping Wells. H. Huffman. *Oil Wkly*, 22.1.40, **96** (7), 16.—In any pumping well there are four factors which determine the amount of fluid which will be produced :—

(1) the fluid level maintained in the casing;
(2) the submergence of the standing valve;
(3) the displacement of the pump;
(4) the reservoir pressure.

The paper deals with the first two items only.

A discussion is given of the advantages and disadvantages of maintaining high fluid levels and high submergence in the well. In general, the high fluid level produces the well under sounder and more economical conditions than low levels, but at the same time it is reducing the rate of production by the pressure it exerts on the sand. The effects of fluid levels on gas/oil ratios, sand, and excessive water intrusion are detailed. When due consideration is given to the numerous factors involved in the determination of the best fluid level, it is shown that the production of two or more horizons through one well does not allow the most scientific means of production to operate.

As the reservoir pressure of a well declines, submergence, through its effects on valve action, becomes increasingly important. The quickness with which the standing valve opens at the start of the upstroke is a function of the pressure on its underside, which pressure is a function of submergence. Thus volumetric efficiency becomes a function of submergence. Graphs as well as a detailed discussion of what occurs on the commencement of the upstroke fully explain this statement.

It frequently happens that when the number of strokes/minute is increased, the actual increase in production does not correspond to the theoretical increase based on calculations of plunger displacement. To explain this, it must be assumed that the barrel is not filling up as much on the faster stroke as on the slow one. After a study of the conditions operating on increasing the number of strokes/minute it is seen that any increase in pumping speed must be accompanied by an increase in submergence in order to obtain the same volumetric efficiency.

The use of the inverted pump—in which the plunger is stationary and the barrel reciprocates—is discussed. There are cases where production of low-pressure wells has been increased by several barrels by converting the inverted pump to the standard type.

As reservoir pressure decreases the use of long gas anchors becomes unnecessary, and sometimes harmful. Submergence becomes of increasing importance. In such cases the long anchor should be reduced and submergence increased. The increased production would pay many times over for the expense of pulling-rods and tubing.

A. H. N.

465.* World Production Sets New Record. Z. H. Mischka. *Oil Wkly*, 29.1.40, **96** (8), 49–51.—World production of petroleum set up a new record of 2,080,498,000 brl. in 1939, and every indication at the turn of the year pointed to an even greater figure for 1940.

A complete production history of the world is given in tabulated form under headings of different countries and year by year from 1857 to 1939 inclusive.

A short study is made of the production of various countries in 1939 as compared with the preceding years. A. H. N.

466.* Sharp Increases in Pumping Installations Indicated. B. Mills. *Oil Wkly*, 29.1.40, **96** (8), 80.—A survey is made of pumping wells and of those which are to be put on the pumps in 1940 in the U.S.A. It is estimated that 15,358 wells will go on the pump during 1940, requiring $25,000,000 worth of new equipment.

A. H. N.

467.* U.S. Production Should Reach New Peak in 1940. Anon. *Oil Wkly*, 29.1.40, **96** (8), 147.—Apart from the forecast for 1940, this paper is interesting, as it presents a complete production history of the U.S.A., under the headings of various states for the years 1859–1939 inclusive. Special studies are also made of the production trend in various States. A. H. N.

468.* New Plan for Setting Well Potentials. W. R. Wardner, Jr. *Petrol. World*, January 1940, **37** (1), 29.—This long paper deals with information gained from subsurface pressure measurements in the determination of well potentials. Such measurements relate the condition of flow to well productivity in a more satisfactory way than estimations of well capacities can be made from surface production data.

The reasons for adopting bottom-hole pressure measurement in evaluating potentials are summarized as :—

(1) to establish a uniform yardstick to apply to all wells in evaluating their productivity under restricted flow ;

(2) to permit a more exact evaluation of well decline factors under restricted flow ;

(3) to minimize waste and eliminate many evils of the open flow test;

(4) to eliminate excess production and over-taxing marketing outlets, and thus necessitating shutting down other wells to offset the excess made by the well under open flow test;

(5) to reduce investment in over-sized equipment.

Similarly the data, which are invaluable in analysing production problems, and some of the more important factors are summarized. Such factors are: (1) initial reservoir pressure; (2) productivity index; (3) depth of fluid level in tubing and between tubing and casing; (4) depth to which well should be tubed for most effective and efficient operation; (5) depth to which hole is open to production and portion filled by sand; (6) the time to discontinue gas lift and instal pumping operations; (7) efficiency of pumping operations; (8) amount and pressure of input gas for gas-lift; (9) data for the studies of the reservoir, such as position and extent of the gas-cap, drainage across property lines, pool reserves, pressure maintenance, and other related subjects.

Methods for bottom-hole pressure determinations are given in detail. The sonic method of using the height of the fluid within the pumping well as a measure of the pressure is illustrated by graphs, and photographs, and actual examples are worked out. The fundamental assumptions in using this method are discussed.

The use of bottom-hole pressure-recorders is similarly illustrated: sections of the Standard depth-pressure recorder and the Amerada instrument are given. Examples of sub-surface pressure tests on flowing and pumping wells are worked out in full, accompanied by typical graphs and numerical values.

Potential factors are calculated by the use of the two methods for pumping wells and of the recorder method for a flowing well. The sonic method is only adaptable to a pumping well. A. H. N.

469.* Problem of Oil-Mining at Egbell (Slovakia). J. Brož. *Oel u. Kohle*, 1.12.39, 35 (45), 765–767.—The north part of the new field at Egbell still contains considerable reserves, but the south part of the new field and the old field have been well drilled and are relatively well known. It is estimated that about 720,000 tons of oil could be extracted by mining, without taking into account the new field. Conditions are favourable for mining, folding being very gentle and the main tectonic disturbances of the nature of block-faulting. Abnormal gas and water pressures are absent, and the field has been well degassed by drilling. The oil-sand stands up under pressure and does not flow; there are no running-water sands above the oil-sand. The thickness of the oil-sand is reasonable, and there is no marked lateral variation. Finally, the dip, although gentle, is sufficient to promote drainage, and the physical properties of the sand are also favourable from the same point of view. S. E. C.

470. Effects of Acid Treatment upon the Ultimate Recovery of Oil from some Limestone Fields in Kansas. R. E. Heithecker. U.S. Bureau of Mines, Report of Investigations, No. 3445, April 1939.—In Kansas it is current practice to treat almost every well drilled in the limestone formation with hydrochloric (muriatic) acid on completion. This, besides increasing daily production, shortens the time required to recover the oil, and moreover materially extends ultimate oil recovery from each well. In certain circumstances acid treatment of wells is even believed to have extended productive limits of limestone fields in Kansas. After such treatment edge-wells showing only small quantities of oil have yielded commercial quantities and have been completed as large oil-wells, whether or not they have been shot with nitroglycerin.

Hydrochloric acid treatment was first used in Kansas in October 1932: by the end of 1934, 944 wells had been treated, and by the end of 1937, 5824 wells. In addition, certain wells were treated more than once, thus bringing the total number of treatments by the end of 1937 to 8070.

With experience certain modifications of the original treatment have been made, it being claimed, for instance, that better results are obtained by mixing chemicals with the acid. Choice of these chemicals is dependent on the area involved and the particular conditions obtaining. In many instances also stage or multiple treatments have proved more effective than the practice of putting all the acid in the well at the same time.

Further research is needed to determine more accurately quantities of acid required and optimum rates of injection. 1000 gal. of 15% acid have in some wells proved more efficient than much larger quantities in adjacent wells, the theory being that too much acid damages the reservoir and even penetrates below the bottom of the well into water-bearing strata. H. B. M.

471. Production Patents. E. E. Johnson. U.S.P. 2,185,999, 9.1.40. Appl. 2.4.35. Process for making screens for use in connection with oil wells.

W. E. Niles. U.S.P. 2,186,035, 9.1.40. Appl. 30.6.38. Method of and apparatus for flowing wells consisting of a tubing extending to the pay, a packer and a heater carried by the tubing in the upper portion of the formation for heating a certain portion of it to generate pressure in the lower portion of the formation, and thus effect flow of petroleum through the formation and tubing to the surface. The patent covers also use of insulating the heater from the flow of moving fluids in the tubings. Back-pressure valves are used.

R. A. Albert. U.S.P. 2,186,151, 9.1.40. Appl. 11.5.39. Sucker-rod rack made of a hooked shaft carrying a conical hollow metallic support having radial slots for reception of sucker-rods.

W. L. Bald. U.S.P. 2,186,230, 9.1.40. Appl. 11.8.38. Hydraulic oil well-packer.

B. Travis. U.S.P. 2,186,309, 9.1.40. Appl. 12.10.38. Rotary washer for casing perforations.

C. C. Brown. U.S.P. 2,186,323, 9.1.40. Appl. 5.4.37. Casing perforator for formation testing consisting of exploding a charge below a packer in a body designed to direct the force of the explosion at certain points in the casing.

C. C. Brown. U.S.P. 2,186,324, 9.1.40. Appl. 26.11.37. Packer and setting-tool combination.

J. T. Simmons. U.S.P. 2,186,349, 9.1.40. Appl. 9.1.37. Method for acidizing wells without affecting the strata below the one to be treated. Packers are used.

J. M. Gurley and A. M. Gurley. U.S.P. 2,186,411, 9.1.40. Appl. 22.4.37. Deep-well hydraulic pump.

M. O. Johnston and W. F. Bettis. U.S.P. 2,186,488, 9.1.40. Appl. 15.4.37. Means of regulating flow of fluid within a well.

G. T. Pfleger. U.S.P. 2,186,494, 9.1.40. Appl. 6.12.37. Submersible electric motor.

P. M. Sieck and R. M. Holloway. U.S.P. 2,186,886, 9.1.40. Appl. 19.5.38. An air-lift system.

J. N. Ice. U.S.P. 2,186,974, 16.1.40. Appl. 10.6.38. Pipe, tubing, and conduit coupling.

K. H. Miner. U.S.P. 2,187,047, 16.1.40. Appl. 22.5.39. Means and method of sampling well-fluid consisting of a combination of gun-perforator and sample-taker, the perforator breaking open the sealed chamber of the sampler.

A. N. McLennan. U.S.P. 2,187,278, 16.1.40. Appl. 12.1.37. Means for locating and cementing off leaks in well-casing consisting of perforated tubings and two packers to locate the cement and means for removing it from the annular space between casing and instrument without moving the latter.

C. E. Burt. U.S.P. 2,187,486, 16.1.40. Appl. 12.12.38. Formation-testing method and apparatus.

J. W. Chambers. U.S.P. 2,187,679, 16.1.40. Appl. 8.10.38. Deep well pump having multiple cylinder-and-piston arrangements and being driven by a motor through a system of gearing and crankshafts for each piston.

A. J. Penick and K. T. Penick. U.S.P. 2,187,839, 23.1.40. Appl. 7.3.38. Casinghead.

A. J. Penick. U.S.P. 2,187,840, 23.1.40. Appl. 9.7.38. A seating-tool for lowering a tubing hanger.

E. Tatalovich. U.S.P. 2,187,845, 23.1.40. Appl. 14.8.39. Clean-out tool for oil wells.

C. S. Sanders. U.S.P. 2,187,895, 23.1.40. Appl. 28.3.38. Method of forming a porous concrete well strainer *in situ* by introducing concrete between a productive formation and a well, and then subjecting the concrete to the action of a material having a selective solvent action on one constituent, thus rendering the concrete porous.

R. B. Prentice. U.S.P. 2,188,119, 23.1.40. Appl. 3.3.39. Centralizer and protector for an oil-well string.

J. S. Abercrombie. U.S.P. 2,188,141, 23.1.40. Appl. 10.6.38. Tool-joint control for blowout preventers.

G. H. Pfefferle. U.S.P. 2,188,302, 30.1.40. Appl. 27.9.38. Means for stopping leaks in pipe-lines.

C. E. Black. U.S.P. 2,188,425, 30.1.40. Appl. 20.10.38. Trap for the polish rod of a pump.

T. A. Larry and E. E. Clive. U.S.P. 2,188,607, 30.1.40. Appl. 16.11.36. Method of making lateral extensions from pipe-lines.

S. A. Guiberson. U.S.P. 2,188,656, 30.1.40. Appl. 28.9.36. Means for flowing wells by gas-lift utilizing two packers and perforated tubing to form a pressure-chamber at the well-bottom.

F. A. Thaheld. U.S.P. 2,188,668, 30.1.40: Appl. 30.3.36. Means for flowing wells by gas-lift, utilizing tubings, packer, and a regulator in form of piston and valve at bottom, in order to adjust rate of flow of lifting fluid.

H. W. Hixon. U.S.P. 2,188,737, 30.1.40. Appl. 26.4.39. Apparatus for recovering oil from subterranean oil pockets by means of injecting air and gas, through two concentric tubings and igniting the charge at well-bottom, and thus pushing oil into formation towards surrounding producer wells. A. H. N.

Transport and Storage.

472.* Comparison of Methods for Estimating Soil Corrosivity. K. H. Logan and E. A. Koenig. *Oil Gas J.*, 17.11.39, 38 (27), 130.—For this particular study soil corrosivity is defined as its power to impair a pipe. Consideration is given to the methods usually adopted to classify pipe as criteria of the corrosiveness of soil. The maximum pit depth on the joint adjacent to the point where the soil sample was taken was selected as the criterion of soil corrosivity in considering the merits of methods for the direct measurement of this property. Other methods considered gave similar results and showed no preponderant advantage over the one selected. A number of methods for the direct measurement of soil corrosivity have been examined, viz. :—

1. Measurement of soil resistivity by Shepard's resistivity meter, the meter used being designed to minimize polarization.
2. Measurement of the total acidity. In this connection P_H value was not considered to be a satisfactory measure of soil corrosivity, as it does not indicate the total available acidity.
3. Acidity–resistivity test involving an equation in which acidity and resistivity are represented. This method does not classify soils of low acidity, and two-thirds of the soils examined were placed in one group.
4. The Columbia rod test, involving measurement of the current between two electrodes, one of ferrous and one of non-ferrous metal, with the soil under test packed between them.

5. The Putnam test, in which consideration is given to soil/pipe potential and polarization as well as resistivity. It consists of measuring the current which will flow across a 1-in. cube of soil subjected to a potential of 1·4 volts.
6. The nipple-and-can electrolytic test which the loss in weight of a 3-in. length of steel pipe caused by the passage of current at 6 volts. The pipe is surrounded by saturated soil in a can 3 in. in diameter.
7. The Denison electrolytic test in which soil corrosivity is determined by the relation between current density and potential in a cell in which the anode is a steel disc and the cathode a steel screen.

Comparison of the methods examined with a record of maximum pit depth are given in detail. It is concluded that all the methods are of definite value in determining corrosivity and give a reasonable degree of accuracy for the corrosiveness of a soil series. The relative merits vary with the type of soil—*e.g.*, the test best suited to alkaline soils might not be the best for acid soils. R. J. E.

473.* Co-operative Problems Involved in Cathodic Protection. L. F. Scherer. *Oil Gas J.*, 17.11.39, 38 (27), 179.—A summary of the history of the application of cathodic protection is provided. A survey of the extent to which cathodic protection has been applied and of the various methods of protection in use carried out by the Mid-Continent Cathodic Protection Association indicates the rapid development during recent years. The aims, accomplishments, and limitations of the Association are discussed in detail. It is held that the increasing recognition and application of cathodic protection call for organization and standardization of the technological work carried out on this subject.

A major problem is the allocation of responsibility in cases where two or more pipe-lines are involved. Up to the present such problems have been solved by friendly co-operation or arbitration, but the need for establishing precedents and rules of procedure is stressed. It is suggested that the American Petroleum Institute is peculiarly suited to act as a medium through which the growing technological work on this subject may be organized and studied with particular reference to such problems as standard terminology, recommended standards on methods and equipments, and kindred problems. R. J. E.

474.* Internal Corrosion of Gasoline Pipe-Lines. L. C. Morris and W. A. Schulze. *Oil Gas J.*, 17.11.39, 38 (27), 205.—Investigation of the causes of internal corrosion of pipe-lines has shown that air and entrained water containing dissolved or suspended materials arising from chemical refining are the principal causes of corrosion. A turbidimeter, based on the measurement of the light from a standard source passing through gasoline, is used to give a measure of the aqueous solution and solids suspended in the gasoline. To explore the possibilities of corrosion inhibitors, laboratory corrosion tests simulating pipe-line conditions have been evolved. These tests revealed that natural inhibitors believed to be cresols and naphthenic acids are present in cracked gasoline. Salts arising from doctor treatment,—*e.g.*, lead sulphide and sodium through sulphate—were found to be corrosion accelerators, whilst non-reactive solids localized the corrosion. Increasing velocity of flow resulted in more uniform but less severe corrosion, and increasing temperature accelerated corrosion.

Of many chemicals tested, mercapto-benzothiazole was found to be the most effective inhibitor, and was tried out in a pilot plant under conditions which ensured that the only difference between test and control was the presence of inhibitor. These trials showed that a concentration of 1–2 lb. of this inhibitor per 1000 brl. of gasoline gave the most satisfactory protection. Moreover, the inhibitor had no deleterious effect on the properties of the gasoline.

In application to a pipe-line the mercapto-benzothiazole is introduced into the gasoline in the form of a slurry with flushing oil. Equipment for this purpose is described. The life of the inhibitor has been found to vary with the nature of the gasoline and the method of sweetening. To determine the length of pipe-line, protected steel-test pieces—inserted at selected intervals—are periodically examined; their condition gives an indication of the protection afforded to the pipe-line. Delicate methods for estimating the amount of mercapto-benzothiazole in gasoline have been evolved and used to indicate the point in a pipe-line at which the inhibitor is exhausted. R. J. E.

475.* Graphic Interpretation of Evaporation Losses from Vented Tanks. R. F. Larson and J. A. Goff. *Petrol. Engr*, November 1939, **11** (2), 42.—An independent method is described of developing the formulæ used for the calculation of evaporation loss from vented storage-tanks described by W. F. Rogers, *Petrol. Engr*, June 1938, p. 39, and July 1938, p. 48. The analysis is based on the following assumptions: (1) a definite vapour-pressure curve, (2) complete saturation at all temperatures, (3) negligible changes in the volume of the vapour space, and (4) applicability of the perfect gas laws, and therefore of Dalton's law. An illustration is given of the application of the formulæ to the evaporation loss from a West Texas crude in a 80,000-brl. tank under definite conditions. It is realized that the assumptions may not necessarily be valid and, in addition, no account is taken of time required for diffusion of oil vapours and of air which, in periods of very rapid temperature rise, may seriously affect the actual loss of vapour. C. L. G.

476.* Protective Coatings for Hydrocarbon Containers. A. Foulon. *Oel u. Kohle*, 1939, **33**, 647.—Concerns prevention of corrosion in hydrocarbon containers in transport and storage by use as lacquers, resins, concentrated drying oils, or solutions of condensation products of polybasic acids. For benzine, benzene, and similar petroleum liquids these lacquers must be prehardened at a temperature above 100° C. to prevent softening and solution. Protection of the container by incorporation of protective metals and protective oils of special properties is discussed. A. V. B.

477. Filling Stations for Liquefied Gas. W. Salnikoff. *Brennst. Waermewirt.*, 1939, **21**, 195–198.—Refueling of vehicles driven by liquefied gas has usually been effected by changing the containers. It is, however, possible to store the gas in large containers at filling-stations and to feed it into the cars, as in the case of petrol. Such a filling-station is described in detail, and it is stated that several of them are already in operation in Germany. The gas is lifted from the lower floor, not by plunger, but by an injector. The standard station fills the containers of a lorry, 70 kg. in 3–4 min. The plant in the Central Garage of the Berlin buses fills 200 litres/min. As liquefied gas in Germany is not considered to be merely an emergency fuel, the filling-station of the kind described will be cheaper in the long run than the operation of changing containers. E. W. S.

478.* Cleaning of Plant Handling Tar, Bitumen, Heavy Oil, and other Viscous Materials. K. S. Low. *Fuel Econ.*, 1939, **15**, 339.—The cleansing of vessels and appliances which have contained viscous, glutinous, or film-forming materials usually involves considerable expenditure of time and labour. The author has witnessed the capabilities of a new appliance which it is claimed has reduced cleaning time from days to less than ½ hr. The appliance is the "Desolvator." This is essentially a pressure vessel of about 70 gal. capacity containing heating coils. A quantity of solvent, suitable for the cleaning operation required, is heated in the vessel, and the pressure developed is utilized to spray the solvent under high pressure on to the walls of the plant or vessel to be cleaned.

In the test observed by the author, a 14-ton tank car in very bad condition, having been in use for tar, was effectively cleaned in 20 min. T. C. G. T.

Crude Petroleum.

479. Properties of Louisiana Crude Oils. II. Additional Analyses. E. L. Garton. U.S. Bureau of Mines, Report of Investigations, No. 3476, November 1939.—This report contains the results of analyses of 72 samples of crude petroleum from 45 oil-fields in Louisiana. It begins with a brief history and production data for each field from which the appropriate samples were derived. The analytical data are compared and discussed, and it is shown that of the 47 crude-oil samples from Northern Louisiana, 28 are classifiable as paraffin base, 9 as paraffin-intermediate, 6 as intermediate, and 4 as naphthene-intermediate. Of the 25 samples from Southern Louisiana, 2 are paraffin base crudes, 4 paraffin-intermediate, 12 intermediate, 2 intermediate paraffin, 4 naphthene-intermediate, and 1 naphthene. Production from Southern Louisiana is from greater depths than in the northern division, and the oil is more often associated with salt-dome structures; these facts are reflected in the comparative analyses, which indicate that intermediate base crudes predominate in the south, whilst the tendency is for paraffin base oils to characterize the northern fields. H. B. M.

Gas.

