Vol. 27. No. 214. October 1941.

SOIL CLASSIFICATION AND ITS BEARING ON SOIL STABILIZATION.*

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Summary.

Soils may be " stabilized " or converted into suitably hard and durable materials for road and runway construction in various ways. Economic stabilization is, however, restricted to certain types of soil, and the choice of the best method of stabilization depends on the character of the soil. This is governed by the size, shape, and nature of the constituent mineral particles. Soil classification tests give a measure of these properties, either directly, as in mechanical analysis, by determining the particle-size distribution, or indirectly by " index tests " which are based on the fact that the amount of water required to reduce a soil to a given consistence depends chiefly on the fineness of the soil particles.

If it is possible by the addition of clay, gravel, or other soils to bring the grading of the soil within prescribed limits, other binders are not essential, but with fine-grained or poorly graded soil, the grading of which cannot be modified or in which the clay binder is unsuitable, suitable stabilizing agents such as bituminous binders, Portland cement, or other materials, must be added. Suitable bituminous binders include cut-back bitumen, " road oil," bitumen emulsion, or tar.

The amount of stabilizer required depends on the nature of the soil, and in particular on its mechanical analysis. With very fine-grained soils such as heavy clays the advantages of using the soil as a material for constructing stabilized surfacings are outweighed by the heavy cost of the large amounts of binder required, or of the equally large amounts of sand and stone that must be incorporated in the mix. American statistics show that the graded soil type of stabilization is the type that has so far been most extensively used in the U.S.A.

Introduction.

In recent years considerable progress has been made in the use of " stabilized soil " for constructing aerodrome runways and low-cost roads. By using soil from the site as the principal constituent in the stabilization process the transport of aggregate and hard core to the site is largely avoided—frequently a matter of great moment, especially when the area to be constructed is large and time is limited.

The widely differing nature of soils affects their suitability for use in the various stabilization processes. A classification that is able to show what soils can be economically used in any particular method of stabilization is therefore of great value. It is proposed in this paper to consider the standard classification tests in their bearing on soil stabilization.

Nature of Soil.

From the engineering point of view the term " soil " is applied to all superficial deposits derived from the natural disintegration of the rock-crust of the earth. It therefore includes a wide range of materials composed of mineral particles of varying size, from gravel and shingle on the

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* Paper presented at a meeting of the Asphaltic Bitumen Group of the Institute held in London on 18th March, 1941. Crown copyright reserved.

one hand to plastic clay on the other. When organic material is associated with the mineral particles, as in peat, it may have a great effect on the nature and behaviour of the soil. In general, the type of the soil is determined by the size, shape, and nature of its mineral particles, but the properties, in particular the consistence, of any given soil depend almost entirely on its moisture content.

Constitution of Clay Particles.

The chemical composition of the coarser particles of a soil is of minor practical concern, but the character of the clay particles has an important influence on the properties of the soil. Only within the last few years has it been possible, by means of X-ray analysis,[1, 2] to establish the nature and structure of these particles. They belong to a class of complex silicates in which the constituent atoms are arranged in alternate sheets to form a crystal lattice, giving a plate-like structure. The minerals occurring in clays belong to three main groups: the kaolin (china clay) group, the montmorillonite group, and the mica group, the latter being relatively unimportant. The principal mineral constituents of ordinary clays in temperate climates belong to the montmorillonite group. Although the chemical composition of these constituents may vary widely, variations normally occurring in this country do not affect the properties of the soil sufficiently greatly to warrant direct account of them being taken in present-day methods of classifying soils (*see* Fig. 2).

The relatively large surface area of the very fine, platy, crystalline particles of which clays are composed causes their properties to differ essentially from those of a powder mixed with water. The montmorillonite type is characterized in addition by a remarkable increase in the basal spacing of its crystal lattice from 10 Å. to 20 Å. (1 Å. = 10^{-7} mm.), according to the moisture content.[2] Clays thus possess the nature of both a jelly and a crystalline substance.

The effect of the chemical nature of the clay particles on the behaviour of soils has recently been studied in the U.S.A.[3] It has been found that soils with silica/sesquioxide (SiO_2/R_2O_3 *) ratios exceeding 2, indicating the presence of the montmorillonite group, tend to have greater volume changes than soils with ratios less than 2, and that this is reflected in the behaviour of stabilized soil roads. In tropical countries lateritic soils having a low silica/sesquioxide ratio are common, and they expand much less than the types of clay usual in this country.

Particle Size.

The wide range of particle-size distribution found in soils is indicated in Fig. 1, where the logarithmic scale covers a range of particle size of 50,000 to 1. Even this does not include the lower limit of size, which is probably below 0·1 μ.† Although very fine, these particles are by no means of molecular size, for 0·1 μ is equal to 1,000 Å., whilst the spacing of the crystal lattice is between 10 Å. and 20 Å. The dotted curve in Fig. 1, showing the grading of a typical Portland cement, gives an idea of the fineness of the clays.

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* $R_2O_3 = Al_2O_3 + Fe_2O_3$.

† 1 μ or 1 micron = 0·001 mm.

CLASSIFICATION OF SOILS.

Classification Tests.

Classification tests meet the need for a more definite method of identifying soils than is possible by visual inspection. The results are quantitative, and independent of the personal factor. In addition to their value in soil classification, the tests provide information necessary in the design of certain types of stabilized soil mixtures.

The tests are of two types: (1) mechanical analysis, a combination of sieving and sedimentation used to determine directly the size distribution of the soil particles; and (2) index tests (confined to that portion of the soil passing a 36-mesh B.S. sieve), by means of which the soil type can be inferred from known relationships between moisture content, consistence, and particle fineness. The classification tests commonly used, many of which have been standardized by the American Society for Testing Materials, include :—

(1) Mechanical analysis :—
  (*a*) Pipette method,
  (*b*) Hydrometer method (A.S.T.M. D422–39).

(2) Index tests :—
  (*a*) Liquid limit (A.S.T.M. D423–39),
  (*b*) Plastic limit (A.S.T.M. D424–39),
  (*c*) Centrifuge moisture equivalent (A.S.T.M. D425–39),
  (*d*) Field moisture equivalent (A.S.T.M. D426–39),
  (*e*) Shrinkage limit.

All these tests give, directly or indirectly, some measure of the size distribution, shape, and nature of the soil particles which have been shown to govern the nature of a soil. They take no account, however, of soil structure, *i.e.*, of the arrangement and closeness of packing of the soil particles, since that structure is destroyed in making the tests. This is immaterial from the standpoint of soil stabilization, which is only concerned with mixed soils in which the original structure plays no part.

Description of Tests.

Soil classification tests are described in detail in textbooks on soil mechanics,[4, 5] but since they may be unfamiliar to petroleum technologists, a brief description will be given of the three most important tests—the mechanical analysis and the determination of the liquid and plastic limits of a soil.

(1) *Mechanical Analysis.*—The mechanical analysis of a soil is made by a combined sieving and sedimentation method. In the method employed at the Road Research Laboratory 100 gm. of the soil are heated to about 60° C. with hydrogen peroxide (to remove organic matter), and then with hydrochloric acid (to remove carbonates and gypsum). After the soil has been washed on a Buchner funnel with hot distilled water and dried, 10 gm. of the dry pretreated soil are thoroughly dispersed in 500 ml. of $N/100$ sodium oxalate solution (used as a deflocculating agent)

by stirring for 15 min. in a high-speed electrical machine. The dispersed soil particles are then passed over a 200-mesh B.S. sieve, and the liquid and solid materials passing the sieve are examined by a sedimentation process.

The dispersing liquid with the suspended particles is shaken up in a large boiling-tube, which is placed in a constant-temperature bath to allow the particles to settle. Particles of different size have different settling velocities in accordance with Stokes' Law, from which, when the velocity is measured, the size can be computed on the assumption that the particles are spherical in shape. After a given time from the initial shaking, samples taken from a given depth below the surface will contain only those particles the velocities of which have been insufficient to carry them further. The samples, taken in a pipette of known volume, are evaporated to dryness, and the weight of the residue is determined. By doing this at various time intervals from the start, the percentage of particles of various sizes can be found. The method is employed for particle sizes down to 1 μ (10^{-3} mm.), but would probably give satisfactory results for even smaller sizes. This method, due originally to Andreasen, has been described in more detail elsewhere.[6]

In the alternative A.S.T.M. method (D422–39) the concentration of soil particles in suspension is determined by means of a standard hydrometer. Both methods have been found at the Road Research Laboratory [7] to give the same results when the tests are carefully done. The pipette method is more precise, but the hydrometer method is more readily adaptable to field-laboratory conditions.

(2) *Liquid Limit.*—The liquid limit is that moisture content at which soil will just begin to flow when lightly jarred 25 times on standard apparatus. A standard groove is cut with a special tool in a pat of soil placed in a cup of standard design. The cup is caused to fall a measured number of times through a height of 1 cm. The groove is carefully watched, and the number of blows is noted at the instant when the groove is closed over a length of ½ in. A sample of this soil is taken and its moisture content determined. The soil is allowed to dry out somewhat and the procedure is repeated. From the results, the number of blows is plotted against the moisture content of the soil and the moisture content corresponding to 25 blows is read off from the graph.

(3) *Plastic Limit.*—The plastic limit is the lowest moisture content at which a thread of soil can be rolled down without breaking until it is only ⅛ in. in diameter. The thread is rolled by hand on a piece of plate-glass, the heat of the body being sufficient to expel moisture at a fairly constant rate until the plastic limit is reached.

The difference between the liquid and plastic limits is termed " plasticity index." It gives a measure of the fineness of the soil, and may vary from as much as 80 for a highly plastic soil to zero for a coarse or fine sand.

Significance of Tests.

The physical meaning of mechanical analysis is obvious, but to ascertain the physical significance of the other classification tests, which are of a purely *ad hoc* character, it is necessary to correlate the results with some appropriate physical characteristic of the soil. Reference to Table I shows that, with the exception of the shrinkage limit, the test values vary in the same order as the corresponding curves in Fig. 1. This suggests

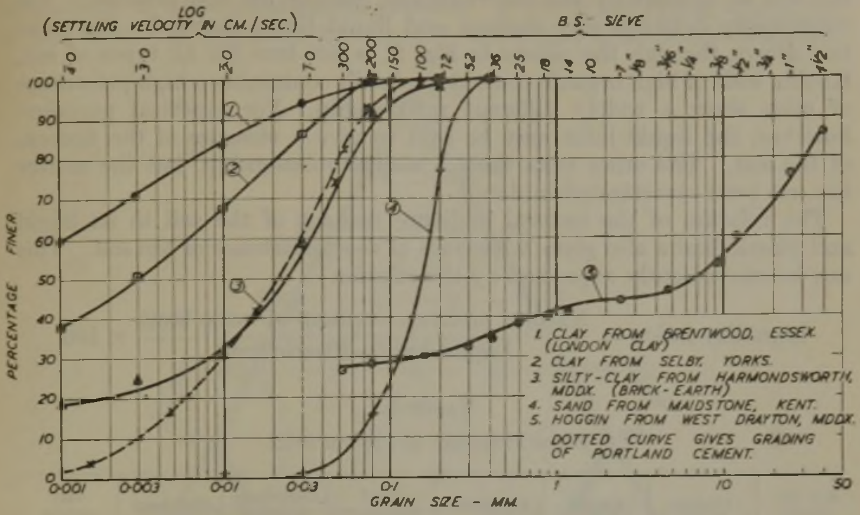


Fig. 1.

MECHANICAL ANALYSIS CURVES FOR TYPICAL SOILS.

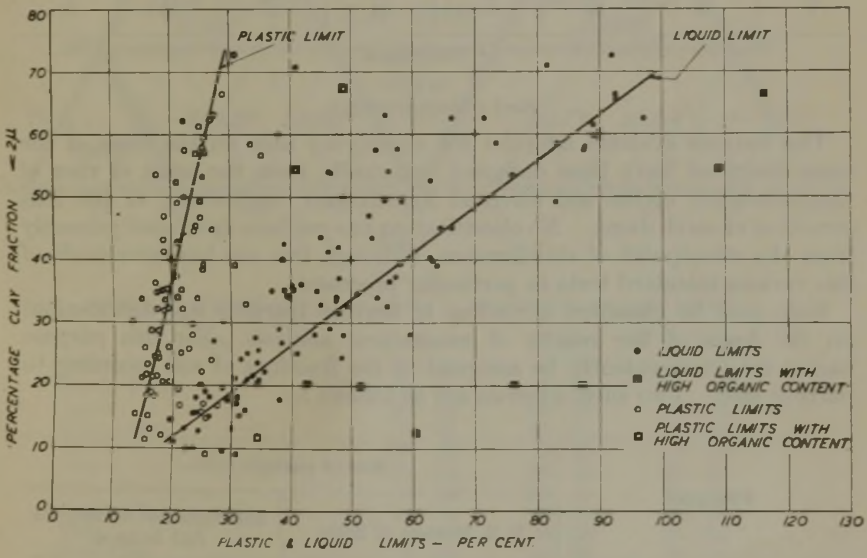


Fig. 2.

CORRELATION BETWEEN CLAY CONTENT AND LIQUID AND PLASTIC LIMITS OF TYPICAL BRITISH SOILS.

that these tests give a measure of the fineness of the soil particles. More detail is shown in Fig. 2, where the liquid and plastic limits of numerous

British soils tested at the Laboratory have been plotted against the percentage of material in each that is finer than 2 μ (the "clay" content of the soil as defined by the International Society for Soil Science). The relationship between clay content and liquid limit, shown by the mean line drawn through the points in Fig. 2, is not true for all types of soil. Kaolin, soils of high organic content, and soils containing a high percentage of mica show a widely different relationship. For practical purposes, however, the liquid limit may be said to give a measure of the fineness of the soil. The other tests show a similar relationship, but the matter has not been investigated in detail.

The relation of the natural moisture content of the soil to its liquid and plastic limits also gives a measure of the consistence of the soil. This can be conveniently expressed by the relation

$$\text{Liquidity index} = \frac{\text{Natural moisture content—Plastic limit}}{\text{Liquid limit—Plastic limit}} \times 100$$

TABLE I.

Index Properties of Typical Soils.

Ref. no. of soil (Fig. 1).	Plastic limit.	Liquid limit.	Plasticity index.	Field moisture equivalent.	Centrifuge moisture equivalent.	Shrinkage limit.	Clay content <2 μ.
	%.	%.	%.	%.	%.	%.	%.
1	29	92	63	47	76 *	14	66
2	24	53	29	34	34	14	47
3	19	34	15	21	20	13	20

* Waterlogged.

Soil Classifications.

The various systems adopted for classifying soils on the basis of the tests described have been designed principally from the point of view of the suitability of the soil for road foundations, earthworks, or the construction of earth dams. No classification has yet been developed primarily from the standpoint of stabilization, although free use has been made of the various standard tests in particular processes.

Soils may be classified according to texture (particle size distribution) on the basis of the results of mechanical analysis. For this purpose names may conveniently be assigned to the fractions of soil according to particle size. Two such schemes are as follows :—

Fraction.	Size of particle (mm.).	
	U.S. Bureau of Soils.	International Society for Soil Science.
Gravel	>2	>2
Coarse sand	2–0·25	2–0·2
Fine sand	0·25–0·05	0·2–0·02
Silt	0·05–0·005	0·02–0·002
Clay	<0·005	<0·002
Colloids in clay	<0·001	—

For the purposes of classification a soil is assumed to consist of only sand, silt, and clay, and soil types are defined according to the relative proportions of these constituents present. A list of soil types, drawn up on this basis, was originally developed by the U.S. Public Roads Administration,[4] and is shown on the triangular chart in Fig. 3. The type to which any soil belongs can be ascertained by plotting on the chart the results of the mechanical analysis.

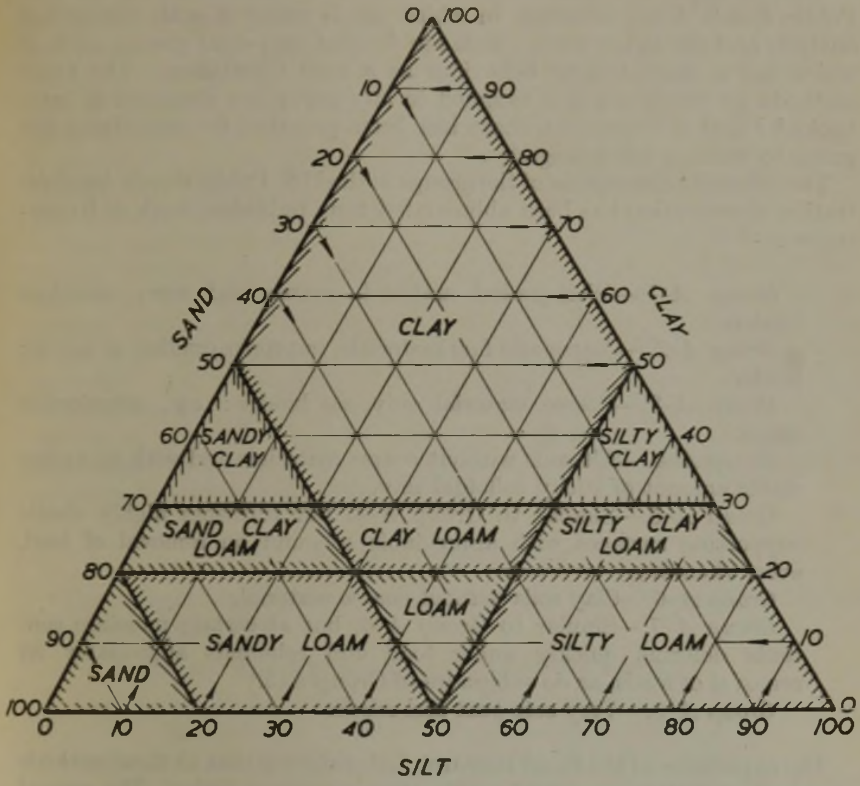


FIG. 3.

TEXTURAL CLASSIFICATION OF SOILS (AFTER PLUMMER AND DORE).

Class.	% Sand.	% Silt.	% Clay.
Sand	80–100	0– 20	0– 20
Sandy Loam . . .	50– 80	0– 50	0– 20
Loam	30– 50	30– 50	0 –20
Silty Loam . . .	0– 50	50–100	0– 20
Sandy Clay Loam . .	50– 80	0– 30	20– 30
Clay Loam	20– 50	20– 50	20– 30
Silty Clay Loam . . .	0– 30	50– 80	20– 30
Sandy Clay. . . .	50– 70	0– 20	30– 50
Clay	0– 50	0– 50	30–100
Silty Clay	0– 20	50– 70	30– 50

Other methods of classification have also been adopted on the basis of the mechanical analysis of soil. In the Kendorco system,[4] which has been applied in the construction of earth dams, the mechanical analysis chart is divided into parallel zones according to particle size. The type to which any soil belongs is determined by the zone in which its mechanical analysis curve happens to lie.

Another important classification scheme is that sponsored by the U.S. Public Roads Administration, in which use is made of both mechanical analysis and the index tests. Soils are divided into eight groups, each of which has a characteristic behaviour as a road foundation. The exact methods by which a soil is assigned to any group are described in textbooks,[4, 5] and a convenient chart has been prepared for identifying the group to which a soil belongs.[8]

The following description of the groups in the U.S. Public Roads Administration classification has been abbreviated from published work of Hogentogler :—[5, 10]

Group A–1.—Well-graded material, coarse and fine; excellent binder.

Group A–2.—Coarse and fine materials, improper grading or inferior binder.

Group A–3.—Coarse material only, no binder : *e.g.*, cohesionless sands.

Group A–4.—Silt soils without coarse materials and with no appreciable amount of sticky colloidal clay.

Group A–5.—Similar to Group A–4, but furnishes highly elastic supporting surfaces with appreciable rebound on removal of load, even when dry.

Group A–6.—Clay soils without coarse material.

Group A–7.—Similar to Group A–6, but at certain moisture contents deforms quickly under load and rebounds appreciably on removal of loads, as do subgrades of Group A–5.

Group A–8.—Very soft peat and muck.

The experience of the Road Research Laboratory is that all these methods of soil classification are useful within their respective limits. The general nature of most soils, however, is revealed by the liquid and plastic limits or by mechanical analysis, and, except in research, further elaboration of classification tests does not seem warranted. More detailed information on the suitability of any soil for a particular use is best sought by tests directly related to that use. For example, direct determinations on mixed material may be made of the water absorption and stability of bitumen emulsion-stabilized soils and of the water absorption and resistance to frost of soil-cement mixtures. Again, in the more general sphere of soil mechanics direct determinations of the various mechanical properties are made on " undisturbed " samples of soil. The primary function of classification tests is to give a general indication of the properties of a soil with the minimum of effort, and this function is fulfilled by the tests described.

Application to Soil Stabilization.

Principles of Stabilization.

Before the application of classification tests to soil stabilization is considered, the principles of stabilization and the processes adopted will be briefly surveyed. The term "stabilization" is applied in general to processes for converting natural soil on the site into a hard and durable constructional material. Non-cohesive soils—*e.g.*, sands—require some form of binder to give them the necessary stability. Cohesive soils, on the other hand, are hard when sufficiently dry, and in theory stabilization is assured if a reasonably low moisture content is maintained at all seasons of the year. The paramount importance of excluding water when cohesive soils are used is therefore obvious.

Since stabilized soil is in general a weaker material than other types of road surfacing, efficient drainage, especially of the subsoil, is even more vital than with stronger surfacings. For surface drainage much greater camber is desirable than that normally provided on bituminous roads; 1 : 24 or 1 : 30 has been recommended, but these cambers are sometimes exceeded. An "A" profile is often preferred to the circular or parabolic cambers usual in this country. It is also frequently advisable to seal the surface or, with cohesive soils, to waterproof the surfacing material itself. Infiltration of water may also be prevented by imparting permanent cohesion to a soil with a suitable binder.

Types of Stabilization.

The principal types of soil stabilization used in constructing roads and runways are as follows :—

1. *Graded Soil Mixtures* (mechanical stabilization).
    (*a*) Without admixture of other materials.
    (*b*) With the addition of water-retentive materials :—
        i. chemicals (*e.g.*, sodium or calcium chloride).
        ii. industrial waste products (*e.g.*, molasses).
2. *Mixtures with Special Stabilizing Agents.*
    (*a*) Bituminous binders :—
        i. bitumen, including "road oils."
        ii. cut-back bitumen.
        iii. bitumen emulsion.
        iv. tar.
    (*b*) Portland or other cements, or lime.
    (*c*) Certain industrial waste products such as resinified molasses, sulphite liquor or lignin liquor (neutralized sulphite liquor) from the wood-pulp industry.
3. *Heat Treatment.*

The choice of any particular process for the construction of surfacings is governed largely by the nature of the soil and by the funds available for construction. If the grading can be brought within certain prescribed limits, the compacted materials will have good stability without the addition of any special stabilizing agent, and the first group of processes may be used. If, however, the grading of the soil is deficient in either fine or coarse material, that deficiency must be made good by adding either granular materials to enable the graded-soil process to be used, or suitable binders such as bituminous materials or Portland cement, as in the second type of process. In this case, too, it is not unusual to improve the grading of the soil by adding coarse material.

The cheapest form of construction is a graded mixture constructed with the best local materials. For heavier service more care is needed with the choice and grading of materials, and some form of bituminous surfacing is generally desirable. Short lengths of experimental road of the soil–cement type built at the Road Research Laboratory indicate that in the British climate surface treatment is almost essential.

In a wet climate such as that of Great Britain it is advisable to seal a stabilized road surface, but this is not done abroad on the cheaper types of road, and is unnecessary on mixtures of the sand–bitumen or sand–tar type.

Some indication of the extent to which the various processes are used in the U.S.A., where the greatest development in the construction of stabilized roads has taken place, is given in a recent survey.[9] Replies sent by forty-seven state highway departments to a questionnaire showed that 14,365 miles of stabilized soil road had been constructed during the years 1925–1939. The percentage mileage constructed according to each process was as follows :—

Graded Soil Mixtures.	
(*a*) Without admixture of other materials . .	59·4
(*b*) With admixture of water-retentive chemicals	13·4
Mixtures with Special Stabilizing Agents.	
(*a*) Asphaltic	19·3
(*b*) Bitumen emulsion	2·2
(*c*) Portland cement	1·7
(*d*) Tar	4·0
Total	100·0

These figures do not include data from municipalities, counties, private concerns, or aerodromes, and are therefore not completely representative, but they show the important position occupied in the U.S.A. by the graded-soil type of stabilization.

General Suitability of Soil for Stabilization.

Relatively few soils in their natural state are suitable for stabilization. Soils containing large percentages of very fine particles cannot be successfully processed by present methods unless coarse material is first added. Mixes containing a large amount of — 200-mesh material become so sticky when wetted that they are difficult to combine with the stabilizing agent.

In addition, they tend to crack badly on drying out unless coarse or fine aggregate is added. As a general rule a soil to be used in the natural state must not contain more than 50 per cent. of material passing the 200-mesh. A large proportion of material finer than 2 μ contained in a soil is also detrimental : for this reason heavy clays are quite unsuitable for existing stabilization processes except possibly heat treatment.

By using the soil tests described the proportion of very fine material contained in any soil can be estimated. An excess of such material is readily detected by determining the liquid limit of the soil, which should not exceed 40 or 45. Hogentogler [10] has stated this in another way by describing soils of the A–5 to A–8 groups as unsuitable for surface or base courses. The presence of undesirable micaceous substances and of peaty and other organic materials causing detrimental sponginess and capillarity is indicated by liquid limits greater than those given by the expression :—

$$LL = 1{\cdot}6\ PI + 14$$

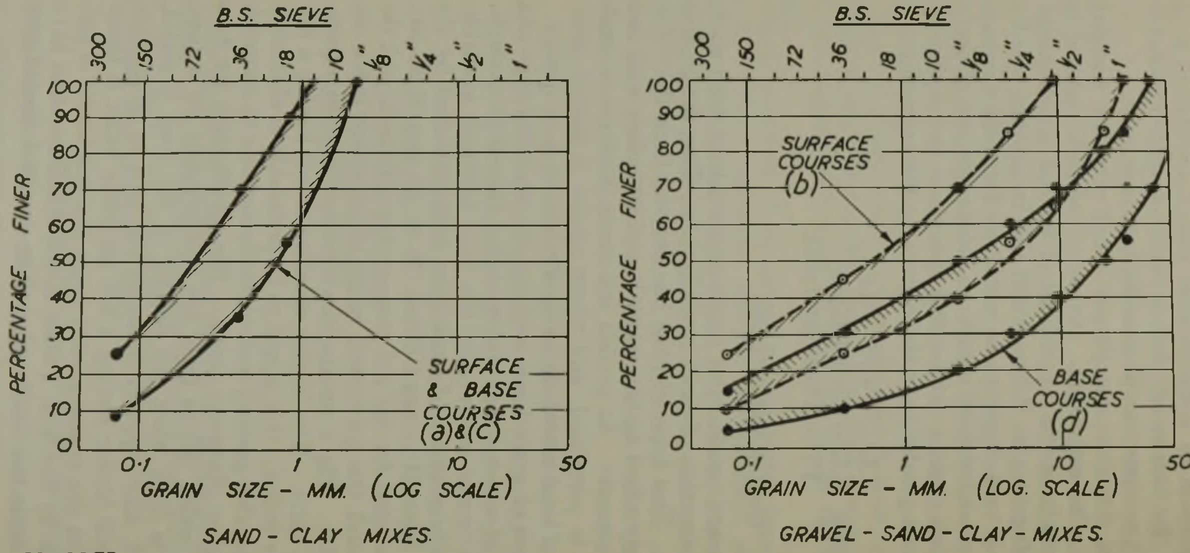
where LL = Liquid Limit
PI = Plasticity Index

Graded Soil Mixtures.