480.* Improvement in the Calorific Value of Town's Gas or Coke-Oven Gas with Reference to Utilization as a Fuel for Motor Vehicles. J. I. Graham and D. G. Skinner. *J. Inst. Fuel*, 1939, **13** (69), 39.—The chief drawback to the use of compressed coal gases is the great weight of container relative to that of fuel (ratio 10 : 1). A 32-seater bus can carry 7 cylinders each weighing empty 1 cwt. and holding 350 cu. ft. of gas at 200 atm. pressure, thus giving a range of about 80 miles per filling, the quantity of gas of 475 B.T.U. per cu. ft. equivalent to 1 gal. of petrol being taken as 265 cu. ft. The thermal efficiency with coal gas is greater than with petrol, but it is necessary to increase the compression ratio in order to obtain a power output at least equal to that when petrol is used. Coal gas costing 2*d*. per therm could be supplied compressed to 3000 lb. in cylinders at a figure equivalent to 6*d*. per gal. of petrol, if the offtake were equivalent to 1200 gal. of petrol daily. The highest item is the cost of compression, which is independent of the calorific value of the gas. For this reason a gas of higher calorific value—*e.g.*, methane (895 B.T.U.'s/cu. ft.)—would be preferable. Attempts have been made to obtain methane from coal-gas by preferential adsorption on active charcoal, but the maximum concentration available in the presence of CO_2 was 44·5% with 27% of CO. Further methane can be obtained by catalytic conversion of CO or by catalytic combination of CO with the H_2 in coal-gas. Gas prepared by this method has been tested on the road in a 12-h.p., 4-cylinder car, a consumption of 13·2 cu. ft. per hour being obtained, compared with a figure of 25 cu. ft. for ordinary coal-gas. During normal running conditions combustion was much more efficient than with petrol, practically no CO being formed, as compared with 6·7% for petrol. The cost of untreated coal-gas compressed to 200 atm. is estimated at 9·2*d*. per equivalent gal. of petrol (at gas 4*d*. per therm), and that of catalytically produced methane (excluding the cost of the catalytic process) at 8·92*d*. The increased mileage obtained for the same cylinder weight as compared with coal-gas should permit of an appreciable expenditure on the catalytic process. By mixing blue water-gas with town-gas in proportions of 1 : 5, the cost of the process should be considerably reduced and a gas of approximately 10% higher calorific value obtained. It is also possible to obtain a gas by the catalytic treatment of coke-oven gas which contains 47% CH_4 and 42% H_2, and on further concentration by the adsorption method a gas of calorific value nearly 900 could be obtained. A mixture of 80% CH_4 and 20% C_2H_6 would be of still greater importance, having a calorific value of about 1140 B.T.U.'s per cu. ft. C. L. G.

481.* Refinery Gas : a Raw Material of Growing Importance. R. E. Wilson. *Chem. and Ind.*, 1939, 58, 1095–1101.—Gas from cracking to-day amounts to 7—8% by weight of the total crude run in the U.S.A. This proportion amounts to about 940 million cu. ft., or 14 million tons per year. The refinery gas referred to in the article is this cracked gas.

About 75% of an up-to-date refinery gas consists of C_4 hydrocarbons (boiling 14–39° C.) and 80% of these latter are stabilized in gasoline. It is common practice to have as much as 7% butanes in summer-grade gasolines and 12% in winter grades.

Attention is directed to the fact that one of the greatest objections to the use of alcohol in gasoline is that the addition of alcohol tends to increase the vapour pressure of the gasoline very substantially, and thus to reduce the amount of butane which might be incorporated. Since butanes are far cheaper and better than alcohol as a constituent of gasoline, either from an anti-knock or other standpoint, the addition of small amounts of alcohol does not increase either the quality or the quantity of the gasoline available, although it greatly increases the cost.

Propane is now established as one of the most efficient solvents for the removal of wax, asphalt, and heavy ends from lubricating oil. Propane owes its versatility as a precipitant largely to the fact that its solvent properties change rapidly over the convenient temperature range between its b.pt., — 44° F., and its critical temperature, 212° F. For instance, its density falls from 0·5 to 0·25 in this temperature range.

Apart from its growing use in solvent refining, 150 million gal. are used every year as bottled gas, etc.

The development of refinery gas as a raw material for the chemical industry dates from about 1921, when *iso*propyl alcohol was produced from propylene with an eventual reduction in the price of the alcohol from $7 per gal. to one-twentieth of that price. The progress of this field is traced through ethylene dichloride, chlorhydrin, and glycol to the present day, when one company is making commercially more than one hundred synthetic chemicals, starting from ethylene, propylene, and the butylenes. This list includes 24 alcohols and alcohol ethers, 4 ketones, 23 esters, 14 amines, 8 ethers, and 7 chlorinated compounds.

Practically all the *iso*propyl alcohol and *sec.*- and *tert.*-butyl alcohols on the market to-day are made from petroleum gases, and most of the acetone is made by the catalytic dehydrogenation of *iso*propyl alcohol.

Dichlorides are readily obtained, and ethylene dichloride from refinery gas is becoming of great importance. It is used in the preparation of the rubber substitute, Thiokol, whilst vinyl chloride is made from ethylene dichloride, and is of great importance as the starting-point in the preparation of the polyvinyl resins.

Butylene can be dehydrogenated to butadiene, and this in turn, is polymerized to " Buna " rubber.

Glycerine can be made by the regulated chlorination of propylene, followed by hydrolysis. This synthesis is of topical interest, as in the case of excessive demand of glycerine during war periods the process may be developed.

The paraffinic gases are not directly useful for such syntheses, but the olefinic gases required are normally prepared by cracking or the catalytic dehydrogenation of the paraffinic gases.

Numerous other synthesis of interest to the chemical industry are instanced.

While the above-mentioned processes are of great importance to the chemical industry, they are not of such great moment in the petroleum industry, as the quantity of available refinery gas is immensely greater than the potential absorption in the chemical industry.

The processes of greatest importance to the oil industry are those such as polymerization which produce high-performance motor fuels. At present the most important process is alkylation, usually with *iso*butane and butylenes or other olefins. *iso*Butane, on account of its tertiary carbon atom, is the only hydrocarbon in refinery gas which will enter this reaction, which takes place in the presence of strong sulphuric acid. Supplies of the essential *iso*butane are limited, but, if necessary, may be immensely increased by the catalytic isomerization of normal butane.

*iso*Butylene is of particular importance to the petroleum industry, as it can, and is being catalytically polymerized to *iso*-octane, a high anti-knock gasoline, and to every petroleum product through lubricating oils to polymers of 400,000 mole. weight.

Reference should be made to the article for numerous other syntheses, both academic and commercial.

The article concludes with a brief discussion of the economic aspect of this utilization of refinery gases. T. C. G. T.

482.* Partial Volumetric Behaviour of the Lighter Paraffins in the Gaseous Phase. B. H. Sage and W. N. Lacey. *Refiner*, 1939, **18** (11), 466.—A method is proposed for the production of the specific volume of complex gaseous hydrocarbon mixtures. The procedure is summarized as follows :

(1) The analysis of the gas, which is expressed commonly as the mole. fraction of each of the components present, is modified to yield a corresponding quaternary analysis. (2) The latter is re-expressed in terms of weight fractions instead of mole. fractions. (3) The residual partial specific volumes of C_1, C_2, C_3, and n-C_4 paraffins for the prevailing pressure, temperature, and weight fraction of the component in question are interpolated from given tables. In general, simple linear interpolation with respect to pressure, temperature, and composition is adequate for the purpose.

The value used for methane is taken as a weighted mean obtained for the binary systems involving methane with each of the other components of the modified analysis. (4) The average molal weight of the gas is computed from the original analysis. (5) The specific volume is calculated directly by substitution of the appropriate values in the derived equation. G. R. N.

483. Helium. A. W. Trusty. *Refiner*, 1939, 18 (8), 325.—A general and concise account of the occurrence and uses of helium. At the U.S. Government plant at Amarillo, Texas, natural gas at 600 lb. is washed with caustic soda solution to remove carbon dioxide. The gas is then cooled to −300° F., which causes 95% to become liquid. The final stage is to subject the residue gas to a pressure of 2000 lb. and cool with liquid nitrogen. The finished helium is 98% pure. The present gross manufacturing cost is $8.20 per 1000 cu. ft. The estimated U.S. reserve of helium is given as 5928 million cu. ft. G. R. N.

484.* Standard Producer Gas Generator Design. Anon. *Fuel Econ.*, 1939, 15, 336.—Attention is directed to the Parliamentry announcement that a design of producer-gas generating apparatus suitable for use with road-transport vehicles has been developed and that the design would be made available to firms able and willing to undertake manufacture.

The article is then continued with a summary of a lecture by K. W. Williams to the Junior Institution of Engineers, in which various types of producers are reviewed. T. C. G. T.

485.* New Developments in Burners. E. L. Dennis. *Refiner*, 1939, 18 (10), 419.—It has been established that higher heater capacity in heat input per hour, increased radiation from walls and floors, and optimum carbon-dioxide and water-vapour content in the combustion products are secured from the burner completing combustion most rapidly. Since the temperature of the gases will vary directly with the rate of combustion and indirectly with the mass occupied, the temperature of combustion will be higher with the least excess air for complete combustion. Incomplete combustion produces a reducing atmosphere in the heater, which results in serious impingement on the tubes. A "neutral" atmosphere is best assured by complete combustion—*i.e.*, the final products of carbon dioxide, water vapour, and nitrogen exist when the gases enter the tube banks and an excess air ratio of less than 10%. Burners fulfilling the above requirements are of the short-flame type—*e.g.* the pre-mix burner, in which the correct quantity of air is premixed with the gas fuel outside the heater by Venturi injection, proportioning, valves, etc., or the multi-jet designs, in which the combustion zone can be varied by changing the angle of the various jets, thorough mixing of the air and gas being completed by the turbulence in the heater. An individual type is the fan-mix burner, which mixes the gas with air essentially in the plane of rotation of a fan, which is propelled by the gas streams emitting from orifices in revolving arms mounted integral with the fan-blades. A 21-in.-diameter fan-mix burner has a capacity of 55 million B.Th.U. per hour with natural gas of 1000 B.Th.U. heating value. These burners show no visible flame in daylight, and there is no fan action in the heater, because the rapid expansion due to the high temperature of combustion kills the forward direction of the air–gas stream. Some of the advantages derived from the use of fan-mix burners in actual operation have been complete combustion with less than 5% of excess air in the flue gases, higher furnace temperatures on walls and floors, and in some cases as much as 40% increase in heat input without increased temperature of flue gases. There is also described a fan-mix type of burner designed on combined oil and gas firing, in which the oil-gun is inserted through the centre of the revolving shaft carrying the gas orifices. G. R. N.

Cracking.

486.* Measurement of Metal Temperatures of Cracking Still Tubes. O. G. Kaasa. *Nat. Petrol. News*, 15.11.39, 31 (46), R.478.—The square end of a length of No. 8 constantan wire is peened into a hole ½ in. deep in the wall of the tube. The wire is insulated with asbestos string and protected by a ½-in.-diam. calorized steel tube slipped over it and welded to the tube at one end. Outside the furnace wall No. 12 iron wire peened into the protector tube terminates with the constantan wire in a standard thermo-couple head connected to a switch panel. The device is claimed to have a useful life of about one year. H. G.

487.* Catalytic Cracking. A. L. Foster. *Refiner*, 1939, **18** (10), 412.—A review and analysis of future trends in this branch of cracking, which concludes as follows :—

(1) Catalytic cracking as now practised appears to be suitable economically for the larger-capacity installations in the larger refineries. The lowest unit capacity which is practicable has not yet been determined, but its size will be greatly reduced during the next two years, from those larger units now in successful operation.

(2) Catalytically cracked gasoline with a blending octane value of 90 or higher has a premium value of more than 1 cent per gall. or 47 cents per brl. as a conservative estimate from which the refiner can pay extra costs of operation. This premium valuation is based on octane-number improvement by saving in lead alone.

(3) Catalytic reforming or dehydrogenation of low-grade gasoline and naphtha appears to offer a means of fuel improvement and saving in refining costs, which is more immediately available to the average to small refinery at a comparatively low cost and long plant and catalyst life.

(4) Manufacture of special, extremely high-quality fuels has been made practicable for the refiner by the application of both thermal and catalytic processes.

(5) Catalytic desulphurization for improvement of octane number and for a remarkable increase in lead susceptibility has been perfected by two processes to a point where the average refiner handling high-sulphur products may apply it economically to his stocks. G. R. N.

488.* Petroleum-ization 1940. H. W. Field. *Refiner*, 1939, **18** (11), 450.—This A.P.I. paper gives a simple exposition of the processes of hydrogenation, dehydrogenation, polymerization, alkylation, desulphurization, isomerization, aromatization, cyclization, and catalytic cracking and reforming. In chart form and discussion, comparisons are presented to assist in locating in the refinery picture where these processes have application and which should be considered for various refinery situations. G. R. N.

489.* High Quality Aviation Fuel Base is Houdry Reforming Objective. A. G. Peterkin, J. R. Bates, and H. P. Broom. *Nat. Petrol. News*, 29.11.39, **31** (48), R.517–R.519.—Since the degree to which basic gasolines are improved by the addition of tetra-ethyl lead and blending stocks of high octane number varies considerably, the properties of those basic gasolines are of importance equal to that of the additives. Hence, in the Houdry process it is aimed catalytically to reform low-grade stocks to improve their susceptibility to additives. The catalyst is a highly activated hydrosilicate of alumina. H. G.

490.* Residuum Stripping. J. C. Allright. *Refiner*, 1939, **18** (9), 347.—At their Grandfield, Okla, refinery Bell Oil and Gas Co. have installed two vertical dry stripping columns in series. Residuum at 800° F. and 55 lb. pressure from the flash tower of the cracking unit is passed through these two columns, the pressure being reduced to approximately that of the atmosphere. The bulk of the vapours formed flash off in the second column and are condensed and cooled, giving a Diesel engine fuel. This product represents an additional 6% (on the cracking plant charge) of distillate yield from the cracking operation. G. R. N.

491.* Catalytic Polymerization of Butanes. F. B. Mack. *Refiner*, 1939, **18** (8), 330.—A description is given of the U.O.P. plant at the Shamrock refinery, Amarillo Texas, in which butanes from natural gas are thermally cracked to give pyrolytic polymer gasoline and unsaturates which are passed through a catalytic polymerization unit to give polymer gasoline. It is concluded that polymer production is useful in blending special gasolines as well as regular motor fuel. The desirable properties of polymer products are : (1) high octane blending value, (2) low percentage of sulphur, (3) low gum content, (4) high inhibitor susceptibility, and (5) motor-fuel distillation range. The latter makes it possible to blend low-grade gasolines to higher fuel specifications. Tables of the characteristics of the polymer gasolines and their blends are given. G. R. N.

492.* Production of Fuels from Alto Udinese Shale. D. Costa. *Chim. e Ind.*, 1939, 22 (11), 609–612.—The author points out the desirability of employing the Resiutta shale oil to better advantage than its present use as liquid fuel oil. These oils, which range from 0·9379 to 0·9496 in specific gravity, give recoveries in the Engler distillation of 24% at 200° C., 29% between 200° and 300° C., and a residue. Refinery experiments on the distillates showed that, owing to the high content of unsaturated hydrocarbons and the high proportion (5·55% S) and nature of sulphur compounds in the crude oil, it was not possible to treat this oil by conventional methods for production of motor fuel. By hydrogenating cracking in a Bergius bomb at approximately 150 atm. pressure and maximum temperature of 390° C. using 4% MoS_3 catalyst, the author obtained a colourless product containing only 0·05% sulphur, and having a very low iodine number, from the fraction up to 260° C. P. G.

493. Patent on Cracking. K. Swartwood. U.S.P. 2,185,757, 2.1.40. Appl. 13.11.36.—Hydrocarbon distillates of low boiling characteristics and containing an appreciable quantity of fractions of low anti-knock value, boiling within the range of gasoline, are so treated as to produce gasoline of materially improved anti-knock value. The method consists in subjecting the distillates in a heating zone to cracking conditions, separating the resultant products into vaporous and non-vaporous components in a separating zone, and thereafter the vaporous components to fractional condensation. H. B. M.

Hydrogenation.

494.* Hydrogenation of Iraq Tar. A. Leopold. *Ann. Off. Combust. liq.*, 1939, 3, 513–530.—The hydrogenation of two Iraq tars has been studied from the heat-of-reaction standpoint. Steel autoclaves were used at pressures varying from 110–258 ats. and 360–450°.

The composition of the steel was found to affect the amount of carbon produced during the hydrogenation considerably, a Ni–Cr steel producing more carbon than a Ni–Cr–Mo steel.

Using an aluminium silicate liner, two Iraq tars of almost identical composition were found to yield different proportions of the hydrogenation products, indicating that the elementary composition of a tar cannot serve as a basis for determining the best conditions for its hydrogenation.

Hydrogenation was found to begin at 360°. In order to reduce the amount of gas produced it was found necessary to vary the conditions of hydrogenation so that the heat absorbed during the endothermic zones was a minimum.

A comparison is drawn between results obtained using the above single-phase process and M. Vlugter's two-phase process, the results being very similar. W. S. S.

495.* Destructive Hydrogenation of Rumanian Residuum. C. Candea and L. Sauciuc. *Refiner*, 1939, 18 (10), 434.—The results of hydrogenation of residues from Bucsani crude oil indicate that (when operating in a stationary autoclave) only satisfactory saturation of unsaturated end products formed at 430° C. can be obtained when using catalysts and by the use of a sufficiently high hydrogen pressure. The hydrogenation takes place more smoothly at 440° C. at the same pressures and in the presence of a similar amount of catalyst, obtaining a much higher yield of gasoline. Operating at higher temperatures was not feasible, since the increased cracking reactions caused the pressures to rise above the maximum considered safe for the apparatus. Molybdenum trisulphide and the trioxide were the catalysts used. The former is a better cracking catalyst and gives higher benzine yields. The trioxide, having a greater hydrogenation action, gave excellent saturated gasolines, even though the yields were somewhat lower. G. R. N.

496.* Oil from Coal—An Intermediate Scale Plant. Anon. *Fuel Econ.*, 1939, **15,** 332–336.—A description of the semi-technical scale plant operated by the D.S.I.R. for the conversion of coal oil into motor spirit, etc.

The raw materials are raised to a temperature of about 300° C. by heat exchange with the products leaving the converter, and then pass to a gas-fired coil (the preheater), where the temperature is raised to 400° C. At this temperature the mixture enters the converter, where the ensuing reactions cause a further rise to the desired reaction temperature (usually 500° C.).

The raw materials consist of hydrogen and low-temperature tar from the Fuel Research Station's narrow brick retorts, to which is added a proportion of "recycle oil."

From a mixing-tank the tar and recycle oil are pumped at the required pressure, about 200 atmos., into a high-pressure pipe-line, where they are mixed with hydrogen at the same pressure and passed through the heat exchange and preheater to the converter.

The plant can operate at 200–400 atmos. pressure with a throughput of 200–400 gal. per day at 200 atmos.

The converter is a vertical cylinder of forged steel 15 ft. long and 16 in. internal diameter, with walls 3 in. thick.

The reaction chamber suspended concentrically within the converter is 11 ft. long and 8 in. internal diameter with walls of $\frac{5}{16}$ in. chrome-nickel steel. It is fitted with internal radial fins to assist the distribution of heat and of liquid raw material, and is filled with a granular catalyst consisting of molybdenum disulphide supported in alumina gel.

The products leaving the converter pass through the heat exchange and a water-cooled condenser to a high-pressure separator, where the residual gas is removed. The liquid products are then released into a low-pressure separator in which dissolved gas is evolved, whilst the oil passes to a still for the removal of the motor spirit by distillation.

The residual gas is about 90% hydrogen and the still residue is recycle oil.

T. C. G. T.

497.* Dehydrogenation, Polymerization, and Hydrogenation. A. V. Grosse, V. N. Ipatieff, G. Egloff, J. C. Morrell. *Nat. Petrol. News*, 29.11.39, **31** (48), R.520.–R.521.—Catalytic dehydrogenation is a new process developed to produce olefins from the gaseous paraffins, with the exception of methane. A mixture of *iso-* and normal butane, for instance, is passed over a catalyst at 1075° F. Hydrogen is removed from the resulting butenes and the latter are polymerized. The efficiency of the dehydrogenation process is 85–95% of the theoretical maximum, as compared with 15% in the thermal cracking process. H. G.

Polymerization.

498.* Polymerization of Unsaturated Hydrocarbons. H. M. Stanley. *Chem. and Ind.*, 1939, **58,** 1080–1083.—The polymerization of unsaturated hydrocarbons is reviewed. Brief reference is made to the commercially developed processes—*e.g.*, for producing polymer gasoline—but the greater part of the article is devoted to the higher polymers, particularly those of styrene and methyl styrene.

Polymers from solutions of styrene in certain chlorinated solvents are considerably lower in mole. weight than those produced under comparable conditions in hydrocarbon solvents. This effect is particularly noticeable in carbon tetrachloride, in which a great reduction in polymer size takes place.

Peroxides and oxygen catalyse polymerization of styrene and reducing substances—*e.g.*, hydroquinone, pyrogallol, benzoquinone, hexamine and phenylnaphthylamine, inhibit the reaction. At elevated temperatures (80–150° C.) certain substances greatly diminish reaction velocity and increase the mean mole. weight of the resulting polymer; paraformaldehyde is one of the most potent agents of this class, which probably function by destroying the naturally occurring catalyst.

A further class of substance simultaneously reduces both the rate of polymerization and the polymer size. Phenylacetylene and hydroquinone are examples of this type which probably act by increasing chain breaking.

The author's work supports the belief that high mole. weight (60,000–120,000) polystyrenes contain one olefin bond.

a-methyl styrene can be readily polymerized by certain solid catalysts, *e.g.*, activated bleaching earths, to yield a whole range of polymers from colourless oily liquids to glass clear brittle solids of 3000–4000 mole. weight. T. C. G. T.

499. Patents on Polymerization. E. I. Du Pont de Nemours and Co. E.P. 516,931, 16.1.40. Appl. 13.7.38.—Process for polymerization of unsaturated organic compounds by bringing a diolefine or halogenated diolefine into contact with hydrated boron fluoride having from 1 to 2 mols. of water per mol. of BF_3. The polymerization is effected at a temperature of 0–30° C. and at a pressure not substantially greater than atmospheric.

H. I. Waterman. U.S.P. 2,188,273, 23.1.40. Appl. 22.7.36. An improvement in the manufacture of bodied oils by heating drying fatty oils to polymerizing temperatures in the presence of SO_2. A current of SO_2 gas is passed into and through the hot oil and the mixture agitated simultaneously to ensure intimate contact between the oil and the SO_2. The polymerization of the oil is in this way considerably accelerated. H. B. M.

Synthetic Products.

500.* Catalytic Hydrogen Peroxide Oxidation of Chain-Olefines. W. Treibs. *Brennst-Chemie*, 1939, **20**, 358–360.—Tests were carried out in the homogeneous phase with a 30% H_2O_2–water solution, using acetone and methanol as solvents. Of the heavy metals tested only vanadium functioned satisfactorily as a catalyst, in the form of pervanadic acid. Under suitable conditions, 100 gm. chain-olefines were converted into oxygen-containing bodies within 30–40 hr.

An examination of the effect of catalytic attack by hydrogen peroxide on oxygen derivatives of paraffins revealed that primary alcohols and aldehydes are very stable; secondary alcohols are slowly oxidized to ketones; unsaturated alcohols easily add H_2O_2 to the double bond; paraffin ketones are much more stable than *cyclo*-ketones and chain-olefines; a-ketone alcohols are cracked to aldehydes and carbonic acids, especially in *statu nascendi*; a-glycols with a central glycol group are very stable, whilst those with a terminal glycol group are transformed on both hydroxyls.

In the primary process of H_2O_2 oxidation chain-olefines are hydroxylated. H_2O_2 is added either to the double bond leading to the formation of a-glycols, or it attacks the adjacent methylene groups and forms a, β-unsaturated alcohols. Further progress of the oxidation depends on the position of the double bond in the original olefine. If it is at the end, the primary products are unstable a-glycols which are oxidized; its a, β-unsaturated alcohols are slowly separated into oxalic acid and a monocarbonic acid. Olefines with the double bond in the centre form stable crystallized glycols which are ultimately converted into a-oxides.

It is concluded that, qualitatively, *cyclo*-olefines are attacked by H_2O_2 in a similar way to chain-olefines. In both cases H_2O_2 is added to the double bond, whilst adjacent methylene groups capable of reaction are hydroxylated. Quantitatively, the former reaction prevails with chain-olefines, the latter with *cyclo*-olefines. L. R.

501. Production of Lubricating Oils by CO–H_2 Synthesis. H. Koch. *Archiv. f. Eisenhüttenwesen*, 1939, 533–535.—The development of synthetic petrol production in Germany is shown as compared with the rest of the world. For synthetic production of lubricating oils the Fischer–Tropsch and the I.G. processes are available. New details are given, and it is stated that the lubricating value of the oils depends largely on the molecular structure of the materials treated. E. W. S.

502. Patents on Synthetic Products. N.V. de Bataafsche Petroleum Maatschappij. E.P. 516,659, 8.1.40. Appl. 4.8.38. Manufacture of *iso*butane from normal butane by contacting normal butane, preferably in the gaseous phase at temperatures below 200° C., with a catalyst. The catalyst consists of aluminium chloride mixed with or brought on to a carrier substance comprising an inorganic substance containing water which normally can only be split off at temperatures above 200° C.

E. I. Du Pont de Nemours and Co. E.P. 516,688, 9.1.40. Appl. 4.7.38. Manufacture of vinylacetylene by polymerization of acetylene in the presence of a liquid mass of catalyst, the latter consisting of water, saturated or nearly saturated with a mixture of ammonium chloride and cuprous chloride.

Deutsche Hydrierwerke A.-G. E.P. 516,879, 15.1.40. Appl. 11.7.38. Capillary active substances are manufactured by condensing organic hydroxyl compounds with aliphatic halogen-ketones containing at least one exchangeable halogen atom, reducing the ketone group of the condensation compound to a secondary alcohol group and thereafter converting the latter into a water-solubilizing group by sulphonation or treatment with alkylene oxides.

Deutsche Hydrierwerke A.-G. E.P. 516,978, 17.1.40. Appl. 13.7.38. Method of manufacturing capillary active products whereby one or more aliphatic, *cyclo*aliphatic, or hydro-aromatic hydroxyl compound having a lipophile group is reacted with one or more halogen ketone having an easily exchangeable halogen atom. The ketone group of the reaction product is thereafter reduced to give a secondary alcohol group, and the secondary alcohol group then converted into a water-solubilizing group.

H. B. M.

Refining and Refinery Plant.

503.* Thermosyphon Treating Plants. D. H. Stormont. *Oil Gas J.*, 21.12.39, **38** (32), 37.—Tests have been carried out to determine the reasons for the low crude capacity of an emulsion-treating gun barrel heated by thermosyphon circulation from an external heater. It was found that the 4-in. swing check-valve installed to guard against back flow required an 0·8-in. head of water to lift it from its seat, the whole head available in the thermosyphon system being only 0·95 in. The long flow-lines in the average system also constitute a bottle-neck. Increasing the heat input into the heater is inadvisable, as the water should not be heated to more than 160° F. to limit precipitation. The thermosyphon automatic method of circulation is preferred to the flow-line method owing to the absence of fire risk and danger of overheating the oil, and to the effect of the wash water in reducing corrosion troubles. To be effective the following factors should be taken into consideration : (1) Circulating lines should be at least 6 in. diameter and as short as possible. (2) No trap should be allowed in the return piping from the heater to the gun-barrel. (3) The return circulating line should be insulated and the feeder circulating line insulated or buried. (4) No check-valve should be installed anywhere. (5) The return circulating line should enter the gun-barrel as high as possible, but below the wash water–oil interface level. (6) The temperature of the water in the heater should not exceed 160°. (7) The gun barrel should either be insulated or a wood tank used. C. L. G.

504.* Catalytic Desulphurization to Improve Aviation Blending Naphthas. W. A. Schulze and R. C. Alden. *Oil Gas J.*, 17.11.39, **38** (27), 199.—It has been shown that various sulphur compounds have a pronounced effect on the lead response of gasoline. Monosulphides, disulphides, and cyclic sulphur compounds present in refined gasolines show this deleterious effect, which is greatest at low concentrations. Complete removal of these sulphur compounds from gasoline can be effected by contacting the hydrocarbon vapours with bauxite catalyst at 700–750° F. Examples of the effect of desulphurization of natural gasoline fractions and straight-run gasoline are given. These show that removal of the sulphur compounds from low-sulphur-base material has a considerable effect on lead susceptibility. This improvement is particularly valuable in the case of gasoline used as a component of high-octane aviation fuel. Commercial *iso*-octane and *iso*-pentane used as blending agents are practically free from sulphur, so that any improvement of aviation blends by desulphurization can only be effected by treatment of the base-stock. Examples of the saving in the amount of commercial *iso*-octane in aviation blends by desulphurizing the blending naphtha are given. R. J. E.

505.* Maintaining Decolorizing Clays at High Efficiencies. T. P. Simpson and J. W. Payne. *Oil Gas J.*, 17.11.39, **38** (27), 147.—The regeneration of spent clay used in mineral oil refining is carried out by burning in a multiple-hearth kiln, which in recent years has displaced the rotary kiln. This type of kiln suffers from inherent disadvantages attributable to poor temperature control. The development of a kiln named "thermofor kiln," which embodies control of temperature burning rate, and heat transfer is described. In this kiln the clay is heated at 900–1200° F. The following comparative advantages are claimed for this kiln : (1) Reactivation of clay to higher efficiency. (2) Low construction and operating costs. (3) Excellent regeneration by partial combustion or carbonization. (4) Economical on small scale. (5) Ease of operation and reduced fire hazard. Detailed descriptions of the design and operation of the "thermofor kiln" are accompanied by illustrations.

R. J. E.

506.* Regeneration Step in the Solutizer Process. D. L. Yabroff, E. R. White, and A. V. Caselli. *Refiner*, 1939, **18** (11), 509.—The solutizer process achieves complete sweetening of sour gasolines by extracting them with caustic solutions that contain a suitable organic solvent or salt—*e.g.*, sodium *iso*butyrate, which acts as a solubility promoter—*i.e.*, a solutizer. The spent solutized caustic solution is regenerated by stripping with steam, and can be used indefinitely to sweeten further quantities of gasoline. Values of K_s, the stripping constant, are presented for the various pure mercaptans, and the calculations are shown for the steam requirements in the regeneration step. These are of value in helping to establish the optimum design and operating conditions of a given solutizer plant. G. R. N.

507.* Thermofor Kiln for Clay Regeneration. T. P. Simpson and J. W. Payne. *Refiner*, 1939, **18** (11), 438.—The kiln consists of a stationary chamber containing vertical heat transfer tubes through which the heat transfer medium flows. This medium, which is molten metal or salt, has a temperature of 850–1150° F. and is designed to add heat to or withdraw heat from the clay as required. Angle irons are stacked between the tubes to form a honeycomb of steel, serving as the necessary burning hearth surface, securing uniform flow of clay through the kiln, making air passages, and aiding heat transfer. A commercial unit with burning capacity of 50 tons clay per day has been operating on clays used for percolating Penna stocks. Some batches of clay have been burned sixteen times with maintenance of their efficiency at 100%. No outside fuel is required for the kiln, the necessary heat being furnished by the burning of the carbonaceous material adsorbed in the clay. Controlled partial oxidation produces an active carbon in the pores of the clay, and this has a good adsorptive power for certain colour substances. Clays that have been "partially oxidized" show from two to four times the efficiency of those from which the carbon has been burned completely in percolating stocks treated by the Duo Sol or other solvent extraction processes. The Thermofor kiln is conservatively estimated to pay out both investment and paid-up royalty in one or two years. G. R. N.

508.* Sulphuric Acid for Algæ Control in Cooling Water. R. D. Koons. *Refiner*, 1939, **18** (10), 397.—At the Norwalk refinery of the Wilshire Oil Co. the cooling water system consists of an 800-ft. cooling tower with a 400,000-gal. cement reservoir below, and closed and open-box condensers. The make-up water is obtained from a 100,000-brl. open, cement-lined pond. The algæ growth occurs on the top decks of the tower, and to remove it commercial sulphuric acid is siphoned into the reservoir at the rate of from one to three 12-gal. glass carboys per 8-hr. shift. The acid must travel 800 ft. along the cement reservoir before it comes in contact with metal, and there has been no corrosive action. No normal carbonates exist in the water if the *p*H is below 7·9–8·1. When the refinery was shut down the closed condensers on inspection showed no slime growth, scale deposits or corrosion. The reduction in maintenance costs alone was 1·8 times the cost of the acid. There were also the gains of better heat transfer and reduced pumping costs. G. R. N.

509. Petroleum Emulsions and their Treatment. F. H. Updike. **Summary of Operations.** *California Oil Fields*, 1937 (1939), **23** (2), 5.—Of the two kinds of emulsions, oil-in-water and water-in-oil, the latter is the most frequent occurrence in oil production, and is considered in this paper. Such emulsion consists of finely divided water particles dispersed within the oil mass, each water particle being encased in an elastic film; this mixture is usually referred to as "cut oil." The emulsions are classified as "tight" and "stable" or "loose" and "unstable," the essential difference being that "tight" emulsions are formed in the presence of emulsifying agents such as silica, rotary mud, asphalt, etc. Such agents are in colloidal suspension at the interface of the emulsion particle. The amount of water in emulsified oil depends on a number of factors, chief of which are the nature of the base, the emulsifying agent, temperature, and degree of agitation to which the emulsion is subjected. Oil-wells producing large amounts of water generally have smaller emulsion cuts than those with less water.

Emulsification is preventable in many cases by eliminating primary causes, as, for instance, by reducing agitation, producing chemical conditions inhibiting emulsification, and separating water prior to formation of emulsion. Of these the most important is agitation, and its reduction can be attempted by decrease in pumping speed, maintaining pump submergence, use of gas anchors, elimination of tubing leaks, care and maintenance of bottom-hole and surface transfer pumps, and avoidance of lead-line turbulence by preventing obstructions, restrictions or bends in the lead lines. To combat the difficulty of "cut oil" apart from the foregoing precautions, various methods of treatment are employed; these depend on the type of oil involved, its gravity, viscosity, asphaltic content, or carbon residue, and size of dispersed water particles; viscosity is regarded as being specially important, a high value being a retarding factor in breaking down the emulsion. "Tight" emulsions are hard to break down, and necessitate special treatment; "loose" or unstable emulsions may be more easily broken by heat or may separate on standing.

The commonest methods of treatment include rolling oil in tanks with gas or steam, heating in tanks or heating large amounts of oil and free water. Heat-treating plants depend on the combined action of heat and water scrubbing, sometimes in conjunction with a chemical, on clean "cut oil." Another method is that of electrical dehydration, which has become increasingly popular with expanding power supply to most producing fields. Chemical dehydration has been in use for many years, and many compounds have been evolved which depend for their efficiency on the characteristics of the oil in each case. It is claimed for chemical dehydration that when carried out at flow-line temperature both installation and upkeep costs are low, no expensive equipment being necessary. In all cases, however, laboratory tests of the emulsified oil are essential to a proper understanding of the nature of the emulsion and of the most efficient means of treating it as a factor in refining process. H. B. M.

510. Petroleum Refineries, including Cracking Plants, in the United States. G. R. Hopkins and E. W. Cochrane. U.S. Bureau of Mines, Information Circular No. 7091, October 1939.—The Bureau of Mines' annual survey of refinery capacity in the United States showed that during 1938 there were fewer plants in existence than in previous years. Several new units were completed, but far more were closed down. Nevertheless, the total capacity to produce crude oil materially increased. On 1st January, 1938, the total completed capacity was estimated at 4,351,151 brl., whilst on 1st January, 1939, it had risen to 4,508,555 brl. During the period under review, however, the number of inactive plants increased by approximately 50%, thus reflecting the comparative slump in the refining industry since the prosperous year of 1937.

As far as cracked gasoline plants were concerned, total capacity continued to be increased during 1938, but the slump was again reflected in the decline in newly constructed units. On 1st January, 1938, these totalled 86,060 brl. per day, whilst on 1st January, 1939, the number had decreased to 47,180 brl. Moreover, in 1938 there was an increase of approximately 40,000 brl. in idle capacity as compared with 1937. The daily average output of cracked gasoline in 1938 was 741,000 brl., representing an operating ratio of 86% for active plants or 77% for both active and inactive equipment. H. B. M.

511.* High-Octane Aviation Gasoline by Sulphuric Acid Alkylation. (A Condensation of "High-Octane Aviation Fuel by the Sulphuric Acid Alkylation Process." S. H. McAllister. 20th Annual Meeting of the A.P.I., Chicago, 17.11.39.) *Nat. Petrol. News*, 29.11.39, **31** (48), R.512–R.516.—The process affects the direct union of olefins and *iso*paraffins, in approximately equal volumes, to produce branched-chain paraffins.

In continuous plants the olefins are diluted with *iso*paraffins and passed, at ordinary temperature, into an emulsion of concentrated H_2SO_4 and *iso*paraffin. The presence of the excess *iso*paraffin effectively controls the extent of olefin absorption. *iso*-Butane is the most widely used *iso*paraffin. The olefins usually receive a light caustic wash to reduce the content of mercaptans, etc., the presence of which cause too rapid reduction in the activity of the acid. H. G.

512.* Thermal Alkylation to Produce Auto and Airplane Fuels. G. G. Oberfell and F. E. Frey. *Nat. Petrol. News*, 29.11.39, **31** (48), R.502.—The alkylation reaction can be conducted either catalytically or thermally to produce *iso*paraffinic fuels of high octane number. In the two-stage process, mixed ethane, propane, and butane may be cracked in one stage to produce olefins from the lighter part of the stock, the olefins being reacted with the heavier part of the stock in the second or alkylation stage.

Neohexane is produced by the thermal alkylation at high pressure of ethylene and *iso*butane. Neohexane is an *iso*paraffin of high octane number and is suitable for use as an aviation fuel. Its volatility is higher than that of *iso*-octane and its lead susceptibility is high. A commercial plant for its production is in course of development. H. G.

513.* Modern Automatic Control Apparatus for Topping, Cracking, and Polymerization Plants. D. J. Bergman. *Oel u. Kohle*, 1939, **35**, 675–678.—Maximum uniformity in plant operation necessitates adequate self-recording and adjusting instruments ; these are considered in relation to a crude-oil topping plant, a Dubbs cracking plant, and a U.O.P. contact polymerization plant. Thus, *e.g.*, an influx regulator in the oil-feed line provides for a uniform charge to the pipe-still, and an automatic temperature recorder in the furnace egress ensures uniformity throughout the plant. Simplified self-explanatory flow-sheets are given, showing the location of the automatic control apparatus. A. V. B.

514.* Combination Unit at the Government Refinery of La Plata. B. Rikles. *Bol. Inform. Petroleras*, November 1939, XVI (183), 43–46.—This is a short description of a new combination unit for primary distillation, cracking of heavy fuel oil and light gas oil, and for production of petrol by vaporization and polymerization of the gas. The plant is capable of dealing with 1500 m.^{3} of crude oil per diem. H. I. L.

515. Patents on Refining and Refinery Plant. J. A. Buchel and R. N. J. Saal. U.S.P. 2,185,291, 2.1.40. Appl. 19.1.38. Separation of hydrocarbon oils into portions of different degrees of paraffinicity by bringing the oil into contact with a selective solvent for non-paraffinic hydrocarbons in the presence of chloroform, under conditions causing the formation of liquid extract and raffinate phases and thereafter separating the phases.

T. L. McGee. U.S.P. 2,185,380, 2.1.40. Appl. 4.10.37. Process for preventing corrosive action of sulphur-bearing petroleum hydrocarbons on metal of the apparatus in which they are being treated. Finely divided iron dispersed in a carrier oil of relatively low sulphur content is continuously injected into the hydrocarbons once they have attained an initial critical corrosive temperature. The iron dispersed in oil is previously heated to approximately 150° F. in excess of the said corrosive temperature.

D. F. Gould. U.S.P. 2,185,406, 2.1.40. Appl. 2.8.37. Method of refining a hydrocarbon oil from the group consisting of benzol, toluol, xylol, or mixtures thereof, solvent naphtha and drip oil, by the addition of sulphuric acid to the oil. The mixture is heated in the liquid phase, and subsequently the oil is distilled off and the acidic constituents of the resultant distillate are neutralized.

R. S. McKinney. U.S.P. 2,185,414, 2.1.40. Appl. 29.3.38. The drying properties of oils are increased by heating at a temperature of 200–250° C. for 2–18 hr. with about 0·1% of an alkaline hydroxide.

T. P. Simpson, J. W. Payne, J. A. Crowley, Jr., and C. S. Teitsworth. U.S.P. 2,185,930, 2.1.40. Appl. 1.9.37. Hydrocarbons are converted into the gasoline type by passing them in vapour phase through a body of contact material at a temperature range in which substantial conversion of the hydrocarbons will take place. The passage of the hydrocarbons through the contact material continues until the deposit on the contact material renders it inefficient. Thereafter it is regenerated *in situ* by blowing combustion-supporting gas through the body of the material in thin streams.

T. P. Simpson, J. W. Payne, J. A. Crowley, Jr., and C. S. Teitsworth. U.S.P. 2,185,931, 2.1.40. Appl. 1.9.37. Apparatus for effecting catalytic conversion of hydrocarbons and concurrent regeneration of the catalytic material *in situ* in another zone of the same apparatus.

F. Rositer and V. Mehuer. U.S.P. 2,185,952, 2.1.40. Appl. 21.7.38. New and valuable unsaturated hydrocarbons are produced by mixing acid sludge from the sulphuric-acid refining of petroleum oils with an inorganic alkaline reagent. The reagent is employed in a quantity in excess of that required to combine with all the sulphur present in the sludge.

N. E. Lemmon. U.S.P. 2,187,883, 23.1.40. Appl. 30.12.37. Method of refining viscous hydrocarbon oil by treating with sulphuric acid. Thereafter it is neutralized with caustic soda and finally heated to a temperature of approximately 350–550° F. in the presence of ammonia while agitating with an inert fluid.

Trinidad Leaseholds, Ltd., and Emil Hena. E.P. 516,019, 20.12.39. Appl. 18.6.38. Treating mineral oil distillates with acid, and particularly the more volatile distillates with sulphuric acid. After the addition of the acid the mixture is allowed to settle for about 5 min. Thereafter a small amount of finely divided adsorptive material is added to promote separation of sludge-forming bodies.

Société Générale de Fours Coke Systèmes Lecocq. E.P. 516,125, 22.12.39. Appl. 20.6.38. Continuous distillation and rectification of liquids by means of rotary distillation chambers in which the distilled vapours are conducted in counter current to the liquid to be distilled. Distillation carried out in a horizontal rotary drum having spaces for the passage of liquid and vapours which reach the condenser by passing through a conduit in the shaft of the rotary drum.

E. I. Du Pont de Nemours and Co. E.P. 516,587, 5.1.40. Appl. 29.6.38. Process for the thermal decomposition of hydrocarbons by means of partial oxidation to produce valuable hydrocarbon degradation products. A hydrocarbon is introduced into a rapidly moving stream of oxidizing gas, preheated to a temperature not lower than the ignition temperature of the hydrocarbon at two or more successive points relatively close together.

A. Schlegel. E.P. 516,831, 12.1.40. Appl. 11.7.38. Oil is refined or cleaned by boiling under vacuum and filtering, an adsorption or refining medium being mixed with the oil before boiling to expedite the operation. If insufficient water is present in the oil, a small quantity is added with the adsorption medium.

A. S. Lee and the Superheater Co., Ltd. E.P. 516,866, 15.1.40. Appl. 7.7.38. Improved method of cooling and washing oil by effecting intimate contact between it and water, and thereafter separating the oil from the water. The water and oil are admitted separately and continuously into a common vessel and passed through each other in the form of fine streams under an appropriate head or pressure.

H. B. M.

Safety Precautions.

516.* Boiler House Precautions When the Siren Goes. Anon. *Fuel Econ.*, 1939, **15**, 337–338.—It is assumed that the steam demand in a works during an air raid would cease, but that immediate dispersal of the steam pressure is not permissible, as the clouds of steam would form an attraction to enemy aircraft.