During the last ten years considerable improvements have been made in the U.S.A. in the construction of earth roads by controlling the grading of the soil constituents. This type of road has evolved from the " dirt road " into a form closely allied to the water-bound macadam road and of the nature of a soil concrete. In graded soil roads, however, a much wider range of grading is permitted, and where money is limited great stress is laid on the use of local materials, even of relatively poor quality.

The two principal types of graded soil road are the sand-clay type and the coarse-graded type, of which the gravel-sand-clay type is an example. The choice of type is governed entirely by the local materials available. Specifications for both these types of road have been published by the American Association of State Highway Officials (M–61–38) and (M–56–38). Limits of grading are specified for the soil coarser than 200-mesh, and the maximum liquid limit and the permitted range of plasticity index are specified for the soil binder. Fig. 4 summarizes these specification requirements in semi-graphical form. The binder specified is soil having a low but measurable plasticity index; this is said to be preferable to absolutely non-plastic soils of comparable grading and decidedly superior to materials with an appreciably higher plasticity index. The specification for base courses intended to be sealed differs from the requirements for a plain surfacing. The reason is that when the surface of the road is sealed, evaporation is prevented, and capillary moisture will tend to accumulate in the base course. A soil binder having a low plasticity index is therefore recommended, and in the coarse-graded types less soil binder is permitted.[11, 12] Tests made by the U.S. Public Roads Administration have shown that for normal soils the limits of grading specified should give good results.

Comparison of Figs. 1 and 4 indicates that to obtain gradings approaching those specified it is in general necessary to mix two or more soils or to import aggregates. Processing is usually done by either mix-in-place



SAND - CLAY MIXES.

GRAVEL - SAND - CLAY - MIXES.

SURFACE COURSES

THE FRACTIONS OF SURFACE COURSE MATERIALS IN a & b PASSING THE N° 200 SHOULD BE LESS THAN 2/3 OF THE FRACTION PASSING THE N° 36 SIEVE. THE FRACTION PASSING THE N° 36 SIEVE SHOULD HAVE A LIQUID LIMIT NOT GREATER THAN 35 & A PLASTICITY INDEX NOT LESS THAN 4 NOR MORE THAN 9.

BASE COURSES

THE FRACTIONS OF BASE COURSE MATERIALS IN C & d PASSING THE N° 200 SHOULD BE LESS THAN 1/2 OF THE FRACTION PASSING THE N° 36 SIEVE. THE FRACTION PASSING THE N° 36 SIEVE SHOULD HAVE A LIQUID LIMIT NOT GREATER THAN 25 & A PLASTICITY INDEX NOT GREATER THAN 6.

Fig. 4

SPECIFIED LIMITS OF GRADING FOR GRADED SOIL STABILIZATION (AMERICAN ASSOCIATION OF STATE HIGHWAY OFFICIALS).

or plant-mix methods. Various types of roller are used, starting with sheepsfoot rollers and finishing with ordinary smooth rollers. An important requirement is that the moisture content of the mix shall be maintained near the optimum for maximum compaction, so that the material can be consolidated to its maximum density.

In appearance, the finished surface resembles a water-bound road, except that the aggregate is less evident. A bituminous surfacing is often laid over the stabilized soil.

Where no protective surfacing is employed, and where the road may be exposed to hot, dry weather, water-retentive chemicals, such as common salt and calcium chloride, have been used in both the construction and the maintenance of the graded-mix type of road surface and base course. The use of these chemicals does not in any way obviate the necessity for controlling the grading and the plasticity index of the constituent materials. Deliquescent salts, however, through their water-retentive properties, tend to preserve a uniform moisture content that is beneficial in (1) assisting compaction during and after construction, (2) retarding abrasion of the surfacing, and (3) lessening or preventing destructive ravelling while the surfacings and base courses are exposed to traffic without a protective coating.

Recent tests [13] have also shown that the presence of 1 per cent. or more of calcium chloride or sodium chloride increases the resistance of the surfacing to damage by frost.

Use of Stabilizing Agents.

The stability of graded mixes depends on both the interlocking of the coarse particles and the cohesion of the clay binder. When the soil is deficient in either of these constituents, that deficiency must be made good according to the principles already outlined. In fine-grained soils, stabilizing agents maintain the necessary cohesion both directly and by preventing water from entering the soil; in non-cohesive soils, however, the stabilizing agent functions solely as a binder.

(1) *Bituminous Materials.*—Bitumen is used in soil stabilization in two main forms: as an emulsion and as a light cut-back or a "road-oil". Tar has also been used to a smaller degree, but it must be remembered that in the U.S.A., where these processes have been most developed, bitumen is cheaper and more abundant than tar.

Much has been written on various methods of using bituminous materials for soil stabilization, but it is possible in this paper to deal with the question only very briefly. Cohesive and non-cohesive soils will be considered separately. Considerable quantities of water must be added to a cohesive soil to obtain a consistence suitable for mixing. All this water has to be evaporated before the soil can be compacted under the roller. In the British Isles this means that the construction season for practical purposes is confined to the period from about April to the beginning of August. A big step forward would be made if it were found possible to obtain efficient mixing with pulverized soils. To non-cohesive soils no water need be added, and the presence of soil moisture is not deleterious, since it is readily squeezed out when the sand-mix is rolled. When the method of stabilization has been chosen, soil tests are used chiefly to define more closely than was done above the type of soil suitable for a given process and to permit the percentage of stabilizing binder required to be estimated. For example, McKesson [14] states that soils suitable for stabilization with bitumen emulsion should contain at least 5 per cent. of clay finer than 1 μ and a minimum of 20 per cent. of material passing the 200-mesh sieve. The object of this provision is to ensure a cohesive soil. McKesson has also given the following empirical formula for the amount of emulsion required :—

$$S = K(0{\cdot}05a + 0{\cdot}1b + 0{\cdot}35c)$$

where S = percentage of stabilizer required,
a = percentage of material passing a No. 200-mesh sieve and coarser than 5 μ,
b = percentage of material finer than 5 μ and coarser than 1 μ,
c = percentage of soil finer than 1 μ,
K = a constant for any particular type of soil and equal to 1 for most soils.

It will be seen that where large percentages of fine material are present, correspondingly large percentages of stabilizer are required. It therefore becomes economical to add sand and coarse aggregate to the mix to reduce the proportion of fine material. The same remarks apply to soils stabilized with "road oils" and cut-backs. W. K. Beckham [15] states, however, that it is possible to stabilize soils containing as much as 45 per cent. of material finer than 50 μ, when rapid-curing cut-back is used. Formulæ similar to that given above have been suggested for determining the percentage of stabilizer required for construction with asphaltic bitumen binders : one such formula [16] is

$$P = 0{\cdot}02a + 0{\cdot}045b + 0{\cdot}20c$$

where P = per cent. by weight of binder in total mix,
a = percentage of soil passing a 1-in. and retained on a 7-mesh B.S. sieve,
b = percentage of soil passing 7-mesh and retained on 200-mesh B.S. sieves,
c = percentage of soil passing a 200-mesh B.S. sieve.

The amount of cut-back bitumen recommended is 25 per cent. more than that of road oil, to allow for the evaporation of the light solvent. For wind-blown sands this formula is stated to give too high a proportion of binder, and the following alternative is suggested :—

$$P = 0{\cdot}03a + 0{\cdot}04b + 0{\cdot}12c$$

A formula of similar type for wind-blown sands suggested by Tilley [17] permits of slight adjustment in the binder content, according to the type of filler and the amount of volatile solvent present in the cut-back bitumen. It also allows for variations in the specific gravity of the soil aggregate.

(2) *Portland Cement.*—Catton [18] has classified soils for soil-cement stabilization into four groups. The first three showed very marked hardening, marked hardening, and substantial hardening respectively on treatment with cement. The fourth group comprised bad soils of limited

occurrence. Group 1 contained predominantly sandy soils of the A2, A3, and A5 classes, Group 2 silty soils from the A4 and A7–4 classes, and Group 3 clayey soils of the A5, A6, and A6–7 classes. Soils belonging to the first two groups were found to have liquid limits below 50, plasticity indexes below 25, and clay contents below 35 per cent. This classification of course gives only a general guide to the suitability of soils for cement stabilization, and in a particular case it is advisable to test actual samples.

The soil and cement are generally mixed when the materials are dry and powdery, and only sufficient water is added to obtain optimum moisture content for proper compaction.

CONCLUSION.

The soil classification tests described have been in general use for over ten years, and have now been adopted as standard by the American Society for Testing Materials. The tests enable a tolerably satisfactory classification of soils to be made. In soil stabilization their primary function is to give a general indication of the nature of the soil and of its suitability for the construction of stabilized roads and runways. This function is satisfactorily fulfilled.

The tests are of especial value in stabilization of the graded-soil type, where the whole design of the mixtures is based upon them. When, however, admixtures of special stabilizers (*e.g.*, bituminous materials, Portland cement) are used, the mixtures are designed on the basis of tests on the mixed materials which are outside the scope of this paper. The classification tests, however, still furnish a preliminary guide as to the suitability of the soil, and the amount of binder is usually estimated on the basis of the mechanical analysis of the material.

In preparing this paper an attempt has been made to view the wide field of soil stabilization as a whole. It is of great importance to select a particular process only after consideration of all the available methods. Bituminous stabilization must therefore be regarded as only one of a number of possible processes, but whatever process is selected for the base, a bituminous surfacing is likely to add considerably to its useful life.

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THE USE OF BITUMEN IN SOIL STABILIZATION.*

By H. Gardner, B.Sc., A.I.C.

Summary.

For the purpose of this paper soil stabilization is defined as a process for treating naturally occurring soil in order that it may be used for the preparation of the foundation of tracks for wheeled traffic.

The load-bearing capacity of a soil varies with its grading and water-content, and all soils exhibit an optimum water-content in relation to load-bearing capacity. The useful water-content range of a soil is that range of water-contents over which the load-bearing capacity is adequate for the purpose in view.

In a consolidated soil the water is the binding agent, and a soil of suitable grading is stabilized when it has been treated to minimize changes in water-content.

A tentative specification for grading has been arrived at experimentally, and the grading of the original soil is modified, if necessary, by the addition of the appropriate fine or coarse material.

The stabilizer must be highly hydrophobic, show no tendency to wet the soil particles and so displace the water film, acquire rigidity in order to resist displacement by capillary forces after distribution, and be stable to inclement weather conditions and age.

Consolidation must be efficient, and an adequate wearing carpet must be applied to the stabilized foundation for the dual purpose of preventing attrition and the undue evaporation of water.

Soil stabilization, in one form or another, has been with us ever since it was found necessary to improve tracks in order that they might the better fulfil their required function. In recent years, however, the term has acquired a somewhat specialized meaning, which becomes clear when the many processes to which the term is applied are examined. The stabilizer used may vary greatly as between different processes. Materials as different as molasses, asphaltic bitumen, and calcium chloride are in use. The common factor in all processes, however, is that the stabilized soil consists essentially of that present originally on the site. The use of the term is restricted to processes in which added material, of whatever type, is present in minimum quantity.

Experience of the process has been somewhat varied in the past. All familiar with the subject will recall instances where results have not fulfilled expectations. On the other hand, particularly in the U.S.A., there is no lack of evidence that when approached on sound lines, soil stabilization is yet another valuable process available to the road engineer.

Failures in the past have, it is believed, been due to many causes, prominent among which is a lack of appreciation of the true functions of the stabilizer.

Water, too much or too little of it, has usually been the primary destructive factor. It is, of course, impossible in practice to remove water completely, so as to coat the soil particles, and it becomes expedient to use the binding properties of the water and to take steps to ensure that the

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* Paper presented at a meeting of the Asphaltic Bitumen Group of the Institute, held in London on 18th March, 1941.

water content is kept within desirable limits. Attempts to use other cementing agents involve numerous difficulties. Hydrophobic binders at once introduce the difficulty of wetting soil particles already wet with water. Assuming that the water can be displaced in useful degree, the effective coating of finely graded aggregates involves the use of uneconomically large quantities of binder. Hence it would appear that processes based on the use of small quantities of binder are foredoomed to failure if the incidence of water is a real hazard.

The process that is the subject of this paper constitutes, it is believed, a new approach to soil stabilization. It recognizes that the elements of bearing capacity are grading and water content. For any particular soil, water content and bearing capacity are interdependent, and the soil is stabilized when changes in water content are prevented or at least minimized.

In order to define the scope of the paper, soil stabilization will be regarded as a process for the improvement of the load-bearing capacity of the foundations of tracks designed to take wheeled traffic, with the reservations that the stabilized layer shall consist largely of the original soil and that the stabilizer shall not act in a cementive capacity.

Load-bearing capacity may be defined as the ability of a surface to support a load without permanent displacement. Every surface suffers displacement when under load, the displacement varying with the load, increasing until a point is reached where shear takes place if the load-bearing capacity of the surface is inadequate. For small loads the surface may be considered to be elastic, so that recovery is complete. At larger loads a certain amount of permanent displacement occurs and the disruptive tendencies of successive loadings become cumulative. To the disruptive tendencies of traffic impact must be added the effects of attrition. Thus an efficient track comprises a layer competent to withstand attrition and a sub-layer able to absorb, without sensible damage, the transmitted load, and in its turn to transmit the load to the sub-soil within the supporting power of the latter. The relative importance of these two layers depends on many factors. In the construction of aerodrome runways the low traffic concentration and economic considerations focus attention on the foundation. Wearing carpets are not called upon to perform a very exacting duty, but any deficiencies consequent upon economies in the construction of the wearing carpet serve to emphasize the importance of the foundation. The very large areas involved in aerodrome construction are adequate reason for economy on an area basis, and any process which enables the work to be carried out without the importation of large quantities of reinforcing material for the foundation is to be welcomed. The process to be described is claimed to be such an one.

At the present time aerodrome construction is a major preoccupation, but the application of the process is not limited. The same principle may be applied to the construction of road foundations. The difference between road and runway construction may lie in the nature of the wearing carpet.

THE SCOPE OF THE PAPER.

The subject will be dealt with under the following headings: Theoretical considerations, preliminary laboratory work, a discussion of some aspects of the behaviour of different soils and the description of a large scale trial of the process.

THEORETICAL CONSIDERATIONS.

It is well known that the load-bearing capacity of a finely graded system varies with the water content, and that there is an optimum water content for load-bearing capacity. Water is able to function as the reinforcing agent in such a system by virtue of surface-tension forces exerted by the water films between contiguous particles, and it is easy to understand that the total cohesive strength may vary with the water film thickness and, therefore, in a particular system, with the total water content. These cohesive forces alone are insufficient to provide adequate bearing strength, but if the shape and grading of the particles are suitable, the frictional resistance and the cohesive forces combine to give a bearing strength adequate for a particular need.

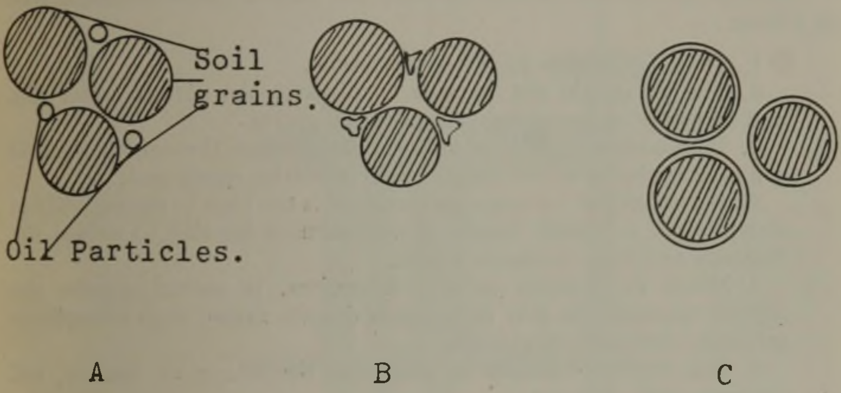

FIG. 1.

In stabilizing a sub-soil, therefore, the principal design characteristics are grading and water content. Laboratory work will determine the optima of these variables.

Having decided on a satisfactory grading and determined the water-content range over which the load-bearing capacity is adequate, the whole object of soil stabilization, according to our ideas, is to devise a means of maintaining the water content within this range.

Water has access to a site not only by virtue of the rain which falls on it, but also by virtue of water which rises from below under the influence of capillary forces. The former may be excluded by the provision of a waterproof seal-coat and the appropriate elevational fall. The latter may be controlled by the blocking of the interstices of the stabilized layer. This is the function of the stabilizing oil. Therefore, the production of an oil with the desired characteristics constitutes the major problem.

In considering the distribution of an oil throughout a system of mineral particles, three different conditions are possible relative to the actual position taken up by the oil.

In *A*, Fig. 1, the oil has not wetted the soil particles, but is present as plugs obstructing the pore spaces, and leaving the water-film unchanged. This is the ideal case.

In *B*, the oil has partly wetted the soil grains, with some disturbance of the water-film. Such a system is presumably unstable. Once the displacement of the water-film is started, further changes from the conditions constituting equilibrium may be towards the further displacement of water and consequent loss of cohesion.

C represents the limiting system in which the oil, by displacing the surface water-film completely, has coated the particles. Here the interstices are merely reduced in size, and since the water-film has been totally removed, its cohesive effect is eliminated. Such conditions are desirable if the stabilizer used is a cement, but in this case very large quantities of cement are required, particularly as, with the class of materials used, high cementing power and high viscosity are usually concommitant properties. A case in point is that of a mastic.

The desirable characteristics of the stabilizer may therefore be enumerated as follows :—

1. The oil should be highly hydrophobic.
2. The oil should not be able to displace the surface water film and so partly or completely coat the soil-grains.
3. It should be capable of uniform distribution throughout the cold soil mixture by means of commercially available equipment.

   If its viscosity at ordinary temperature is too high to ensure uniform distribution, it should require a minimum of heating to reduce the viscosity to within workable limits.
4. When in position in the interstices, it should acquire the rigidity necessary to stay in position despite forces, such as capillary pressure, tending to displace it.
5. The stabilizer should be stable to the effects of weather, soil bacteria, frost, and age.

It must suffice now to record that such an oil has been produced and has shown itself to be a satisfactory stabilizer.

LABORATORY WORK.

Grading. The elements of the load-bearing capacity of a soil are: (1) Cohesion, (2) Internal friction.

Cohesion comprises the attractive forces exerted by contiguous soil particles and apparent cohesion due to capillary forces in the interstices. Both factors are manifest as resistance to displacement when the soil is subject to a load.

In general, the coarser fragments, larger than 0·05 mm., develop great internal friction, whilst it is the particles smaller than 0·005 mm., clay particles, which contribute cohesion. Since the magnitude of the capillary forces, or rather their effect on the frictional resistance, depends on the size of the pore spaces, the fine particles, of size between 0·05 and 0·005 mm. have an important part to play.

Now, investigatory work has shown that if, of the passing 10-mesh particles (soil mortar) 20–30 per cent. is smaller than 200-mesh, and if

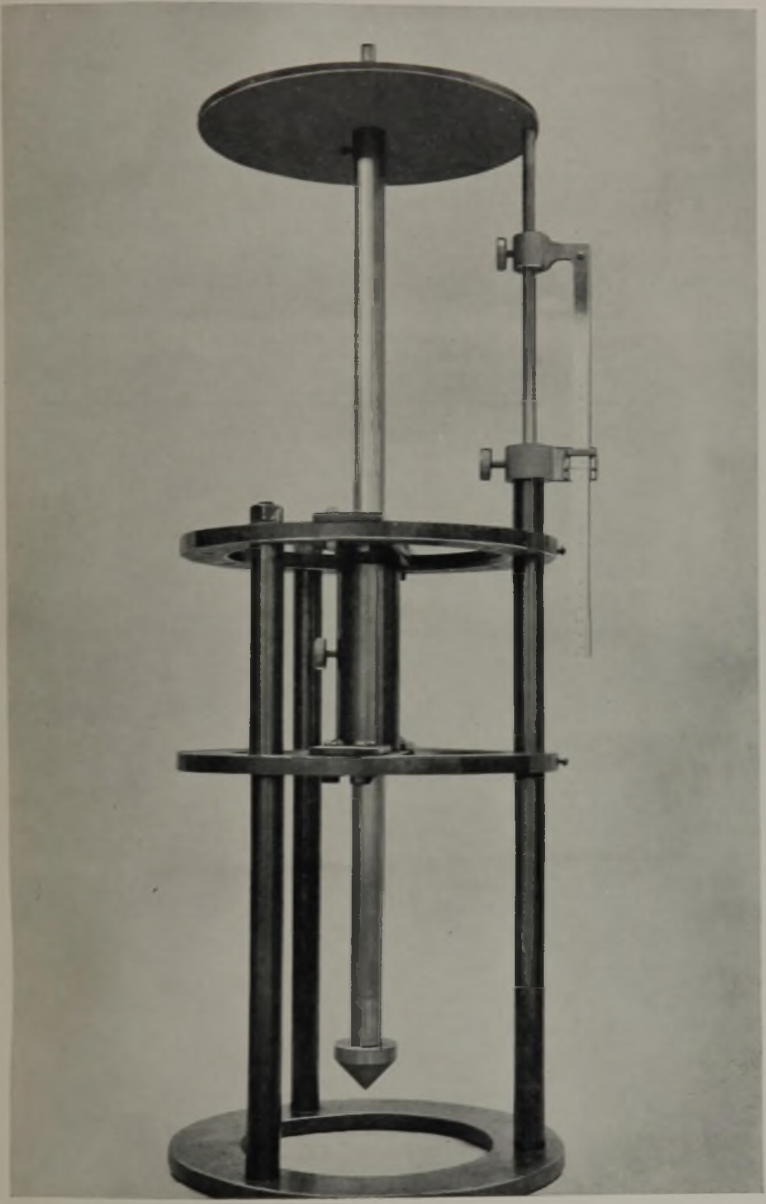

FIG. 2.

[To face p. 332.

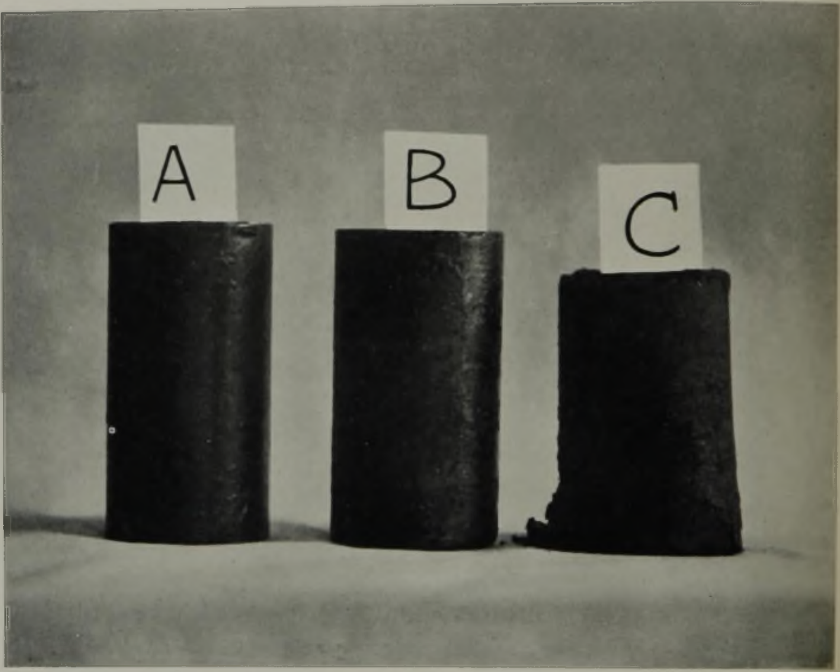

FIG. 8.

at least 60 per cent. of the passing 200-mesh is smaller than 50 μ, the soil will show a useful load-bearing capacity over the water-content range of approximately 5–12 per cent.

The term "useful load" requires some amplification. It must always be interpreted in the light of the demands to be made on the surface. In the investigation which led to this process it was assumed that the minimum load-bearing capacity should be 20 kgms./cm.^{2}, or approximately 284 lb./sq. in. This is probably a very generous estimate, but, since it is not difficult to obtain, it constitutes a very safe figure.

The granulometric composition of the smaller than 50 μ portion is of great importance, but nothing resembling a general specification for this fraction can yet be given. It must, obviously, contain a sensible proportion of particles down to 1 μ or smaller. However, it has not yet been possible to correlate the behaviour of clays with their particle size. This is not surprising in view of the complex nature of clay and the fact that clays have significant properties distinct from, and independent of, their granulometric composition. This point is made clear in Table I.

TABLE I.

		Soil A.	Soil B.
	Smaller than 2 μ	1·44	1·64
Larger than 2 μ	,, ,, 5 μ	0·44	3·88
,, ,, 5 μ	,, ,, 20 μ	4·92	3·52
,, ,, 20 μ	,, ,, 50 μ	5·20	2·68
,, ,, 50 μ	,, ,, 200-mesh	8·40	4·56
,, ,, 200-mesh		79·60	78·62
Load-bearing capacity at optimum water content		27 kgm./cm.^{2}	105 kgm./cm.^{2}

These two soils are not very different from the point of view of their gradings, but, since their load-bearing capacities at optimum water content are so different, a simple expression of their grading cannot constitute a complete statement of their properties from this point of view.

Gradings are carried out by a simple sedimentation process for particles smaller than 50 μ, both on the soil in its original state and after pretreatment to remove organic matter and to deflocculate it. The grading is completed by shaking on dry sieves.

Load-Bearing Capacity.

This is determined by means of the cone penetrometer. One such instrument is depicted in Fig. 2. It consists essentially of a rough, 90°, solid steel cone, mounted on a shaft capable of free movement in a vertical plane, and fitted with a device for measuring its downward movement.

If a loaded rough cone be allowed to bear upon a consolidated soil surface, penetration will take place to a depth dependent on the angle of the cone, the load upon it, and the resistance offered by the soil.

At equilibrium the conditions could be imitated with a truncated cone. If the diameter, *ab*, of the truncated end were the same as that of the buried cone at the line AB, the original surface of the soil, the cone would just not penetrate.

Hence Cone Resistance $$(CR) = \frac{W}{\pi\left(\frac{ab}{2}\right)^2}$$

where W = the total load.

If a right-angled cone is used :—

$$CR = \frac{W}{\pi d^2}$$

where d = depth of penetration.

The manipulation details of the test are as follows :—

The appropriate soil mixture, wetted to the desired water content, is consolidated in three layers in a circular steel mould 15 cm. I.D. and 12 cm. deep, by means of 25 blows from a 5-kgm. hammer falling freely through 30 cm. on to a steel plate 2 cm. thick, placed on the soil specimen. This method gives a degree of consolidation comparable with that obtained in practice. Consolidation by steady pressure is not satisfactory unless it is accompanied by vibration.