It is therefore recommended that the following minimum precautions should be taken before the firemen take cover :—

(1) Close dampers.

(2) Stop mechanical stokers.

(3) Draw fires or damp them down with ashes or similar inert material.

(4) See that there is plenty of water showing in the gauge glasses (suggested about three-quarters full).

(5) Adjust feed-pump and feed-check valve on the boiler to deliver water at the normal rate of evaporation.

(6) See that the blow-down valve is closed. (On no account should the valve be opened.)

(7) Open an escape-valve on the boiler to allow of a moderate discharge of steam to atmosphere. T. C. G. T.

Chemistry and Physics of Petroleum.

517. Sulphonation Reactions with Sulphuryl Chloride. M. S. Kharasch and A. T. Read. *J. Amer. chem. Soc.*, 1939, **61**, 3089–3092.—The free-radical mechanism accounting for the chlorination of various types of organic molecules by sulphuryl chloride (*J. Amer. chem. Soc.*, 1939, **61**, 2142–50; *J. Inst. Petr.*, 1940, **26**, Abstr. No. 308) should also apply for simultaneous sulphonation. This was found to be the case although peroxides did not exert the beneficial effect on the sulphonation that they showed towards the chlorination, and such compounds as were found to catalyse the sulphonation did so only in the light. The most effective of these were the aromatic nitrogen ring compounds, the pyridines and quinolines. The reaction was quite general for aliphatic hydrocarbons, and when applied to an aromatic compound with an aliphatic side-chain the sulphuryl chloride always attacked the molecule at the side-chain, indicating, as before, a free-radical mechanism. R. D. S.

518. The Peroxide Effect in the Addition of Reagents to Unsaturated Compounds. XXIII. The Reaction of Styrene with Bisulphite. M. S. Kharasch, R. T. E. Schenck, and F. R. Mayo. *J. Amer. chem. Soc.*, 1939, **61**, 3092–3098.—This work confirms the formation of benzoic acid, 2-phenylethanesulphonic acid, and 2-phenylethylenesulphonic acid in the oxygen- or nitrite-catalysed reaction between ammonium bisulphite and styrene, but shows also that 2-hydroxy-2-phenylethanesulphonic acid is formed to a greater extent than the other products. The substitution of bisulphite in styrene is explained by a mechanism which functions in the presence of oxygen, and the formation of the hydroxy-compound is based on a mechanism of a different type, not depending on the nature of the oxidant. R. D. S.

519.* Relative Effect of Inhibitants on Adsorption and on Catalytic Activity. Part II. E. B. Maxted and H. C. Evans. *J. chem. Soc.*, 1939, 1750–1754.—The velocity of adsorption of hydrogen by platinum is retarded in a similar way to the inhibition of the velocity of hydrogenation catalysed by platinum, so that it may be considered as a special case of the latter in which the catalyst is the ultimate acceptor of the hydrogen. This similarity is emphasized in this paper, which describes how the effect of a poison on the catalyst is comparable throughout the poisoning graphs of both phenomena. R. D. S.

520.* Liquid-Phase Reactions at High Pressures. Part V. The Polymerization of *cyclo*Pentadiene and α-Di*cyclo*pentadiene. B. Raistrick, R. H. Sapiro, and D. M. Newitt. *J. chem. Soc.*, 1939, 1761–1769.—This paper deals with the liquid-phase polymerization of *cyclo*pentadiene at pressures up to 5000 atm. over a temperature range of 0–40° C. According to conditions of temperature and pressure, *cyclo*pentadiene undergoes polymerization in three distinct stages : (1) dimerization, where the products are α-di*cyclo*pentadiene and unchanged monomer only ; (2) association to higher polymers, amongst which the trimer and tetramer have been identified, and (3) an explosive decomposition reaction producing gas and a highly carbonized residue. Stage (3) is discussed in the following paper, but the first two are considered here with reference also to the dissociation and polymerization of α-di*cyclo*pentadiene which was carried out at 138°. The latter polymerizes after first dissociating into *cyclo*pentadiene, the polymers being of the same type as formed in stage (2) above. The kinetics of the dimerization reaction are given. R. D. S.

521.* Liquid-Phase Reactions at High Pressures. Part VI. The Explosive Decomposition of *cyclo*Pentadiene. B. Raistrick, R. H. Sapiro, and D. M. Newitt. *J. chem. Soc.*, 1939, 1770–1773.—An investigation into the carbonization of *cyclo*pentadiene (Stage (3) observed in the above paper) is reported in this communication, with the results of the study of the effects of temperature, diameter, and nature of the material of the reaction tube and pressure of a diluent on the carbonization pressure. The critical carbonization pressure increased with decreasing diameter of the reaction tube at 20° and 30°, and this effect was also brought about by increasing dilution with polar and non-polar solvents. The material of the tube also affected the critical pressure. The gas formed in the reaction was chiefly methane. Ultimate analyses are given on the carbonaceous material and the semi-transparent shell round it. All these results are considered with regard to the mechanism of the reaction.
R. D. S.

522.* A.P.I. Hydrocarbon Research Project. D. P. Barnard. *Oil Gas J.*, 17.11.39, **38** (27), 117.—This project was undertaken to provide basic data on the combustion characteristics and the physical and thermal properties of gasoline hydrocarbons. The organization and administration of the project are outlined. As many hydrocarbons in the gasoline-volatility range as experience shows to be practical and possible will be examined; the scope is likely to be limited to those falling within the C_5 to C_{12} range inclusive. So far three procedures have been adopted for the preparation of hydrocarbons :—

(1) Synthesis of tertiary carbinols from ketones or esters with Grignard reagent and dehydration to produce olefines. The olefines may, if desired, be hydrogenated to give saturated hydrocarbons.

(2) Synthesis of olefines from alkyl unsaturated halides by the Grignard reaction. The olefines may be hydrogenated to give the corresponding paraffins.

(3) Direct hydrogenation of aromatics to give the corresponding *cyclo*hexane derivatives.

The procedure adopted and the apparatus used for the purification of the hydrocarbons prepared are described in detail.

The engine-testing procedure programmed consists in determining the critical compression ratio of the hydrocarbon over a wide severity range, which includes conditions which are milder than those of the C.F.R. Research method and conditions which are more severe than those encountered in aircraft practice.

Whilst no set programme for the determination of physical and thermal properties has been arranged, the hydrocarbons prepared will be made available to workers who specialize in the testing involved, so that full advantage will be taken of the availability of pure hydrocarbons. Specialized workers who are interested are invited to approach the Committee with a view to co-operating in this aspect of the project.
R. J. E.

523.* Pyrolytic Alkylation of Hydrocarbons. R. Fussteig. *Petrol. Engr*, November 1939, **11** (2), 45.—A discussion is presented of investigation work on the pyrolytic alkylation of hydrocarbons, and of the reactions occurring under different conditions and with different catalysts. In the presence of H_2SO_4 alkylation of aromatic hydrocarbons with ethylene requires a pressure of 58 atm. With butylene the higher the concentration of the acid, the more complete the alkylation and the higher the boiling range of the product. Thus 90–96% acid produces alkylation, 80% acid polymerization, and 20% only the ester. Catalysts giving simpler and more complete alkylation include phosphoric acid, phosphoric pentoxide, and 85–90% *ortho*phosphoric acid, aluminium chloride, boron fluoride, zirconium chloride, and nickel oxide-alumina. In general, the higher the molecular structure of the olefin, the smaller its tendency to alkylation and the stronger its polymerization power. Alkylation is generally accompanied by secondary reactions such as condensation and cyclization, higher pressure tending to simplify the reaction. Boron fluoride is a stronger and more selective catalyst in the alkylation of cyclic compounds, reacting only with carbon atoms having tertiary bonds. With *iso*paraffinic hydrocarbons aluminium chloride may result in undesirable reactions, since normal paraffins also react—viz., alkylation, isomerization, polymerization, and catalytic cracking; this process is termed autodestructive alkylation, as the olefins formed take part in a further alkylation reaction. Similar alkylation takes place with the aromatic hydrocarbons. It is suggested that controlled alkylation will be used to produce high-quality lubricating oils and paraffin waxes in addition to high-octane-rating gasoline and special *iso*paraffins. C. L. G.

524.* Chemical Composition of Synthetic Gasolines. A. N. Sachenen. *Refiner*, 1939, **18** (12), 521.—Gasolines from mixed-phase cracking at medium pressures contain 30–40% unsaturates distributed in decreasing proportion with increase in b. pt. of the fractions. The paraffin content decreases, whilst the aromatic content increases, with the boiling range. The composition of these gasolines is greatly influenced by the crude sources and the cracking conditions. Vapour-phase cracked gasoline contains more unsaturates and more aromatics than the mixed-phase product. Houdry gasoline is rich in paraffins and comparatively poor in unsaturates and aromatics; the paraffins are of the highly branched type. Hydro-gasolines contain about 1–2% unsaturates. Their aromatic content depends on the reaction temperature and is high when this is above 500° C. Catalytic polymer gasolines contain more than 50% unsaturates, whereas thermal polymer gasolines contain around 35%. A short discussion of the phenolic and sulphur compounds present in synthetic gasolines is also given. G. R. N.

525.* Density and Viscosity of Glycerol Solution at Low Temperatures. E. Green and J. P. Parke. *J. Soc. chem. Ind.*, 1939, **58**, 319–320.—Densities and viscosities of aqueous glycerol solutions containing 30–80% of glycerol have been determined at temperatures between — 5° C. and — 40° C.

The viscosities were found to be higher than the published figures, notably those of Herz and Wegner. T. C. G. T.

526.* Induced Pyrolysis of Methane. W. J. Hessels, D. W. van Krevelen, and H. I. Waterman. *J. Soc. chem. Ind.*, 1939, **58**, 323–327.—The pyrolysis of methane is promoted by the addition of foreign substances—in fact, radicals formed by the pyrolysis of methane react with each other and with undecomposed methane. Examples of foreign substances that act as inductors are halogens, aliphatic hydrocarbons, and hydrocarbon derivatives, such as halogen, sulphur, or oxygen compounds, and a series of these have been investigated. Aromatic hydrocarbons were found to have no inductor effect.

At 1170° C. with a contact time of 0·06 sec.—conditions under which methane, in the absence of inductors, is unaffected—various examples of inductors mentioned above have been demonstrated to promote the formation of ethylene, acetylene, benzene, and naphthalene.

In all the experiments a remarkable dilution effect has been observed. The greater is the excess of the methane compared with the quantity of the inductor, the more methane is involved in the reaction by an equal quantity of inductor.

Induced pyrolysis may be applied to methane in natural gases. These gases normally contain compounds capable of acting as inductors. T. C. G. T.

527.* Stoichiometric Calculations of Exhaust Gas. G. W. Gleeson and F. W. Woodfield, Jr. *Nat. Petrol. News*, 1.11.39, **31** (44), R.461–R.464.—In the calculation of the composition of the exhaust gases from internal-combustion engines reasonable accuracy is achieved by using the equilibrium constants of the water-gas reaction,

$$\text{K.w.g.} = \frac{(H_2O)\ (CO)}{(H_2)\ (CO_2)}$$

The composition of the fuel must be known. Since the calculations are not specific to any particular type of engine, appreciable discrepancies between experimental and theoretical values may indicate mechanical or operational deficiencies. H. G.

528.* Preparation of Some Pure Hydrocarbons. Parts I and II. H. I. Waterman, J. J. Leendertse, D. W. van Krevelen, and J. F. Sirks. *J. Inst. Petrol.*, 1939, **25**, 801–812.—A description is given of the preparation and properties of octylbenzene, octyl*cyclo*hexane, hexadecane, octadecylbenzene, octadecyl*cyclo*hexane, and hexatriacontane. G. R. N.

529. Patent on Chemistry and Physics of Petroleum. George William Johnson. E.P. 516,160, 22.12.39. Appl. 7.6.39.—Conversion of carbon monoxide with hydrogen into hydrocarbons with more than one carbon atom in the molecule in the gaseous phase in the presence of catalysts. This comprises passing over the catalyst vapours of organic liquids in which the conversion products of high molecular weight deposited on the catalyst are soluble, under such conditions that at least a partial condensation of the vapour occurs, thereby regenerating the catalyst by extracting the said products. H. B. M.

Analysis and Testing.

530.* Significance of Viscosity in the Use of Petroleum Oils. W. L. Nelson. *Oil Gas J.*, 23.11.39, **38** (28), 46.—The viscosity of petroleum products is of obvious practical significance in connection with pressure drop in pipe-systems, heat-exchangers, pipe-lines, etc., and with flow through filtering equipment and wicks of lamps. For fuels in steam atomizing burners the viscosity should be 150 secs. S.U. at the firing temperature. It is suggested that grading of fuel oils according to viscosity is a more reasonable basis of price than their gravities. For automotive oils viscosity is related to (1) pumpability, (2) power consumption, and (3) surface lubrication. (1) Pumpability determines the amount of oil circulated and the lowest starting temperature. A table for the rate of flow of motor oils at crank-case temperatures of 160° F. and 70° F. indicates that oil circulation is not greatly dependent on viscosity at high crank-case temperatures, but at low starting speeds or temperatures the heavier oils do not circulate freely. The time after starting for oils of different viscosities to appear above the pistons has been measured, and been found very high for heavy oils (above 30 min.). For starting the engine the viscosity of the oil should not exceed 40,000 secs. S.U. at the starting temperature. (2) Frictional resistance is best measured by gasoline consumption, the higher consumption of lubricating oils of low viscosity being more than offset by the saving in gasoline. (3) From the point of view of engine wear it has been shown that even the lightest grades of automotive oils (S.A.E. 10 W and 20 W) provide adequate lubrication. Even S.A.E. 30 oils diluted with 75–90% kerosine did not cause excessive wear. In many cases faulty lubrication has been traced to the lack of oil rather than to its low viscosity. C. L. G.

531.* Carbon Residue Test Not Closely Related to Performance. W. L. Nelson. *Oil Gas J.*, 11.1.40, **38** (35), 48.—The carbon-residue test provides a good indication of the amount of carbonaceous residue deposited from gas-oils in gas-enrichment chambers, owing to the similarity between the conditions of the test and actual practice. It is also related to the quantity of deposits on burner nozzles or other heated surfaces from fuel oils, but this is affected by so many other factors that no great significance can be attached to the test.

No definite relationship exists between carbon residue content of lubricating oils and carbon deposits in I.C. engines, although a fair agreement has been found in the use of oils from a single base of crude oil. Carbon formation in engines depends on (1) Volatility of the oil at engine conditions; (2) stability to heat and oxidation; (3) type of carbon deposit produced, and (4) mechanical factors. The varied nature of these factors, as well as the effect of *e.g.* gum in the fuel or dust in the air, renders the formulation of a single test very difficult. (1) Volatility is of importance since an oil of high boiling range will remain on the combustion-chamber walls for a long time, and is thus more subject to decomposition by heat than a more volatile oil. It has been suggested that the 90% boiling point under 1 mm. pressure is related to carbon formation, and also that the loose, fluffy nature of deposits from naphthenic base oils is due to their comparatively low boiling range, so that decomposition takes place in the vapour phase rather than the liquid. (2) It is shown that there is no relationship between the carbon residues of used oils and the amount of engine carbon. Asphaltenes, carbenes, and floridin tars, but not pure paraffins and naphthene hydrocarbons, have been shown to produce carbon in the carbon residue test. (3) The type of engine carbon is of more importance than the quantity, it being shown after extensive road tests that a naphthenic base oil of relatively high carbon residue content caused less trouble with engine deposits and the engine required far less frequent cleaning than when using paraffin base oils. (4) Excessive quantities of oil above the piston, due to overfilled crank-cases, loose rings, and worn pistons, will cause excessive carbon formation. Faulty ignition or overheated engines or any maladjustments causing smoky combustion will also be contributing factors.

C. L. G.

532.* Four-ball Apparatus Predicts Hypoid Lube Performance. H. R. Kemmerer and F. L. Garton. *Nat. Petrol. News*, 27.12.39, **31** (52), R.551.—The four-ball apparatus for the testing of E.P. lubricants consists of an oil cup in which three steel balls may be clamped, so that each is in contact with the other two. A fourth ball is held above the other three in a member which can be rotated at a controlled speed.

During the test the fourth ball is in contact with the lower balls. The contact pressure is adjustable through a lever system. The oil-cup rests on a ball thrust-bearing and its rotation is limited by a spring. A graphic recording system records the torque. The test period is normally of 1 min. duration. Scoring time can be determined for any load, and by plotting these data the load to produce scoring at any particular time may be extrapolated. Reproducibility has been found to be best by determining the load required to produce scoring in 2·5 sec. Alternatively, the diameter of the wear spots on the lower balls can be measured. It has been found that a promising method of assessing the relative merits of different lubricants comprises the comparison of the extent of wear at 200° F. (93·3° C.) and 80° F. (26·6° C.).

This has led to the conception of the wear-temperature constant "*K*"

$$K \text{ Max.} = \frac{W_1 - W_2}{93{\cdot}3 - 26{\cdot}6} \times 1000$$

where W_1 and W_2 are the wear in mm. at 200° F. and 80° F., respectively, K being taken at the load where W_1 and W_2 are maxima.

H. G.

533. Hazard of Mercury Vapour in Analytical Petroleum Laboratories. C. F. McCarroll. U.S. Bureau of Mines, Report of Investigations No. 3475, October 1939.—Liquid mercury is in constant use these days in analytical petroleum laboratories, but so far little consideration has been given to the dangers occasioned by liberation of the toxic vapours—for instance, by accidental spilling of the mercury. Inhalation of mercury vapour and dusts is now recognized as definitely harmful to the human body, and there is already published an extensive literature on what is known as industrial mercurialism. This includes data on the disease in both its acute and chronic forms as contracted during the process of mining and smelting mercury-bearing ores, also in the hatter's fur-cutting industry. Owing to the comparatively rare incidence of chronic mercurialism in analytical laboratories and other concerns not directly engaged in these industries, few specific data are available in the former connection.

The author of this paper undertook certain investigations with a view to determining the concentrations of mercury vapour present under various operating conditions in analytical laboratories and to discovering ways of minimizing hazards attendant thereon. In addition, available literature on chronic industrial mercury poisoning was studied in an attempt to correlate these findings with conditions obtaining in petroleum laboratories.

Results show that the use of reagents, such as hydrogen sulphide, have proved successful in some instances in combating the effect of exposing liquid mercury in laboratories. Nevertheless, inasmuch as hydrogen sulphide is extremely toxic in itself, preventive measures of this kind should only be used by experienced operators having an intimate knowledge of the hazards of this gas.

H. B. M.

534.* Present Position Relative to Viscometry. F. Jostes. *Oel u. Kohle*, 1939, **34**, 663–665.—Empirical methods for the measurement of viscosity as used in different countries afford no accurate standard for comparison of oils. Accordingly attempts are being made to introduce absolute methods based on the capillary and falling-sphere viscometer. Thus in Germany the viscometers of Höppler, Ubbelohde, and Vogel-Ossag, are in use. The reliability of these viscometers depends on the accuracy of calibration, and at the World Petroleum Congress in London 1933 an international committee was established on this question. On two capillary viscometers calibrations of an accuracy of ±0·3% and of 3·0%, respectively, were reported. In the Brussels session, therefore, a resolution was reached whereby collaboration accrued between Physikalisch-Technische Reichsanstalt, Berlin, and Ecole Nationale Supérieure du Pétrole, Strasbourg. It was anticipated that complete agreement in calibration would be attained, and accurate conversion of empirical to absolute measurement established. Attention is also directed to the uncertainty existing in the measurement of flow properties of plastic substances, such as Krämer–Sarnow softening method for bitumen, the ring and ball and penetration tests, etc., none of which is satisfactory. It is suggested that a similar procedure as for viscosity outlined above is necessary. A. V. B.

535.* Determination of Phenols in Hydrocarbon Solvents. L. A. Wetlaufer, F. J. van Natta, and H. B. Quattlebaum. *Industr. Engng Chem. Anal.*, 1939, **11** (8), 438.—A 25-ml. sample of the hydrocarbon solvent is extracted five times with equal volumes of 0·2N-potassium hydroxide. Each extract is neutralized with 25 ml. of 0·2N-sulphuric acid and diluted to 100 ml. with glacial acetic acid. A portion is heated on a steam-bath with a few drops of concentrated sulphuric acid and nitric acid. A pale yellow colour develops. The solution is then cooled in ice and made alkaline by the gradual addition of concentrated ammonium hydroxide. The yellow colour is intensified and its depth is compared in a Duboscq or Klett colorimeter with that given by standard solutions prepared by carrying out the above procedure on solutions of known amounts of phenol (in water) and *p-tert.*-butylphenol (in acetic acid). The method is considered to be rapid and direct and gives checks within 5–10 parts per million. G. R. N.

536.* Determination of the Molecular Weights of Oils. W. E. Hanson and J. R. Bowman. *Industr. Engng Chem. Anal.*, 1939, **11** (8), 440.—The apparatus employed consisted essentially of a modified form of the Cottrell boiler and adapted for use with the Menzies–Wright water differential thermometer. Benzol and *cyclo*hexane were used, the former being preferred, since a good grade of the commercial product requires no further purification and may be used directly. Results on pure compounds and on a variety of petroleum products, mol. wt. range 200–1500, indicated a precision of 1% or better at all times. A complete determination of mol. wt. requires 2 hr. G. R. N.

537.* Determination of Total Sulphur in Asphalts. S. Pellerano. *Industr. Engng Chem. Anal.*, 1939, **11** (8), 446.—About 0·25 gm. of the asphalt is placed in a porcelain combustion boat and 3 ml. chloroform are added to dissolve the sample. 3–5 gm. catalytic combustion mixture (manganese dioxide–cupric oxide) are added and incorporated in and cover the asphalt solution. The chloroform is evaporated off and the boat is placed in the combustion apparatus. After combustion the contents of the boat are digested with boiling water and filtered. The sulphates in the filtrate are determined quantitatively using barium chloride. The results agree closely with those determined by the bomb method. G. R. N.

538.* Change in Solvency during Evaporation of Thinners. E. H. McArdle. *Industr. Engng Chem. Anal.*, 1939, **11** (8), 450.—A simple air-lift glass laboratory film evaporator is described; 100 ml. of "mineral spirits" and related solvency naphthas can be evaporated in the form of a film during less than 3 hr. at room temperature. Since aniline point is generally accepted as a measure of solvency of a hydrocarbon thinner of a given boiling range, this test was applied to small samples taken at regular intervals from the naphtha during evaporation. Graphs relating per cent. evaporated and aniline point showed that the several naphthas tested possessed marked characteristics with respect to the change in solvency during evaporation. It was found that time and temperature within fairly narrow limits were not factors affecting the operation of the evaporator. G. R. N.

539.* Solvency of Petroleum Spirits. S. S. Kurtz, Jr., W. T. Harvey, and M. R. Lipkin. *Industr. Engng Chem. Anal.*, 1939, **11** (9), 476 and 484.—Part I. There is no definite relation between the kauri butanol solvency of petroleum spirits and the viscosity of cold-cut solutions of resins dispersed in these spirits. The resin solvency for cold-cut dispersions defined by the equation

$$\text{R.S.} = \frac{\text{kinematic viscosity of solution of X\% resin in standard spirit 1}}{\text{kinematic viscosity of solution of X\% resin in spirits under test}} \times 100$$

is approximately independent of the concentration at which the test is made and also of the temperature of test. The resins recommended for test purposes are: (1) Beckacite 1001, a straight phenolic resin and ester gum 6. The relative solvent power of spirits depends on the type of resin with which the resin solvency is determined. Spirits which contain approximately equal proportions of paraffins, naphthenes, and aromatics, however, have good solvency for any of the spirit-soluble resins. The logarithm of the kinematic viscosity is proportional to the concentration expressed as grams of resin per gram-mol. of solvent. The conclusions are confined to spirits or cuts lying within the boiling range of 300–400° F. 33 References.

Part II. Graphs are developed so that the resin solvency of spirits for phenolic and ester-gum resins can be determined from the A.S.T.M. 50% boiling point, the density (d 20/4), and the refractive index (n 20/D). Conversely, specifications of boiling point and resin solvency for these resins automatically specify the physical properties and approximate composition of the solvent. G. R. N.

540.* Determination of High Viscosities. E. L. Baldeschweiler and L. Z. Wilcox. *Industr. Engng Chem. Anal.*, 1939, **11** (10), 525.—The barrel of a Gardner mobilometer was fitted with a brass jacket so that water from a Hoeppler thermostat could be used to maintain accurate temperature control of the mobilometer during test. By rigid control of the temperature and time, it was found that the relation between absolute viscosity and mobility was a straight line at various temperatures, for high-viscosity oils—*i.e.*, 800 poises at 77° F., 300 poises at 150° F., etc. The slope of the straight line depended on the number of holes in the disc being steeper the fewer the holes. It was concluded that if care is taken the Gardner mobilometer can be used as a precision instrument to determine the absolute viscosity of viscous oils. G. R. N.

541.* Determination of Specific Gravity of Gases. G. V. Feskov. *Industr. Engng Chem. Anal.*, 1939, **11** (12), 653.—A description is given of an automatic effusiometer, which is considered more accurate than the regular manually operated type. It eliminates personal error in handling a stop-watch. Mercury is used as the displacing medium, whilst the automatic timing system is operated without a relay. The instrument is recommended for routine use in the determination of the specific gravity of petroleum gases. G. R. N.

542.* Capillary Flowmeter with Variable Orifices. J. H. Bruun. *Industr. Engng Chem. Anal.*, 1939, **11** (12), 655.—A simple flowmeter with a vertical capillary tube is described. The capillary tube was 60 mm. long and 1·1 mm. in diameter, being designed for the maximum gas flow expected. By inserting accurate wires in the capillary the gas flow could be varied according to the size of the wire. It was necessary to calibrate the flowmeter for each wire, and a range of 0·2–7·0 litres per minute gas flow for this capillary was obtained. G. R. N.

543.* Quantitative Determination of Aromatic Hydrocarbons. A. V. Grosse and R. C. Wackher. *Industr. Engng Chem. Anal.*, 1939, **11** (11), 614.—The method described is based on the measurement of the specific dispersion of the sample, and applies to hydrocarbon mixtures boiling within the gasoline range. Either the Abbé or the Pulfrich refractometer can be used. The formula employed is as follows :—

$$\text{Wt.\% of aromatics} = \frac{\delta \text{ mixt.} - 0{\cdot}16 \times \text{bromine number} - 99}{\delta \text{ arom} - 99} \times 100$$

99 = specific dispersion of the saturates—*i.e.*, the paraffins and naphthenes, 0·16 = increment of specific dispersion per unit of bromine number. The theory underlying the method is given and checked, using a number of synthetic mixtures. Comprehensive tables are included. G. R. N.

Motor Fuels.

544. Co-operative Fuel Research Motor-Gasoline Survey, Winter 1938–39. E. C. Lane. U.S. Bureau of Mines. Report of Investigations No. 3455, June 1939.—The above report is the seventh of a series prepared by the Co-operative Fuel Research Committee and the U.S. Bureau of Mines. It includes data on 1875 samples representing the products of eighty-three different companies, and also data on samples from the Pacific Coast which were averaged by the Pacific Coast Technical Committee before submission. For the purposes of the report, gasoline is divided into three price-grades : regular, premium, and third-grade. Characteristics of each grade are reported, based on inspections made in oil-company laboratories and submitted to the Bureau of Mines for compilation and comment. Detailed study of these shows that gasolines in the various price classifications fall equally into definite groups in so far as their characteristics are concerned. H. B. M.

545.* Starting Properties and Volatility of Automobile Fuels. Z. V. Veksler and N. I. Kuzmin. *Neft. Khoz.*, July 1939, 20 (7), 40–44.—Tests were carried out in a tractor engine with seven petrols of varying volatility. The results show that a correlation exists between the ease of starting at varying temperatures and the temperature of 10% distilled, the equilibrium evaporation, and the vapour pressure determined according to the methods of Reid and Sorel—N.A.T.I. The 10% point has the greatest practical value, and the formula developed by G. G. Brown is confirmed. Basing on average summer and winter temperatures in the mean latitudes of the U.S.S.R. of +10 and —10° C., and considering a certain evaporation loss during transportation and storage, the 10% point of summer- and winter-standard petrol is recommended to be not higher than 75 and 60° C., respectively. L. R.

546.* Fuels and Tetraethyl Lead. F. Ramorino. *Chim. e Industria*, 1939, 21 (10), 578–580.—The author briefly summarizes the position in France and Germany with regard to fuel anti-knock characteristics and compression ratio of automobile engines. It is pointed out that, whereas in France the fuel is adjusted to meet the requirements of newly developed engines, in Germany the engine must fall into line with the self-sufficiency policy, and while a minimum octane number of 65 is prescribed by Government regulations in France, no vehicle is licensed in Germany unless it is able to employ a fuel of 74 octane number. The position in Italy is similar to that in France. It is stated that the production of alcohol in Italy is not sufficient to enable suitable blends, which would be stable under the climatic conditions, to be obtained, and since the average octane number of present supplies of gasoline is very low, the author suggests using sufficient tetraethyl lead to bring the octane number up to 65. Tetraethyl lead is now manufactured in Italy, and some latitude should be permitted in regard to the proportions which may be used, consistent with satisfactory operation of the engine, the addition of lead being prohibited during the period when the use of 10–20% of alcohol is obligatory. In conclusion, the author suggests that fuels of higher anti-knock characteristics should be introduced in order to conform with practice in other countries and to keep abreast of developments in the Italian automotive industry. P. G.

547.* Low Quality of Distillate Fuels Hinders their Use in Farm Tractors. E. L. Barger. *Nat. Petrol. News*, 15.11.39, 31 (46), R.482.—A plea is made for an improvement in the quality of distillate fuels. It is shown that whereas 90% of the farm tractors in America are capable of running on distillates, the major part of the tractor fuel is gasoline. This is due to the variable and low average quality of distillates. Laboratory tests and practical ploughing trials have shown that although 70 octane gasoline gives the greater power output, distillate fuel has a considerable price advantage. A proposed specification for distillate tractor fuel is as follows :—

Octane Number 30 min.

Distillation.

Minimum	5%	not below		325° F.
	95%	,,	,,	464° F.
Maximum	10%	not above		400° F.
	25%	,,	,,	420° F.
	95%	,,	,,	515° F.
End Point		,,	,,	540° F.

The sulphur content and gum content may be higher than for gasoline. H. G.

548. Patent on Motor Fuels. Texaco Development Corporation. E.P. 516,521, 4.1.40. Appl. 30.5.38.—Production of anti-knock motor fuel hydrocarbons from a cracked distillate. The distillate is alkylated with a low-boiling *iso*paraffin—*e.g.*, *iso*butane or *iso*pentane in the presence of sulphuric acid. The *iso*paraffin is at least equal in weight to the weight of the olefines present in the cracked distillate.

See also Abstract No. 492. H. B. M.

Gas, Diesel and Fuel Oils.

549.* Application of Graphical and Statistical Methods to the Analyses of Diesel Fuels. J. C. Vlugter, H. I. Waterman, and H. A. van Westen. *J. Inst. Petrol.*, 1939, **25**, 678–683.—After a general discussion of these methods and of available data, it is concluded that a more thorough investigation of a large number of diesel fuels will be necessary in order to study the influence of chemical composition on the cetene or cetane value. G. R. N.

550.* Diesel Fuel Characteristics Influencing Engine Output. A. J. Blackwood and G. H. Cloud. *J. Inst. Petrol.*, 1939, **25**, 684–694.—The effects of volatility, ignition quality, viscosity, gravity, and heating value of diesel fuels are discussed and summarized. G. R. N.

551.* Evaluation of Certain Normal Alkylated Benzenes as Diesel Fuels. G. Shen, C. E. Wood, and F. H. Garner. *J. Instn Petrol.*, 1939, **25**, 695–703.—A paper, which describes the preparation and properties of the normal alkyl benzenes ranging from *n*-amyl to *n*-nonyl, and which gives their cetane numbers as determined on the C.F.R. diesel fuel-testing engine. G. R. N.

552.* Effect of Tractor Kerosine Admixture on Freezing Point of Diesel Fuel. I. A. Ptashinski. *Neft. Khoz.*, July 1939, **20** (7), 44–45.—Present Russian diesel fuel standards prescribe, in general, a freezing point not higher than —25° C. Tests have shown that a linear relation exists between the volume of kerosine added, up to 40%, and the reduction of the freezing point of diesel oil. The effect is small, and 10% of a kerosine freezing below —65° C. reduced the freezing point merely 2–3° C. The effect of paraflow on Surakhany gas-oil was considerable. The importance of using different components for blending summer- and winter-grade diesel fuels is stressed. A standard method of determining the freezing point of diesel fuels is required, whilst the freezing-point standard specification should be revised. L. R.

553.* Miscibility of Fuel Oils. —Demann. *Oel u. Kohle*, 1939, **36**, 685–686.—Fuel oils can be derived from L.T.C., H.T.C., syntheses and petroleum. The miscibility of two fuel oils of different source or origin is defined by flocculation of hard asphalt and free carbon. In absolute miscibility no precipitation of asphalt or carbon occurs, and these are assumed absent. Relative miscibility expresses to what extent a fuel oil containing hard asphalt and free carbon is miscible with other oils. In opposition to absolute miscibility, it is dependent on constitution of the added oil.

There are two main groups of fuel oil, the one asphaltic preponderately of aromatic naphthenic structure, and the other asphalt free of predominantly aliphatic nature such as some petroleum origin fuel oils.

These two groups, when mixed, cause flocculation of asphalt. It is stated that by deasphalting asphaltic fuel oils complete miscibility of oils from L.T.C., H.T.C., or syntheses ensues. A. V. B.

Lubricants and Lubrication.

554.* Oxidation Resistant Motor Oils Producible by Present Methods. M. R. Fenske, C. E. Stevenson, and R. E. Hersh. *Nat. Petrol. News*, 15.11.39, 31 (46), R.471.—Although the degradation of a lubricating oil may have many aspects and symptoms, the chief basic cause of the degradation is oxidation. Information relative to the degree of oxidation resistance of a lubricant may be obtained by considering the neutralization number and volatile-acid-forming characteristics of the oil, together with its oxygen absorption curve at constant time and/or constant temperature and the rate of change of viscosity index with time in service.

Little information is at present available concerning the chemical constitution of lubricants, but such work as has been carried out indicates that an increase in this knowledge should throw considerable light on the problem. At the present time the application of solvent extraction to the refining of lubricants and the addition of anti-oxidants to lubricating oils have been responsible for a noteworthy improvement in their oxidation resistance. H. G.

555.* Hypoid-Lubricant Requirements. H. R. Wolf. *Oil Gas J.*, 17.11.39, 38 (27), 162.—The development of hypoid lubricants from the motor-engineer's point of view is discussed. Attention is directed to the need for differentiation between lubricants used under widely different conditions. To distinguish between a hypoid lubricant suitable for high-speed operation of passenger cars and one suitable for low-speed operation in trucks, the names " passenger-car duty hypoid lubricant " and " truck-duty hypoid lubricant " have been used. The word " duty " is included to emphasize that operating conditions, and not the type of vehicle, must be the determining factor in the choice of lubricant. General Motors' procedures for test of both types of lubricants are described in detail, and grades recommended for their vehicles have to satisfy specified requirements.

In a consideration of future developments of hypoid gears it is considered that requirements with respect to lubricant are likely to become more critical, so that new types of extreme-pressure addition agents may have to be developed. R. J. E.

556.* Some Aspects of Steam-Engine Lubrication. J. D. Watson. *Fuel Econ.*, 1939, 15, 329–331.—The requirements of lubricating oil for steam engines and of reciprocating air compressors, which have much in common with steam engines, are reviewed. Lubrication feed-systems receive noteworthy attention.

Acidity and tendency to gum are stressed as being of paramount importance in choosing a steam-engine lubricant, and a warning is sounded against any misconception of the value of viscosity and flash point, etc. The use of branded oils from reputable firms is commended.

In the case of reciprocating air compressors it is essential to deliver air as free from oil as is possible and to avoid an excess of air in the cylinder—one of the main causes of faulty valve operation, with the attendant risk of explosion.

The high temperatures prevalent in air compressors induce carbonization, and the oil must be judged accordingly. It is considered that a heavy oil is not necessary—a light oil is more easily atomized and is more completely burned away by the heat. If the lubrication is kept to the minimum requirements, there is no danger of explosive vapours.

A suitable oil should have a flash point of at least 400° F. and low carbon formation.

A light oil is best, providing it has sufficient body to stand up to 150° F.—the temperature of the cylinder walls—and seals the rings without oil drag.

Oils prepared from an asphaltic-base crude are preferable to those prepared from a paraffinic base, because the carbon formation from the latter type is considered to be much harder than that from asphaltic-base oils. T. C. G. T.

557.* Behaviour of Various Engine and Gear Lubricants in Seizure Tests. D. Clayton. *J. Inst. Petrol.*, 1939, **25**, 709–728.—A paper in which the results are described of an investigation of the effect of various lubricants on the seizure characteristics of hard steel in the four-ball apparatus. Some discussion is given of the applicability of the results to gear lubrication. G. R. N.

558.* Practical Methods of Testing Lubricants. J. H. Evans. *J. Inst. Petrol.*, 1939, **25**, 729–750.—The various kinds of greases and lubricants are discussed with reference to their composition and characteristics as revealed by the test methods employed by the Timken organization. G. R. N.

559.* Test for the Ring Sticking Properties of Lubricants. J. C. McNichol, C. G. Williams, and P. V. Lamarque. *J. Inst. Petrol.*, 1939, **25**, 751–759.—A description is given of a simple laboratory test for assessing the oxidation and ring-gumming propensities of engine lubricants. It consists principally in measuring the strength of a thin oxidized film of the lubricant. The test results are discussed in relation to the service characteristics of lubricants. G. R. N.

560.* Extreme Pressure Lubricant Tests with Pretreated Test-Pieces. J. P. Baxter, C. I. Snow, and I. T. Pierce. *J. Inst. Petrol.*, 1939, **25**, 761–770.—Experiments with the Timken and Four-Ball lubricant testing machines are described in which considerable increases in the breakdown loads of doped and undoped oils were obtained by pretreatment of the test-pieces with chlorinated or sulphurized dope or with hydrochloric acid. G. R. N.

561.* Testing of Engine Lubricants. C. A. Bouman. *J. Inst. Petrol.*, 1939, **25**, 771–778.—A paper which gives a critical survey of the laboratory testing of lubricants and their interpretation in making a choice of a suitable motor oil. G. R. N.

562.* Lubricating Oils by Solvent Treatment of Lignite Coal Tars. M. Marder. *Oel u. Kohle*, 1939, **33**, 649.—Lube oils comparable to naphthene-base petroleum oils stated to be obtained by selective solvent treatment of lignite coal-tars; specific gravity, asphalt content, coke number, and viscosity temperature characteristics are in improved contrast to those of an acid-refined oil. Mention is made of a subsequent treatment of the raffinate with small quantities of condensation agent, aluminium chloride. The reaction product after vacuum distillation shows a further improvement in properties. A. V. B.

563.* Oil Filters. J. E. Hurn. *Refiner*, 1939, **18** (10), 405.—To determine whether an oil will be a satisfactory lubricant, it is necessary to estimate the moisture, corrosive materials, and asphaltenes, because these cause the formation of sludge and lacquer, which are responsible for engine wear. The asphaltenes must be removed from the oil as fast as formed and while they are still in the liquid state. They increase in viscosity as the temperature rises, and tests were made to determine the temperature at which they become more viscous than the oil. The tests showed that when the viscosity of the oil was reduced to about 100 sec. S.U., the asphaltenes could be separated by using an absorbent filter, not a strainer. The proper use of filters makes it unnecessary to change the oil at the usually stated intervals. Trucks tests are cited which show the advantages of filtration with regard to longer use of the oil and reduction in cylinder wear. G. R. N.

564. Patents on Lubricants and Lubrication. E. F. Pevere. U.S.P. 2,186,271, 9.1.40. Appl. 25.6.36. Manufacture of a cutting oil comprising a light mineral oil having a viscosity within the normal range for the lubrication of cutting tools and 2–10% by weight of an organic polysulphide.

B. H. Lincoln and W. L. Steiner. U.S.P. 2,186,646, 9.1.40. Appl. 20.2.39. Production of lubricant incorporating lubricating oil and a small percentage of sulphurized synthetic ester of a low-molecular-weight monohydric or dihydric alcohol and a high-molecular-weight organic acid.

N. Geiser. U.S.P. 2,187,704, 16.1.40. Appl. 20.12.35. Method of manufacturing lubricating oil from olefines by adding aluminium chloride as polymerizing catalyst, and thus obtaining a hydrocarbon mixture consisting mainly of aliphatic hydrocarbons and being rich in olefines. Subsequently the polymerizing catalyst is separated from the lubricating oil and used again.

P. G. Colin. U.S.P. 2,187,802, 23.1.40. Appl. 25.9.37. Mineral hydrocarbon oil for lubricating bearings which have substantially the corrosion susceptibility characterizing cadmium–silver, cadmium–nickel, and copper–lead alloys. The oil is such that it would normally tend to corrode these surfaces, but the addition of suitable proportions of tin tetra-butyl to the oil prevents this.

Union Oil Company. E.P. 516,276, 28.12.39. Appl. 17.3.39. Manufacture of mineral lubricating oil containing 0·8–3% oil-soluble metal soap of saponifiable petroleum acids produced by the oxidation of petroleum fractions. The soap is present in sufficient quantity to control deposition of gummy and resinous materials and overcome ring-sticking tendencies in severe service internal combustion engines. The oil product has practically the same viscosity as the original mineral lubricating oil.

E. I. Du Pont de Nemours and Co. E.P. 516,182, 27.12.39. Appl. 22.6.38. A small proportion of an acetal containing at least one free hydroxyl group is incorporated in lubricating oils and greases to aid in providing thin film lubrication and retard sludge formation. H. B. M.

Asphalt and Bitumen.

565.* Adhesiveness of Bitumin to Silica Sand. H. F. Winterkorn and G. W. Eckert. *Industr. Engng Chem. Anal.*, 1939, **11** (10), 546.—McLeod's mixing test and the authors' wash test are compared. It is concluded that the ease of covering a sand with a bituminous material by means of simple mixing may be a general indication, but is not a dependable measure of the adhesion relationship between the bitumen and the sand. The best agreement of the mixing-test data with those from the wash test occurs where wetting agents are used in conjunction with aluminium, iron, and lead ions—*i.e.*, with those ions which are generally recognized as favourably affecting adhesion of bitumen to aggregate. For such cases, and where the aggregate has to be coated in the wet condition with the help of soap-type activators, the McLeod test appears to have some merit. The mixing test cannot be substituted for the wash test if definite information on the adhesion relationship between bitumen and aggregate is desired. G. R. N.

566. Physical Properties of Bitumen. P. C. Blokker. *Angew. Chemie*, 1939, **52**, 643–648.—The authors have surveyed the literature on the physical properties of bitumen and collected together a mass of data which they have supplemented by their own tests. The latter were confined to commercial bitumens of Venezuelan and Mexican origin. The latest designs of testing apparatus are described in detail.
E. W. S.

567. Bituminous Stabilization Practices in the United States. L. Muir, W. Hughes, and G. Browning. *Highway Res. Board Proc.*, 1938, **18** (II), 306–313.—Owing to cost, local materials must be used when possible for U.S. roads, and stabilization with bitumen provides a method of economically rendering these materials suitable for use, since it makes the soil resistant to water and increases its natural stability. It is generally conceded that moisture is essential, and that for best results compaction must be carried out at the optimum moisture content, determined by the Proctor test.