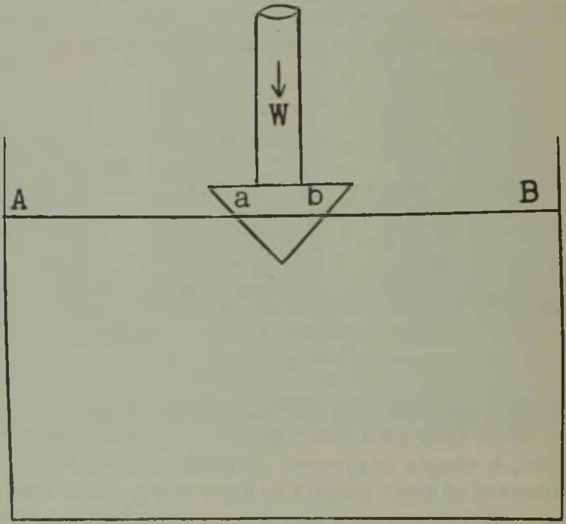

Fig. 3.

The actual mixing process calls for some care. Reliably reproducible data can be produced only if the intermixing of the ingredients is thorough and the water is uniformly distributed. The admixture of clay and sand, unless they are mixed together as a slurry, is somewhat difficult. Hand-mixing is usually not effective. Any apparatus which provides a shearing or kneading action is suitable, and quite a number of mixers suitable for laboratory operation are available.

In the laboratory in which this work has been carried out a " Beken Duplex " mixer is used. This machine is of the twin opposed paddle type. The swept volumes overlap, and one paddle-shaft travels at twice the speed of the other.

A procedure sometimes adopted is to dry the ingredients, pulverize and mix them, and then to add water up to the desired water contents, but, in many cases, such a procedure involves undesirable errors. Some clays, on drying, suffer an irreversible change which impairs their reinforcing properties. In such cases the maximum load-bearing capacity and the useful water-content range are reduced and the optimum water content is lowered. The load-bearing capacity curves should, therefore, always be produced by mixing the ingredients in their original condition, due allowance being made for their water contents when proportioning.

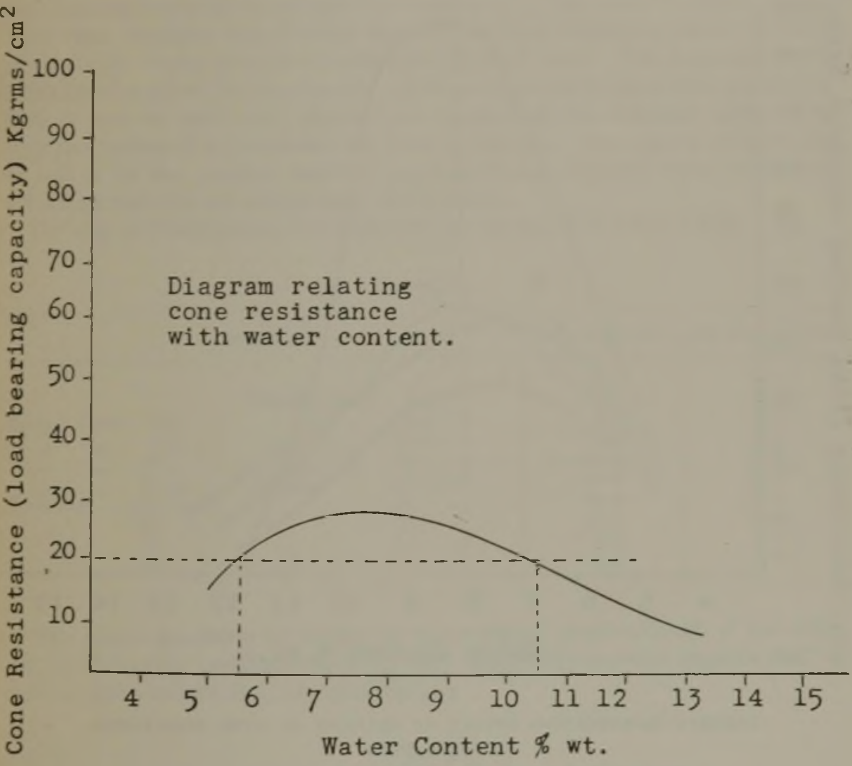

FIG. 4.

The tip of the cone is adjusted to scratch contact with the soil surface, and is locked. The appropriate load is placed on the cone-shaft platform, and the cone assembly is released. The penetration is measured correct to 0·5 mm. Penetration is usually complete in less than 10 secs.

Since there is an induction period during which the cone resistance rises, the actual penetration is not determined until 24 hours after preparation. There is no significant increase in the cone resistance after 24 hours.

It is usual to prepare a series of five or six specimens containing different amounts of water between 5 and 15 per cent. Thus the optimum water content for maximum cone resistance or load-bearing capacity is determined for a particular grading.

Fig. 4 shows the type of curve which is obtained. In this case the optimum water content is approximately 8 per cent., and the soil mixture has a load-bearing capacity exceeding 20 kgm./cm.^{2} over the water content range of 5·5–10·5 per cent.

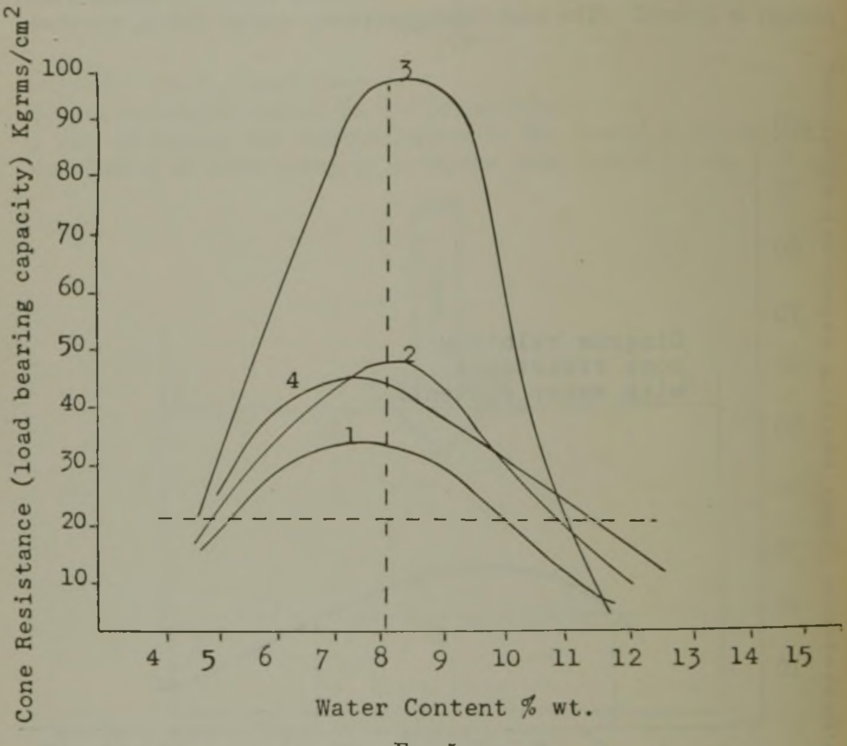

FIG. 5.

DIAGRAM ILLUSTRATING EFFECT OF GRADING ON CONE RESISTANCE.

1. Original soil.
2. Plus 10% sand.
3. Plus 20% sand.
4. Plus 30% sand.

Curves may then be prepared from other soil mixtures in order to obtain the optimum grading.

In Fig. 5 it is shown that for this particular soil there is an overall increase in the load-bearing capacity with additions of sand up to 20 per cent., and that a further addition of sand produces a less stable mixture.

The maximum cone resistance usually coincides, as in Figs. 4 and 5, with a water content of 7–8 per cent., a figure which is lower than that for maximum density by 4–5 per cent.

The cone resistance is always carried out on specimens containing no oil. In view of the fact that the oil does not wet the soil particles, possesses no binding properties, and is present in relatively small quantity, it contributes nothing to the load-bearing capacity. As already stated, the essential function of the oil is merely to restrict the capillaries of the soil mixture.

The Behaviour of Different Soils.

Figs. 4 and 5 must not be regarded as typical of soils in general. They refer to only one soil. If soils have common properties they are manifest only on the broadest lines. The range of water contents at which useful load-bearing capacity is obtained is usually 5–12 per cent. to within about 1 per cent. at either end, but the trend of the load-bearing capacity between these limits varies greatly as between different soils. The reaction of the addition of sand on the maximum load-bearing capacity cannot be predicted. This is not to infer any mysterious properties for different soils. The complex nature of soil does not need any emphasis. Any aspect of the study of soil is, in the present state of our knowledge, fraught with anomalies, for which there is no satisfactory explanation.

By way of illustration, two soils will be discussed in some detail.

TABLE II.

Grading.		A Surrey soil.	An Essex soil.
		%.	%.
	Smaller than 2 μ .	3·6	4·1
Larger than 2 μ	,, ,, 5 μ .	1·1	9·7
,, ,, 5 μ	,, ,, 20 μ .	12·3	8·8
,, ,, 20 μ	,, ,, 50 μ .	13·0	19·2
,, ,, 50 μ	Passing 200-mesh .	15·5	10·4
Retained 200-mesh	,, 85 ,, .	26·5	12·0
,, 85 ,,	,, 36 ,, .	23·5	11·0
,, 36 ,,	,, 18 ,, .	2·0	6·0
,, 18 ,,	. . . . .	2·5	18·8

The above gradings were carried out without pretreatment of the soils. In the following gradings the soils were treated to remove organic matter and to deflocculate the clay particles.

TABLE III.

Gradings by Sedimentation before and after Deflocculation.

	A Surrey soil.		An Essex soil.	
	Before treatment.	After treatment.	Before treatment.	After treatment.
	%.	%.	%.	%.
Smaller than 2 μ .	3·6	15·1	4·1	10·8
Larger than 2 μ } Smaller than 20 μ } .	13·4	19·0	18·5	23·4
Larger than 20 μ } Smaller than 50 μ } .	13·0	16·3	19·2	22·1
Total smaller than 50 μ .	30·0	50·4	41·8	56·3

The pretreatment process has, it will be seen, increased the amount of material smaller than 50 μ by nearly 70 per cent. in the case of the Surrey soil, whilst the Essex soil has had its content of similar material increased by only about 30 per cent.

The inference is that, in its original state, the Surrey soil is in the more flocculated condition. This presumably means that in this soil the pore spaces are larger in size and smaller in number.

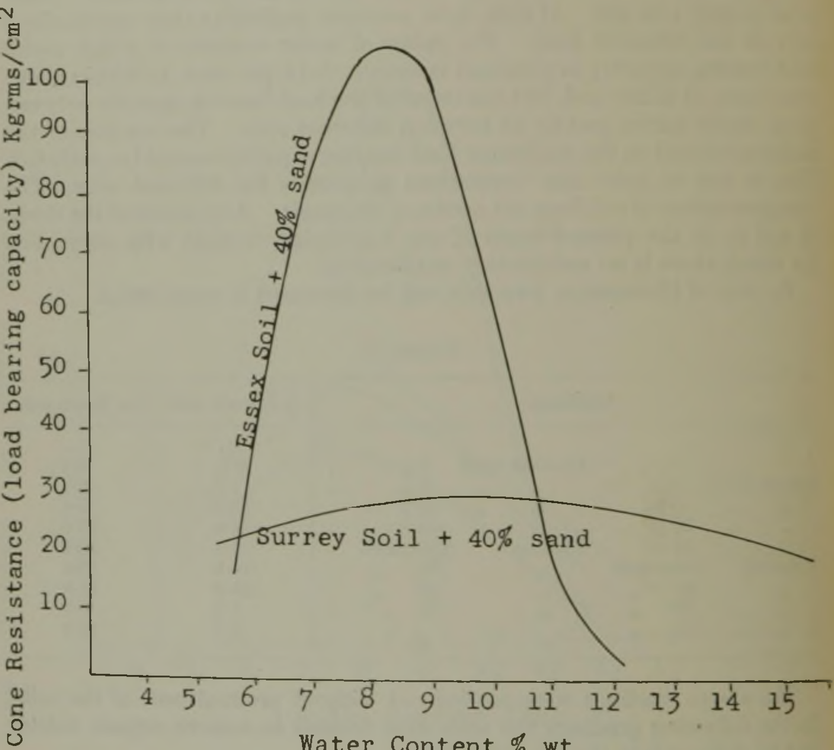

FIG. 6.

An increase in the pore size and a decrease in the number of pore spaces portend a decrease in the sum total of the capillary forces, and therefore a decrease in the cohesive strength. A decrease in the load-bearing capacity may therefore be expected. This expectation is amply fulfilled by the figures in Table IV, which were obtained on mixtures prepared from these soils.

The load-bearing capacity of the Surrey soil is seen to be almost unaffected by changes in water content until the saturation point is approached. On the other hand, in the case of the Essex soil the correlation of the two factors follows a definite curve with a well defined maximum.

Both these soils were top-soils, and the discussion of their differences has concerned only the constituents passing 200-mesh. It might be argued that the coarser fractions play their part, but similar differences

TABLE IV.

Load-Bearing Capacity of Mixtures of 60 *Per Cent. Soil and* 40 *Per Cent. Sand.*

Surrey soil.		Essex soil.	
Water Content.	L.-B.C. Kgm./cm.²	Water Content.	L.-B.C. Kgm./cm.²
%.		%.	
5·5	22	5·9	17
7·4	27	6·3	33
10·0	27	8·1	105
11·4	27	10·8	30
16·6	22		

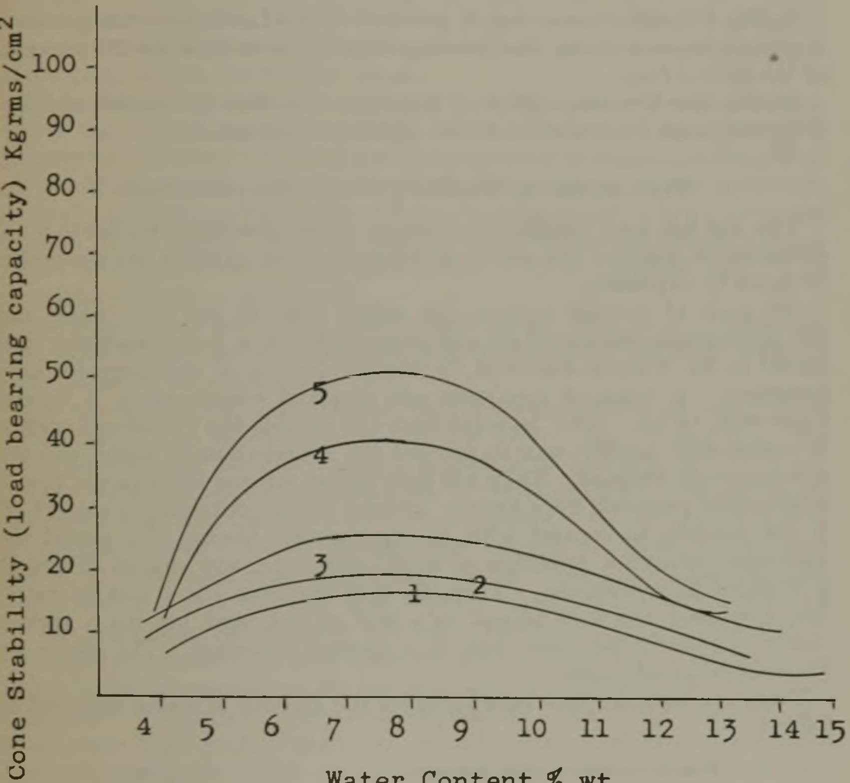

FIG. 7.

1. Original Soil.
2. Plus 10% Surrey Clay.
3. Plus 20% Surrey Clay.
4. Plus 10% L'shire Clay.
5. Plus 20% L'shire Clay.

can be found where the coarse fractions are kept constant and different mixtures are produced by adding different clays to the same sand.

Fig. 7 illustrates the result of adding first 10 per cent. and then 20 per cent.

of each of two clays to the same sand. The gradings of the clays are given in Table V.

TABLE V.

Gradings of Clay (not pretreated).

	A Surrey clay.	A Lancashire clay.
	%.	%.
Smaller than 5 μ .	5·5	29·2
Larger than 5 μ ,, ,, 50 μ .	23·5	46·0
,, ,, 50 μ ,, ,, 200-mesh .	14·0	5·0

In Fig. 7 it will be seen that 10 per cent. of the Lancashire clay produces a greater increase in the load-bearing capacity than does the 20 per cent. of the Surrey Clay.

In this case the composition of the coarse fractions is constant and any difference must be attributed to the added fine fractions.

Water Resistivity (Capillary Water Absorption Test).

This test has been designed to examine, under conditions similar to those obtaining in practice, the ability of the treated soil to resist the absorption of water by capillarity.

400 gms. of the soil mixture are mixed with 10 per cent. water and the appropriate amount of oil and consolidated in a 2-inch-diameter steel mould in the manner described for the preparation of specimens for cone resistance. A series of specimens are prepared containing 2, 3, 4, and 5 per cent. of oil. After removal from the moulds the cylindrical surface is coated with paraffin wax to prevent the evaporation of water, and the specimens are weighed. They are then stored for one week in the humid atmosphere provided by a loosely covered vessel containing water which is not actually in contact with the specimens. During this period the specimens achieve a condition of equilibrium, and any change in weight is recorded by re-weighing. Normally they lose from 1 to 2 gms. of water. The specimens are then placed on a bed of wet sand bearing a surface excess of water a few mms. deep in a covered container. The specimens are weighed at intervals.

Tentative maxima have been fixed for the amount of water absorbed as follows :—

Water absorption after 2 weeks . . .	15 gms.
,, ,, ,, 4 ,, . . .	20 gms.

The test has been continued for much longer periods in many cases. Normally the water absorbed by a satisfactory specimen is less than 10 gms. in 4 weeks, and even after 6 months does not greatly exceed that figure. Specimens containing no oil absorb up to 20 gms. in 24 hours and collapse in about 48 hours.

It is rare that the addition of oil in quantity greater than 3 per cent. weight is accompanied by a further increase in water resistivity. Frequently 2 per cent. weight suffices to impart adequate water-resistant properties.

In Fig. 8 specimen *A* is a cylinder of stabilizer soil before the C.W.A. test and specimen *B* a similar one after three months in contact with water. *B* has suffered no visible change. Specimen *C*, of soil containing no stabilizer, has collapsed after 36 hours in contact with water.

Practical Trials.

The process calls for no equipment which is not already available. The most important details concern the mixing and consolidation. Mixing must be thorough, in order to ensure the disintegration of the clay, if this has to be used, and the uniform distribution of the clay and the oil. Double, opposed paddle-mixers have been found to be satisfactory. When using this type of plant the sand and clay are boxed into the delivery hopper from heaps alongside. The oil is added in the mixer, and with materials of water content in the neighbourhood of 15 per cent. the mixing time is of the order of 1–3 minutes per batch.

If conditions are such that mixing is carried out at a moisture content within the desired range, spreading may be carried out straight away. If, however, the water content is above the permissible maximum, the mixed soil should be spread in a windrow until a desired moisture content is reached. Normally the process will involve the evaporation of only a little water and a small time delay. Any of the load-bearing-capacity/water-content curves presented illustrate the wide range of water contents over which consolidation may be performed.

One trial carried out during 1940 in this country warrants a full description, since it has been an unqualified success, despite deficiencies in almost every phase of its preparation.

The site was on old pasture land, and the soil a clayey silt some 10–15 inches deep. The sub-soil was stiff yellow clay. The whole site is very badly drained, and the water-table is almost at ground level in the winter.

The top 4 inches was discarded in order to eliminate vegetable matter as far as was practical, and the next 6 inches was scarified. Owing to the demands of emergency work a double paddle-mixer was not available, and recourse had to be made to a small single shaft mixer. Very little disintegration occurs with this type of plant, and in order to compensate to some extent for this drawback the scarified soil was passed through a $\frac{1}{4}$-inch screen. Its moisture content was then approximately 9·0 per cent. Pit sand was added in the proportion of 60 per cent. soil and 40 per cent. sand, and 3 per cent. of stabilizing oil was incorporated. The mixed material contained some 20 per cent. of unbroken nodules of soil completely covered with finer soil mixture, in which the oil was well distributed. These unbroken nodules occasioned some anxiety, but the view was taken that their number was such that in general, they would each be surrounded by oiled soil, and so would not constitute a real danger, a view that was justified in the light of subsequent observations. It was decided to lay the treated material to a consolidated depth of 6 inches and to consolidate in two layers of equal thickness. The first layer was spread as mixed, a procedure which proved to be a technical error. The work was carried out in hot weather in July, and after 24 hours the moisture content had fallen to 4·0 per cent., 3·0 per cent. below the optimum and 1·0 per cent. below the minimum for design load-bearing capacity. Attempts were made to remedy this defect by remixing with water, but such were the water-resistant properties of the treated soil that this proved to be impossible. Long-continued agitation in the mixer failed to achieve proper distribution of water, and efforts to spray the site with water and to rake it in availed nothing. As these efforts established that the soil obviously possessed excellent water-resisting properties, the work was continued. The material for the second layer was mixed at a higher water content (11 per cent.), and placed in heaps until sufficient for the whole layer had been prepared for laying.

Rolling constituted the next departure from sound practice. Fine mixes such as these do not respond to compaction by the conventional type of rollers, which tend to produce, if they can be used at all, only a relatively thin consolidated surface layer, the bulk of the thickness benefiting not at all by the treatment.

This type of work calls for the use of a " sheep's foot " roller, or a roller comprising a number of pneumatic-tyred wheels mounted side by side on a single shaft. Such rollers produce adequate compaction by cutting through the loose layer and building up compacted material from the bottom upwards.

Equipment of this type was not available, and such compaction as the site received was produced by a 2½-ton roller. The site was now sampled in eight different places. The mean of the moisture-content determinations was 8·1 per cent.

Cone-penetration tests carried out on the actual surface indicated the load-bearing capacity to be 17 kgms./cm.^{2}, whereas according to preliminary laboratory tests it should have been 28. These figures indicate, in some measure, to what extent compaction had been deficient, but nevertheless the results have been very good.

The site was sealed by the application of a sand carpet 1½ inches thick.

For the purpose of checking changes in water content, specimens have been cut from throughout the total treated thickness. The results are shown in Table VI.

TABLE VI.

Date.	Moisture content.
	%.
17.7.40	8·0
30.7.40	6·1
10.9.40	5·1
1.11.40	4·6
7.11.40	4·4
18.12.40	4·6
21.1.41	6·2
20.2.41	6·1

The weather had been unusually dry up to 10.9.40, when wet weather set in. Rain was almost continuous during the early part of November, but the water resistivity of the soil is well demonstrated by the figures shown. On one occasion, towards the end of November, when the site was sampled, the water content of the sub-soil immediately below the stabilized layer was 30·4 per cent., while that of the stabilized soil was 4·35 per cent.

The line of demarcation was perfectly sharp. On this occasion, within 5 minutes of removing the sample core the hole was half filled with water which had seeped up from below. This indicated that the water table was above the bottom of the stabilized layer.

It will be noted that the water content of the treated soil had actually fallen, and it may occasion surprise that while water can obviously escape from the stabilized soil, it does not re-enter the soil to any significant extent.

When water is present in quantity insufficient to saturate, it can be removed only by virtue of evaporation—that is, in the vapour phase. But re-entry must be in the liquid phase, in which phase the water-repellant properties of the stabilized soil are adequate to reduce the rate of ingress to an insignificant minimum.

These results are particularly encouraging, since they were obtained in spite of conditions which, at one time, seemed likely to prejudice complete success. This should not be taken as licence to ignore the proper precautions to ensure good incorporation of the ingredients and optimum consolidation, but should serve as a reassurance that soil stabilization is a process which, when approached on sound, well-founded lines, has a promising future.

THE INSTITUTE OF PETROLEUM.

ASPHALTIC BITUMEN GROUP.

TUESDAY, MARCH 18, 1941.

J. S. JACKSON, Esq., in the Chair.

A MEETING of the Asphaltic Bitumen Group was held at the Royal Society of Arts, John Adam Street, London, W.C.2, on Tuesday, 18th March, 1941, at 3 p.m., MR. J. S. JACKSON occupying the Chair.

The following papers were presented and discussed: "Soil Classification and its bearing on Soil Stabilization," by A. H. D. Markwick, M.Sc., A.M.Inst.C.E., and "The Use of Bitumen in Soil Stabilization," by H. Gardner, B.Sc., A.I.C. (see pages 313 and 329).

DISCUSSION.

THE CHAIRMAN said that he would like to remind members that the group had been trying to tackle the subject of soil stabilization along logical lines. It was too broad a subject for any man to deal with in one paper, and a series of papers had therefore been arranged. They had had one dealing with past experience; Mr. Markwick had dealt with methods of testing, and Mr. Gardner with experiments with a new process.

He was beginning to regret that at some stage a paper on sampling had not been arranged, because the problems connected with the proper sampling of soil were obviously considerable. Many of Mr. Markwick's tests would be misleading if the sample were not thoroughly representative of the material on the site. The soil would naturally vary from place to place on the site and, moreover, the development of the site would probably produce further variations. Possibly at some future date someone would accumulate sufficient information to present a paper on the subject of systematic sampling. It seemed desirable that the soil should be taken at a certain moisture content, taken to the laboratory without change of moisture content and examined in that condition. This is important, since certain characteristics of the soil might be permanently altered by heat treatment.

He would like to hear comments on Mr. Gardner's interesting observation that the optimum load-bearing capacity was usually obtained between water contents of 7 per cent. and 9 per cent. This observation was particularly interesting, since it did not seem to matter what variations there were in the grading or the nature of the soil.

It seemed to him a pity that Mr. Gardner had not recorded fuller information concerning the Surrey and the Lancashire clays. It would be distinctly interesting to apply Mr. Markwick's methods to those samples, since the results might possibly provide an explanation of their very different behaviour.

Mr. Gardner said that in the water-absorption test the sample should not take up more than 15 grams of water. Could that figure be usefully expressed as a percentage of water calculated on that particular quantity of earth?

What was most striking about Mr. Gardner's paper was that it was possible to take a soil and stabilize it with 3 per cent. of oil. That was a very remarkable statement, and certainly the experimental evidence seemed to support the view that the soil was really stabilized. A good deal of previous work had been done with relatively large percentages of oil, but it was felt that such propositions were not practical. Presumably the small percentage of oil used in the process described by Mr. Gardner was due to the fact that the process depended on the plugging of capillaries and that no attempt was made to coat the particles of soil.

MR. C. F. JACKSON was struck by the confusion which already existed in connection with the nomenclature of this subject. What was "stabilization" and what was "soil"? Mr. Markwick, he thought, regarded all material on the surface of the earth as soil. He would like to ask him whether he had considered the definition of "soil" in, say, the Oxford Dictionary. Would he indicate how the term was to be defined? It might be reasonable to consider all materials, including all aggregates used for roads, as soil, but he wondered whether such a definition was not rather wide. Mr. Gardner obviously restricted the term "soil" within much narrower limits. He did not know who the authorities were who should lay down the international nomenclature, or the nomenclature to be used in this country, but it seemed to him that it would be useful if that authority would decide what was "soil."

On the question of the binder, the process described by Mr. Gardner consisted of plugging the capillaries with oil, and not of binding the particles together, and the use of the term "binder" in the case of this particular process was really quite wrong. It seemed to him that clear, generally accepted definitions of such terms as "soil," "stabilization," and "binder" were essential.

Mr. A. H. D. Markwick replied that on the question of definitions, it was very largely a matter of opinion, but he and others had adopted the definition that "soil" included all materials which had disintegrated from rocks. It was easier to make the term "soil" cover all the superficial deposits, and then classify these into gravels, boulders, and so on, although he quite agreed that to classify boulders as soil seemed to be "drawing the long bow." The definition which he had given, however, was one commonly used in soil mechanics.

The question of the "binder" raised a difficulty, because in the case of the sand-clay roads that were built in the United States the clay was referred to as a "binder." That was probably correct, because the clay was there to give cohesion, and in the same way in a sand mix the bituminous "binder" was there to give cohesion. In the process described by Mr. Gardner it was the clay that gave the cohesion, as he understood it, and the oil was merely a waterproofing agent.

Mr. H. Gardner said that the water was the binder and no other binder was necessary in this process; he hoped that he had made it clear that the stabilizer was not a "binder" in any sense of the word. It must not act as a "binder," because if it did it would at least partly wet the soil particles and disturb or displace the capillary water film. All the laboratory work, except the capillary water-absorption test, was done on specimens containing no oil at all, but on specimens containing water only. The addition of the stabilizer did not affect the load-bearing capacity at all.

The Chairman asked what Mr. Gardner's binder was—the clay or the water or both?

Mr. Gardner replied that in the case of the clay particles the binder was the "bound" water film, contributing a cohesive effect; so that in the case of the coarser particles, the silt, it was the "free" water film adhering to the surface of the particles and giving rise to capillary forces. The coarser material gave frictional resistance to movement by virtue of the angular character of the soil particles.

Mr. C. F. Jackson remarked that Mr. Markwick—quite legitimately, he thought—regarded all materials which tended somehow or other to give a surface which would take a load as examples of stabilization; in other words, whether bitumen was used to produce macadam, or asphalt or cement was used to produce concrete, the resulting products would all be regarded by him as examples of stabilization.

If rock in its natural state were coated with bitumen, would he regard this as stabilization?

His point was that in Mr. Markwick's definition of stabilization—which he was not criticizing—the "stabilizer" might or might not be acting as a "binder." If the "coating" of sand with an oil constituted stabilization, the term "stabilization" was immediately put on a much broader basis than Mr. Gardner suggested. On the other hand, the method of obtaining stabilization described by Mr. Gardner did not include the use of a binder, but only, should he say, a "plugger"; but Mr. Gardner called that process "soil stabilization." There was obviously a certain amount of confusion.

Mr. Markwick replied that in "soil stabilization" soil must obviously be the principal constituent, and a product based on crushed rock would not be regarded as an example of "soil stabilization," since such aggregate was a manufactured product.

Mr. Gardner said that he seemed to have been misunderstood. When he defined soil stabilization he was not attempting a complete definition; he was delimiting the discussion by defining one aspect of soil stabilization with which they were concerned that afternoon. There were many other different processes which were nevertheless soil stabilization, in that they enabled soil to do a better job. If one injected a fine bituminous emulsion into the deep sub-soil underneath a bridge pier, one was stabilizing the soil, in that the soil was enabled to do its job better, or to do it over a greater range of adverse conditions, and he suggested that from that point of view it was soil stabilization; but he could not deal with the whole of a very wide subject on such an occasion as the present one, and he had defined soil stabilization in somewhat narrow terms for the purpose of the discussion.

General Wace said that Mr. Markwick had mentioned a number of tests to which he submitted soil, but only one of those tests, as far as he remembered, had been taken up by Mr. Gardner, and that was the test for the grading of the soil. All the other tests, of plasticity and liquid limit and so on, did not seem to him to lead anywhere; he could not gather that they led anywhere. He had read a number of papers in which all sorts of wonderful formulæ were given, with liquid limit results and plastic limit results and so on, but when one looked to see how much binder to put in one was told "take 3 per cent.," and all those formulæ were just forgotten. Mr. Gardner was admittedly aiming at getting stabilization of the soil with one particular product by one particular process, but he had a very simple system of testing; he first got his grading, and then the load-bearing capacity, and he obtained his answer. Mr. Markwick had not touched on the load-bearing-capacity test. If such tests as the plastic limit and the liquid limit and so on were necessary, how was it that Mr. Gardner obtained such an excellent answer without any regard to them at all?

Mr. Markwick said that the answer was that as a rule they did not do all the tests. The tests that were most commonly used were the liquid and plastic limits tests; and, as he explained when showing the slides, they had a very intimate relation to the mechanical analyses. They were really another way of telling exactly the same story, but the mechanical analyses were troublesome to do and were time-consuming whereas the index tests could be done much more quickly and easily.

If the American Public Roads Administration classification were used, other tests had to be done when there was doubt as to the group to which a soil belonged; but the liquid and plastic limits and the difference between them, which was known as the plasticity index, told most of the story about the soil. They told how much water was necessary to get it into a really liquid state, and that really indicated the amount of colloids.

The Chairman asked whether that knowledge could be translated into practice. Did it help to indicate how much binder or stabilizer had to be added?

Mr. Markwick replied that it did. With regard to the graded mix type, the grading of the soils within certain limits had to be obtained, and the clay that was added as a binder had to be of a certain quality, which followed directly from these tests. With regard to the other types of stabilization, first of all whether the soil was suitable at all for stabilization depended on the amount of material finer than 200 mesh. The liquid limit was obtained entirely for that purpose. The formulæ which he had quoted for determining the amount of bituminous binder, depended on the grading; so much was added for the amount passing the 200-mesh sieve, so much for the amount passing the 7-mesh sieve, and so on.

Mr. Mitchell asked whether the difference between Mr. Markwick and Mr. Gardner was not that Mr. Markwick was looking at the matter from the American standpoint, where soil stabilization was probably carried out with dry soil, as against Mr. Gardner's treatment of wet soil.

Mr. Markwick replied that that was not so; the American processes of bituminous stabilization were done very wet, and, as he saw it, it was the merit of the process described by Mr. Gardner that he got over the serious difficulties met with when the wet process had been tried in this country, by doing it very dry. Any soil when it was sufficiently wet was extremely soft, and the water had to be got rid of before it would bear any load. The only way of doing that was evaporation, so that one relied on a hot summer; but if water was not put in, it did not have to be got rid of, which was very much better, if a satisfactory mix could be obtained.

Mr. Hope said that Mr. Gardner had been privileged to have a very fine summer. That was a very limiting factor to soil stabilization in this country. He would like to ask Mr. Gardner a little more about this stabilizer. He spoke of "oil," but "oil" covered a wide field. He would like him to give an illustration of the type of petroleum product which was suitable for use with these damp crusts or soils. He did not ask for a specification. He would also like to ask Mr. Gardner what his experience was as to the effect of these soil mixes on the wear and tear of plant. When he worked with aggregates already carrying about 8 per cent. of moisture and added a fairly glutinous, golden-syrup-like binder—or, in Mr. Gardner's case, stabilizer—his experience had been that the wear factor was appreciably increased, to an extent which would make it interesting to know whether Mr. Gardner had any observations to make on the modifications of standard plant suitable for the mixing of these crusts which were taken for stabilization.

Mr. Gardner, dealing first with the question of plant, said that undoubtedly there was more wear with the sandy mixtures on the conventional plant than there was with coarse aggregates, and he did not see how that could be avoided; but so far this amount of wear had not caused any catastrophic results. For the past 12 months sand mixes had been made on a conventional plant, and he was not aware that that had caused any plant failure.

He said that the oil used was a petroleum residual treated so that it would not "wet" wet sand or wet soil particles, and further treated so that when in position in the capillaries it became rigid. He believed that it could be regarded as somewhat revolutionary; at any rate the conception of not adding a binder at all was revolutionary.

Dealing with the Chairman's remarks about the capillary water-absorption test, on the average cylinder the maximum amount of water, 20 grams, was about 5 per cent. on the cylinder, but an expression of that increase in weight as a percentage was misleading. It was impossible to make all those cylinders up to the same weight. If the water were evenly distributed throughout the cylinder it could be safely expressed as a percentage, but there was a falling off in the proportion of water from the bottom to the top of the cylinder, and therefore it was probable that a cylinder of half the height might absorb just as much water, and that would double the percentage. It was therefore expressed as the total weight absorbed by the cylinder.

Mr. Kelly remarked that he was interested in the impact instrument which had been shown, and which seemed to show quite remarkable fluctuations in the load-bearing capacity. Could the peak curve be brought down with the Bentonitic clay?

Mr. Gardner replied that the peak could be altered by grading, but grading and water content were interdependent, and in general one could not be altered without altering the other. If the grading was altered, a different load-bearing capacity, and probably a different useful water-content range would be obtained. In general, the finer the materials the lower was the lowest water content at which they could be consolidated at all. Coarse materials had short useful water-content ranges, but finer ones had longer ones.

Mr. Gardner added that he had had very limited experience of bentonites. They had many qualities which were not found in ordinary, naturally-occurring soil clays; thixotropy, of course, was the principal property of bentonite, which, while it was present in an ordinary clay, was not present to any significant degree, especially over the significant water-content ranges.

On the motion of the Chairman, a vote of thanks was accorded to the two authors for their excellent papers, and the proceedings then terminated.

MEANS OF IMPROVING IGNITION QUALITY OF DIESEL FUELS.*

By E. M. Nygaard, G. S. Crandall, and H. G. Berger.

Summary.

The increasing use of high-speed diesel engines demands fuels of improved ignition quality. The majority of straight-run fuels, excepting those derived from highly aromatic or naphthenic crudes, possess an adequate ignition quality for present-day requirements. However, the increasing demand for high anti-knock fuels for gasoline engines may utilize higher proportions of these stocks in cracking processes. This, coupled with growing markets for diesel fuels of high ignition quality, may necessitate the utilization of stocks of as poor ignition quality as 25 cetane number in the production of diesel fuels.

The refiner has at the present time two distinct problems in order to provide diesel fuels of satisfactory ignition quality: one is the raising of fuels of poor ignition quality (about 25 cetane number) to 50 cetane number; the other is the increasing of fuel of slightly sub-standard ignition quality (40–49 cetane number) to 50 cetane number. A third problem may arise, due either to competition or engine demand—that of producing premium fuels of higher than 50 cetane number. The second and last of these problems may be solved by the use of small amounts of materials added to the fuels to improve their ignition quality. The problem of raising a 25-cetane-number fuel to 50 cetane number is comparable to raising a 24·5-octane-number gasoline to 68 octane number with tetraethyl lead. This procedure would be both impracticable and uneconomical with either gasoline or diesel fuel.

Since the problem of raising a 25-cetane-number fuel to a minimum requirement of 50 cetane number cannot be solved practically nor economically by the use of fuel additives alone, solvent treating, or a combination of solvent treating and utilization of fuel additives, may be a happier, but still costly, solution to the problem.

Introduction.

The increasing use of high-speed diesel engines demands fuels of improved ignition quality, and the ever-widening market for fuels of higher octane number for automobile and airplane engines requires gasolines of superior anti-knock quality. The fuel characteristics demanded by the two types of engines are by nature opposed to each other. As a result, any cracking process designed to produce fuels of high octane number would tend to yield diesel fuels of poor ignition quality. A brief comparison of the combustion processes in the gasoline and diesel engine will clarify this point.

In the gasoline engine the fuel and air are mixed, compressed in the cylinder, and ignited by means of a spark. Efficient burning of the fuel to yield the maximum power and smooth performance depends on the progressive burning of the fuel–air mixture from the point of ignition to the extremities of the combustion chamber. Spontaneous ignition of the charge ahead of the flame-front produces knock, with consequent loss of power, overheating of the motor, and inferior performance.

On the other hand, in the diesel cycle the air to support combustion is

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* Paper received 6th March, 1941.

first compressed in the cylinder, and into this hot compressed gas the fuel is injected. Smooth performance here depends on immediate, spontaneous ignition of the fuel as it is injected, otherwise a large proportion of the fuel ignites at once, resulting in a too-rapid rise in pressure. This causes rough running, overheating of the motor, and excessive peak pressures.

From the very nature of the two combustion processes it can be seen that the types of hydrocarbons possessing high ignition temperatures, such as unsaturates, aromatics, *cyclo*-paraffins, and highly branched paraffins, which are best suited for high-quality gasoline, are undesirable constituents for diesel-engine fuels. Straight-chain paraffins possessing relatively low ignition temperatures operate much better in diesel engines. It is a well-known fact that straight-run products contain hydrocarbons of the type best suited to perform well in the diesel engine, whereas cracking processes diminish the concentration of these compounds and increase the proportion of hydrocarbons ill-suited for use in this type of engine.

General Discussion of Problem.

As long as sufficient quantities of straight-run products can be diverted from cracking processes to meet the requirements of diesel engines, there should be little difficulty in supplying fuels of adequate ignition quality, but if the supply of those products becomes inadequate the situation would be altered. Even straight-run products originating from highly aromatic and/or naphthenic crudes do not meet the ignition-quality requirements of modern high-speed diesel engines. If, therefore, the time should come when both gasoline and diesel fuels must be derived from cracking operations, other means must be employed to provide diesel fuels of adequate ignition quality. It should be pointed out that a limited number of selected charging stocks in spite of yielding motor fuels of high octane number also produce diesel fuels of satisfactory ignition quality. There are, however, many more cracking stocks which produce diesel fuels of inferior ignition quality. This latter class of fuels must be improved in this respect by some means, such as blending with straight-run fuels of superior ignition quality, solvent treating, hydrogenation, or resorting to the use of additives. The latter are substances which are added to the fuel to improve its ignition quality or, less frequently, are added to the inducted air to accomplish the same result. In anticipation of possible future demands for premium-quality diesel fuel, the problem of preparing such fuels from fuels of a good ignition quality by similar means to those listed above must be considered.

The ignition quality of a diesel fuel is usually expressed in terms of its cetane number, just as octane numbers are used to designate the antiknock properties of gasoline. Cetane numbers are determined according to the method given in *A.S.T.M. Proc.*, 1938, **38,** I, 392. Various other methods of determining ignition quality have been proposed. Most of these methods, such as the diesel index, viscosity-gravity constant, etc., may be calculated from physical constants and are applicable only to straight hydrocarbon mixtures. However, in the last analysis the behaviour of the fuel in a diesel engine is the deciding factor in determining its suitability as a fuel.

Thus far the ignition quality of a diesel fuel has been defined solely in terms of its cetane number. In order properly to relate this number to the combustion process in the diesel engine, it will be necessary to examine the latter in more detail. According to Ricardo,[1] the combustion process in a diesel engine takes place in three distinct phases. The first is a delay period, during which fuel is admitted to the combustion chamber but practically no ignition takes place. During the second phase ignition takes place and the accumulated fuel burns rapidly, giving a sharp pressure rise. In the third phase the fuel burns as it enters the cylinder from the injection nozzle. During the delay period the pressure in the cylinder follows the compression line, during the second stage there is a rapid uncontrolled pressure rise as the accumulated fuel burns, and in the third stage there is a gradual pressure rise controlled by the rate of fuel injection. It is readily seen that the duration of the delay period, which determines the cetane number of a fuel, is an important factor in the smooth operation of a diesel engine. In cases where the delay period is extremely long, a large portion or all of the fuel may enter the combustion chamber before ignition occurs. Once combustion starts, it will spread throughout the chamber, resulting in a rapid pressure rise and excessive maximum pressure, which will be evidenced by the phenomena known as knocking and rough running. The delay period may even be so long that misfiring occurs. This is due to the air–fuel mixture being cooled below its ignition point during the expansion stroke of the piston. With a short delay period only a minor portion of the fuel enters the combustion space before ignition takes place. This results in a less rapid rise in pressure, followed by a smooth supply of power during the final stage of the combustion. A short delay period is particularly necessary for high-speed engines in which the crank-angle change for any given delay period (measured in milliseconds) is greater than for engines of lower speed. This condition enables more unburned fuel to accumulate in the cylinder of a high-speed engine prior to ignition, with the above-mentioned ill effects on its performance. Therefore, high-speed engines are likely to be more critical of ignition quality than those of lower speed.

Since the ignition quality of diesel fuels is one of the refiners' chief concerns, it is well to inquire still further into the relation between the injection period and the delay period and to what extent the latter can be reduced. Table I is given to show for specified engine speeds and compression ratios the relation between cetane number and delay, the latter expressed in degrees crank angle and in milliseconds. It can be inferred from Nos. 1, 2, 5, 10, and 11 (Table I) that in an engine similar to the C.F.R. testing engine operating at 900 r.p.m. the delay period cannot be reduced below a value of approximately 1 millisecond, the equivalent of 4–5° crank angle. Even at extremely high compression ratios (Nos. 10 and 11), which would favour a short delay period, it will be noted that the delay period is still 0·9 and 0·93 milliseconds for fuels of 100 and 55 cetane numbers, respectively. From these data it would appear that nothing is to be gained by utilizing fuels above 55 cetane number to decrease the duration of the delay period in this engine. It should be pointed out, however, that at higher speeds, and under load, there is evidence that the delay period can be reduced below the 1 millisecond minimum at 900 r.p.m.

TABLE I.

Relation between Cetane Number and Delay Period at Various Engine Speeds and Compression Ratios.

No.	Cetane No.	Compression ratio.	R.p.m.	Original delay period.		Decrease in delay due to pilot injection.		Final delay period.		Reference.
				Degrees crank angle.	Milliseconds.	Degrees crank angle.	Milliseconds.	Degrees crank angle.	Milliseconds.	
1	55	15·8 : 1	900	6	1·11	1	0·19	5	0·92	2
2	55	15·8 : 1	900	9	1·67	3	0·56	6	1·11	2
3	55	15·8 : 1	900	12	2·23	3	0·56	9	1·67	2
4	Not given	15·8 : 1	900	9	1·67	1	0·19	8	1·48	3
5	,,	15·8 : 1	900	8	1·48	2	0·37	6	1·11	3
6	,,	Not given	1000	14	2·4	—	—	—	—	4
7	,,	,,	1750	11	1·1	—	—	—	—	4
8*	53	,,	900	10	1·8	—	—	—	—	—
9*	53	,,	1800	4	0·4	—	—	—	—	—
10	100	24 : 1	900	4·8	0·9	—	—	—	—	5
11	55	24 : 1	900	5·0	0·93	—	—	—	—	5
12	0	24 : 1	900	8·0	1·48	—	—	—	—	5

* Full load.

(see Table I, No. 9). In fact, depending on the type of combustion chamber and load conditions, the delay period in degrees crank angle may increase with speed, remain practically constant or diminish (see Fig. 1, reproduced from P. M. Heldt's "High-Speed Diesel Engines," 3rd edition, page 40). The inconsistency in these results is seen to be more apparent than real when it is remembered that the delay period is influenced primarily by the conditions of the air charge (temperature, pressure and turbulence), and that these factors in turn are determined by the design of the combustion chamber and the operating conditions of the engine with respect to load and speed. It is highly probable that for a given engine operating at a given speed there is a minimum delay period which cannot be reduced further by any alteration in chemical properties of the fuel. This may be due in part to a physical delay period, corresponding to the time required for the injected fuel to mix with the air charge.

In most diesel-engine cycles the duration of the injection period is anywhere from 10 up to 30 crank-angle degrees. This means that at 900 r.p.m. with a minimum delay of 5 crank-angle degrees that between one-fifth and one-half of the fuel would be injected before ignition would occur. It would appear, therefore, that engines utilizing the shorter injection periods would be quite critical of the ignition quality of fuels.

MODIFICATION OF IGNITION QUALITIES OF DIESEL FUELS CHEMICAL ADDITIVES.

In the practical utilization of ignition accelerators in the preparation of diesel fuels having the desired ignition quality, the petroleum refiner is presented with three rather distinct problems. These depend on the types of stocks that are available and the type of fuel it is desired to prepare. Thus the stocks available may consist of (1) straight-run stocks of adequate ignition quality (50 cetane number or better); (2) straight-run or cracked stocks of slightly substandard ignition quality (40–49); and (3) cracked stocks of low ignition quality (as low as 25 cetane number). The present-day specification requires 50-cetane-number fuels, but future demands may require fuels of somewhat higher ignition quality. Thus the three problems presented are (1) the preparation of 50-cetane-number fuels from substandard stocks—*i.e.*, those requiring an improvement of 10 cetane numbers or less; (2) the preparation of 50-cetane-number fuels from low-ignition-quality cracked fuels—*i.e.*, those requiring an improvement of up to 25 cetane numbers; and (3) the preparation of premium fuels from stocks of good ignition quality—*i.e.*, those requiring an improvement of 10–15 cetane numbers.

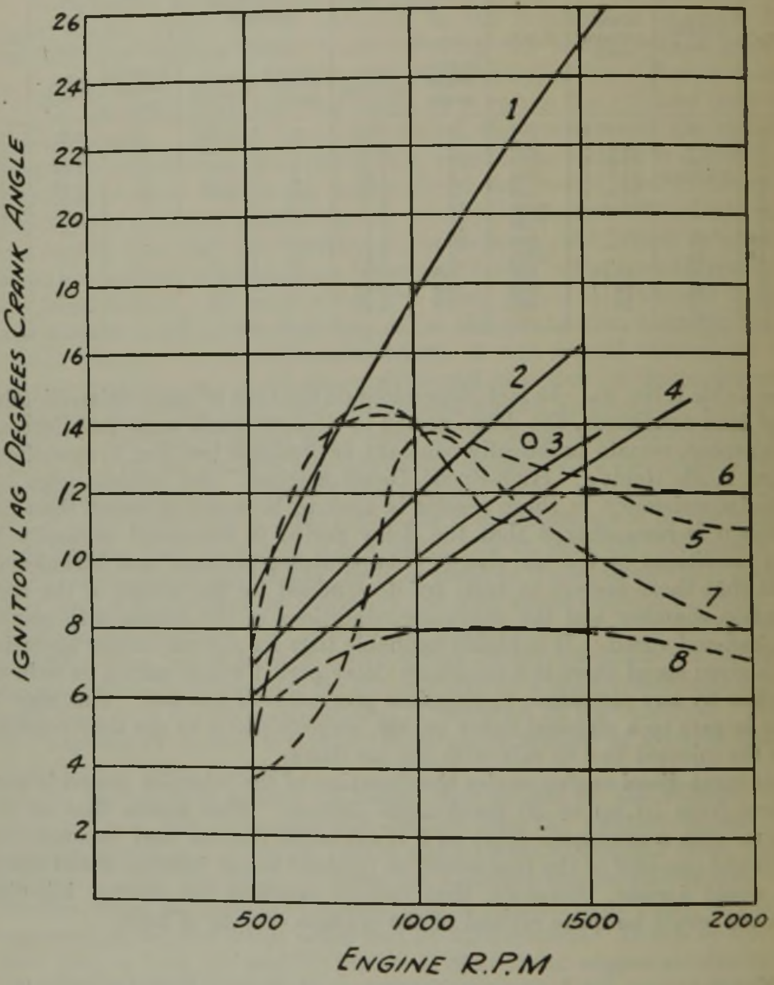

FIG. 1.

The first and third of these problems may be capable of practical solution by the use of fuel additives; however, the second case would require about 5 per cent. of even the best ignition accelerators known. This problem can probably best be solved by blending the low-ignition-quality stock with fuels of high ignition quality, or by solvent extraction. The improbability of finding any material which is sufficiently effective to be used economically to raise the ignition quality of a 25-cetane-number fuel to 50 cetane number becomes more apparent when it is considered that such a change would correspond to raising the anti-knock quality of a gasoline from 24·5 octane number to 68·5 octane number, which is a change far too great to be accomplished by even as effective a fuel additive as tetraethyl lead.

At this point it may be of interest to make a comparison of the relative efficacies of the best ignition accelerators with that of tetraethyl lead. Although the methods by which we may make this comparison seem to involve some difficulties and some unsubstantiated assumptions, it is possible to make a reasonable comparison, which indicates that the efficiencies of the two types of combustion modifiers are not substantially different. Two of these methods will be considered here. The first involves the comparison of the effectiveness of ignition accelerators in improving the ignition quality of a diesel fuel with that of tetraethyl lead in decreasing the ignition quality. The second method consists of comparing the effectiveness of the best ignition accelerators in diesel fuel with that of the tetraethyl lead in gasoline under conditions similar to those at which the latter is normally used—*i.e.*, at comparable concentrations and for comparable changes in ignition quality.

The first method is probably the simplest to use. However, it does involve the assumption that the effect of tetraethyl lead on the combustion of fuels in the diesel cycle-engine is the same as its effect on the combustion of gasoline in the Otto cycle-engine. The following table shows that the effectiveness of the two types of materials is substantially the same. The concentrations used are somewhat higher than those at which tetraethyl lead is usually used (1 c.c. T.E.L. gal. = approx. 0·2 lb./bbl.); however, the test of tetraethyl lead at 0·36 lb./bbl. concentration in diesel fuel gave an indeterminate result.

TABLE II.

Effectiveness (E) * *of Tetraethyl Lead Compared with Thionitrites* † *at Several Concentrations.*

Material added.	*E* at 0·9 lb./bbl.	*E* at 1·8 lb./bbl.	*E* at 3·6 lb./bbl.
Tetraethyl lead	−14·6	−11·4	−11·4
Amyl thionitrite	15·06	7·53+‡	3·77+‡
tert.-Butyl thionitrite	15·06	7·53	3·77

* *E* = Change in cetane number/concentration in pounds per barrel.

† See Table V.

‡ In these cases the cetane numbers of the blends were too high to be evaluated under the conditions of the test.

In the second method it is necessary to use some means of conversion of ignition characteristics expressed in octane numbers to cetane numbers or vice versa. For this purpose a chart (see Fig. 2) is used which shows the relationship between the octane- and cetane-number scales. The average slope of this curve is 1·5 octane numbers per cetane number—*i.e.*, change of ignition quality of 1 cetane number corresponds to a change of approximately 1·5 cetane numbers. By making this conversion it is then possible to calculate the effectiveness factor for tetraethyl lead in the same manner as used for the comparison of ignition accelerators.

For the purposes of this comparison, two types of application of ethyl fluid are considered: first, the use of tetraethyl lead for ethylizing base fuels to make premium-grade gasoline; second, the addition of various quantities of tetraethyl lead to catalytically cracked gasoline. For the first application nine base fuels ethylized to make 76·0-octane-number gasoline were investigated. The amount of tetraethyl lead needed to reach the required anti-knock quality was determined for each fuel. In order to get a more general figure, the results for the various fuels have been averaged, and are given in Table III. For the second application the data from numerous tests made in this laboratory on various samples of catalytically cracked gasoline are used. The average values of anti-knock rating obtained by the addition of 1, 2, and 3 c.c. of tetraethyl lead per gallon are given in Table III.

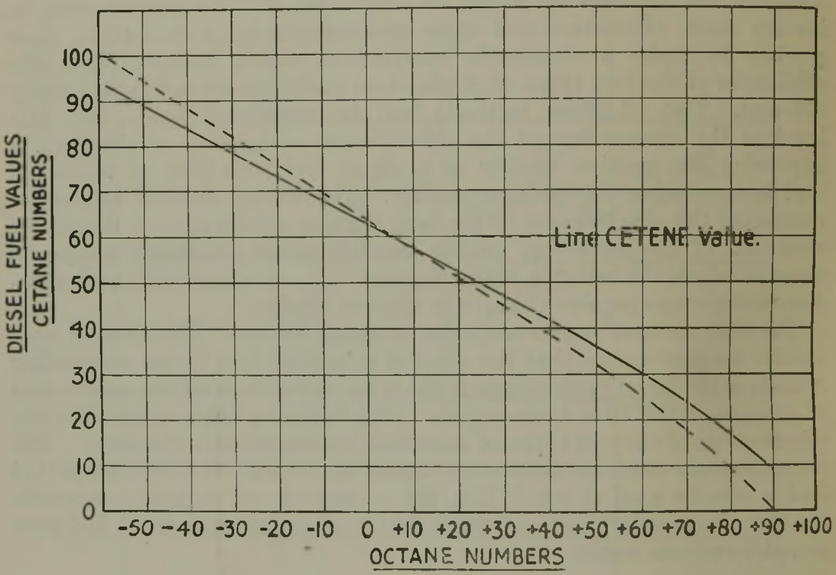

Fig. 2.