Less moisture is required the less viscous the bitumen. Complete mixing of bitumen and material is essential. All types of bituminous materials have been used, but the contradictory statements made in various States show that much remains to be learned regarding the types, grades, and methods of manipulation best suited for any particular purpose. Construction methods are similar in all States reporting the use of asphaltic oils. Generally good results have been obtained by those using residual and cutback oils. The general behaviour of tars has been found to be substantially the same as that of asphalt. The general practices of all States using asphalt emulsions are substantially the same, and it has been found that (1) ample water must be available, (2) the stack must be kept moist at about the plastic limit until mixing is complete, and (3) spreading, rolling, and dragging must be done when the material is at the proper consistency, which is about the optimum water content. It is important that the asphalt emulsions should contain no appreciable amount of soap or other soluble emulsifying agent. In Missouri, Idaho, and California it has been found that emulsions disperse much better through the soil than other asphaltic materials, but they must be stable, capable of mixing with water, must lose water rapidly, and must be uniformly dispersed as a light film on all soil particles. It has not yet been proved whether the increased cost of the emulsified product is followed by longer life. A *résumé* of the practices used in the following States is given: Missouri, South Carolina, North Carolina, Kentucky, Ohio, Iowa, Nebraska, Florida, Wyoming, California, Idaho, and Nevada. Formulæ for ascertaining the amount of bitumen required on a project are given by Iowa and Nebraska States, whilst Florida has been unable to develop a formula, and uses the method of trial laboratory mixes, whilst pointing out the need for warm, dry weather during construction.

It is concluded that all bituminous materials can be used successfully under the proper conditions, that the bitumen must be thoroughly admixed with the soil, and that efficient drainage is of the first importance. H. G. W.

568. Compendium on Soil Testing Apparatus. C. M. Johnson and E. S. Barber. *Highway Res. Board Proc.*, 1938, 18 (II), 371–433.—This is a compendium, complete with illustrations and details, of the physical tests used in soil laboratories in U.S.A., Canada, and Europe. It is pointed out that if further details are required, reference must be made to the original papers. The subject-matter is divided into nine sections with tests as outlined.

Consolidation tests give information on the amount and rate of consolidation of soil samples due to pressure. In all types the sample is placed between two porous stones, provision is made for the water extruded in the process, and a piston is used to transmit the pressure (cf. *ibid.*, 9–33). The apparatus is grouped according to the pistons and method of applying the load.

Direct shear tests determine the resistance of soils to distortion (cf. *ibid.*, 9–33), and are grouped into the box, plate, double, and torsion methods, the normal loads being applied in three ways, while the shearing loads are applied in five ways.

Compression tests on soil cylinders give information on the distortion and volume change of soils when under known compressive stresses. The sample may be confined on all faces as in the fixed and free rubber types, or open and loaded only on the ends in the unconfined type (cf. *ibid.*, 9–33).

The compaction test determines the densities for varying moisture contents so as to show the maximum dry density. The devices are grouped into impact, static, and vibration (cf. *ibid.*, 9–33).

Capillarity tests determine the amount, rate, and height of water taken up and held by soils, and the apparatus is divided into four groups: open-tube, negative-head, compressed-air, and indicator.

The permeability test is useful for determining the amount of water under pressure which will flow through soils under various conditions. The permeameters are divided into three types, depending on the method of applying the head of percolating water—viz., constant-head, variable-head, and horizontal capillarity, whilst the sample containers are also divided into individual, consolidometer, and Proctor mould.

The penetration and extrusion tests furnish data on the relative bearing capacity of soil samples, and some may be used *in situ*. Four groups are considered—viz., needle, cone, bearing, and extrusion.

If a soil is not already saturated, the swell test will show the increase in volume obtained on the absorption of water. Consolidometers may be used as well as the Proctor mould and Californian apparatus.

Field tests and sampling equipment are described, including the portable surface shear-testing-machine, the combination-foundation exploration drilling-rig, and various soil samplers. H. G. W.

569. The Trend of Soil Testing. C. A. Hogentogler and E. S. Barber. *Highway Res. Board Proc.*, 1938, **18** (II), 9–34.—This paper consists of a *résumé* of soil-test methods and points out the significance of the test data. Clays are adsorbed by the sand to various extents, and the resultant wet mixtures may or may not have air in the interstices, depending on the electrical attraction between the materials. The adsorbed moisture is called the film moisture, and is found mainly on the colloidal particles; decreasing the ratio of free to film moisture increases the soil stability. This may be effected by reduction of the temperature and by replacement of the natural ions with others which have greater attraction for water; at the " critical " moisture content the abrupt change from the plastic to the semi-solid state is observed. The purpose of soil tests is to disclose in some manner the effect of moisture and air content of samples on the bearing value and stability of soil masses, and the four general types of test are: (1) consolidation, (2) shear, (3) compaction, and (4) indicator, all carried out at constant temperature. The " voids ratio " is defined as the ratio of the volume of the pores to the volume of solids. In test (1) the time–pressure and moisture content-pressure curves are obtained as characteristics of the soil, and if the shape of a building, etc., is known, the amount and rate of consolidation it produces in the soil can be determined, and the distance it can settle without lateral displacement of the undersoil. In test (2) the theory and method of test are given, and it is found that sand shears abruptly and clay only after considerable deformation. It is seen from the stress–strain relationships that only part of the soil strength can be used in construction. The speed of embankment construction, for example, can be so controlled that the pore pressure, shown by stand pipes in the undersoil, will not be developed to such an extent as to make failure imminent. From tests (3) can be determined the maximum soil density possible and the corresponding optimum moisture content, and from these data can be found the safe height of embankment for soil compacted to a given density. The tests (4) which indicate the engineering properties of the soil are the plasticity tests and mechanical analyses and are used so that suitable soils can be obtained by blending. H. G. W.

570. Soil Stabilization with Tar. G. E. Martin. *Highway Res. Board Proc.*, 1938, **18** (II), 275–282.—By the proper use of tar, as described, existing soils can be made resistant to water, and their bearing power can be materially increased. Sand, etc., may be added to the soil to increase its bearing power, but a tar stabilized soil, however, does not depend on the grading for its stability. In general, soils containing more than 5% of material passing the no. 200 sieve will be materially improved by the addition of sand, etc., and the heaviest grade of tar which can be mixed satisfactorily should be used. The amount of tar generally lies between $\frac{1}{4}$ and $\frac{1}{2}$ gall./sq. yd./in. of consolidated depth, and a formula is given for calculating the amount required for a given project. The optimum moisture content can be determined by the Proctor method, and a 4-in. consolidated depth at least should be carried out. Details of the tests used are given, but these are at present only tentative. It is required that the soil shall be so treated with tar as to give a capillary water adsorption for 14 days of not more than 25% of that of the untreated soil. Specimens are prepared by means of the standard moulds and tampers used in the Hubbard–Field stability test; moisture and apparent density determinations are made on these, and the conditions to give maximum weight per cubic foot are determined under the conditions of compaction used. The percentage of water absorbed on immersion in water after 14 days is also determined. The specimens are tested for stability in a Hubbard–Field Stability Testing Machine before and after immersion in water and satisfactory mixes derived from these results. The large-scale construction methods are then given complete with illustrations. These are mixing with aggregate if required, loosening and pulverizing the soil, adding water followed by tar, mixing, consolidating (generally by sheepsfoot roller) and adding a " tack coat." The seal coat should not be added until the moisture content is reduced to 6–8%. Improvement in mixing and consolidating machinery may be expected. H. G. W.

571. Bituminous Emulsion Stabilized Roads. C. L. McKesson. *Highway Res. Board Proc.*, 1938, **18** (II), 283–288.—It has been found in general, that, if a small amount of bitumen in the form of a suitable emulsion is mixed with clay-bearing soils and allowed to dry, an entirely changed material is obtained, which can be used in place of imported aggregates. A careful laboratory study has shown that the emulsion particles became admixed with the soil colloids during mixing, and on evaporation the particles formed thin bitumen films, which were adsorbed on the soil. Hence the cementing value of the soil colloids, due to water, was replaced by that due to bitumen. According to the author the bitumen was adsorbed so well that only a small portion could be recovered by the usual solvents. Too small an amount of bitumen did not render the soil water-resistant, and too much (still below the usual binding quantities) lubricated the soil so that it lost its natural stability. Two tests were used for estimating the efficiency of the treatment: (1) to measure the resistance to aqueous capillary absorption and (2) to measure the resistance to plastic flow of the material after it had absorbed as much water as it would. The author reached the conclusion that, of two equal soils with equal water contents, that containing asphalt was the more stable. The amount of emulsion required to act as a continuous coating can be reduced by introducing imported gravel, the final complete process then being cheaper. The author states that considerably more research is required and that a well-stabilized foundation with only a thin asphaltic wearing surface is preferable. It is also considered that the emulsified bitumen should be mainly of microscopic and sub-microscopic size, so that the whole of the soil colloids are coated, and that unrestricted loss of water should be possible. The most important construction items are proper mixing, adequate compaction, thorough drying and proper surface protection, and the author discusses the practical aspects of each of these. It has been found in practice that, if considerable water enters the bottom of the stabilized layer during drying, a thin layer should be laid first and allowed to dry, or the bottom surface should be treated with emulsion, cut back, etc. before placing the stabilized material on top. An adequate surface course is necessary to prevent the stabilized soil raveling under traffic and to protect from surface leakage. For soils subject to flooding considerably more fines, and hence bitumen emulsion, are required. Another satisfactory addition is the application of a penetrating prime coat to the surface of the dry stabilized base before applying the surface course. H. G. W.

572. Asphalt Emulsion Stabilization on Cape Cod (Massachusetts). A. V. Bratt. *Highway Res. Board Proc.*, 1938, **18** (II), 289–291.—Contrary to the rest of Massachusetts, this is an area of fine, poorly graded sand only. Owing to the high cost of properly constructed secondary roads, it was found necessary to stabilize the base courses instead. Details of experiments made with asphalt emulsions as soil stabilizers are given, the formulae being derived by means of the Hubbard–Field Asphalt Stability machine. The author considers that in cohesionless materials, like this sand, it is essential to establish a base upon which to start compaction. H. G. W.

573. Asphaltic Binder Stabilized Roads. F. V. Reagel. *Highway Res. Board Proc.*, 1938, **18** (II), 292–298.—The author gives the general history of soil stabilization and shows how by the use of bitumen, soil can be stabilized without or with the addition of only limited quantities of granular materials. In Missouri it has been found that if the soil is between 40% and 60% of the total soil aggregate mixture it can be stabilized by about 8% bitumen based on the weight passing the no. 40 sieve. Details of the three methods used in this State are given—viz., (1) the plant mix method, (2) the suboiling method—in which the water and bitumen, etc., are introduced by tubes below the surface of the prepared soil, and (3) the road mix method, which has been developed from method (1). The author points out that test methods are not yet standardised, but are concerned with

(*a*) determination of the granulometric composition of the soil material to be treated, (*b*) determination by the original or Proctor test of the moisture content inducive to best compaction of the soil material and

(*c*) the testing for water affinity of soil mixtures which have been treated with varying amounts of the admixtures contemplated for use.

Besides the usual tests, it is considered that repeated freezing, thawing, wetting and drying tests are necessary. The use of bitumen in soil stabilization is to prevent excessive swelling and softening of the soil, but not to reduce the natural cohesive strength due to its adsorbed water. The bitumen best does this when present as a fine lattice-work rather than the absolute coating of each particle, which would probably result in the entire loss of the desirable soil characteristics. In non-cohesive soils the function of the bitumen is to increase cohesion by cementing the soil particles together, and the bitumen must be chosen for the purpose required. The use of emulsions can only be justified if their superiority can be shown by actual experiment. The author concludes by pointing out that no reliable method exists, other than empirical, to determine the necessary depth of stabilization required under given conditions, and if found would save considerable sums of money. H. G. W.

Special Products.

574.* New Aviation Gasoline Ingredient. Anon. *Oil Gas J.*, 5.10.1939, 38 (21), 40.—The manufacture of neohexane (2 : 2-dimethylbutane) has been accomplished in the pilot-plant stage by the Phillips Petroleum Co., and will shortly be commercially available for incorporation into aviation gasoline. It will be manufactured by thermal alkylation from ethylene and *iso*butane, using a furnace temperature of 900° F. and a pressure of over 1000 lb. per sq. in. Neohexane has the following properties : specific gravity 0·6498, boiling point 121° F., Reid vapour pressure 9·5 lb. The octane number is 95, and owing to its high volatility, it is not necessary to add straight run gasoline, as in the case of *iso*-octane. Blends of neohexane, *iso*pentane, and *iso*-octane, with the addition of lead, will provide an adequately balanced aviation gasoline of O.N. 115. Neohexane has a better lead susceptibility than *iso*-octane at higher octane ratings, although a little poorer at low ratings.

It is estimated that there is sufficient *iso*butane and ethylene (or ethane) in the U.S. to manufacture 1,000,000,000 gal. per yr. of neohexane. C. L. G.

575.* Catalytic Oxidation of Olefinic Hydrocarbons. W. L. Faith and M. S. Dendurent. *Refiner*, 1939, 18 (10), 393.—Amylene may be converted into maleic acid by vapour-phase oxidation over a V_2O_5 catalyst. At temperatures between 350° and 500° C. from 12 to 22% conversions into maleic acid are obtained. The optimum temperature is about 425° C. Variations in space velocity and air–amylene ratio have little effect on percentage conversion. Hexene, heptene, and octene also yield maleic acid by the same process. Conversions are higher than those from amylene, and appear to increase as the number of carbon atoms in the hydrocarbon is increased. A discussion of economic possibilities of the process is given. G. R. N.

576.* Fractionating Equipment for Obtaining Special Products in Natural Gasoline Plants. H. C. Givens. *Petrol. Engr*, Nov. 1939, 11 (2), 51.—A description is given of a six-column fractionation unit designed to separate propane, butane, *iso*pentane, *n*-pentane, hexane, and cleaners' naphtha from natural gasoline. The recovery of these products is estimated to increase the revenue per gall. of gasoline manufactured by 50% (under maximum fractionation conditions) at an increased material and labour cost of 20% over that of a normal natural gasoline plant. The highest plate efficiency in the columns is necessary. For propane extraction a 15-in. spacing between the trays is recommended, whilst for the heavier cuts 12-in. is adequate. For the extraction of propane, butane, *iso*pentane, or mixtures, a column of 26–30 trays gives the best results, for normal pentane and hexane 22 trays, and for all heavier cuts 12–15 trays. The diameter of the column is based on the charging rate, a ½-in. of cross-section being allowed per gal. of liquid feed per hr. In general, reflux is preferably fed by pumping from the ground accumulators rather than by gravity from a condenser on the top of the column, where a gasoline of freed vapour pressure is to be made. For special-product manufacture, however, overhead condensers are more easily controlled and cheaper to operate. Reboilers are preferably built into the foot of the column, and should be of larger size than usual for ease of control, and the steam heating should be controlled by a low-sensitivity air-operated temperature recorder controller of the reset type. Back-pressure regulation of the column is best controlled by the air-operated recorder or indicator-controller of high sensitivity connected to an air-operated motor valve. A flow controller on the charging-pump is a useful adjunct. Standard cooling and condensing equipment may be used; a heat transfer of 1 B.Th.U. per min. per sq. ft. of surface per degree logarithmic mean-temperature difference being allowed. C. L. G.

577. Dihydronaphthalene Polymers. N. D. Scott and J. F. Walker. Symposium on Plastics and Resins from Hydrocarbons. *Amer. chem. Soc. Meeting, Boston,* Sept. 1939, 93–99.—There are two isomeric dihydronaphthalenes: (1) 1 : 4-compound prepared by the reaction of Na with a solution of naphthalene in absolute alcohol and with m.pt. 24·5–25·0° C.; (2) 1 : 2-compound produced by the quantitative rearrangement of the 1 : 4-derivative on exposure to a hot solution of sodium ethylate—m.pt. —8° to —7° C. Literature on the polymerization of these products is scanty.

The 1 : 2-dihydronaphthalene reacts with sodium naphthalene ($C_{10}H_8Na_2$) to form a polymer in the form of a colourless powder which does not melt at 250° C. and chars at a point only somewhat below red heat. It is completely insoluble in water and most organic solvents. Under different conditions, polymerization to a brittle resin m.pt. 165° C. and mean molecular weight 749 is obtained. Dimerization of the 1 : 2-derivative with sulphuric acid yields a light-yellow viscous liquid distilling 235–250° C. at 15 mm. pressure.

The 1 : 4-compound will also react with $C_{10}H_8Na_2$ to form brittle hydrocarbon resins and a colourless material, m.pt. about 100° C. and mean molecular weight 400–450 can be obtained. A liquid dimer distilling 195–205° C. at 1 mm. pressure can also be formed. Resins obtained from the 1 : 4-compound are brittle, glass-like solids, refractive index 1·6, insoluble in water and alcohol, moderately soluble in gasoline, and very soluble in a number of organic solvents. Dihydronaphthalene resins can be hydrogenated, and this effects improvement in their properties, especially colour stability. D. L. S.

578. Influence of Chemical Composition upon the Properties and Uses of Certain Vinyl Resins. S. D. Douglas. Symposium on Plastics and Resins from Hydrocarbons. *Amer. chem. Soc. Meeting, Boston,* September 1939, pp. 101–110.—Polyvinyl chloride is an unusually strong and water- and chemical-resistant resin, but it softens so slowly with rise in temperature that decomposition begins before it can be properly moulded. Polyvinylacetate, on the other hand, softens just above atmospheric temperature, is brittle, and has a relatively high water absorption.

When these monomeric vinyl compounds are polymerized simultaneously, a resin is obtained that combines the strength and water-resistance of the chloride with the beneficial properties of the acetate. This co-polymer type of resin has the following industrial uses.

Surface Coatings. The resin used for this purpose has molecular weight 8500–9500, contains 85–87% vinyl chloride, and is used in solution in ketones supplemented by aromatic hydrocarbons.

Coated Paper.—This resin is similar in composition to the above type, but has molecular weight 9500–10,500. In this application suitable modifiers including pigment, plasticizer, and stabilizer are incorporated.

Phonograph Records—Floor Tile.—Identical with resin used for paper coating.

Injection Moulding.—Most suitable for this process is a resin of molecular weight 9500–10,500 and a vinyl chloride content of 85–87%. This allows of maximum strength and toughness in the moulded article and adequate fluidity at the moulding temperature.

Compression Moulding.—A resin of average molecular weight 12,000–13,000 and containing 85–88% vinyl chloride is generally used.

Sheet-Stock Resin.—In the manufacture of plastic sheets outstanding strength and toughness are required, but as high plasticity at moulding temperatures, as for injection moulding, is not necessary. Thus a resin of molecular weight 15,000–16,000 and containing 88–90% vinyl chloride is used.

Synthetic Textiles.—Two types of resin have been developed, both containing 88–90% of the chloride, one with molecular weight 16,000–19,000 and the other 20,000–23,000.

Coated Wire.—A resin with molecular weight 20,000–22,000 and containing 95% vinyl chloride has been successfully used for this purpose. D. L. S.

579. Polystyrene. A. J. Weith, V. H. Turkington, and I. Allen, Jr. Symposium on Plastics and Resins from Hydrocarbons. *Amer. Chem. Soc. Meeting, Boston,* September 1939, pp. 111–119.—The lower polymers of styrene—molecular weight 20,000–30,000 or below—are characterized by low mechanical strength and brittleness, as contrasted with the toughness of the higher members of the series. The latter serve as ideal material for the injection moulding process.

The thermal stability of polystyrene can be considered from two angles. Long exposure at temperatures above 100° C. causes a decrease in molecular weight without formation of volatile products. The second type of breakdown is more or less complete thermal decomposition or pyrolysis, resulting in the formation of a large percentage of volatile products. The first type of breakdown has been shown to be due to surface oxidation. The second does not become evident until a temperature of 330–350° C. is reached—*i.e.*, 100° C. or more above the temperature used in the practical applications of polystyrene.

When the polymer is heated in a distilling-flask to 360–375° C., a fairly rapid distillation of liquid products takes place, and in a case cited 80% distillate was obtained containing 50% styrene.

The high-molecular-weight polymers are incompatible with most of the ingredients commonly used in paints and varnishes, but recent work has made practical the production of polymers of relatively low molecular weight which are readily soluble in drying oils to form oleo-resinous finishes.

Styrene is formed as a by-product in various hydrocarbon cracking processes, and it is expected that a large supply of this material will be available in the near future.

D. L. S.

580. Study of the Effects of Lubricating Oils on Neoprene Vulcanisates. D. F. Fraser. Symposium on Plastics and Resins from Hydrocarbons. *Amer. Chem. Soc. Meeting, Boston,* September 1939, pp. 121–132.—In writing control specifications for fabricated neoprene parts a volume increase test after immersion in a lubricating oil is frequently included.

Experiments were carried out by immersing specimens of vulcanized neoprene compound in thirteen different oils at various temperatures. It was found that after a short time the compound showed a maximum swelling in each oil and the oil–neoprene system attained a swelling equilibrium. This equilibrium was reached more rapidly in the case of those oils having the least effect, and the length of time before equilibrium was reached decreased with rise in temperature. Swelling was found to increase with increase in the temperature of immersion.

Neoprene is very resistant to members of the paraffin group of hydrocarbons, whereas naphthenes cause severe swelling and aromatics a very severe swelling.

As a result of this work it has been shown that at swelling equilibrium the percentage volume increase is a logarithmic function of the viscosity–gravity constant, and that there is a direct relationship between percentage volume increase at equilibrium and the gravity indices of the oils used.

There is no simple correlation with specific gravity, refractive index, or viscosity index. D. L. S.

581. Production of Phenol from Benzol by Means of the Raschig Process. W. Mattes. *Angew Chem.*, 1939, 52, 591.—This process works without pressure and is continuous and catalytic. It differs from all other methods hitherto used, in that there is no consumption of chemicals. Production is carried out in two stages : (1) chloro-benzol is made from benzol, hydrochloric acid and air, (2) the chlorobenzol is saponified with steam and transformed into phenol and hydrochloric acid. The chief problem was to find a catalyst which would make it possible to work at a temperature low enough to ensure that no benzol would be burnt during chlorination. The catalyst is composed of activated aluminium chloride in combination with copper salts. Higher chlorinated benzols—*e.g.*, dichlorobenzole, etc., up to hexachlorobenzole—are also obtained.

A plant producing 1400 tons per year has been working in Germany for several years, and another plant to produce 20 tons per day is under construction in the U.S.A.