It will be noted that the change in cetane number in the case of stocks used to make premium-grade gasoline is approximately eight cetane numbers. To get this degree of improvement in a diesel fuel would require approximately 0·1 per cent. by weight of thionitrites (see Table V) which have an effectiveness at this concentration of 20·9, which is practically the same as that of tetraethyl lead. In the case of the catalytically cracked gasoline tests using 1 c.c. T.E.L./gal. (= approx. 0·06 per cent.

TABLE III.

Effectiveness of Tetraethyl Lead in Gasoline.

	Quantity of T.E.L. added.		Octane number.		Cetane number.		E.*
	C.c./gal.	Lb./bbl.	Original.	Final.	Original.	Final.	
Base fuels for premium grade gasoline	2·14 ± 0·8	0·39	63·9 ± 6·5	76·0	28	20	−20·5
Catalytically cracked gasoline	1·0	0·18	77·7 ± 1·1	85·3 ± 1·8	18·8	13	−32
,, ,,	2·0	0·36	77·7	88·1 ± 1·3	18·8	11	−21·4
,, ,,	3·0	0·55	77·7	90·0 ± 2·6	18·8	9	−17·9

* E = Change in cetane number/concentration in lb./bbl.

by weight), we have no data on the effectiveness of the thionitrites at this concentration. It may readily be seen, however, that the values for the effectiveness of 2 c.c. T.E.L./gal. are entirely comparable with those obtained on the stocks used for making premium-grade gasoline. With the effectiveness of tetraethyl lead at a concentration of 3 c.c./gal. (0·55 lb./bbl.) in catalytically cracked gasoline ($E = -17{\cdot}9$) we may compare the effectiveness of ethyl thionitrite at 0·72 lb./bbl. ($E = 15{\cdot}3$) and that of amyl and *tert.*-butyl thionitrites at 0·9 lb./bbl. ($E = 15{\cdot}06$).

Thus it may be seen that where ignition accelerators are used in comparable concentrations or to obtain comparable effects, there is no marked difference between their effectiveness and that of tetraethyl lead as used in gasoline.

The two types of combustion modifiers may also be compared on the basis of the cost for unit effect. In Table IV the estimated cost of several

TABLE IV.

Comparative Costs of Combustion Modifiers.

	Addition agent.			Cetane number.		E.§	Cost, cents/bbl./cetane-number increase.
		Cost per lb.	Concn., lb./bbl.	Original.	Blend.		
		Part A.					
		Dollars.	Average.				
1. Base fuels for premium grade gasoline	Tetraethyl lead	0·66*	0·39	28·0	20·0	−20·5	3·36
2. Catalytically cracked gasoline	,,	0·69	0·182	18·8	13	−32	2·25
		0·69	0·364	18·8	11	−21·4	3·22
		0·69	0·546	18·8	9	−17·9	3·85
3. Diesel fuel	Sulphur	0·03	1·79	50·5	58·0	4·18	0·72
4. ,,	Amyl nitrate	0·10†	1·0	56·5	71·5	4·18	2·38
5. Catalytically cracked fuel	,,	0·10†	5·0	27·0	49·0	1·23	8·15
		Part B.					
6. Diesel fuel	Tetraethyl lead	4·50	0·89	56·0	43	−14·5	31·0
7. Base fuels for premium grade gasoline	,,	4·50	0·39	28·0	20·0	−20·5	22·0
8. Diesel fuel	Chloropicrin	2·50	0·89	39·0	46·0	7·81	32·4
9. ,,	Ethyl thionitrite	1·40‡	0·36	52·0	59·0	19·5	7·2
10. ,,	*tert.*-Butyl thionitrite	7·33‡	0·36	52·0	59·0	19·5	37·6

* Calculated on the basis of 0·25 cents/c.c.

† This is the cost estimated by a commercial supplier if the material is used in large quantities.

‡ Materials cost estimated from cost of mercaptan.

§ E = Cetane number change divided by concentration in lb./bbl.

TABLE V.

Relative Effectiveness of Various Ignition Accelerators.

Ignition accelerator.	Patent information.	Fuel.	CN.	$E_{0\cdot25}$.	$E_{0\cdot5}$.	$E_{1\cdot0}$.	$E_{2\cdot0}$.	$E_{5\cdot0}$.	Cetane-number change at 0·5% by wt.
		Approx. lb./bbl.	—	0·896	1·793	3·59	7·17	17·93	—
(1) Amyl thionitrite	U.S. 2,169,186 (1939)	Straight-run	52	11·2	5·02	3·77+	—	—	—
		"	52	15·06	*7·53+*	3·77+	1·88+	—	13·5+
		Catalytically cracked	27	3·35	2·23	1·67	1·74	1·50	—
		" "	27	3·35	1·67	1·39	1·39	1·12	—
(2) *tert.*-Butyl thionitrite	U.S. 2,169,186	Straight-run	52	15·06	*7·53*	3·76	1·88+	2·44	13·5
		Catalytically cracked	27	3·35	2·51	1·12	2·51	0·89	—
(3) Ethyl thionitrite	U.S. 2,169,186 (1939)	Straight-run	52	7·81	5·02	3·76+	—	—	13·0
		"	52	12·27	*7·25*	—	—	—	—
		Catalytically cracked	—	—	1·12	1·12	1·32	1·45	—
(4) Chloropicrin	U.S. 2,200,260	Patent data	39	7·81	*5·58*	4·18	2·51	1·9	10·0
		Straight-run	52	—	—	3·9	—	—	—
		Catalytically cracked	25	—	—	1·81	1·25	—	—
(5) Amyl nitrite	U.S. 1,820,983 (1931)	Straight-run	54	—	*(5·3)*	4·46	2·23	—	(9·5)
		"	52	—	—	2·79	—	—	—
		Catalytically cracked	27	—	—	—	—	0·89	—
(6) Acetyl peroxide	U.S. 2,174,680 (1939)	Straight-run	42	—	*5·02*	4·74	—	—	9·0
		"	53	—	—	3·90	—	—	—
(7) Amyl nitrate	U.S. 2,158,050 (1939)	Straight-run	56·5	—	*(5·0)*	4·18	2·44+	—	(8·9)
	Fr. 821,211 (1937)	"	56·5	—	—	—	1·67	—	—
	Can. 384,497 (1939)	"	52	—	—	3·77	1·88+	—	—
		Catalytically cracked	27	—	—	1·39	1·67	—	—
		" "	27	—	—	2·37	1·81	1·26	—
(8) *n*-Butyl nitrate	Brit. 374,481	Straight-run	56·5	—	*(4·88)*	4·04	2·44+	—	(8·75)
	Fr. 730,208	—	—	—	—	—	—	—	—
	U.S. 2,031,497	Catalytically cracked	—	—	—	2·65	2·16	1·45	—
(9) Ethyl nitrate	Brit. 352,350 (1930)	Straight-run	52	—	*4·46*	—	—	—	8·0
	Brit. 354,398 (1930)	—	—	—	—	—	—	—	—
	Fr. 564,899 (1931)	—	—	—	—	—	—	—	—

(10) Tetralin peroxide	U.S. 2,011,297 (1935)	Patent data	42	—	*4·46*	3·90	—	—	8·0
	Ger. 651,771 (1937)	—	—	—	—	—	—	—	—
(11) Sulphur	—	Straight-run	50·5	4·18 at 0·3	*4·18*	—	—	—	7·5
		,,	42	—	3·07	—	—	—	—
		,,	56	5·58+	—	—	—	—	—
		Catalytically cracked	30	—	5·58	—	—	—	—
		Thermal cracked	36	—	2·23	—	—	—	—
(12) Diamyl disulphide	U.S. 2,177,719 (1939)	Straight-run	50	—	*4·18*	1·95	—	—	7·5
		—	42	—	3·35	—	—	—	—
(13) Tetranitromethane	U.S. 2,185,157 (1939)	Straight-run	42	—	*3·9*	2·93	—	—	7·0
		Catalytically cracked	27	—	1·12	1·25	1·18	—	—
		,, ,,	23	—	1·39	—	—	—	—
(14) *iso*Amyl mercaptan (sweetened)	U.S. 2,167,345 (1939)	Straight-run	—	3·8 at 0·4	*3·8 –*	—	—	—	7·0 –
	U.S. 2,184,440 (1939)	—	—	—	—	—	—	—	—
(15) Diethyl tetrasulphide	U.S. 2,034,643 (1936)	Patent data	44	—	(*3·7*)	3·07	—	—	(6·6)
(16) Nitrogen tetrasulphide	Fr. 764,721 (1934)	Straight-run	—	3·72 at 0·3	(*3·7 –*)	—	—	—	(6·6 –)
(17) Nitroso triacetone amine	Brit. 405,658 (1934)	Straight-run	—	—	*3·63*	—	—	—	6·5
(18) Ethyl nitrogen sulphide	—	—	—	—	*3·35*	—	—	—	6·0
(19) Acetone peroxide	U.S. 2,107,059 (1938)	—	39	—	*3·35*	2·23	—	—	6·0
	Brit. 428,972 (1935)	—	67	—	—	5·02	—	—	—
	Ger. 617,492 (1935)	—	—	—	—	—	—	—	—
	Can. 355,519 (1936)	—	—	—	—	—	—	—	—
(20) Ethyl diphenyl pentazdiene	U.S. 2,188,262 (1940)	Straight-run	—	—	*3·35*	—	—	—	6·0
(21) Ethyl xanthic disulphide (xanthogen or bis(thionocarbethoxy)disulphide)	—	Straight-run	42	—	*3·35*	3·35	1·18	—	—
		,,	42	—	2·51	1·95	—	—	6·0
		Thermal cracked	36	—	2·23	2·09	1·12	—	—
		Catalytically cracked	30	—	1·18	1·12	0·70	—	—
(22) Ethyl diphenyl triazene	U.S. 2,136,456 (1938)	—	—	—	*3·07*	1·81	0·98	—	5·5
(23) Ethyl-di-*p*-tolyl pentazdiene	U.S. 2,188,262 (1940)	Straight-run	—	—	*2·79*	1·95	—	—	5·0
(24) Di-*p*-tolyl triazene	U.S. 2,136,456 (1938)	Straight-run	—	—	*2·79*	1·39	—	—	5·0
(25) Hydrogen persulphide + sulphur	U.S. 2,206,594 (1940)	Straight-run	—	—	*2·79*	—	—	—	5·0
(26) Dibenzyl disulphide	—	Straight-run	—	—	*2·51*	—	—	—	4·5
(27) Benzyl bromide 50 + ethyl nitrate 50	Brit. 404,682 (1934)	Gasoline	19·5	—	(*2·5*)	2·09	—	—	(4·5)
	Fr. 757,326 (1933)	—	—	—	—	—	—	—	—

TABLE V—*continued.*

Ignition accelerator.	Patent information.	Fuel.	CN.	$E_{0\cdot25}$.	$E_{0\cdot5}$.	$E_{1\cdot0}$.	$E_{2\cdot0}$.	$E_{5\cdot0}$.	Cetane number change at 0·5% by wt.
		Approx. lb./bbl.	—	0·896	1·793	3·59	7·17	17·93	—
(28) Butyl thiamine	U.S. 2,218,447	Straight-run	—	—	*(2·5 −)*	2·09 (0·8)	—	—	(4·5 −)
(29) Propionyl peroxide	U.S. 2,178,327 (1939)	—	34	—	*2·3*	1·95	—	—	4·1
(30) *o*-Toluidine disulphide	U.S. 2,164,151 (1939)	Straight-run	42	—	*2·23*	—	—	—	4·0
(31) Aniline disulphide	U.S. 2,164,151 (1939)	Straight-run	42	—	*2·23*	—	—	—	4·0
(32) Phenyl-*p*-tolyl triazene	U.S. 2,136,456 (1938)	Straight-run	—	—	*2·23*	1·39	—	—	4·0
(33) Penta-methylene-*p*-tolyl triazene	U.S. 2,136,456 (1938)	Straight-run	—	—	*2·23*	1·39	—	—	4·0
(34) Di-*p*-tolyl tetrasulphide	U.S. 2,034,643 (1936)	—	44	—	*(2·0)*	1·67	—	—	(3·6)
(35) Di*iso*amyl disulphide	—	Straight-run	—	2·1 at 0·4	*(2·1 −)*	—	—	—	(3·6 −)
(36) Di-ethyl disulphide	—	Straight-run	—	—	*1·95*	—	—	—	3·5
(37) Diphenyl triazene	U.S. 2,136,455 (1938)	Straight-run	—	—	*1·95*	2·51	—	—	3·5
(38) Tetraethyl lead	—	Straight-run	—	− 14·5	− 11·4	− 11·4	—	—	− 21

of the best ignition accelerators are compared with that of tetraethyl lead. In Part A the costs are calculated on the prices of the additives when bought in commercial quantities. In Part B the costs for materials not at present available in commercial quantities are compared with that of tetraethyl lead, all based on prices of the materials purchasable in small quantities from a supplier of reagent chemicals. It is highly probable that some of these prices could be reduced considerably if a sufficient market were presented, just as has happened in the case of tetraethyl lead, which was a chemical curiosity prior to the discovery of its effectiveness as an anti-knock agent.

In Table V the most effective ignition accelerators are arranged in order of their effectiveness at a concentration of 0·5 per cent. by weight in straight-run diesel fuels. This information is taken from our own experimental data and that appearing in the patent literature. The materials are tabulated on the basis of the value of the effectiveness factor at 0·5 per cent. (*E* 0·5). *E* represents the cetane-number increase per lb. per barrel of ignition accelerator, an dis obtained by dividing the cetane-number increase by the concentration of the addition agent in lb./bbl. For example, for a material which gave a 5-cetane-number rise at a concentration of 0·33 lb./bbl., the value of *E* would be 15. From the value of *E*, the cost per bbl. per cetane-number increase can be readily obtained by dividing the cost of the addition agent by the effectiveness factor (*E*). The subscripts indicate the concentration of the addition agent for which the value of *E* is calculated. The value of *E* is not a true constant for a given material, but is dependent on various other factors, particularly the concentration in which it is used and the type of fuel to which it is added. In general, the value of *E* is higher at low concentrations, and also in straight-run paraffinic fuels. It may be noted here that the combustion of cyclic fuels is harder to modify by addition agents in diesel fuels, just as they are harder to modify in gasolines. In the table, wherever available, data are given for several concentrations and different types of fuels. However, for the purpose of classification, the values obtained at 0·5 per cent. by weight in straight-run fuels are used. In some cases data are not available at 0·5 per cent.; here the value of $E_{0·5}$ has been estimated from data at 0·5–1·0 per cent. In these cases the value of $E_{0·5}$ is given in parentheses. The table also includes references to pertinent patents and the cetane number increase obtained at 0·5 per cent.

In the table heading is given the concentration of ignition accelerator in lb. per barrel corresponding to the concentration in weight per cent. indicated by the value of *E*. The actual improvement in cetane number corresponding to a value of *E* is obtained by multiplying *E* by the concentration in lb. per barrel.

Apart from its property of improving the cetane number (decreasing the delay period) of a diesel fuel, an additive, to be of practical value, should possess the following characteristics: it should be relatively insoluble in water and chemically stable in the presence of the same, since it is common practice to store fuels in contact with water. It should be sufficiently soluble in the fuel to obtain concentrations up to 5 or 10 per cent. by weight. Even greater solubility is desirable if the additive is to be marketed in the form of a concentrate in fuel oil.

The additive should be stable in the fuel towards variations in storage temperature. It should not cause the formation of a sediment or sludge—factors which might cause depreciation of the cetane number of the fuel and fouling or clogging of the injection equipment of the engine.

The additive initially as well as on combustion of the fuel should not yield any products which are corrosive to the engine parts with which they come in contact. The additive should also be non-toxic and, above all, it should be economical in its manufacture and use.

The relationships between the effectiveness (*E*) and the cost of the material used as an ignition accelerator and the resulting cost per bbl. per cetane-number increase are shown in Fig. 3. *E* is plotted as ordinates and the cost of the compound in cents per lb. as abscissa. The lines radiating from the origin are lines of equal cost per bbl. per cetane-number increase. If the value of *E* for a particular compound and its cost per lb. are known, the cost per unit of improvement can be estimated. Conversely, if the value of *E* for a proposed ignition accelerator is known and the maximum allowable cost for increasing the ignition quality of the fuel is known, then the maximum price which may be paid for the compound may be estimated. (Locate the point on the line corresponding to the maximum allowable cost in cents per bbl. per cetane-number increase corresponding to the value of *E* and read the maximum cost per lb. corresponding to this point.)

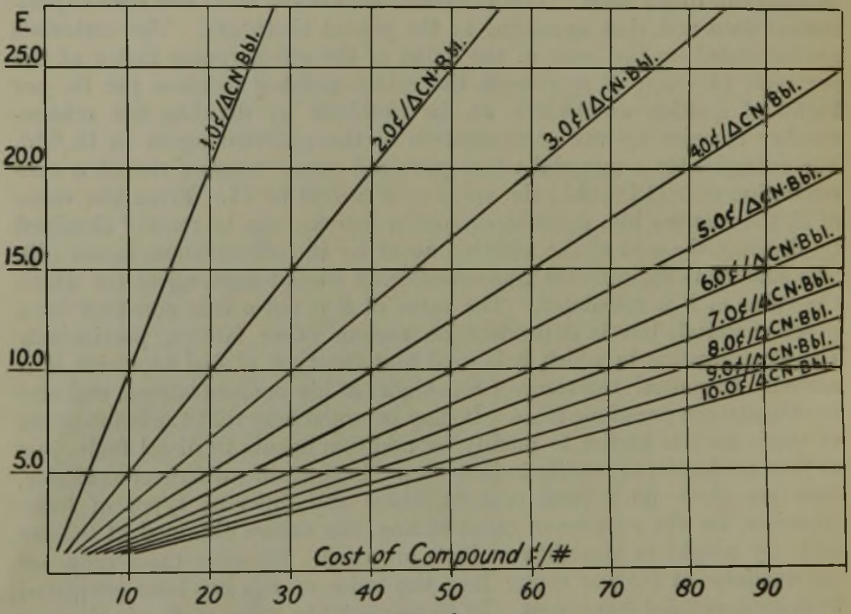

FIG. 3.

Of the various materials on which we have information, the most effective are the thionitrites. In straight-run fuels these materials give a cetane-number rise of 10 to more than 13·5 at 0·5 per cent. concentration. These materials are prepared from the interaction of mercaptans and nitrous acid or its derivatives.

Chloropicrin gives an increase of approximately 10 cetane numbers at 0·5 per cent. concentration. This material is also used as an emetic war gas, so that its use in fuel might present some difficulties.

Alkyl nitrates and nitrites have been known for some time as effective addition agents for diesel fuels. Amyl nitrite and amyl nitrate were the most effective of those tested. These gave an ignition-quality improvement of approximately 9 cetane numbers at 0·5 per cent. concentration. Ethyl and butyl nitrates were somewhat less effective.

Peroxides have about the same effect on ignition quality of diesel fuels as the alkyl nitrites and nitrates. The most effective ones are acetyl peroxide, tetralin peroxide, acetone peroxide, and propionyl peroxide. These materials are hazardous to prepare and handle in the free state, but some may be prepared directly in the fuel, in which case the blends are comparatively stable. Fuels containing acetyl peroxide, although stable in the absence of water, rapidly hydrolyze when stored over water.

Tetranitromethane improved the ignition qualities of straight-run fuels by 7 cetane numbers. This is then somewhat less effective than trichloronitromethane (chloropicrin).

Another type of compound that shows considerable effectiveness in improving the ignition quality of diesel fuels is the aryldiazo-derivatives of amines. The effectiveness of these compounds seems to parallel their instability. The quite stable triazenes (diazo-amino-compounds) which are formed from the condensation of a diazonium halide with an amine have a moderate effectiveness (about 1·9–3·1) as ignition accelerators. The pentazdienes (bisdiazoamino-compounds), which are more unstable and hazardous to handle in the pure state, range in effectiveness from about 2·8 to 3·4.

An inexpensive and fairly effective ignition accelerator is elementary sulphur. This has an effectiveness of 4·18 at 0·5 per cent. (cetane-number improvement = 7·5). It was found to be particularly effective in catalytically cracked fuels. Its practical use is hampered by (1) fuel specifications limiting total sulphur content of fuels, (2) relatively low solubility in the fuels, and (3) possible corrosive action of it or its combustion products on engine parts.

A relatively broad class of fairly effective ignition accelerators consists of compounds containing nitrogen and sulphur linked together. The thionitrites (R–SNO) are members of this class which have already been mentioned. Others in order of effectiveness are: (1) dialkylamine disulphides ($R_2N–S–S–NR_2$), (2) nitrogen sulphide (N_4S_4), (3) alkyl nitrogen sulphides (RN_2S_2), (4) thiamines ($(RNS)_4$). The amine disulphides and thiamines are readily prepared by the action of chlorides of sulphur on secondary and primary amines. Nitrogen sulphur is a somewhat explosive material having low solubility in fuels; the alkyl derivatives are made from it.

In general, the organic di- and poly-sulphides improve the ignition quality of diesel fuels. The most effective types tested were those prepared from mercaptans by sweetening in the presence of sulphur. Other effective materials are hydrocarbon tetrasulphides, xanthic disulphides, hydrogen persulphides, dibenzyl disulphide, alkyl disulphides, and aminoaryl disulphides.

Other materials which have an effectiveness of more than 2·5 at $\frac{1}{2}$ per cent. concentration—*i.e.*, gave more than a 3·5-cetane-number increase—are nitrosotriacetone amine, and a combination of ethyl nitrate and benzyl bromide.

SOLVENT TREATING.

The ignition quality of diesel fuels may also be improved by various types of treatment. Since an increase in the paraffinicity of the fuel will tend to improve its cetane number, it is to be expected that methods which are successful in the refining of lubricating oil will be applicable to the enhancement of the ignition quality of diesel fuels. A definite parallelism is found to exist, and the most useful treatments for diesel fuels are solvent treatment and treatment with aluminium chloride.

In order to compare the economic value of such treats with one another and with the use of fuel additives, an effectiveness factor (E_t) has been calculated for the various treatments. It is obtained as indicated in the following equation :

$$E_t = \frac{\%\text{ Yield (by vol.)} \times (\text{C.N. of raffinate} - \text{C.N. of base fuel})}{100}$$

Thus in the treatment of a 50·5-cetane-number fuel with aluminium chloride a 78 per cent. yield of a 58·0-cetane-number fuel was obtained, in this case

$$\begin{aligned} E_t &= 78\ (58{\cdot}0 - 50{\cdot}5)/100 \\ &= 5{\cdot}95 \end{aligned}$$

In determining the comparative costs of treatments, the cost per bbl. per cetane-number increase may be readily obtained by dividing the treating cost per barrel by E_t. For example, if a solvent treat with sulphur dioxide costs 67·5 cents per bbl. and has an effectiveness of 13·3, the cost per cetane-number increase will be 5·05 cents per bbl., or 0·1 cents per gal.

In the accompanying table (Table VI) are given data on several types of treatments of several types of diesel fuels. In Part A of the table are

TABLE VI.

Solvent Treating of Diesel Fuels.

No.	Type fuel treated.	Treating agent.	Cetane number.			Yield, %.	E_t.
			Original.	After treatment.	Change.		
		A. *Straight-run Stocks.*					
1	Mid-continent	Aluminium chloride	50·5	58·0	7·5	78	5·95
2	,,	Ethyl alcohol extraction	50·5	54·5	4·0	78	3·12
3	,,	Sulphur (heat at 100° C.)	50·5	58·5	8·0	100	8·0
4	,,	Furfural extraction	51·5	60·0	8·5	76	6·45
5	,,	,, ,,	51·5	63·5	12·0	46	5·40
6	,,	Acetone extraction	51·5	58·5	7·0	56	3·92
7	,,	Phenol extraction	52·5	56·0	3·5	77	2·69
8	,,	,, ,,	52·5	58·5	6·0	62	3·72
9	Zistersdorf	Sulphur dioxide extraction	49	62·5	13·5	78·7	10·6
10	,,	,, ,,	49	62·5	13·5	73	9·85
11	,,	,, ,,	49	65·5	16·5	54·4	9·02
		B. *Cracked Stocks.*					
12	Zistersdorf catalytically cracked	Sulphur dioxide extraction	34·0	59·0	25·0	53·4	13·3
13	,, ,,	,, ,,	34·0	65·5	31·5	44·6	14·0

listed treatments of several straight-run stocks, and in Part B are listed treatments of a cracked stock.

Where large increases in ignition quality are required for making diesel fuels, the most economical method appears to be the use of solvent treating or a combination of solvent treating with the addition of small quantities of fuel additives. In order to raise a 25-cetane-number cracked fuel to 50 cetane number, 5 per cent. of amyl nitrate would be required ($E_{5\cdot 0} = 1\cdot 25$). At a cost of 10 cents per lb. for amyl nitrate, this would cost 8 cents per bbl. per cetane-number increase or $2·00 per bbl. for the desired improvement. By solvent treating with sulphur dioxide (assuming $E_t = 13\cdot 3$ and the cost of treating as 67·5 cents per bbl., see Table VI, B, No. 12) the cost would be 5·05 cents per bbl. per cetane-number increase or $1.28 per bbl. for the desired improvement.

Appended is a list of United States and foreign patents corrected to 1st September, 1940. It embraces all materials that have been patented for addition to diesel fuels to improve their ignition quality, but does not include refining operations which improve ignition quality, unless specific claim is made for their use as addition agents. For example, patents on solvent treating have been omitted as being outside the scope of this survey, except for a few patents on the preparation of high-ignition-quality blending stocks by the Edeleanu process. Beside the patent numbers are given the treatment or material added, patentee or assignee, and the date the patent was issued.

United States Patents.	Treatment or material added.	Patentee or assignee.	Date issued.
928,803	Picrate or aromatic hydrocarbon alone or with a peroxide.	G. B. Selden.	20.7.09
1,423,048	Alcohol, ether, ester, ketone, and combinations thereof.	U.S. Industrial Alhol Co.	18.7.22
1,423,049	Ester of organic acid, alcohol, ether, ketone, and combinations thereof.	,, ,,	18.7.22
1,423,050	Aromatic hydrocarbon and/or aromatic nitro-hydrocarbon.	,, ,,	18.7.22
1,493,874	Acetone.	F. Hostettler.	13.5.24
1,534,573	Ether plus a compound containing a non-hydroxyphenyl radical or a metallic phenyl compound.	J. F. P. de La Riboisiere.	21.4.25
1,558,967	Compound of a hydrocarbon radical and a metal, specifically mentions dibenzyl diselenide.	,, ,,	27.10.25
1,766,501	Organic peroxide (*e.g.*, benzoyl peroxide) also per salts.	C. A. Buerk.	24.6.30
1,800,997	Peroxide and amido-derivative.	C. J. Greenstreet.	14.4.31
1,813,882	Slaked lime, rosin, formaldehyde, ammonia, turpentine, followed by contact with air.	H. Behm.	7.7.31

United States Patents.	Treatment or material added.	Patentee or assignee.	Date issued.
1,820,983	Nitro-paraffins or alkyl nitrites.	Standard Oil Development Co.	1.9.31
1,849,051	Primer and another compound (*e.g.*, ethyl nitrate and at least one other compound having the property of spontaneously igniting in the air).	Imperial Chemical Industries, Ltd.	8.3.32
1,916,735	Manganese soap, alone or with a hydrocarbon solvent.		4.7.33
2,009,818	Compound having the type formula ${}^{R}_{R_1}\!>\mathrm{N{-}N{=}O}$, where R and R_1 are aliphatic radicals.	E. I. du Pont de Nemours & Co.	30.7.35
2,011,297	Tetraline peroxide.	Shell Development Co.	13.8.35
2,028,308	Fluid aliphatic hydrocarbon containing more than two carbon atoms and having more than one multiple carbon bond (*e.g.*, diacetylene).	I. G. Farbenindustrie Aktiengesellschaft.	21.1.36
2,031,497	Nitrates of the mixture of open-branched chain aliphatic monohydric alcohols obtained by the catalytic hydrogenation of carbon monoxide and having at least four carbon atoms and containing *iso*butyl alcohol.	E. I. du Pont de Nemours & Co.	18.2.36
2,034,643	Compound of the general formula R–S–S–S–S–R, in which R is a hydrocarbon radical; also a compound of the general formula R–S–S–S–S–R', in which R is an alkyl radical and R' an aryl radical.	The Texas Co.	17.3.36
2,054,628	Ethyl nitrate and an oxygenated organic compound of copper.	Imperial Chemical Industries, Ltd.	15.9.36
2,065,588	A primer selected from the class consisting of the lower alkyl nitrates and nitrites and a second primer consisting of benzyl bromide.	,, ,,	29.12.36
2,066,506	Nitrate of an aliphatic polyhydric alcohol.	E. I. du Pont de Nemours & Co.	5.1.37
2,093,008	Dialkyl peroxide (*e.g.*, diethyl peroxide).	A. C. G. Egerton.	14.9.37
2,107,059	Acetone peroxide alone and acetone peroxide plus a substance selected from the group consisting of tetraline, peroxide, nitrogen sulphide, esters of nitric or nitrous acid.	Shell Development Co.	1.2.38
2,115,275	One or more compounds selected from the group consisting of triazoacetone, triazoethanol, ethyltriazo formate, triazoethyltriazo acetate, and 1 : 2-diazidoethane.	Socony-Vacuum Oil Co., Inc.	26.4.38

United States Patents.	Treatment or material added.	Patentee or assignee.	Date issued.
2,125,875	Paraffin wax and a pour-point depressor.	Standard Oil Co. of Indiana.	9.8.38
2,136,455	Diazo-aminobenzene.	Socony-Vacuum Oil Co., Inc.	15.11.38
2,136,456	Compound having the probable formula $\genfrac{}{}{0pt}{}{R'}{R''}{>}\text{N–N} = \text{N–}R$, in which R represents an aryl radical or a substituted aryl radical and R' and R'' represent hydrocarbon radicals or the hydrocarbon portion of a heterocyclic radical containing a nitrogen atom.	,, ,,	15.11.38
2,137,410	Sulphurized terpene.	,, ,,	22.11.38
2,146,265	Ozone containing gas.	Union Oil Co. of California.	7.2.39
2,158,050	A pentyl nitrate or mixture thereof.	E. V. Bereslavsky.	16.5.39
2,164,151	Bis(aminoaryl)disulphide.	Socony-Vacuum Oil Co., Inc.	27.6.39
2,167,345	A mercaptan or mercaptans which have subsequently been sweetened in the presence of sulphur; also includes mercaptans fixed by spent caustic wash liquors from the washing of sour raw petroleum distillates and which are subsequently sweetened in the presence of sulphur and the fuel.	Socony-Vacuum Oil Co., Inc.	25.7.39
2,169,186	An organic compound having the general formula $R\text{SN}X_n$, in which R is a radical selected from the group consisting of alkyl and aryl radicals, X is an element selected from the group consisting of oxygen and sulphur and n is a whole number having a value not greater than two.	Standard Oil Co. of Indiana.	8.8.39
2,174,680	Acetyl peroxide prepared in oil.	Socony-Vacuum Oil Co., Inc.	3.10.39
2,177,719	Bis(dialkylaminedi)sulphide.	,, ,,	31.10.39
2,178,327	Dipropionyl peroxide.	The Texas Co.	31.10.39
2,184,440	Treatment of fuel oil of high sulphur content with sodium plumbite solution and a large excess of sulphur.	Standard Oil Co. of Indiana.	26.12.39
2,185,157	Tetranitromethane.	Socony-Vacuum Oil Co., Inc.	26.12.39
2,188,262	Substituted pentazdiene.	,, ,,	23.1.40
2,200,260	Chloropicrin.	Standard Oil Co. of California.	40.5.40
2,205,126	Alkyl polysulphides prepared and dissolved in a hydrocarbon solvent.	Standard Oil Co. of Indiana.	18.6.40

United States Patent	Treatment or material added.	Patentee or assignee.	Date issued.
2,206,594	Hydrogen persulphides alone or with elementary sulphur.	Socony-Vacuum Oil Co., Inc.	2.7.40
British Patents.			
174,712	Camphor, naphthalene, benzene, methyl alcohol, ammonia, turpentine, ether, and sulphur.	Steele and Clifton.	22.11.20
238,299	Acetylene, ammonia, or other gaseous hydrocarbons.	Heide.	15.5.24
243,357	Ether plus a compound containing a non-hydroxyphenyl radical or a metallic phenyl compound.	La Riboisiere.	18.11.24
247,797	Compound of a hydrocarbon radical and a metal, specifically mentions dibenzyl diselenide.	,, ,,	15.12.24
294,129	Primers which will explode below the spontaneous ignition temperature of the oil (*e.g.*, nitrous and nitric esters, chlorates, acetylenic compounds, superoxides).	Sims.	14.4.27
331,966	Tetralin, sulphonated castor oil, water containing sulphite lye.	Menz *et al.*	30.4.29
352,550	Methyl or ethyl nitrate in the air charge with or without other addition agents (*e.g.*, benzoyl peroxide, picric acid, etc.).	Helmore.	13.2.30
354,398	Two or more primers consisting of an igniting primer (*e.g.*, ethyl or methyl nitrate) and an exploding primer consisting of benzoyl peroxide, picric acid, and trinitrotoluene.	,,	13.2.30
358,484	An explosive such as nitroglycerine, nitroguanidine, nitrocellulose, etc., emulsified in vegetable oil.	Compagnia Italiana S.I.S.A.	5.7.30
374,481	Alkyl nitrate containing from two to four carbon atoms.	Imperial Chemical Industries, Ltd.	13.6.32
375,525	Ethyl alcohol.	Rutzbeck.	30.6.32
376,286	Alcohol, ethyl acetate, acetone, acetylene plus ozonization.	Wolff & Co.	6.7.32
379,725	Activator consisting of a nitro-compound and an hydrazo- or diazo-compound.	S.E.B.I.	29.8.32
381,941	Sulphur dioxide raffinate or sulphur dioxide refining.	Edeleanu.	10.10.32
399,150	Diolefinic or acetylenic compounds (*e.g.*, diacetylene, butadiene).	I. G. Farbenind.	26.9.33
403,124	Aliphatic diketone or aromatic diketone (*e.g.*, acetyl acetone, benzoyl acetone).	Imperial Chemical Industries.	15.12.33

British Patents.	Treatment or material added.	Patentee or assignee.	Date issued.
404,682	Two primers consisting of (*a*) an alkyl nitrate containing two to four carbon atoms, (*b*) an organic bromine compound or an oxygenated copper compound.	,, ,,	22.1.34
405,658	A non-explosive, non-aromatic heterocyclic nitroso compound (*e.g.*, nitrosotriacetone amine).	,, ,,	5.2.34
421,928	One or more organic peroxides.	Shell Development Co.	2.1.35
428,972	Acetone peroxide.	,, ,,	22.5.35
429,763	Non-aromatic organic compound containing an oxime group.	E. I. du Pont de Nemours & Co.	6.6.35
434,109	Water emulsified in oil with or without boron compounds and salt.	Roberts.	27.8.35
443,562	Dialkyl peroxide (*e.g.*, diethyl peroxide).	Egerton.	2.3.36
461,320	Nitroxyl ethylene halohydrin.	Bristow and Buist.	10.2.37
461,671	Furfural with or without benzene, benzine, alcohols, etc.	Fleming.	17.2.37
491,648	Nitration of fuel.	Standard Oil Development Co.	5.9.38
523,143	Organic compound containing a thiocarboxylic acid radical.	,, ,,	5.7.40
523,522	Soluble organic salt or an organo-metallic constituent selected from the class consisting of barium, mercury, arsenic, antimony, and bismuth.	,, ,,	16.7.40
French Patents.			
705,958	Alcohol, acetone, ethyl acetate, acetylene plus ozonization.	Wolff & Co.	20.11.30
710,496	Colloidal carbon with or without (limon).	Leroy.	21.1.31
717,817	Activator consisting of nitro-compound and a hydrazo- or diazo-compound.	S.E.B.I.	27.5.31
718,688	Sulphur dioxide raffinate or sulphur dioxide refining.	Edeleanu.	15.6.31
730,208	Alkyl nitrate containing from two to four carbon atoms.	Imperial Chemical Industries, Ltd.	20.1.32
746,116	Diolefinic or acetylenic compound (*e.g.*, diacetylene, butadiene).	I. G. Farbenind.	23.5.33
757,326	Two primers consisting of (*a*) an alkyl nitrate containing two to four carbon atoms, (*b*) an organic bromine compound or an oxygenated copper compound.	Imperial Chemical Industries, Ltd.	23.12.33

French Patents.	Treatment or material added.	Patentee or assignee.	Date issued.
764,721	Nitrogen sulphide.	Shell Development Co.	26.5.34
812,649	Aldehydes, ketones, and nitro-compounds.	Weber.	13.5.37
817,379	Nitration of fuel.	Standard Oil Development Co.	1.9.37
821,211	A pentyl nitrate or mixture thereof.	Bereslavsky.	30.11.37
828,861	Polymerized *iso*butylene.	I. G. Farbenind.	1.6.38
German Patents.			
518,232	Iron carbonyl with aldehyde, ketones, etc.	I. G. Farbenind.	24.7.33
564,899	Two or more primers consisting of an igniting primer (*e.g.*, ethyl or methyl nitrate) and an exploding primer consisting of benzoyl peroxide, picric acid and trinitrotoluene.	Helmore.	26.3.31
573,211	Sulphur dioxide raffinate or sulphur dioxide refining.	Edeleanu.	18.6.30
611,968	Colloidal active carbon with furfurol.	Classen.	10.4.35
612,073	Auto-oxidizable substance, partial oxidation products, or lead soap.	Hagemann.	15.4.35
617,492	Acetone peroxide.	Shell Development Co.	20.8.35
651,771	Tetralin peroxide.	Hoch.	19.10.37
Canadian Patents.			
346,022	Sulphur dioxide raffinate.	Shell Development Co.	13.11.34
355,519	Acetone peroxide.	,, ,,	21.1.36
384,497	A pentyl nitrate or mixtures thereof.	Bereslavsky.	10.10.39

Socony-Vacuum Oil Company, Incorporated,
General Laboratories,
Research and Development Division,
Paulsboro, N.J.

References.

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ABSTRACTS.

AUTHOR INDEX.

The numbers refer to the Abstract Number.

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

Geology and Development.

781.* Central Basin of Appalachian Geosyncline. Robert C. Lafferty. *Bull. Amer. Ass. Petrol. Geol.*, 1941, **25**, 781–825.—The Appalachian geosyncline comprises three major basins of deposition—namely, (1) a northern basin, with its deepest point near Altoona, Pennsylvania; (2) a central basin, having its deepest point near Elkins, West Virginia; (3) a southern basin, with its thickest sediments centred near Birmingham, Alabama. In his paper the author summarizes and critically examines existing information and opinion relative to the structure and stratigraphy of the *central basin only.*

A map is given, showing, by means of contours, relative sizes and shapes of the three major basins, with an outline of the central basin, represented by presently exposed Permian beds, also structural and depositional sections of two cross-sections at right angles to each other. The one from north-west to south-east is across the deepest part of the basin, the other, north-east and south-west, roughly paralleling the strike of the basin, thickness and areal distribution of the rocks being obtained from drilling records.

The author, in his summary, states that the accumulation of oil and gas in most of the silica sands in the central basin is primarily a matter of proper sand conditions, with anticlinal structure of secondary importance. Devonian shale-gas production is apparently related to the lower margin of an epi-continental shelf that helped to create a fracture-type reservoir.

Based on well records, the earliest indications of movements on the north-east–south-west anticlinal trends occurred during Medina time, and on the north–south trends movement apparently began in late Devonian. R. J. W.

782.* Sediments of Fresh-water Lakes. W. H. Twenhofel and V. E. McKelvey. *Bull. Amer. Ass. Petrol. Geol.*, 1941, **25**, 826–849.—This paper deals with the studies of lake sediments, largely limited to fresh-water lakes of the Upper Mississippi Valley, together with the published literature relating to lake sediments, and it is believed that most of the generalizations suggested have somewhat general application. Results so far obtained indicate that the sediments of each lake are, to some degree, of individual character.

Sediments are products of inheritance and environment, and this is true of the sediments of lakes, as of those of other realms of sedimentation. Sediments deposited in lakes depend on many environmental factors, and combinations of these factors are almost infinite, probably being different for each lake and different in each lake from time to time. Characters of the sediments should reflect the combinations. Important factors of sedimentary control are the origins of the lake basins, size and depth of basins, relief of drainage areas, extents of shallow waters adjacent to shores, degree of vegetable protection over drainage areas, characters of surrounding rock and soil terrains, topography of bottoms of basins, circulation of lake-waters, climatic conditions, character of lake-water, sources of lake sediments. All these factors are considered in as much detail as seemed necessary.

Lake basins result from damming, excavation, and crustal movement. Damming is probably responsible for most basins and crustal movement for fewest. Size and depth of a basin may be related to origin, some of the largest and deepest being of structural origin. Lakes of glacial origin are of all sizes and depths. The largest and deepest of the glacial lakes are due to over-deepening and damming of pre-glacial valleys. Other glacial lakes, although maybe large, are mostly less than 100 ft. in depth. River lakes may attain great size, especially in length, but are usually shallow. Basins due to volcanic explosions may be of large size and great depth.

Under humid conditions, size and depth of a basin determine the size and depth of the lake therein, which in turn determine the strength of the waves and their attack on the shores and bottom and the character of the shore and bottom deposits. The greater the lake the more severe the wave action and the more vigorous and greater the erosion of the shores, giving much turbulence, which may result in high turbidity. With small lakes, waves are weak and wave attack on shores is small. Plants accordingly colonize shallow bottoms and shores. Whilst the inorganic sediments from shores are limited, organic sediments, brought to or deposited outward from the shores, are correspondingly greater. Deposition proceeds more slowly on large and deep lakes than on small, shallow lakes. Size and depth of lakes have a direct bearing on the extent of currents present, and are limiting factors where circulation is concerned. Processes of chemical deposition and diagenesis may be directly related to the size and depth of lakes, as these factors affect conditions of oxidation, reduction, temperature, and agitation of the water.

Deposits over the deep parts of almost every lake contain a high content of matter of organic origin. Profound changes take place on lake sediments after their deposition. Organic matter is eliminated, content of carbonates increase or decrease, and there are other important changes. Much formation of combustible gas, thought to be methane, is present, and a paraffin wax is extracted, bacteria and other micro-organisms being responsible for these changes. A bibliography of published literature referred to in the paper is given. R. J. W.

783.* Laboratory and Field Observations of Effect of Acidizing Oil Reservoirs Composed of Sands. P. E. Fitzgerald, J. R. James, and Ray L. Austin. *Bull. Amer. Ass. Petrol. Geol.*, 1941, **25**, 850–870.—The successful use of chemicals on oil and gas reservoirs composed of limestones has induced engineers and geologists to experiment with many wells producing from sands. Early results were not uniformly successful, probably owing to the same technique being applied as used for wells producing from limestones, but in some cases good increases resulted. During the past several years the authors have been collecting cores from various producing formations, most of which have been studied in the laboratory. Results, together with a compilation of well-treating data, are given in this paper. Three hundred cores were examined and studied, of which 80% showed an increase in permeability when acidized in the laboratory, the average increase being more than 300%. Average acid solubilities of the more than eighty different oil-producing sands was 8·5%. In the acidizing of sandstone formations the percentage of soluble material is by no means a criterion by which the possible success of a treatment may be predicted. In some instances better results have been obtained in sandstone formations containing low percentages of acid-soluble material than in those containing comparatively high amounts of soluble material. The usual tests on sandstone cores—that is, porosity, permeability, oil saturation, acid solubility, and chemical analysis—generally do not indicate with any degree of certainty results to be expected from acidizing. Additional tests were devised which gave more positive results, such as determination of permeability before and after acidizing the core in the laboratory, and determination of the compressive strength of the rock before and after acidizing. The procedure of these tests is described. A chart showing production increases with quantity of acid required to saturate 1 ft. of sandstone and acid penetration in feet is given, from which is gleaned the gallons of acid per foot of "pay" required to saturate a sandstone of 20% porosity to a given radial distance. For example, 250 gals. of acid will saturate 1 ft. of formation a radial distance of 7·5 ft. If a 300% increase in permeability results from the presence of this acid in the pores, at least 50% increase in production can be expected. The occurrence of channelling due to formation irregularities will sometimes lead to even much greater production increases than indicated by the chart.

A summary of core studies by States and formations is given, and the authors hope to give all the core data in a future paper. R. J. W.

784.* Cross-section of Chester of Illinois Basin. P. L. Dana and E. H. Scobey. *Bull. Amer. Ass. Petrol. Geol.*, 1941 **25**, 871–882.—This paper deals with correlations of the formations of the Chester series in the Illinois basin, where, in the course of subsurface studies, certain critical lithologies have been observed, thus permitting the correlation of formations over wide areas. Over a zone 25 miles wide north and south, and out of some eighty sample logs, a group of seventeen logs were selected to construct east–west cross-sections of the basin, which are illustrated. The maximum distance between wells used was 15 miles, with an average of 11 miles. The results of the authors' studies and conclusions are described and a skeleton log is made, based on average thicknesses of formations, thus enabling the construction of a table to show relationship of formation names as used by subsurface workers in Illinois, Indiana, and Kentucky. A list of the wells and their locations is given. R. J. W.

785.* Geology of Freezeout Mountain—Bald Mountain Area, Carbon County, Wyoming. Milan D. Maravich. *Bull. Amer. Ass. Petrol. Geol.*, 1941, **25**, 883–897.—This paper forms a thesis submitted to the Department of Geology and the Committee on graduate study at the University of Wyoming, for the partial requirements of the degree of Master of Arts. It is a description of the geology of the south-eastern part of the Freezeout Hills, which are 15 miles north-west of the town of Medicine Bow, Carbon County, Wyoming, the mapped area covering 43 sq. miles of the north-eastern part of Carbon County. The geologic work was undertaken for the purpose of (1) obtaining an accurate geologic map; (2) describing and interpreting the structural geology; (3) measuring in detail the stratigraphic sections; and (4) investigating possible mineral deposits and ground-water resources of the area. The topography of the area is controlled by two north-west trending anticlines and an intervening syncline. The anticlines form ridges which increase in height and width south-westward, and the syncline forms a valley increasing in depth but decreasing in width to the south-west. The evidence available indicates that the mountain-making folding of the Laramic basin began in late Cretaceous time and continued intermittently to early Eocene time. R. J. W.

786.* Hawkins Field, Wood County, Texas. H. J. McLellan. *Bull. Amer. Ass. Petrol. Geol.*, 1941, **25**, 898–899.—The Hawkins oil-field is located in South-eastern Wood County in the north-central part of the East Texas basin, and was discovered by use of surface geology and core-drilling.

A small surface structure was reported in 1930, but core-drilling in 1937 proved the structure to be much larger and more pronounced on the subsurface formations.

The discovery well, completed in December 1940 at a depth of 4963 ft., in the Woodbine, was plugged back to 4917 ft. and put on pump to produce 124 brl. of oil and about 290 brl. of salt water per day. The oil was black, with a gravity range of 15–18°. A second producing well completed in the same month had an initial production of 122 brls. per hour through a 1-in. tubing, choke-depth being 4648 ft. This oil was brownish black, with a gravity of 28·5°. The structure of the field appears to be an elliptical dome with its major axis bearing north 7° east. Wells drilled to date indicate that the gravity of the oil *decreases* with depth, being about 29° near the gas-oil contact and 15° at the water level. The field has a 20-acre spacing order with allowable based 50% on acreage and 50% on the well. R. J. W.

787.* Applied Sedimentology. Henry Carter Read. *Bull. Amer. Ass. Petrol. Geol.*, 1941, **25**, 899–901.—The author, following a review of a comprehensive report on the shoestring sand areas of Kansas and Oklahoma for the purpose of extending existing productive areas and developing new sand bodies with the least possible cost, has projected a method which he considers applicable to many sedimentary problems in general and to the shoestring areas in particular.

In this instance the lenticularity and sporadic occurrence of the sand bodies, accompanied by the absence of any surface reflection of subsurface conditions, precluded the use of ordinary exploration methods, the stimulus being shallow productive depths (2000–2500 ft.) combined with long life and low operating costs. His idea is that normal sedimentary units do not terminate abruptly, but " wedge " or thin out laterally, so that the problem resolves itself into a detailed study of the sediments involved.

He considers that if the cuttings from a number of previously drilled wells in several adjacent sand bodies are studied microscopically, and particular attention is paid to the characteristics of the material immediately overlying the sand body for a vertical distance of about 50 ft. and laterally beyond the limits of the actual sand occurrence, the data obtained can be used for control and location of other wells within the immediate area. Again, if the cuttings from the sand bodies are examined in a similar manner it will be noted that as the sand lens thins towards the edges, there is a proportionate loss of certain constituents, until the limit of the body is approached. At this point there are : (*a*) very few sand grains ; (*b*) no sand grains ; (*c*) a different type of grain ; or (*d*) a transitional phase of the sand into the enclosing siltstone mass. By recording these data on a map it is evident that the percentage amount or kind of certain types can be interpolated between any two wells within the given sand body. The edge of the sand body can also be located by extrapolation.

The author considers that in addition to the ordinary microscopic examination of well-cuttings, the material should be examined under ultra-violet light, infra-red rays, and, if possible, be photographed by X-rays, in an attempt to ascertain diagnostic diffraction patterns of any of the constituent grains. Cuttings should also be subjected to the action of the common laboratory reagents, to determine whether certain characteristics can be chemically induced. As an accessory index geochemical analysis for gas content in the overlying siltstone can be used. Practical application of the proposals would necessitate the drilling of at least three wells in the area studied. The first two would be exploratory or " informative " wells, the third being located after studying cuttings from the first two as outlined. The formations passed through in the first two wells would be considered in a very different light than so much sandstone and shale, and the thin stringers of sand passed previously as a " stray " would be highly significant. The method would be more economical than drilling on the " hope-we-hit " basis. R. J. W.

788.* Potential Oil Area Disclosed in Southern South Dakota. *Petrol. Engr*, May 1941, **12** (8), 40.—A large anticline which may be of interest as regards oil has been found between the Big Bend of the Missouri river and the Bijou Hills in South-central South Dakota. Small gas-shows have been noted in water-wells on it. It is thought that the depth of sediments which may be petroliferous does not exceed 2500 ft.

About 8,000,000 acres are under lease in North and South Dakota for oil prospecting, but the area in question lies outside this region of leasing activity. G. D. H.

789.* Eastern Venezuela's Promising New Fields. *World Petrol.*, March 1941, **12** (3), 26.—In February Santa Barbara No. 1 came in at an estimated rate of 4000 brl./day of 29° oil from 87 ft. of sand. It lies 10 ml. from the Jusepin field, in an area which had been investigated by seismograph, torsion balance, gravimeter, and soil analysis. The well was stopped at 4320 ft. in shale, having encountered oil-sand at 4158 ft. Its bottom-hole pressure is 2000 lb./in.^{2}. The oil-sand resembles the upper sands at Jusepin.

Indications of another important field of high-gravity oil are shown by Santa Rosa No. 2, which came in at 6530 ft. with 2239 brl./day of 44·1° A.P.I. oil. It lies on one of a series of domes, extending about 30 ml. north-east from Santa Ana, four of which are already known to be oil-bearing. This is the Santa Ana–San Joaquin–El Roble–Santa Rosa area, which has nineteen producing wells, the deepest being

10,197 ft. San Joaquin has fourteen wells in a 20-ml. by 3-ml. area, whilst Santa Ana has two.

Oficina has 148 producing wells in an area 8 ml. by 5 ml. In the Leona–El Tigre region 30 ml. to the east, three producers have been completed. Anaco No. 1 is now at 7000 ft., and is expected to be a producer. Sites have been selected for four wells at Guario, where two wells are already giving more than 1000 brl./day, each of 40–41° oil. Two producers have been brought in at San Joaquin. 30 ml. south-west of Oficina the wildcat Panchita No. 1 is under way. A wildcat at Los Carito near Bocadeuracoa has been abandoned at 5756 ft. About 100 ml. due south of Caracas a showing of oil has been found in Mercedes No. 1. Rincon No. 1 is fishing at 9605 ft.

West of Santa Ana is the Las Oilas test. A third well has been completed at more than 2000 brl./day at El Roble. The well has two separate oil zones, the lower one at 9620–9650 ft. Apparently the area has three or more separate oil zones.

A map shows the fields, wells, pipe-lines, and refineries. G. D. H.

790.* Geology and Economic Significance of the Northern Great Plains Basin. J. A. Kornfeld, *World Petrol.*, March 1941, **12** (3), 36.—Recent drilling has indicated promising new objectives in a sedimentary section about 15,000 ft. thick in the Northern Great Plains Basin, which extends from Eastern Alberta to South Dakota.

In December 1940 the Princess field was discovered at Steveville, east of the Alberta foothills. The oil is in truncated, bevelled Palæozoic limestones, the structure of which beneath the thick Mesozoic mantle was outlined by the reflection seismograph. It is on the Sweetgrass Arch. The discovery well was drilled to the Devonian limestone at 4250 ft., and plugged back to the Madison at 3920 ft. It yields 520 brl. of 26·3° A.P.I. oil/day, with 12,750,000 cu. ft. of gas. Other tests are planned. Here and at Turner Valley the Madison limestone responds to acid treatment. Important reserves are believed to exist in the Jurassic, Mississippian, and Devonian.

At Del Bonita a well gives oil from the Upper Madison, and on the Blood Indian Reserve a well has had a fair showing of 36·5° oil in the Madison, but is drilling below 6440 ft. for the Devonian limestone. Palæozoic oil production is to be sought on the Baker–Glendive anticline, Montana, following geophysical work. Since 1936 two oil wells have been completed in the Big Snowy Group of the Mississippian at about 6750 ft. The Cedar Creek field gives shallow gas from the Judith River beds of the Upper Cretaceous.

The Bottineau gas-field of North Dakota was discovered in 1907. Its producing horizon is shallow. The production of gas at Lansford in glacial sands is probably migrant from the underlying Upper Cretaceous. A small gas-pool was developed in the La Moure county area at depths of 1150–1450 ft. in the Dakota sandstone. The Deslacs anticline had shallow gas. A gas-flow was found on the Nesson anticline at 750 ft., and a gas-showing was logged at 4300 ft.