E. W. S.

582. Patents on Special Products. A. Lazar. U.S.P. 2,186,248, 9.1.40. Appl. 30.4.34. Manufacture of an emulsifying oil incorporating unsaturated and aromatic hydrocarbons derived from heat treatment of a petroleum fraction heavier than kerosine and containing organic acids.

C. L. Schuttig. U.S.P. 2,186,308, 9.1.40. Appl. 25.2.36. Manufacture of sulphonated oil by reacting a fatty oil with sulphuric acid, treating the reaction mixture with an aqueous salt solution, and allowing to settle in order to produce an aqueous layer. The aqueous layer is then separated from the sulphonated product and alkalised. The mixture is finally allowed to stand until the sludge containing the unsulphonated oils and fatty acids separates as an upper layer.

V. Ipatieff and H. Pines. U.S.P. 2,187,034, 16.1.40. Appl., 17.12.36. Production of alkylated aromatics by subjecting a mixture of an aromatic hydrocarbon and an olefin of higher molecular weight than butylene to depolyalkylation.

H. J. Robertson. U.S.P. 2,188,770, 30.1.40. Appl., 20.11.37. Production of mineral-oil sulphonic acids by subjecting the oil to sulphonation, adding to the reaction product, while agitating, a sufficient quantity of an aqueous alkaline solution to neutralise the sulphuric acid in the reaction product. The sulphonic acids are finally separated by stratification.

J. E. Pollak. E.P. 516,024, 20.12.39. Appl. 20.6.38. Method of preparing drying oils wherein Isano-oil is mixed at room temperature with one or more drying or semi-drying oils of vegetable or fish origin.

Deutsche Hydrierwerke A.-G. E.P. 516,188, 27.12.39. Appl. 11.7.39. Method of manufacturing capillary-active substances whereby organic hydroxyl compounds of the general formula R–Ar–OH or metal compounds thereof, in which R stands for a substituted or unsubstituted aliphatic or *cyclo*aliphatic residue containing at least three carbon atoms and Ar stands for an aromatic residue, are reacted with a benzyl chloride sulphonic acid or a salt thereof.

May and Baker, Ltd. E.P. 516,288, 29.12.39. Appl. 23.6.39. Preparation of amino-substituted pyridine-sulphonamides of the type $NH_2{\cdot}B{\cdot}SO_2NR'R$, where B is the pyridine radical and R′ and R may be hydrogen or an alkyl, aryl, or aralkyl group, and when R is hydrogen R′ may be a pyridine residue, by condensing the sulphonyl chlorides $NH_2{\cdot}B{\cdot}SO_2Cl$ with ammonia, alkyl-aryl, or aralkyl-amines or amino-pyridine compounds.

André Marie Ghislain Maurice Luyckx. E.P. 516,329, 29.12.39. Appl. 20.7.39. Catalytic preparation of liquid hydrocarbons from carbon monoxide and hydrogen. This comprises contacting a mixture of the said gases at atmospheric pressure and at a temperature between 200° and 215° C. with a finely divided binary uranium oxide cobalt catalyst on an inert support.

George William Johnson. E.P. 516,352, 1.1.40. Appl. 9.5.39. Catalytic conversion of carbon monoxide with hydrogen into hydrocarbons with more than one carbon atom in the molecule, in contact with stationary catalysts and in the presence of liquid medium containing a considerable amount of constituents which are gaseous or vaporous under the reaction conditions.

Distillers Company, Ltd., and Thomas Bruce Philip. E.P. 516,360, 1.1.40. Appl. 6.3.39. Apparatus for carrying out the conversion of alcohols to olefines by dehydrating catalysts in the gaseous phase. The apparatus comprises a number of catalytic reaction chambers connected in series by conduits through which the reactants pass, a temperature control unit to each reaction chamber, etc. H. B. M.

Detonation and Engines.

583.* Cooling of Diesel-Engine Pistons reduces Lacquer Formation. A. T. McDonald and L. A. Blanc. *Nat. Petrol. News*, 15.11.39, **31** (46), R.494.—Practical experiments carried out on a small-bore diesel engine were designed to investigate the condition conducive to piston deposits and lacquer formation. It was concluded that the products of combustion contribute little in these respects, provided that combustion is properly controlled. There were indications that such deposits may be aggravated by the effect of hot blow-by gases, consisting almost entirely of air, and acting on thin films of lubricating oil.

Reducing the piston temperature by oil or water-cooling reduces the tendency for carbon and lacquer deposits, but since this is not a practically possible device, the use of compounded lubricating oils is the more feasible way to minimize fouling. The type of fuel used, if kept within the limits of distillate fuels commercially available, has practically no influence on piston deposits and ring-sticking. H. G.

584.* Engine Bearings—from Design to Maintenance. A. B. Willi. *J. Soc. aut. Engrs*, 1939, **45** (6), 513—525.—It is considered that there are six major causes of bearing failures. Excluding corrosion troubles, the lubricant is seldom to blame, provided reputable oils are used. Four classes of lining material are commonly used : tin-base babbits, high-lead babbits, cadmium alloys, and copper–lead mixtures. Each has its own field of usefulness, and these fields are defined in terms of maximum unit pressure, Zn/P, PV, oil reservoir temperature and crankshaft hardness. Unfavourable design factors are considered, including oil-flow to the rod-bearing, restrictions in oil-feed grooves, oil-clearance, and mechanical considerations. Photographic illustrations of typical failures are included. K. A.

585.* Aircraft Engines and their Lubrication. A. Nutt. *J. Soc. aut. Engrs*, 1939, **45** (6), 501–512.—The author reviews past and probable future development of aircraft engines, with special reference to the work of Wright Aeronautical Corporation. In fourteen years the output of the " Cyclone " engine has been raised from 400 to 1200 h.p. ; the B.M.E.P. has been doubled, the speed raised from 1900 to 2500 r.p.m., and the specific weight halved. This evolution is attributed to improvements in cooling, supercharging, crankshaft design, spark-plugs, fuels, oils, dynamic suspension, and materials. Discussing these features he foresees further refinements in air-cooling, giving less sensitivity to detonation and better performance, together with a considerable increase in the use of exhaust turbo supercharging during the next five years. There is a need for better spark-plugs.

A comparison is drawn between the Junkers compression-ignition engine and an equivalent gasoline motor, leading to the conclusion that the aircraft diesel has little prospect of overtaking the spark-ignition type in performance. A more likely trend is the use of the so-called safety type of fuel in injection engines with spark ignition. The author has no doubt that there will continue to be scope for both air- and liquid-cooled motors.

It is claimed that the introduction of new oil specifications has produced a definite improvement in available lubricants. The deposition of oxidation products often sets a limit to the permissible hours run between overhauls, and better resistance to oxidation must be achieved. The author considers that oil refiners must intensify their research work if the desired advance in high-output engines is to materialize. K. A.

586. Henschel-Lanova Air Chamber Diesel for Coal Tar Oil. E. Scheruga. *Brennst. Waermewirt.*, 1939, **21**, 199–202.—The ignition temperature of coal-tar oil is 66° C., as compared with 350° C. of a suitable diesel fuel. Early designs of diesel engines for tar oil employed for initial ignition a pilot drop of gas oil in each injection. Later, the Hesselmann spark ignition engine gave a smooth operation with tar oil. The diesel

engine with precombustion chamber was also able to run on tar oil if special incandescent grids were inserted in the cylinder. The author describes an air-chamber engine —also with heat convector—which gives good results with coal-tar oil if the intake air is heated during idling speed and half load. Under full-load conditions the ignition temperature in the cylinder is reached without preheating the intake air.
E. W. S.

587.* Efficient Burning of Fuel in High Speed Oil Engines. A. T. Wilford. *J. Inst. Petrol.*, 1939, **25**, 649–656.—A paper which gives an account of the measures taken by a large passenger-transport organization to ensure efficient combustion of the fuel used in its oil-engined vehicles. The application of exhaust-gas analyses to combustion control is discussed. G. R. N.

588.* Experiments with Doped Fuels for High-Speed Diesel Engines. J. J. Broeze and J. O. Hinze. *J. Inst. Petrol.*, 1939, **25**, 657–677.—The subject is thoroughly discussed under the following items: requirements from a dope, influence of a dope on the ignition delay of a fuel, the effect of a dope on the combustion process, and the influence of a dope in a fuel on wear and incrustations in the engine. G. R. N.

589.* Piston and Piston Ring Temperatures. P. V. Keyser and E. F. Miller. *J. Inst. Petrol.*, 1939, **25**, 779–790.—The subject is discussed under the following items: piston deposits, methods of measuring piston temperature, cylinder-wall temperature measurement, laboratory experiments, effect of design on piston temperature. G. R. N.

Coal and Shale.

590. Sulphur in Products of Combustion of Fuels. L. R. Burdick and J. F. Barkley. U.S. Bureau of Mines, Information Circular No. 7065, May 1939.—Sulphur in the atmosphere is regarded as a potential source of much damage, since it readily unites with oxygen to form corrosive acids. Its source is usually traceable to the burning of fuels containing sulphur, and in this connection investigations have been made to discover, if possible, what actually happens to the sulphur—*i.e.*, how much of it remains in the refuse, how much is carried away with the gases, and how much lodges in the fuel-burning equipment. The authors of this Circular review published information on these questions. H. B. M.

591.* Toxicity of Coal-Tar Naphtha Distillates. H. Taylor. *Chem. and Ind.*, 1939, **58**, 1078;1080.—Coal-tar naphtha distillates are being used for the fumigation of houses against bed-bugs, and it is generally supposed that no detrimental effect on human beings ensues. This supposition is not supported by the author, who has conducted a series of experiments to determine the physiological effect of the naphtha vapour on rats.

All the samples of naphtha tested showed definite narcotic action at concentrations greater than 0·10% by volume, and in one experiment a single exposure of 6 hr. at a concentration of 0·16% caused the death of all the experimental rats.

There was considerable variation on the effect on internal organs with different samples, but definite liver degeneration was caused by two out of four samples, and slight effects were noted in the case of a third. T. C. G. T.

Economics and Statistics.

592.* Technology, Employment and Output Per Man in Petroleum and Natural Gas Production. O. E. Kiessling. Work Projects Administration, National Research Project. In co-operation with U.S. Bureau of Mines. Report E-10, July 1939.—In 1937 the output of petroleum and natural gas reached a peak for the United States, but employment in the industry did not rise commensurately. A fundamental economic problem raised by this fact was whether growth of employment in the oil industry has been permanently arrested, and what are the probable employment opportunities in the future. These constitute the essential objectives of the investigations dealt with in this report. It is pointed out that from an economic standpoint the oil and gas industry is far more ramified than merely raw-material production, in that, apart from the actual producing oil-wells, it includes refineries, natural gasoline plants, oil and gas pipe-lines, and delivery of refined products to consumers (marketing). Consequently, the broadest view of this complicated industry is taken in this study, which, while economic in perspective, is at the same time inevitably technical in treatment.

The main sections of the report are devoted to long-time trends in production, employment and output per man; influence of migration to new flush-production areas; development of exploration and discovery techniques; development of drilling techniques; technologic advances in production and progress in natural gas and gasoline recovery; difficulties incident to increasing productivity; advances in transportation and storage techniques; technical advances in refining and employment prospects in the industry.

Among the interesting points elucidated in the course of this survey are that the industry has the highest annual gross income in the American extractive industries; that its total employment is second only to the coal industry; that it supplies more than a third of that country's total energy requirements; that, in spite of considerable progress in preventing waste, contemporary practices by no means represent efficient production from a strictly technical standpoint, though by increased refinery efficiency double the amount of petrol is now obtained from a barrel of crude oil than formerly. The main conclusion reached is that the outlook promises increased opportunities for employment, but that advances in the technology generally will alter the "composition of the working force." Unskilled labour is disappearing, particularly in the development, refinery and transport branches of the industry; trained technicians and skilled workers are replacing the old-time "roustabouts"—in short, the industry is being run by specialists, and vocational training is now the qualifying factor in recruiting personnel for all branches. H. B. M.

593. Industrial Research in 1939. W. A. Hamer. *Chem. and Chem. Engng News*, 10.1.40.—It is estimated that in the U.S.A. in 1939 almost 32,000 scientific men and 16,000 assistants were engaged in research on behalf of 2000 firms. The chemical, petroleum, and electrical laboratories employed nearly half of the total industrial research workers. B. T.

594. Oil in Brunei. Anon. *Bull. Imp. Institute*, 1939, **37** (4), 629.—In a report received from the British Resident oil produced in the second quarter of 1939 amounted to 186,062·94 tons, and in the third quarter 195,126·5 tons. These figures are net production after allowing for water run-off and pumping losses between field and refinery. H. B. M.

595. Assessment of Petroleum Production in Rumania During 1939. Anon. *Monit. Petr. Roum.*, 1940, **41**, 3–7.—The effects of hostilities in Europe are traced in economic aspects of the Rumanian oil industry during 1939. It is indicated that not only belligerent countries, but also neutrals are anxious to obtain ample stocks of petroleum products. So far, the only marked effect in the Rumanian industry has been an increase in the price obtained for such products.

The prices of various crudes during each month of 1939 are tabulated. These indicate a steady increase, amounting to 50% by August and leaping to a 196–259% increase (according to crude) by the end of the year.

The prices of refined products, again tabulated, have not had such spectacular advances, but these have registered price increases of 92—136% over the year.

Drilling in Rumania reached its peak in June with 28,172 metres, compared with 18,857 in January and 21,000 in December.

Production has remained fairly steady, with no increase towards the end of the year. The maximum monthly figure was 538,719 tonnes in March and the minimum 497,025 in February.

The greater part of the crude produced is processed, and this again has showed no remarkable change, though the November figure of 430,000 tonnes is only 86% of that for January.

In the export market monthly crude exports reached a peak in February with 44,455 tonnes, whilst the November figure was 25,060. Refined products had their peak export period of 386,762 tonnes in April, and have fallen away towards the end of the year to 274,828 in November.

Internal consumption has shown a steady increase during the latter months of the year, rising from 115,421 tonnes in June to 180,000 in November.

Comparing the 1939 statistics with previous years it is apparent that the marked decline since 1935 in the export of Rumanian petroleum products has been continued. In 1935 the total exports were 6,611,000 tonnes, and in 1939 4,150,000 tonnes.

T. C. G. T.

596. Statistics on the Rumanian Oil Storage Capacity. Anon. *Monit. Petr. Roum.*, 1940, **41**, 63–71.—The average oil storage of 43 named companies is analysed according to the particular petroleum product and its location—*i.e.*, field, refinery, or port storage. All these statistics are then condensed in one table.

From the condensed table it is seen that the total of petroleum crude and products held in the country amounts to about 3 million tonnes, in 5000 storage units, 1780 field units store 588,000 tonnes, 2830 refinery units hold 1,555,000 tonnes and 390 port storage tanks hold 840,000 tonnes. Constanza with 290 tanks holds 765,500 tonnes of the port storage.

Astra-Romana on an average holds 614,567 tonnes, or 20·49% of the country's total, Steaua-Romana holds 14·5%, Concordia 10·87%, and Romano-Americana 10·56%.

The figures do not represent the maximum possible amount held in storage, but merely average stocks. Further, they do not include large quantities of material held in unrecognized storage—*e.g.*, in wooden tanks or in pits in the fields. T. C. G. T.

597.* 1938 Crude Production Results and 1939 Perspectives of Azneftedobycha. K. A. Mashkovich. *Az. Neft. Khoz.*, January 1939, **19** (1), 16–20.—The 1938 plan of crude-oil production has been fulfilled 98·5%, that of gas production 93·3%. Oil and gas production have increased 772·7 thousand tons over 1937 figures. The main reasons for the non-fulfilment of the plan are examined and necessary measures to improve production given. L. R.

598.* Records of Yields in the Argentine Oilfields. M. Soifer. *Bol. Inform. Petroleras*, November 1939, XVI (183), 55–63.—Modern methods of exploitation are based on getting the most out of every deposit of oil by maintaining or increasing the pressure by injecting gas or by introducing water in order to secure maximum recuperative results at the finish. In order to achieve the desired result, it is necessary to have, for reference, the most exact possible records of production, of gas and of water in the oil-bearing zone, in conjunction with the results obtained from each well individually. The author develops the subject in detail, describing the necessary measuring apparatus, tank batteries, etc., for different types of wells, explains the calculations, and shows the different forms which should be used for keeping the necessary records.

H. I. L.

599.* Further Legislation governing Oil Companies in Brazil. Anon. *Bol. Inform. Petroleras*, November 1939, XVI (183), 69–72.—This note refers to the law No. 961 of 17.12.38 by which the holding of shares, etc., in Brazilian oil companies and refineries is restricted to Brazilian nationals. The note contains additional clauses regulating the holding of shares by husband or wife when the parties are married, and where one of the parties is a foreigner.

The decree No. 1369 of 23.6.39 is also published, transferring to the National Petroleum Council the functions in respect to oil which have hitherto been controlled by the Ministry of Agriculture. H. I. L.

600.* World Legislation concerning Petroleum. Anon. *Bol. Inform. Petroleras*, November 1939, XVI (183), 74–84.—This record of world legislation, which was started with No. 174 of this journal, includes Paraguay, Persia, Peru, Poland, and Rumania among other countries. H. I. L.

601.* Decrees by the Argentine Government concerning Purveyors of Petrol, Gas Oil, etc. Anon. *Bol. Inform. Petroleras,* November 1939, XVI (183), 85–91.—Decrees published regulating the period for which a licence will be granted to purveyors of petrol and the like, regulating the methods of measuring cargos and freights for inter-port transport, prohibiting the export of any kind of fuel, ensuring declaration of destination and ports of call by all ships of the merchant marines of all countries, limiting the amount of bunker fuel that may be shipped by boats leaving the Argentine for oversea ports, fixing of maximum prices for kerosine and other fuel oils, permitting the reshipment of petrol to Brazil and Paraguay, permitting the export of petroleum and its derivatives to Paraguay, regulating prices of fuels, etc. H. I. L.

602.* Export of Petroleum Products from Rumania during 1939. M. Pizanty. *Monit. Petr. Roum.,* 41, 5, 1.3.40, 249–260.—This is an authoritative and detailed statement of the export trade in petroleum products of Rumania during 1939. The value of these products (11·2 milliards of lei) represented 41·9% of the total value of exports of all merchandise—the largest single item in Rumanian foreign trade. Total petroleum exports were 4,177,571 tons (4,494,762 tons in 1938). The distinctive feature of 1939 was the increase in exports from Giurgiu and the decrease in exports from Constantza. The following are the principal statistical Tables included :

From official sources (*Statistique financière et economique*).

1. Exports by product and country of destination (1938–39). The principal features of this Table are as follows :

Consigned to :	Crude Oil.	Motor Spirit.	Kerosine.	Gas and Fuel Oil.	Lubricants.
	(In thousands of tonnes.)				
Germany, Czechoslovakia and Austria	196	636	206	234	9·5
United Kingdom	—	347	137	119	16·2
Italy and Albania	23	83	106	419	4·6
France	22	148	46	22	—

2. Exports by product and port of consignment (1938–39).
3. Monthly values of exports by product (1939).
4. Annual quantities of petroleum products exported (1930–39).
5. Exports through Giurgiu by ownership of tank-barges (1936–39).
6. Exports from Constantza by nationality of tanker (1939).
7. Monthly quantities by countries of destination (1939).

From statistics supplied by oil companies.

8. Exports from different companies classified by product and port of consignment (1939).

9. Exports from different companies classified by product and country of destination (1939).

Information supplied by oil companies indicated a total volume of exports of petroleum products of 4,095,443 tons. This source of information is independent of that derived from Customs returns which appear in the official statistics. The difference in the two totals is less than 2%. S. J. A.

BOOK REVIEWS

Volumetric and Phase Behaviour of Hydrocarbons. By Bruce H. Sage and William N. Lacey. pp. 299. Stanford University Press, California, 1939. Humphrey Milford, Oxford University Press, $5.00.

The quantitative application of scientific principles in petroleum technology has been retarded by the lack of data, but in recent years a considerable amount of quantitative experimental knowledge of hydrocarbons has been accumulated. The majority of this information has resulted from experimental studies carried out by the authors of this book through the American Petroleum Institute's Research Project 37.

In this book the quantitative liquid–gas phase behaviour of hydrocarbons with emphasis on volumetric behaviour is dealt with, and the subject discussed finds its major application in processes handling natural gas and natural gasoline.

Without a doubt the logical and scientific treatment of this subject has never before been equalled, and the authors are to be congratulated on their work.

After the preface and list of symbols employed, the book opens with an introductory chapter on general definitions and phase equilibrium, followed by a useful chapter on the mathematical concepts involved.

The one-component system is next dealt with in the order gases, liquids, two-phase region, and critical region. Twenty out of the twenty-three diagrams appearing in this chapter are quantitative in nature, and deal exclusively with saturated hydrocarbons, mostly methane, ethane, propane, and butane.

In chapter four, two-component systems are discussed in the order, single-phase region, two-phase region and three-phase region, with proper emphasis on critical behaviour, the diagrams being about equally divided between illustrative sketches and quantitative figures.

The discussion on three-component systems is confined almost entirely to liquid–gas phase behaviour, and is the most comprehensive and exhaustive description of this subject so far published. It is here that the lack of quantitative data is most pronounced, this chapter being the only one in the book where the authors have been forced to employ illustrative sketches rather than quantitative diagrams.

The chapter on multi-component systems is outstanding. Here an attempt is made to describe the behaviour of multi-component systems in the light of experimental data available on such diverse and complicated materials as natural gas, gasoline, crude oil, and natural gas–crude oil mixtures. The inclusion of such a chapter in a book on phase equilibrium is a welcome novelty, and the authors are to be complimented on their initiative and courage. Nearly every one of the many diagrams included in this chapter is quantitative in character, and the text is destined to be long quoted as a classic.

The work is continued with chapters on the phase rule, partial quantities, and ideal solutions, and concludes with a short appendix on retrograde condensation.

The illustrations are clear, and out of a total of 194 a large proportion are quantitative in character and supplied with references to the original data in the literature.

No one engaged in quantitative work on hydrocarbons or petroleum can afford to be without a copy of this book. T. G. Hunter.

De la Carbonization aux Carburants d'Aviation Vol. 1. Le Pétrole et ses Succédanés. By Ch. Berthelot with a preface by G. Claude. pp. 327. Published by Dunod, 92 Rue Bonaparte, Paris 1939. Price 107*frs*. Paper cover, 90*frs*.

This volume is the first of a series of three, which will include coking, gas production, and carbonization in general.

In an interesting foreword Claude directs attention to the need, due to the impact of war, to draw from one's own resources by an enormous industrial effort all materials that are indispensable, neglecting those the precarious arrival of which might well prove a special danger to the community. He points out that M. Berthelot has put forward " une idée titanesque "—the production of 25,000,000 tons per annum of gasoline or substitutes before the right exists " de dormir tranquille," in which he contemplates the use of coal shales, lignites and wood.

Apart from the topical interest of the subject, the author has produced a well-balanced account of the sources and production of fuels alternative to petroleum.

He begins with an account of the Falmouth Committee, the report of Sir David Rivett to the Australian Government, and the progress put forward by the Labour Party on the oil-from-coal situation. Then follows an *exposé* of the corresponding position in France, where, in the event of hostilities, he visualized the trebling of peace-time requirements. Petroleum from Morocco, colonial wood, fatty oils, and alcohol are briefly discussed, and then the general development of the carbonization of shales, cannels, and other bituminous material in France, Scotland, and Estonia, with a critical examination of the various methods adopted in oil production. The utilization of compressed gas is detailed and the various methods of storage are described. Low-temperature carbonization in England, France, and Germany, and the retorting practice therein involved, are given due consideration.

In a very careful and thoughtful summing up of his conclusions he points out that France in war-time will need from 15 to 25 million tons of fluid fuel a year. He asserts that nine-tenths of all material received overseas by the Western Powers arrives by the Atlantic, and that in the last war 200,000 tons of shipping were sunk in the course of one week. All these facts, he says, demand the development of a self-contained policy. Autarchy is veritably in the air.

He makes a very pleasant reference to the Institute's Glasgow conference on Shales and Cannels in 1938, and justly points out that the petroleum industry is very far from opposing the technique of the carbonization process, knowing well the value of its long experience.

Your reviewer, although in general agreement with M. Berthelot's thesis that every reasonable attempt should be made to increase the supply of indigenous fluid fuel, would wish to emphasize this fact, perhaps more cogent for Great Britain than for France : The ultimate success of the Allies depends on the maintenance of the open seas. Without command of the oceans we shall surely perish, not so much for the lack of oil, but of food, and of that trade which is so vital.

A. E. Dunstan.

Sulphated Oils and Allied Products : Their Chemistry and Analysis. By D. Burton and G. F. Robertshaw. Pp. 163 + iv. A. Harvey, Publisher, 17, Leathermarket Street, S.E. 1. Price 12*s*. 6*d*.

The book commences with a very interesting historical survey of the sulphation of oils from Fremy and Runge's experiments on the action of concentrated sulphuric acid on olive oil to the recent work on the analysis of petroleum sulphonic acids. The compounds which have been isolated from the oils used for sulphation are given, together with the occurrence of each acid or alcohol. The methods of the preparation of a few sulphated oils are described, whilst some of the modern refinements by which the action of the acid is controlled are illustrated. Although much is still to be learned regarding the mechanism of sulphation, this monograph contains a useful chapter on the " Chemistry of Sulphation," in which are discussed the various main reactions occurring.

However, the real service of this book is the complete guide to the analysis of sulphated oils, sulphated fatty alcohols, and petroleum sulphonic acids. Complete schemes of analysis for all these products are tabulated. Furthermore, each test, of which full experimental details are given, is reviewed critically, and the analyst is told where wrong conclusions may be reached owing to a deficiency in the test. The book will undoubtedly be invaluable to all who have to deal with both the analysis and development of these complex products, particularly as very full lists of reference are given at the end of each chapter. A foreword has been written by Professor T. P. Hilditch, D.Sc., F.I.C.

F. A. Fidler.

BOOKS AND PUBLICATIONS RECEIVED

1. **The Waverley Handbook.** Ninth Edition. Compiled and edited by S. G. Symons. Pp. 902. Waverley Oil Works Company, Pittsburgh, Pennsylvania.

The editor and publishers of this Handbook tried to condense " the most complete and comprehensive text as yet made available to those interested in the Petroleum Industry " in between the 902 pages constituting this edition. How far they have succeeded is a matter of opinion; but it must be admitted that at least an extensive field has been covered with regard to lubricating oils and lubrication in general. The ambitious claim cannot be entirely justified with a complete omission of such subjects as drilling for, and storage and transport of oil—to mention only three major items.

The volume contains 18 chapters dealing with lubricating-oil properties and their preparations, animal and vegetable oils, fuel oil, crude-oil production records, gasoline preparation and treatments, secondary recovery methods, dealing particularly with gas- and water-drives, benzole, A.S.T.M. standard methods of testing oil properties, motors for oil and gasoline. Chapters dealing with general problems include those discussing business law and banking tables for weights, measures and capacities, workshop formulas and what are termed " Waverley formulas," dealing with multitudinous and varied subjects.

References are attached in abundance to most chapters.

2. **Carbon Monoxide. Methods for the Detection of Toxic Gases in Industry.** Department of Scientific and Industrial Research. Leaflet No. 7. Pp. 9. H.M.S.O., London. Price 1*s.* 6*d.*

The standard method developed for the detection of carbon monoxide in industry consists in drawing samples of the atmosphere under test through a known area of test-paper, treated with palladium chloride, at a slow and constant rate, by means of a 5-litre aspirator. Interfering gases are removed by allowing the sample to pass first through a tube of activated charcoal. Sampling is continued until a stain is produced on the test-paper which compares with the standard colour chart, a copy of which is included in the pamphlet. The concentration present is then determined by comparing the time required to reach the necessary colour with the times given on the chart.

3. **Report of the Road Research Board for the Year ended 31st March, 1939.** Department of Scientific and Industrial Research. Pp. viii + 172. H.M.S.O., London. Price 3*s.* 6*d.*

This report contains a summary of progress of the work carried out during the year under review on (1) Soil Mechanics, (2) Materials and Methods of Construction, and (3) Road Mechanics.

Attention may be directed to the work on bituminous binders, which includes a comparison of durability tests with road performance of surface dressings and thin carpets containing these binders. Full-scale trials are in progress on tar-rubber binders designed in the laboratory for surface dressing and for thin surfacing, and a series of carpets containing asphaltic binders has been laid on the Colnbrook By-Pass with a view to relating their physical properties with road behaviour.

INSTITUTE NOTES.

MARCH 1940.

TELEGRAPHIC ADDRESS

Telegrams and cablegrams for the Institute may be addressed:
Instpetech Birmingham.
The telephone number of the Institute is: Birmingham, Selly Oak 1181
(Extension 5).

FORTHCOMING MEETINGS.

Tuesday, 16th April, at 6.45 p.m. At the Chemical Society's Rooms, Burlington House, Piccadilly, London, W. 1.

"**The Manufacture and Testing of Roofing Felts and Dampcourses,**" by Major D. M. Wilson.

Meeting of the Asphaltic Bitumen Group.

CANDIDATES FOR ADMISSION.

The following have applied for admission to the Institute or transfer to another grade of membership, and in accordance with the By-laws the proposals will not be considered until the lapse of at least one month subsequent to the issue of this *Journal*, during which 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 any candidate.

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

The names of the candidate's proposer and seconder are given in parentheses.

BRADFORD, Job Ronald Tremellen, Representative, Aviation Dept., Shell-Mex & B.P., Ltd., Victoria Embankment, London, W.C.2. (*A. E. Hope; F. N. Harrap.*)

CLARKE, Geoffrey Jardine, Student (*Royal School of Mines*), 5, The Grove, Aberdare, Glam. (*S. E. Coomber; G. D. Hobson.*)

EISNER, John Hans, Engineer (*Lobitos Oilfields, Ltd.*), Dol-y-Wern, Great Sutton, Cheshire. (*J. S. Parker; J. C. Wood-Mallock.*)

GASCOIGNE, George Norman, Director (*Anglamol, Ltd.*), 34, Grove Way, Esher, Surrey. (*E. A. Evans; H. C. Tett.*)

GREIG, Alan Lancelot, Geologist, c/o Midland Bank Ltd., Gloucester Road, London, S.W.7. (*S. E. Coomber; G. D. Hobson.*)

HIGGS, Percival George, Chemist, c/o Anglo-Egyptian Oilfields, Ltd., Suez, Egypt. (*J. Kewley; W. K. McGavin.*) (Trans. to Member.)

KENYON, Harold Frederick, Chemist (*Asiatic Petroleum Co., Ltd.*), 13, Victoria Road, Cambridge. (*J. Kewley; C. H. Barton.*)

ROGER, Arthur, Chemist (*Carbohydrol, Ltd.*), "Leckonby," Whitbarrow Road, Lymm, nr. Warrington. (*J. E. Haslam; H. O. Clayton.*)

SCHARGES, Walter Herbert, Assistant Superintendent (*Texas Co. (S.A.), Ltd.*), P.O. Box 714, Cape Town, South Africa. (*E. W. Ramsay; J. W. Weitz.*)

Temple, George Edward Maskell, Chemist, c/o Anglo-Iranian Oil Co., Ltd., Abadan, Iran. (*H. Macniven ; P. W. Wright.*)

Tokayer, Oscar, Editor (*Petroleum Press Service*), Glenthorne, Links Way, Northwood, Middx. (*J. Kewley ; H. E. Medlicott.*)

CANDIDATES FOR ADMISSION AS STUDENTS.

Proposed by A. W. Nash, Seconded by A. H. Nissan.

Austin, John Martin, The University of Birmingham, Dept. of Oil Engineering.
Buxton, Geoffrey ,, ,, ,, ,,
Cheetham, Harry Alan ,, ,, ,, ,,
Cude, Arthur Leslie ,, ,, ,, ,,
Chivers, Harold Victor ,, ,, ,, ,,
Grunberg, Leander ,, ,, ,, ,,
Hawkes, John Cecil ,, ,, ,, ,,
Metcalfe, John Leslie ,, ,, ,, ,,
Neilson, Ian McIntosh ,, ,, ,, ,,
Shackell, Douglas Ashton ,, ,, ,, ,,
Simpson, Alan Murray ,, ,, ,, ,,
Tonge, Peter ,, ,, ,, ,,
Wiseman, Kenneth William ,, ,, ,, ,,
Wood, George Frederick ,, ,, ,, ,,

NEW MEMBERS.

The following elections have been made by the Council in accordance with the By-Laws, Section IV, Para. 7.

Elections are subject to confirmation in accordance with the By-Laws, Section IV, Paras. 9 and 10.

As Fellows.

Roth, Francis	Sweden.

As Members.

Marshall, John Macintosh	West Kirby.
Park, James Harris	Birmingham.

As Associate Members.

Evans, Frederick Neville Stuart	Reading.
Phipps, Leonard Fredrick	Singapore.

As transfer to Associate Member.

Holloway, Gilbert Lloyd	Birmingham.

As Student.

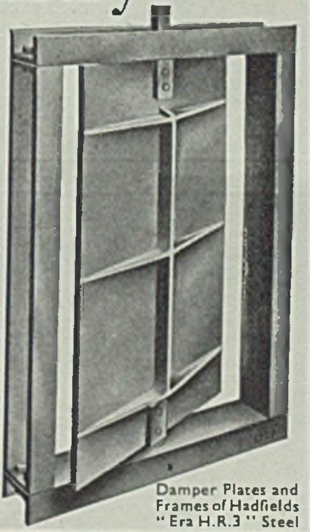
Khalili, Jawad	Sunbury-on-Thames.

The following transfers have been approved by Council :—

From Member to Fellow.

D. S. Paul. P. E. Spielmann.

ARTHUR W. EASTLAKE,
Honorary Secretary.



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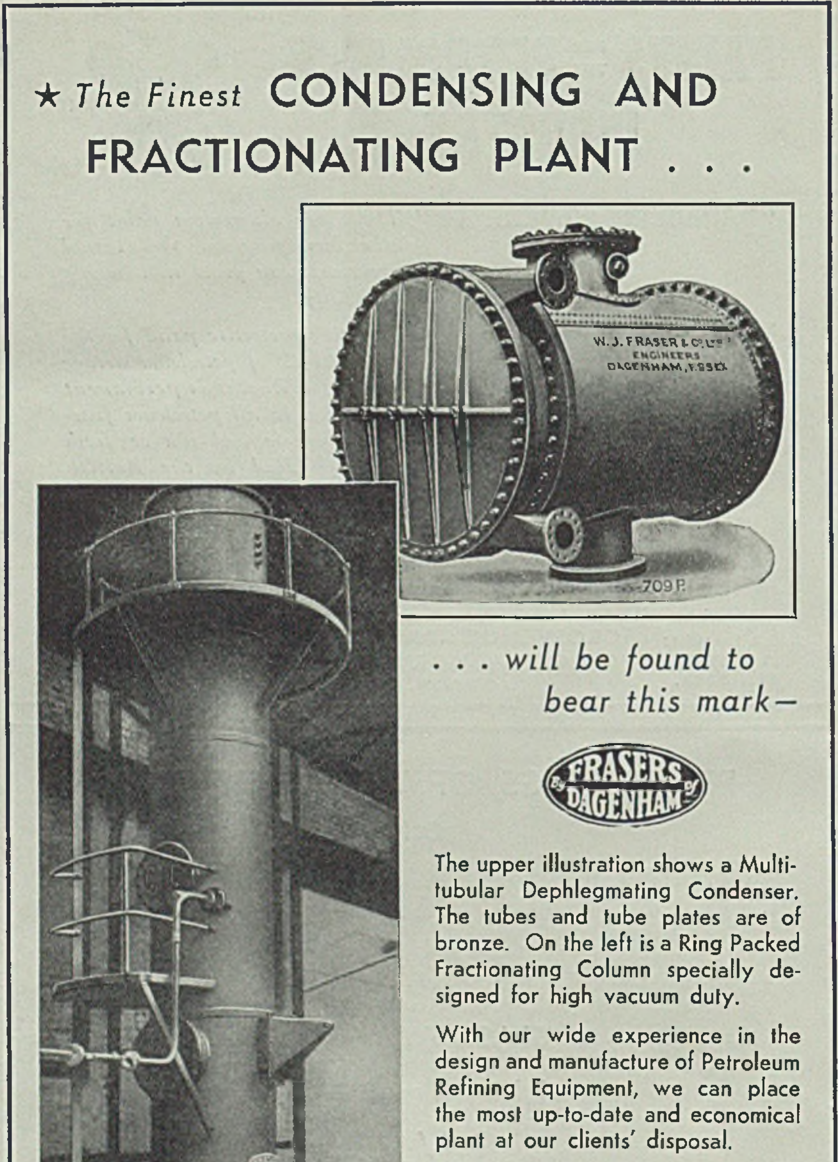

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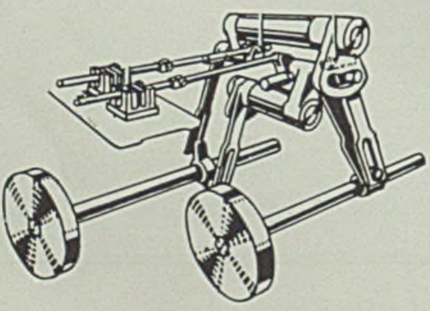
PUMP RODS MADE OF RUBBER

That's what an engineer said looking at a lively Duplex steam pump that was struggling with a highly volatile product. This odd behaviour is more usually described as 'short-stroking,' and it occurs whenever the ordinary Duplex steam pump draws gas instead of a full charge of liquid; piston accelerations become erratic, and the steam ports are closed before the completion of the stroke.

Some users have discarded Duplex pumps on this account; others have purchased Hayward-Tyler Duplex pumps with Twells' valve gear, and are now getting the economic advantages of this type combined with positive action.

With Twells' valve gear each piston rod closes its own steam port at the end of the stroke, the opening of the port being effected by the opposite piston as with the standard Duplex. The result is ability to work with gas-laden liquids or even against a vacuum, and incidentally a saving in steam.



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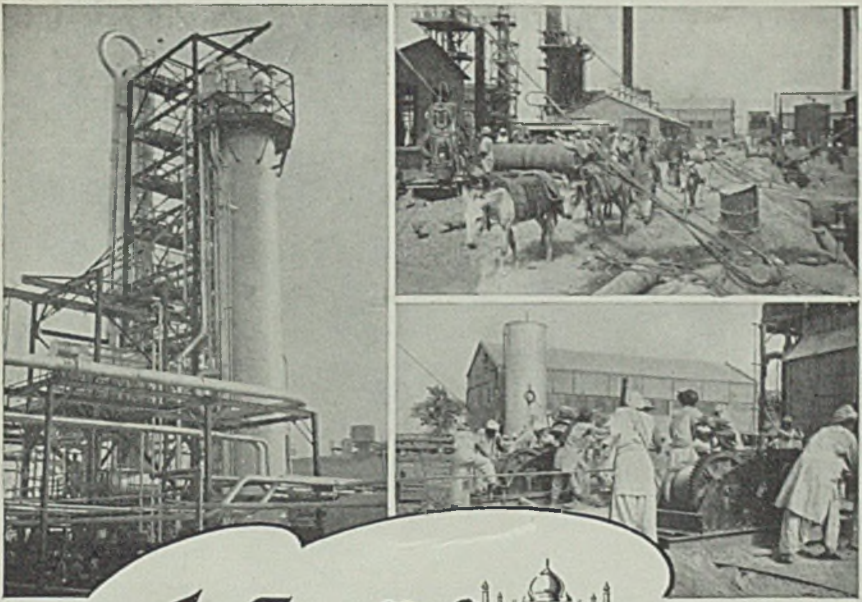

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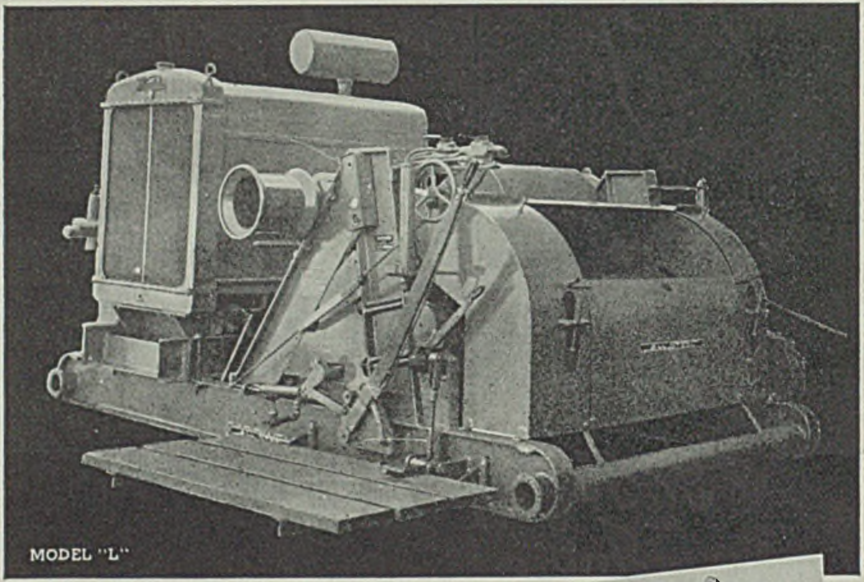

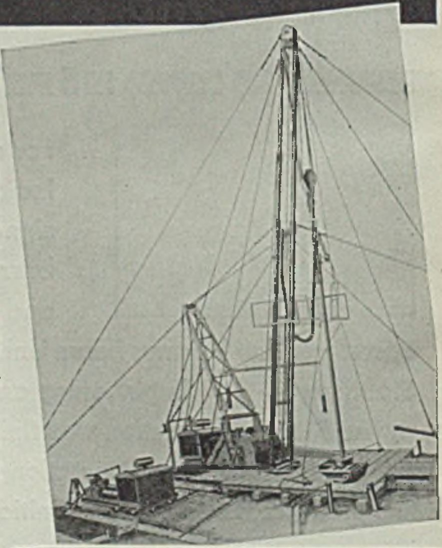

The speed, flexibility and smoothness of steam are yours by a turn of the throttle on this new draw works. The entire engine power is constantly available at maximum speed WITHOUT SHIFTING GEARS.

When you want to "kick-up" the travelling blocks, just flip the finger-tip air control into "high" and the friction clutch "Hi-Lo" drive instantly doubles the line speed without increasing the speed of the engine. This feature saves drilling time. Air controls operate the two "Hi-Lo" friction clutches, rotary drive friction clutch and countershaft brake. Rotary table brake is automatically operated.

"Cardwell" friction clutches are used throughout, saving time and load shocks at every operation. The new type dual, fully equalised, single adjustment safety brakes will hold the full capacity load even if one brake should fail. Brake flanges are alloy heat-treated steel, with three to four times the life of ordinary steel flanges.

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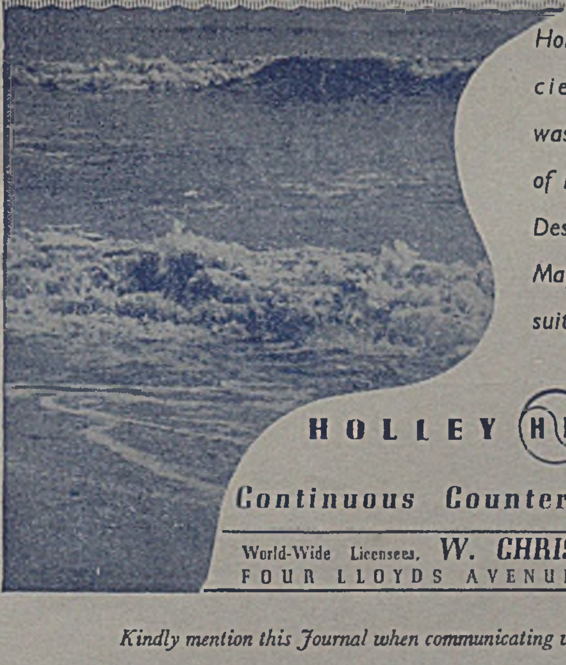


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