In South Dakota a commercial well was drilled on the Barker structure in 1929, finding black oil at 1328 ft. On the east flank of the Black Hills uplift is the Elm Springs structure, on which the Lakota sand series showed oil at 3178–3520 ft. A gas-show was found in the Minnelusa below 4282 ft. The Deadwood formation showed oil at 7820 ft. on the Camp Crook anticline. A belt of shallow gas production from the Dakota sandstone occurs in Central and North-central South Dakota. It is on a broad structural terrace on the south-east flank of the Lemmon syncline.

8,000,000 acres have been leased in North and South Dakota since late in 1939.

Extensive geophysical work has been done in Alberta, North Dakota, Montana, and Saskatchewan. In Alberta it has been found possible to outline the structure of the surface of the Palæozoic limestone at depths of several thousand feet. In the Blood Indian Reserve on the north end of the Sweetgrass Arch south-west of Lethbridge, southern closure has been shown.

The Black Hills uplift is an irregular dome-shaped anticline 125 ml. long and 60 ml. wide, with a pre-Cambrian core surrounded by Upper Cambrian to late Cretaceous beds. There are many subordinate flexures, some due to laccoliths. The Sioux Arch is a low, broad arch with a pre-Cambrian core and Ordovician beds on the flanks. Within the Williston Basin, north-east of the Black Hills, is the Baker–Glendive anticline, which stretches 115 ml., and apparently overlies a pre-Cambrian basement fault. There is a Cretaceous inlier within the Tertiary. Several domes on the anticline have given gas, and two deep tests have found Palæozoic oil production

The Lewis fault separates the Rockies from the disturbed belt on the west of the Alberta syncline. The Sweetgrass Arch is a broad fold, 200 ml. long and 40–70 ml. wide, which dies out northwards at Medicine Hat. Its highest point is the Kevin–Sunburst dome on which the Madison is productive. The arch is modified by terraces and faults, and has truncated Palæozoic beds in the north, where the Madison is cavernous. Post-Cretaceous beds occupy the central part of the Alberta syncline, which extends from the Lesser Slave Lake to the International boundary.

Throughout South Alberta and Montana Middle Mesozoic beds overlie the Middle Palæozoic. In Manitoba the Palæozoic dips gently south-west from the edge of the Canadian shield, whilst South-west Saskatchewan has a broad basin of Mesozoic and Tertiary.

The stratigraphy of the area is described in brief. Oil-shows have been found in the Cambrian, Devonian, Mississippian (the Madison has yielded much oil and gas at Turner Valley, Kevin-Sunburst, etc.), and in the Jurassic.

The article is illustrated by a number of maps, outcrop, structural, and lease, and by a correlation chart for the Palæozoic of Iowa, Wyoming, and South Dakota.

G. D. H.

791.* Hungary's Expanding Oil Industry. *World Petrol.*, March 1941, **12** (3), 52.—Recent discoveries and increased drilling have brought the Hungarian oil output from 100 brl. in 1936 to about 1,725,000 brl. last year. Now the production is at the rate of 2,000,000 brl./year, and should be sufficient for domestic needs. The main source of new production is in the south-west (formerly known as the Lispe field), from which a pipe-line is being constructed to Budapest. The newest field is at Lovaszi, with four wells aggregating 800–900 brl./day of 39° A.P.I. oil from 4950–5380 ft.

The Budafapuszta (Lispe) field averaged 5200brl./day of 41° A.P.I. oil from forty wells at 3960–4950 ft. Sixty wells have been drilled at Bukkszek, where there is a declining production of 40 brl./day.

In Jugoslavia, just across the border from Lovaszi and Budafapuszta, are the two small oil-fields of Selenico and Peklenico.

A map is appended. G. D. H.

792.* Maljamar Area Lime Wells Have Long Flowing Lives. D. H. Stormont, *Oil Gas J.*, 15.5.41, **40** (1), 23.—Lime-pay producers in the Artesia–Maljamar area of South-east New Mexico are characterized by their long flowing life and responsiveness to acidization. The average initial yields were about 150 brl./day, and now, after 14 years, the wells have almost the same potentials as when completed.

The first Maljamar production was discovered in 1926 at 4140 ft. Two other lime-fields to the west—Jackson and Grayburg—were found in 1929 and 1936, respectively. Together with later drilling this established the existence of an eastward-plunging anticline, with which nearly all Eddy County's present production is associated. The fields mentioned are all on or near the crest. Cementation and porosity to a large extent control the size of the wells in the sandy lime-pays, and the actual producing level differs in the different fields. In drilling at Maljamar oil-shows were also met at 2400 ft., and some production was obtained.

Production and completion data are given for the earliest wells in the Maljamar–Jackson area, together with production curves for some wells and a lease.

G. D. H.

793.* Lower Ordovician Found in Laurel County, Kentucky. W. V. Howard. *Oil Gas J.*, 15.5.41, **40** (1), 34.—Wells drilled around the Lexington dome have encountered a well-rounded porous sand, identified as the St. Peter. Farther to the east it fades out and a shaly formation takes its place. Recently oil-shows have been found in the St. Peter in Springfield Township, Erie County, Pennsylvania. A well on the Sinking Creek dome, Laurel County, Kentucky, met the St. Peter at 2972 ft., with a small gas-show and oil-stains, but the sand was too compact to produce. Shows were also reported in the Glen Dean, Golconda or Cypress, the Corniferous at 1190 ft., and the Trenton limestone at 1775, 1810, and 1820 ft. Correlation with two tests to the north showed the St. Peter to be lensing rapidly southwards.

The Sinking Creek dome covers 20,000 acres. The sands appear to thicken on the flanks, and possibly an oil-field will be found there. Practically all the structures of any importance in Laurel and Clay Counties are under lease. G. D. H.

794.* Recent Increase in Drilling May Bring Year above 1940. W. V. Howard. *Oil Gas J.*, 22.5.41, **40** (2), 41.—Records for the first four months of this year are almost equal to those for last year, and recent increases in activity will probably bring 1941's completions above that of 1940. Ohio is 21% ahead of last year, due mainly to extensive search for gas. Indiana is also ahead of last year as a result of wildcatting and drilling up of the Griffin and New Harmony areas. Kentucky has begun a keen search for gas. Illinois is 5% behind last year, Louden having been drilled up and the Devonian play at Centralia and Salem having passed its peak. However, several Illinois fields have not yet reached their limits. Continued wildcatting in Michigan has met with unfavourable results. No field in Kansas is particularly active, and except for East Texas all the major sub-divisions of that State show declines in activity compared with last year. The same is true of the Louisiana Gulf Coast, but in North Louisiana the activity is at about the 1940 level. Mississippi is ahead of last year, and, due chiefly to the development of gas-fields, the same is true of Montana and Colorado. Wyoming and New Mexico show declines, probably connected with marketing conditions. California seems unlikely to show much greater activity unless the Inglewood and Dominguez deep zones develop into town-lot plays.

The numbers of completions are tabulated by States for the first four months of 1940 and 1941. G. D. H.

795.* Orderly Development Indicated for Louden Devonian Play. W. V. Howard. *Oil Gas J.*, 29.5.41, **40** (3), 16.—A well has been completed in the Devonian at Louden, giving 681 brl. of oil in 8 hrs. through a ⅝-in. choke. The Devonian discovery at Centralia led to a rise in production from 200,000 brl./month to a peak of 2,953,650 brl./month, and a subsequent decline in six months to 350,000. 318 Devonian wells were completed with an initial average of 1304 brl./day. It appears as though the ultimate Devonian production will be 13,000,000 brl., or 40,880 brl./well.

At Salem 542 wells were brought in in the Devonian, the average initial production being 1655 brl. The ultimate Devonian production here is expected to be 36,000,000 brl., or 66,420 brl./well.

Based on the Devonian history of Salem and Centralia, and the orderly development and production of Louden, it is expected that the Devonian will yield 4500 brl. of oil/acre. The productive area will probably be less than that of the Cypress, Paint Creek, and Benoist sands.

Devonian production has also been obtained at Bartelso, Irvington, Sandoval, Tonti, Sorento, and Decatur. The old Martinsville field gave Devonian oil. Dry Devonian holes have been drilled at Carlyle, Fairman, and Patoka.

Completion and production data are tabulated for the Devonian at Centralia and Salem. G. D. H.

796.* Nueces County Distillate Sands Carry Oil on Flank of Structure. N. Williams. *Oil Gas J.*, 12.6.41, **40** (5), 24.—Oil production has been developed down dip in the distillate sands of the Stratton field on the Lower Gulf Coast. Similarly, drilling on the east flank of the Agua Dulce field has shown oil down dip, although the work is too scattered to correlate the oil-sands with the crestal distillate sands. Both structures are on a north-east–south-west elongated anticline, some 12–14 ml. long and 2–2½ ml. wide in the distillate zone. They are separated by a narrow saddle. Recycling is carried out in certain sands in both fields.

The Stratton oil was discovered in June 1940, and forty-three oil-wells have now been drilled, twenty-four to the Bertram sand at about 6300 ft., two to the upper Sellers sand about 40 ft. below, three to the lower Sellers sand 60 ft. deeper, and fourteen to the Wardner sand a further 100 ft. below. The northern closure of the area is due to lensing of the sands in that direction, and on the east or down-dip side edge water has been located in some of the sands. There is speculation as to whether the productive area will swing round the south end of the distillate area or continue southwards, for there is evidence of either another structure or of a southern continuation of the Agua Dulce–Stratton structure.

The Wardner and the Bertram are the main oil-producing horizons and the main recycling sands of the gas-distillate production. In addition to the sands mentioned, there are others which carry only gas and distillate. These are at 4800, 5000, and 6000 ft., and do not appear to have such extensive productive areas as the other sands. The Comstock is the only one of these sands which extends over the Agua Dulce area also. G. D. H.

797.* Brazilian Oil Campaign Given National Support. E. de Carvalho. *Oil Gas J.*, 12.6.41, **40** (5), 34.—Geological and geophysical surveys have been and are being carried out on the east coast of Brazil near São Salvador. The stratigraphical knowledge of this region is very scanty.

In the Lobato area a second well has been completed with a yield of 8 brl./day from 1300 ft. Structurally the field is an intricate arrangement of normal fault-blocks of widely differing displacements. In Alagoas a great thickness of sediments has been disclosed, and a fold with several domes and other structures favourable for oil accumulation have been indicated. There are also unconformable conditions.

The oil province of Brazil embraces several basins formed along the coastal belt of sedimentary rocks. The area is largely obscured by Pliocene beds (Barreiras formation). North of Alagoas Eocene beds underlie the Pliocene, whilst to the south Cretaceous rocks predominate. The coastal belt is only about 20 ml. wide, with pre-Cambrian rocks to the west. G. D. H.

798.* Well Logs and Field Data of Active Oil and Gas Areas—West Virginia. *Oil Gas J.*, 12.6.41, **40** (5), 54.—West Virginia is a part of the Appalachian geosyncline where the early development was best in the Mississippian, for the Devonian is rather shaly. On the margin of the basin in Ohio, Indiana, and Kentucky there was production from older beds, but for a long time they were deemed to be too deep in the centre of the basin for successful prospecting. At present in West Virginia there is shallow production down to the Berea (base of the Mississippian) with seventeen known sands, any of which may produce small quantities of oil or gas. In 1934 deep Oriskany production was found in West Virginia in the Elk district. In 1936 the Onondaga or Huntersville chert yielded gas, also in Kanawha County. These fields lie on the Chestnut Ridge, which seems to have the best petroliferous possibilities in West Virginia. Below the Oriskany the Clinton has given gas in the Kanawha district, and may prove important, although the Oriskany is generally considered to be the lowest important formation in West Virginia at present. The State is virtually untested below this level.

A map, stratigraphical column, and several well sections are included. G. D. H.

799.* Record of 1941 Completions Shows Drilling Trend. W. V. Howard. *Oil Gas J.*, 19.6.41, **40** (6), 17.—During the first five months of 1941, 7951 oil wells, 1030 gas wells, and 2554 dry holes were completed in U.S.A. Tables show the completions by States and districts, with the numbers and percentages of wells in each category, and the distribution of wells according to depth for the first five months of 1941. Deep wells predominate in West Texas, along the Gulf Coast, in California, and Wyoming, and in coastal Louisiana 287 of the wells were deeper than 10,000 ft. Wells 2500–5000 ft. deep predominate in Ohio, Indiana, Illinois, Kansas, Oklahoma, North, East and South Texas, New Mexico, Arkansas, and Montana. The average depths in the more active areas are more than 10% above the 1940 averages, but 897 wells were less than 1000 ft. deep, and 4365 wells 1000–2500 ft. deep. G. D. H.

800.* Leasing in Oklahoma Panhandle may Revive Drilling Campaign. R. Ingram. *Oil Gas J.*, 19.6.41, **40** (6), 18.—One of the many U.S.A. areas being closely examined for oil possibilities is the Oklahoma Panhandle, especially the extreme western edge, which probably lies on the westernmost flank of the Anadarko basin. Little is known of sub-surface conditions. Possible oil-bearing strata lie 4000 ft. deep, calling for geophysical work coupled with the scanty surface evidence and data from a few scattered wells.

About 1927 there was activity in the Panhandle, and by the beginning of February 1927 the Seminole production was more than 200,000 brl./day. Several tests on the Boise City dome, one of the few areas with useful outcrops, failed to give important production. The Pennsylvanian oil obtained at 4095 ft. was Oklahoma's deepest then.

It is believed that wrinkles with oil and gas possibilities in the Upper Pennsylvanian and Lower Permian will be found paralleling the Rockies, but these traps are not easy to find. During the last two years there has been extensive leasing, generally along north-west to south-east trends on the tip of the Anadarko basin, the eastern flanks of which have been highly productive at Oklahoma City, and on the south oil has been obtained at Cement and Chickasha.

Two maps are appended. G. D. H.

801.* Development of New Fields Boosts Illinois Production. H. F. Simons. *Oil Gas J.*, 26.6.41, **40** (7), 26.—After a period of stable or slightly falling production, Illinois has shown a rise since mid-May, and the rise may continue. The main field, Salem, has declined 22,000 brl./day since the beginning of the year, due to reduced output from the Devonian and upper zones, and failure to get large Trenton production. Centralia and Louden have declined 3000 and 5000 brl./day, respectively.

Continued wildcatting and the rapid development of extensions and discoveries have more than offset the declines mentioned. The chief discoveries are the Benton field, yielding Tar Springs production, and the proof that the Louden Devonian is productive.

It is believed that development can continue at the present rate for three to five years before exhausting possibilities to the extent that wide-scale prospecting will become uneconomic.

This year's discoveries are listed, and curves show the production, completions, dry and oil producing, and wildcatting results. G. D. H.

802.* Well Logs and Field Data of Active Oil Areas—North Texas. *Oil Gas J.*, 26.6.41, **40** (7), 50.—Development in North Texas (Wichita, Archer, Clay, and Montague counties, etc.) began more than twenty years ago with Burkburnett, Electra, and other shallow pools, and was largely limited to the Cisco (Upper Penn.). Production spread eastward without outstanding finds, and development was retarded by poor transport facilities. In 1933 commercial production was found in the Gunsight lime near Archer City, and in a Canyon lime of the Johnson pool. In 1934 Bend lime production was opened up in the Anarene pool and a small show was discovered in the Ellenburger east of Vernon. The K.M.A. field was the site of deep sand (Strawn) development in 1937, and this raised its output from 100,000 brl. in 1936 to 4,800,000 brl. in 1938. The sand was found to cover 70,000 acres. The Hull-Silk field came in in 1938 with two Strawn pays and one in the Bend lime. The rich Walnut Bend pool was opened in the Bend. Thirty-one discoveries were recorded in 1939, many being deeper sands in known pools; in 1940 there were thirty-two finds. Ellenburger production was found at K.M.A., and Mississippi lime production in Young County, whilst Hull-Silk now has ten distinct sands.

The major structural features are the Bend Arch and folds associated with the Wichita Mountains.

A map, stratigraphical column, and series of well logs are included. G. D. H.

803.* Benton is Best Field Found in Illinois this Year. H. F. Simons. *Oil Gas J.*, 3.7.41, **40** (8), 14.—The Benton pool, in the heart of Franklin County, gives more than 25,000 brl./day, and is the best field discovered in Illinois this year. It represents the first large sand production discovered in the southern part of the basin. The structure was delineated from data contained in mines and mine-prospecting bore-holes, and the area was later seismographed.

The first oil in Franklin County came from the St. Louis lime of the one-well Whittington pool, and late last summer a good McClosky lime-pay was discovered in the Thompsonville pool. The Benton field obtains oil from the Tar Springs sand, and has more than 100 producing wells. Tho Tar Springs sand has been found productive elsewhere in Illinois, although not so prolifically. Recently a new Tar

Springs pool was discovered near Sailor Springs in Clay County. The producing area at Benton is estimated to be about 1700 acres. The sand averages 34 ft. in thickness and has a break in some places. Wells have initial outputs of 50–912 brl./day and averaging 327 brl., and most have to be pumped. Practically all the wells produce some water, even those high on the structure. G. D. H.

804.* World Crude Output Rises in Face of War Crisis. J. L. Logan. *Oil Wkly*, 12.5.41, **101** (10), 39.—During 1940 2,150,356,000 brl. of crude were produced, 3·5% more than in 1939. The rise was due to an increase of 7% in the U.S.A. output, for the total production of the rest of the world fell. About 110,000,000 brl. of petroleum substitutes were made. Increases in production took place in U.S.A., Russia, Iran, Colombia, Trinidad, Argentina, Canada, and Burmah. Statistics are given of oil production for each country by years. G. D. H.

805.* Argentina's Oil Position Improved during 1940. *Oil Wkly*, 12.5.41, **101** (10), 45.—In 1940 Argentina's oil production was 20,642,298 brl., as compared with 18,642,755 brl. in 1939. Several pipe-lines were constructed, and two refineries were nearing completion.

Near Comodoro Rivadavia a field was found south of the Tordillo area, in the Pampa sandstone at 1700–1750 m., and 8 km. west of Plaza Huincul a gas reserve with some high-gravity oil was located in the Loma Negra district at 1000–1100 m. Several good wells were brought in in established fields. The main activity was in the Comodora Rivadavia area.

Tables give the production and well data, and a map shows the sites of oil-fields, refineries, and pipe-lines. G. D. H.

806.* Canada's Oil Industry Geared for War. C. J. Penn. *Oil Wkly*, 12.5.41, **101** (10), 50.—In 1940 Canada's oil output exceeded that of previous years. 130 ml. east of Calgary the Princess field was discovered, giving 26·3° A.P.I. oil from a depth of 3220 ft. at the rate of 520 brl./day with 12,750,000 cu. ft. of gas. Thirty-six wells were completed at Turner Valley during 1940.

Extensive exploration campaigns for gas are being planned for southern Ontario, where there has been a shortage of gas.

Political aspects of Canada's oil industry are discussed, together with Government regulations.

Tables give data about drilling at various points in 1940. G. D. H.

807.* Japanese Boost Mexican Drilling in 1940. *Oil Wkly*, 12.5.41, **101** (10), 64.—Sixteen oil wells and three gas wells were completed in Mexico in 1940. There were twenty-five failures. A Japanese company drilled thirteen wells in the Northern district and two on the Isthmus of Tehuantepec. Out of 6572 completions to the end of 1940, 2616 have yielded oil or gas.

During 1940, 44,000,000 brl. of oil were produced, Poza Rica giving about 28,000,000 brl. 20,555,000 brl. of oil were exported, the bulk of it to U.S.A.

Tables summarize the production and well data for 1939 and 1940 by districts. G. D. H.

808.* New Eastern Fields Improve Venezuela Possibilities. J. V. Hightower. *Oil Wkly*, 12.5.41, **101** (10), 87.—In 1940 Venezuela produced 186,134,390 brl. of oil, against 205,432,654 brl. in 1939, the reduction being due to the war. Eastern Venezuela gave 48,700,000 brl., as compared with 35,060,000 brl. in 1939. This rise was the result of the discovery of new fields, the opening of the Mene Grande pipe-line, and the reduced demand for the heavy Maracaibo oils. The El Roble field was expanded. It yields oil from the lower Oficina formation of the Oligocene at depths of 8000–10,000 ft. North-east of the San Joaquin field oil production was obtained on the Guario dome. 10 ml. south-west of San Joaquin Santa Ana found oil in 1939, whilst 2 ml. to the east Rincon Largo 1 was giving 385 brl./day from 8775–8790 ft.

In the Leona field oil is found at 6486–6504 ft., 6312–6321 ft., and 6293–6305 ft., but this field is closed in. This year oil has been found at Santa Rosa and Santa Barbara.

22 ml. west of Oficina a little oil was found in Socorro 1, although later wells were dry. Information is given about other dry wells.

There have been pipe-line and refinery extensions during 1940.

A map shows oil-fields, pipe-lines, and refineries, and a table provides data on production in 1939 and 1940 as well as data for 1940 by fields. G. D. H.

809.* Colombian Wildcatting to Continue over Wide Area. J. V. Hightower. *Oil Wkly*, 12.5.41, **101** (10), 104.—In 1940 the Colombian production was 25,556,000 brl., against 23,848,000 brl. in 1939, the bulk being exported. There were no outstanding developments from wildcatting in 1940. The Restrepo concession of the upper Magdalena valley was abandoned. More than three-quarters of the 1940 production came from Infantas and La Cira, whilst Petrolea provided almost all the remainder. Results on the Barco concession were not very encouraging, but late in 1940 a new producing area was found by the successful completion of a small producer, Tres Bocas 1, which came in at 3000 ft. after plugging back 5000 ft.

In the Magdalena valley there was considerable activity following the discovery of a sand at 2500 ft. on the Monte Oscuro anticline, east of Nare, but several wells have had to be abandoned. Narino 3 found a small but unimportant amount of oil, and Las Monas 1 gave a few barrels of oil/day. These latter wells are on the Restrepo concession.

During 1940 new concessions were granted in the Magdalena valley and the Llanos region.

A map shows the pipe-lines, fields, and concessions. G. D. H.

810.* Development Programme in Prospect for Ecuador. *Oil Wkly*, 12.5.41, **101** (10), 117.—Concessions cover the entire Pacific coastline of Ecuador and much of the interior, especially that part east of the Andes. Only in the Santa Elena area has production been obtained, but elsewhere there has been geological and geophysical work, with drilling apparently about to be undertaken at several points. The various holders of the concessions are enumerated, with brief details of the area, work done, etc. G. D. H.

811.* Ecuador Shows Steady Upward Trend in Crude Output. *Oil Wkly*, 12.5.41, **101** (10), 120.—Ecuador's production rose from 1925 to 1931, but fell in 1932. The upward trend was resumed in 1933. During 1939 2,312,520 brl. of oil were produced, making a total of 21,752,351 brl. in fifteen years.

Refining began in 1930, and in 1939 420,711 brl. of refined products were made. The exports in 1939 were to France, Uruguay, England, Japan, Brazil, Germany, and Argentina. A table gives the outputs of the various companies by years, and a map shows the fields, refineries, and concessions. G. D. H.

812.* Eight Drilling Rigs at Work in Brazil. *Oil Wkly*, 12.5.41, **101** (10), 132.—More than twenty years ago petroleum studies were begun in Brazil, but the first producing field, Lobato, was only discovered early in 1939. At present eight rigs are in operation in the coastal region, four being at Lobato. Three tests are reported to have found two distinct producing levels of possible economic value, which are now being tested.

A map shows the positions of the present and past drilling operations. G. D. H.

813.* Ancon Oil Field in Ecuador Continues Active. *Oil Wkly*, 12.5.41, **101** (10), 144.—The Ancon field, the only important oil field in Ecuador, was discovered in 1923. Its two producing formations have proved quite prolific, probably due to the considerable thickness of sand. It is a flat-topped anticlinal structure involving Oligocene and Miocene beds, with considerable surface fracturing and faulting, and it covers 12,000 acres. The shallow Socorro sand lies at 200 to 1300 ft., giving 17° Bé oil, whilst the more important Atlanta sandstone yields 40° Bé oil at depths of 1200 to 3600 ft. from a formation which is 2500 ft. thick in places. The Socorro oil is under water drive, but gas is the driving force in the Atlanta. Initial outputs up to 2000 brl./day, with a slow decline, are features of the latter horizon. The wells in the former average only 30–40 brl./day initially.

Drilling is hard, and producing wells have to be cleared of paraffin every nine months.

A table gives the age, area, production during 1939 and 1940, and the total production to the end of 1940, together with data about wells, for the various producing areas of Ecuador. G. D. H.

814.* West Central Wyoming Outlook Brightened by Deeper Pays. F. B. Taylor. *Oil Wkly*, 16.6.41, **102** (2), 24.—Prolific high-gravity oil production has been developed in recent years on several structures in the Lost Soldier district of Wyoming. Gas had previously been found at a number of points, some of which yielded oil also, but the characteristics of the oil led to its not being in demand. The deeper crude has proved more desirable, and thus in the past two years efforts have been made to develop this deeper zone. Prior to 1936 eight of the structures tested gave only gas, and that was chiefly from the Frontier, Dakota, Morrison, and Sundance. Lost Soldier, however, gave 19,000,000 brl. of light oil from the Frontier, Sundance, and Dakota. The Embar and Tensleep had been exploited only in the Dallas, Derby, and Lander fields, structures which were near the mountains, with the younger horizons deeply eroded and the oil heavy. In 1936 a 5870-ft. well to the Tensleep in the Wertz gas-field came in at 2000 brl./day, starting the search for the deeper production. The oil reserve at Wertz is estimated at 30,000–40,000 brl./acre.

All the fields of this region lie around the edge of a main sedimentary basin and relatively near the surface outcrops of the basement complex. Tertiary beds rest unconformably on older beds. The various oil- and gas-fields, Alkali Butte, Big Sand Draw, Bunker Hill, Dallas, Derby, Lander, Ferris, Middle Ferris, West Ferris, Lost Soldier, Muskrat, Mahoney, and Wertz, are all on domes. The structure and producing horizons of each of these fields are briefly described.

Maps, correlation-penetration charts, and tabulated field data are included.

G. D. H.

815.* Wells Deeper and Footage Off Less than Completions. *Oil Wkly*, 14.7.41, **102** (6), 97.—In the first six months of this year there were 3·9% fewer completions in U.S.A. than in the corresponding period of last year. 14,425 wells were drilled with a total footage of 43,246,211 ft. The average depth was 3061 ft. for new wells. 355 wells were deepened by an average of 499 ft. Most deep drilling took place in Southern Louisiana, where the average depth was 7724 ft., whilst the Texas Gulf Coast and California, with 6512 ft. and 5708 ft., respectively, were second and third as regards average depth of drilling.

Tables show the numbers of wells completed, footage and average depth by years from 1925, and by districts for the first halves of 1940 and 1941. G. D. H.

816.* War takes a Hand in Foreign Drilling. J. V. Hightower. *Oil Wkly*, 14.7.41, **102** (6), 104.—In Canada the Princess field, 130 ml. east of Calgary, was opened in January with a well giving 520 brl. of oil/day from a depth of 3260 ft. The Athabasca tar sands are now being exploited commercially by a plant which processes 400 tons of oil-sand per day.

During the first four months of 1941 Mexico's output was 11,800,000 brl., compared with 13,000,000 brl. in the same period of last year. Lack of outlet has caused the fall. Export recovery has given a rise in Venezuela's production. Several new fields have been discovered in the east—Santa Rosa, Santa Barbara, Las Ollas. Details are given concerning some of the wildcats. Drilling activity has revived in western Venezuela.

The bulk of the Colombian oil is still derived from the De Mares concession. Argentina's oil output rose 10% during the first three months of 1941 by increasing the withdrawals from old fields. Several wildcats seem to have failed to give encouraging results, and the amount of drilling in the new field 20 ml. south of El Tordillo Oriental is not disclosed.

The combined output of Bahrein, Iran, Iraq, and Saudi Arabia in the first four months of 1941 was only 83% of that for the corresponding period of last year, the fall being due largely to the 60% decline in Iraq's output. G. D. H.

817.* United States Sustains High Discovery Rate. *Oil Wkly*, 14.7.41, **102** (6), 116.—During the first six months of 1941 about 130 fields were discovered in the U.S.A., and old fields yielded 100 new pay horizons. North Texas provided fourteen new oil areas and thirteen new oil levels, mainly in deep lime and sand zones. The Mississippian lime showed further promise of being a good source of high-gravity oil. Ellenberger oil was found at Electra, and also in Pecos County, West Texas, in which region there were major extensions at Foster, Goldsmith, Sand Hills, and Abell. In East Texas the Hawkins field has been virtually defined, and oil has been found on the west flank of the Willow Springs deep gas-distillate field. There has been extensive leasing in the Anadarko Basin in the Panhandle, with the object of testing below the Permian.

On the Texas Gulf coast three Wilcox fields, four Cockfield-Yegua, four Frio, and one Miocene field have been discovered. In the Agua Dulce–Stratton area a series of new sands was opened up in the Frio at 6000–7200 ft. A revival of shallow activity has taken place in the San Antonio region with a number of completions in the Cretaceous.

Benton, giving oil from the Tar Springs at about 2160 ft., is outstanding amongst the eighteen Illinois discoveries. Four oil-pools and two gas areas were opened in Indiana, but wildcatting was at a very low level in Michigan, with only a few minor discoveries. The majority of finds in Oklahoma have been small, but Guthrie, Tecumseh Lake, Apache, and Deep Bromide (Velma) may become sizeable fields. There were no outstanding discoveries in Kansas. Activity centred on Falls City and Shubert in Nebraska. The flank of the Cambridge Arch was tested in Dawson County. Twelve new fields were located in Southern Louisiana, and in the north distillate production was found in the Smackover lime on the north-east flank of the Lisbon field. The Sentous deep zone appears to have been the most important new development in California. G. D. H.

Aerial Survey.

818.* Mapping from Aerial Surveys. A. T. Britton. *J. Instn Engrs* (*Australia*), May 1941, **13**, (5), 121–126.—This report is a general survey of mapping from aerial surveys, dealing with cost, instruments, planimetry, determination of heights, ground control, and organization. While good flying is one of the first essentials, and by no means easy to achieve, the paper points out what plotting really involves, and shows that it is of greater importance than the flying. B. M. H. T.

Drilling.

819.* Characteristics and Application of an Oil-base Mud. H. W. Hindry. *Petrol. Tech.*, May 1941, A.I.M.M.E. Tech. Pub. No. 1322, 1–6.—Oil-base muds of suitable constitution have excellent plastering properties which reduce damage to reservoir horizons such as may be caused by infiltrating water, give a thin filter cake, and hence greater clearances, remove trouble from heaving shales, give an easily removable mud sheath, and provide cores not contaminated by water. These muds are made of stove oil, oyster shells, limestone (bulk passing 200 mesh), or barite for weighting, lampblack to give gel strength, and blown asphalt to give plastering properties. A series of curves shows how weight, viscosity, settling and filter loss are affected by varying the proportions of these materials. Filter loss is markedly affected by the proportion of blown asphalt, whilst the amount of lampblack profoundly affects the viscosity. Muds weighing up to 95 lb./cu. ft. have been prepared. The amount of lampblack ranges up to 11%, asphalt to 18%, barite to 54%, and oyster shells to 44%. Facilities for handling oil-base mud are similar to those for ordinary muds, but there should be storage facilities for the various constituents of oil-base mud, rubber fittings for pumps and drill-pipe protectors should be oil-resisting, and of course precautions must be taken against fire. Contamination with much water should be avoided, as well as exposure to high temperatures for several hours. Gas-cutting does not occur readily. Electric logs can be made by using special electrodes which make contact with the well walls. Drilling rates are slightly slower than with water-base muds, and costs are rather higher. G. D. H.

820.* Power-Drilling Rigs. N. A. D'Arcy, Jr. *Petrol. World*, May 1941, **37** (5), 43.—After a brief historical review of the development of power-rigs, their advantages are discussed. The greatest advantage achieved is that a power-rig will drill a hole with approximately one-tenth the fuel required on a similar job by a conventional steam equipment. Power-rigs are compact and simple to move. A complete power-drilling installation, including pipe-racks, mud-sumps, derrick, and internal-combustion engines, can be set up in approximately half the space normally required for a steam-drilling rig, including the boilers and boiler-feed water-tanks. This compact rig often saves thousands of dollars on hillside locations, and sometimes makes possible town-lot installations that would not be possible with steam-rigs.

Moving a large power-rig in from 12 to 18 hrs. from completion to spudding in is common practice, and this moving time can be made as easily on locations several hundred miles apart as on those a few hundred yards apart. Tables give comparative studies of power- and steam-rigs.

The hydraulic clutch is similar to the fluid-drive in automobiles. This clutch is about 95% efficient, and transmits to the driven shaft a torque equal to that developed in the engine. Provision is made to cool the oil when the clutch is slipped, and it is reported that the fluid-clutch has satisfactorily transmitted the full torque of the engine to stalled slush-pumps for several hours at a time.

The fluid-clutch has a slip at slow speeds when placed on a hoisting drive. This produces a lag in acceleration on the drum and decreases the time required to hoist a stand of pipe. On slush-pump drives the speed is more nearly constant, and this device should be very advantageous. It will not only allow the operator to hold pressure on a stalled pump, but it should also absorb much of the impact developed in the pump.

The torque converter is another hydraulic drive, but it is very different from the hydraulic clutch. It is in reality a hydraulic pump which develops high kinetic energy in the fluid, that in turn is transmitted to the driven member. The torque converter develops from two to five times the torque developed by the engine when the driven shaft is stalled. This results in very high line-pulls when starting each hoisting cycle and a rapid acceleration up to maximum hoisting speed. The torque converter is only about 85% efficient, but it is claimed that the overall efficiency of hoisting is greater with a torque-converter installation than without.

An experimental converter with an internal hydraulic reversing mechanism is briefly discussed.

Field installations show that the torque converter has a decided possibility when installed in the hoisting end of a power-rig. It is doubtful if torque converters should be used on pump-drives or rotary drives. The extreme torque developed on a stuck drill-pipe could easily produce " twist offs," and the excessive load imparted to slush-pump piston-rods and cylinders when the pump is installed could blow up the fluid end.

Methods of compounding engines are discussed. A. H. N.

821.* Field Care of Rotary Tool-Joints. R. I. Gardner. *Petrol. World*, June 1941, **38** (6), 54.—New tool-joints should be thoroughly cleaned and inspected at the rig prior to use. There are good reasons for doing this. If a tool-joint galls after being placed in service it is almost impossible to definitely locate the cause of the galling. Therefore it is important to know that the joints are in good condition when first put together.

New joints should not be re-doped until they are on the derrick floor. This extra precaution is necessary because new joints should be absolutely clean when first put together. Before re-doping, all traces of the original lubricant, wood splinters, and grit should be removed.

When re-doping, it is good practice to use the lubricant recommended by the tool-joint manufacturer. However, most of the available tool-joint lubricants, consisting of a heavy oil mixed with finely ground lead or zinc, are satisfactory. The lubricant should be applied in a light, even layer on all mating surfaces. A shoe-brush has been found very effective in applying lubricant to the box-end threads, whilst a long-bristled paint-brush is satisfactory for the pins.

It is of paramount importance not to use a spinning rope while the joints are new. New joints should be put together with hand-tongs as far as possible. At this point the regular power-tongs should be used, but not in the usual manner. The joint should be tightened and loosened two or three times, beginning with moderate torque and increasing each time. Before the final tightening the joint should be unscrewed and re-doped. By following this procedure, numerous strings of drill-pipe have been put in service without any joint trouble.

Cleanliness is of prime importance in the life of tool-joint threads. Although it is not practicable to clean the joints each time they are made-up, any effort spent in making sure that the joints are clean will yield dividends in better tool-joint service. If the threads are thoroughly cleaned just prior to arriving on the derrick floor, it is a simple matter to keep them free from foreign matter thereafter.

Damage to tool-joint threads while the pipe is lying on the derrick rack probably accounts for the greater part of tool-joint thread trouble. In general appearance a joint of drill-pipe looks very sturdy and hard to damage. That is not the case, however, for it takes only a light blow on the end to destroy entirely its usefulness. The blow resulting from a bit or similar object striking the end of a tool-joint is often sufficient to damage it. That such light blows can cause serious damage is not generally recognized because the threads are usually covered with a thick layer of lubricant, which hides the damage. After inspecting numerous tool-joint failures it has been found that most of them resulted from undetected damage to the threads or shoulders.

A detailed procedure for periodic inspection is given, and this includes inspection of (1) straightness of pipe; (2) galling and damage to threads and tool-joint shoulders; (3) outside wear of tool-joints; (4) field repairs; and (5) condition of pipe.

A. H. N.

822.* Combination Rotary and Cable-Tool Drilling in Michigan. H. G. Hunt. *Oil Gas J.*, 24.4.41, **39** (50), 65.—*Paper Presented before American Petroleum Institute.*—The State of Michigan has made more progressive strides in the use of rotary than any other State in the East of the U.S.A. with the exception of Illinois. Michigan is more similar to the other eastern States than Illinois, because of more lime formations occurring in it than in the latter State. The use of combination drilling in Michigan came about through trial and error due to the thickness of glacial beds, pencil caves in the central part of the State, and difficulties encountered in cable-tool drilling and resultant under-reaming.

The Michigan law requires a string of pipe to be set through the Marshall brine sand. As a result of the expense and difficulties in connection with cable-tool drilling, rotary operations started in Michigan in 1928, and increased gradually as pioneering work was done. The combination outfits came into use in 1934. Experience is at present insufficient to determine the difference in pipe-saving through the use of rotary, but the saving is appreciable. There is also a time saving of 37% in favour of the rotary. It is believed that the rotary has justified its retention not only in light-weight drilling and slim-hole operations, but even in the heavy-duty rotary type of operations. However, it is not thought that the cable-tool rig will disappear, as it has advantages in the lower sections of a hole. A. H. N.

823.* Building Up Shoulders on Worn Tool-Joints. Anon. *Oil Gas J.*, 15.5.41, **40** (1), 46.—The point of greatest wear on a tool-joint is at the lower end of the box. The shoulder between the tool-joint and pipe receives the full force of the cutting action of the mud-stream as it rises in the hole. This mud-stream carries the small particles of formation which have been cut by the bit, and the continuous bombardment of these particles will cause a rounding-off, or stream-lining, of the shoulder. Another factor contributing to the wear at this point is the contact with the walls of the hole as the pipe is lowered while making a trip or while drilling. The shoulder on the pin end escapes much of this wear, as the channel for the fluid stream is expanded instead of being contracted as it passes over the shoulder on the pin and the contact with the wall of the hole is less frequent and severe.

Removal of the metal body of the joint produces another danger zone at the threaded portion of the box. A substantial reduction in the thickness of the walls of the tool-joint at this point may produce a slight spreading which would permit shouldering of the two faces and produce a leaky and weakened joint.

Special equipment and technique of building up shoulders by welding are described and illustrated. A. H. N.

824.* Obtaining Maximum Efficiency in Firing Oil-Country Boilers. R. Reed. *Oil Gas J.*, 15.5.41, **40** (1), 51–52.—The standard type of oil-country boiler is a prolific generator of steam when given an opportunity to perform. Standard practice with these boilers is to provide a very large firebox made of steel. Water is on all sides of the firebox, where a tremendous radiant heat-absorption factor may be realized. Recent experiments seem to indicate that larger fireboxes add to the steaming rate of oil-country boilers.

Tremendous increments of available energy are being realized through superheating the steam. The higher the superheat within the limits of the machines being operated the more efficiently can they be made to operate. Some operators set up separately fired furnaces to superheat the steam. It is said that in this manner two boilers may be made to do the work of several.

Provision should be made to use all the exhaust steam possible to preheat the feed-water. Saturated steam at 250-lb. pressure has a total heat content of 1201·2 B.Th.U./lb. Of this heat content, 381 B.Th.U. are introduced before steaming begins. After steaming begins 819 B.Th.U. are introduced to cause the water to change its state from liquid to vapour at 250-lb. pressure. The 381 B.Th.U. are referred to as " specific " heat, the 819 B.Th.U. as " latent " heat. A good portion of the specific heat may be taken care of through the use of preheating devices. For instance, if water is preheated from 60° to 200° F., 140 B.Th.U. of the specific heat are put into the water before the burners take charge.

Where the gas is burned quickly and entirely consumed before it strikes heating surfaces, efficient operation may be obtained. Where the gas burns slowly and wanders around in the firebox until it comes in contact with the relatively cold metal surfaces, the burning gas is chilled below the kindling point of the gas and carbon monoxide is released in the firebox. This monoxide comes from the relatively cold zone into a zone above its kindling temperature and re-ignites. When this phenomenon occurs at a relatively high rate, " drumming " occurs. The so-called drumming is the sound made by the concussion produced as the gas re-ignites. While everyone understands that monoxide or incomplete combustion causes drumming, no one is prepared to say why a particular type or make of burner will drum in one case and will not drum in another. It may be said, however, that drumming is a characteristic of steel firebox boilers.

Burners are discussed. A. H. N.

825.* Mud Flow in Drilling. R. J. S. Pigott. *Oil Gas J.*, 22.5.41, **40** (2), 62. *Paper Presented before American Petroleum Institute.*—Tests made on 4-in. pipe, on capillary tubes, on ½- and 1-in. pipes and a modified McMichael absolute viscosimeter were used to demonstrate that the flow of mud can be predicted in the viscous region by utilizing the variable apparent viscosity in place of the usual constant viscosity for a liquid.

In the turbulent region of flow all plastic effects, and consequently variation of viscosity, disappear : then mud can be treated as a true liquid. Experiments show that in this region the viscosity of mud is surprisingly low. The two different formulæ which must be used for suspension of cuttings respectively in viscous and turbulent flow are discussed, together with modifications necessary for cuttings other than round particles.

The general conclusions are : (1) The pressure drops and the sustaining effect of any mud can be computed quite accurately, given the complete viscosity–velocity relations and density of the mud. (2) Attention should be given to balancing pressure drops as between drill-pipe and hole, whenever feasible, to keep the total pressure in the pumps down. (3) Velocity is useful for lifting, but is limited by the pump pressures required. Reasonably high density is valuable for lifting, but also opposes dropping cuttings. (4) Viscosity is generally objectionable ; it raises pumping pressures ; and because in muds it is practically inversely proportional to velocity in the viscous region (mud pit), it is the most serious obstacle to dropping cuttings. Gelling to sustain cuttings when circulation is stopped is now easily obtained without high apparent viscosity in motion.

The paper is well illustrated by sixteen quantitative graphs and seven tables.
A. H. N.

826.* Deep Michigan Test Uses New Mud System and Treatment. H. F. Simons. *Oil Gas J.*, 29.5.41, **40** (3), 34.—Principal features of the mud system are the tanks for circulating, storing, and treating the mud, and a de-gasser. In addition, should it prove necessary, the mud can be passed through an oil-gas separator. The mud treatment which has allowed the operation to be successfully pursued incorporates a new compound which imparts a colloidal property to the drilling fluid in the presence of salt water. The drilling fluid at present being used was made from admixtures and salt water instead of the usual fresh water.

The problem of mud control on the Bateson well is not a simple one, as there are three complicating factors : high gas pressures, a large salt section and salt-water-bearing sands, and hydrogen sulphide gas. In addition, there are several sands which will allow a thick filter cake to be built up in case the filtration qualities of the mud are not properly maintained ; also a washed-out section which requires that a reasonably high viscosity be maintained for the mud-stream to carry the cuttings out of the hole.

A detailed account is given of the problems met and the methods adopted for their solution, giving exact data and properties of muds used. The plant is similarly discussed and illustrated in detail.
A. H. N.

827.* Deep-Well Practices in Oklahoma City. H. F. Simons. *Oil Gas J.*, 19.6.41, **40** (6), 34.—Oklahoma City was not the first place in which a well was washed with tubing, at least one previous place in Oklahoma being recorded. However, it was in Oklahoma City that the practice reached prominence, and this is currently the most commonly used method of completing high-pressure wells. The method used was to core or drill the pay, run and cement the casing, and drill the plug with rotary. The tubing was then run to bottom and the mud displaced with clear water until the well kicked off and started to flow. Previous to the introduction of this way of doing it, completions had been attempted with cable tools, but trouble occurred with sticking.

Another method of completion was to set the pipe, drill in with heavy mud, and then string up a bailing line. After running the bailer a few times, the wells start to head, and as soon as the mud was blown out into the pits, the stream would be turned into the separators.

The first wholesale attempt to decrease the time required for drilling a well by proper mud treatment was at Oklahoma City. Contractors found by experimenting that a thin mud with other desirable qualities was sufficient for drilling most of the hole, and that the rate of penetration was increased. The mud was weighted at the proper time to prevent blow-outs.

Other practices are credited to the same place. The greatest contribution made by Oklahoma City has been in the science of pumping. Had the field not returned a profit it would have been a benefit to the petroleum industry because of the improved pumping practices developed. Practically every conceivable method for lifting oil has been tried in Oklahoma City and many pieces of equipment have been perfected there. While deeper wells have been pumped, it is the largest single application of deep pumping. Prior to its development, fields above 5000 ft. had been the testing ground for pumping equipment. The stepping up of the depth to 6500 ft. created so many additional problems that some then believed it would be impossible to pump the wells in Oklahoma City. The solutions of the various problems are briefly discussed.
A. H. N.

828.* West Lake Field Practices. N. Williams. *Oil Gas J.*, 26.6.41, **40** (7), 42–44.—Production at West Lake Verret previously has been found in sands ranging in depth from 7400 to 8900 ft. Eight wells had been completed in these sands ; in addition, there is a gas well, completed in a shallower sand, which was drilled to supply fuel for field operations. The deep producer is one of seven tests that have been drilled to greater depths in exploration of lower horizons, two of which were carried to depths below that of the deep producer.

Drilling and completion of the deep producer involved no major problems or difficulties other than the normal hazards of deep drilling. Only two minor fishing jobs marred the record of the well, which was drilled and completed in an overall time of only 52 days.

From an operating standpoint, conditions in the West Lake Verret field generally have been unusually favourable. Porous formations and cavities that have caused loss of returns have been encountered at shallow levels in several wells. Also in one of the deep tests (4 Jeanerette) a salt-water flow at 11,890 ft. necessitated quitting the hole at that depth and plugging back to one of the regular sands for completion; otherwise drilling has been more or less uneventful. So far no excessive gas pressures have been encountered, although every precaution is taken to guard against any eventualities. The operations are described in some detail. A. H. N.

829.* War May Affect Many Practices in the Petroleum Industry. H. F. Simons. *Oil Gas J.*, 3.7.41, **40** (8), 28–30.—At the present time there is little actual shortage of equipment in the drilling and producing departments, but there is considerable fear that a scarcity is in the offing. Key to the situation is the Priorities Board, which to date has not looked into the oil business sufficiently to get an idea of its requirements. The accompanying article does not predict a shortage of material, but points out some of the things that may be done to avert shortages and the methods being considered by oil-company and drilling organizations to keep operations going smoothly.

A reduction in the steel tonnage necessary for casing is being brought about by three methods : the elimination of surface and intermediate strings whenever possible, the use of second-hand casing and obsolescent sizes and types, and the wider use of small-diameter pipe. This latter has been an important move in the past several years, and each month sees more companies using 6¼-, 5½-, 5-, and 4½-in. pipe. With only a certain amount of steel available, a 50% reduction in the weight of casing used is an important saving. The reduction in casing size can be carried too far, however, and in the final analysis it is more important to see that the well is properly cased than it is to save the steel tonnage. In most cases the reduction can be made without harm to the well, but this is by no means a universal rule.

The most important threat to the producing branch is the withdrawal of nickel-alloy steels from all but defence industries. The oil industry has been one of the leaders in the use of special alloys, particularly nickel steels, and its acceptance and willingness to pay for better materials have been a contributing factor in building up the nation's normal production of these items.

Most important uses of such steel have been in the sucker rods used in deep wells, special types of rod-pumps, polish rods, valves, etc. In deep wells and in wells where corrosion or embrittlement is a problem the improved rods and metal-to-metal pumps have been important factors in reducing operating costs. Rod breakage has been almost entirely eliminated in deep holes, due to the development of the nickel-steel rod over a period of years. The number of times it has been necessary to pull the rods and tubing in order to repair the pump has been substantially reduced through the use of the advanced types of pumps.

In shallow wells in which corrosion is not present the problem will not be severe, but will add slightly to the production costs. In the deep wells, or in those handling sour crude oil or large quantities of salt water, it will be an important problem, and will greatly increase the number of pulling jobs. The number of machines and crews engaged in this work will probably increase considerably over the next two years. A. H. N.

830.* Skidding Rigs on Savannahs of Eastern Venezuela. F. E. Hatfield. *Oil Gas J.*, 3.7.41, **40** (8), 33.—The flat, treeless savannah was ideal for skidding of derricks. Although the well-depths of from 5500 to 6000 ft. required quite heavy equipment, by close co-operation of both drilling and transportation personnel a technique was evolved which permitted the rapid skidding of rigs and derricks for considerable distances and made possible the rigging up of equipment within satisfactory time limits.

The first step was to equip the derrick for skidding. There were 14 × 14-in. native hardwood timbers called " vera " already on hand which proved ideal for derrick sills. This wood is harder than oak—so hard that to drill bolt-holes tool-steel drills had to be used. Its resistance to abrasion, however, permitted the employment of the rapid skidding method finally adopted, and following many skids, only a few sills have been replaced. After some initial experiment using 4-in. pipe rollers and 3 × 12-in. skid boards it was discovered that, because of the flat, grassy surface, very little more power was needed to move the derrick over the savannah without the use of rollers or board tracks; that the job could be accomplished much cheaper and quicker, with no damage to derrick or substructure.

The method is detailed and illustrated. A. H. N.

831.* Analysis of Mud Returns Locates Oil and Gas Zones. E. Sterrett. *Oil Wkly*, 31.3.41, **101** (4), 49.—Mud-analysis logging finds particular application in areas where production is from lime, or where muds have high saline content. Where coring is difficult or hazardous, or where core recoveries are bad, mud-analysis logging furnishes a means of obtaining corroborating data on those formations carrying oil or gas.

In wildcat drilling in hard-rock formations, where drilling is relatively slow, the usual programme is to drill ahead for 3 ft. and then circulate mud until known returns appear from the bottom. Showings thus obtained determine the advisability of coring or going ahead with routine drilling, and prevent the unprofitable coring of shale or other non-productive formations.

Mud analysis for gas- and oil-showings is especially well fitted for determining productive formations, and for locating the gas-oil contact, when drilling in formations which have comparable penetration rates, and where no other change in drilling data is observable.

Various tests and methods of mud analysis are described. The gas detector using a hot filament is also described. An instrument is also available for use with gas detectors of the filament type, in which a known volume of drilling mud is trapped and subjected to a given increment of pressure. Since the drilling fluid is non-compressible, the reduction of volume must take place in the gases carried in the mud, the gas volume being measured by calibrating the plunger or reading direct from the scale.

The volume is considered as being composed of a volume of non-compressible fluid and a volume of compressible gas. The initial pressure is atmospheric. By advancing the calibrated plunger through the packing gland and into the chamber, the pressure within is increased. Since the determination may be made in a few seconds, temperature changes are negligible and remain at the equilibrium established by continuous mud-flow through the instrument until a determination is begun.

Since the volume of the cylinder is constant, if the pressure ratio be held constant, the percentage of gas is in direct proportion to the volume of the plunger which enters the chamber. Thus direct readings are obtainable, and no calculations need be made.

When the presence of gas is indicated by the gas detector, a check on the mud returns for possible oil content is possible by means of the fluoroscope. Minute quantities of oil, of the order released when penetrating 1 ft. of saturated formation/hr., with 25% porosity, are invisible to the eye, and do not alter the mud as to viscosity or weight within the scope of instruments normally used for these determinations. Such diffusions, however, may be determined by a fluoroscope, utilizing a light-ray functioning in a band of from 2000 to 4250 Ångstrom units, or from the lower limits of violet in the visible spectrum through the range of ultra-violet emanations. Radiations below 3100 Ångstrom units are especially useful in determining oil in drilling mud.

A. H. N.

832.* Modern Field Technique Adopted in Trinidad. Anon. *Oil Wkly*, 12.5.41, **101** (10), 60.—The high-pressure conditions traditionally encountered in Trinidad drilling continue to demand careful attention to mud conditions. Accordingly, the " mud department " to-day is an elaborate and highly specialized scientific activity. Vibrating screens and mud-laboratory equipment are in evidence everywhere. Trinidad pressure conditions have called for muds weighing as much as 130 lb./cu. ft.

Straight hole is also a guide-word of the local operator, and inclination readings with up-to-date equipment are taken at frequent intervals. Even in some of the deepest holes permissible deviation is limited to between 2½° and 3°. It has been proved that the time spent in deviation corrections pays full dividends in the end when it becomes necessary to install and maintain pumping equipment or to correct faulty pipe settings.

The average drilling depth in Trinidad is between 3000 and 4000 ft., but several wells are going down to the deeper horizons, between 6000 and 8000 ft., with regularity.

Much experimenting has been done with various types of screen-liners and fine-gauge wire-wrapped screen-pipe. Recently attempts were made to pack the production section with prepared gravel. This has not been tried sufficiently to reveal what benefits may result when properly applied.

More recently the pre-packed gravel liner has been considered. Several new wells in different fields are scheduled to be produced with this completion method. These liners will be set either in open hole or within perforated casting. A. H. N.

833.* Unitizing Speeds up Operations on Highly Portable Unit. G. M. Wilson. *Oil Wkly*, 23.6.41, **102** (3), 14–18.—The unit consists of three major pieces, each mounted as a self-contained, separate unit on track-laying wheels, that permit them to be moved by tractor from one location to another. When spotted and joined together on the location, each unit becomes an integral part of a smoothly functioning assembly that is definitely aiding in lowering the transportation and drilling costs of each well.

The three principal units are essentially: an 87-ft., specially built derrick with an 18-ft. base, and draw-works powered with a 185-h.p. butane engine; a 40-ft. long by 16-ft. wide pipe-rack connected to the derrick on the side opposite to the draw-works; and the mud-pump unit, consisting of a 7¼ by 14 power pump and a 185-h.p. butane engine, mud-section line, and mixing gun. A fourth unit—a 20-ft. long by 8-ft. wide dog-house, containing lockers, lavatory, and desk—was not mounted on track-laying wheels, but was carried on two large, steel-spoked, flat steel wheels.

With the exception of the fourth unit, each of the units has a steering end, to which is attached a sturdy draw-bar to be used by the tractor for pulling and manœuvring of the unit. A large-diameter king-pin made from a section of 9⅝-in. 40-lb. casing, about which the front trucks turn as a steering unit, provides a large bearing surface and results in easy control of each unit while being moved.

Each component is described, together with the method of moving and installing it.

While only five or six wells have been drilled with this unit up to the time of the paper being written, proof of the initial success of the original intentions of the design may be seen in the fact that all four units, including butane tank and several miscellaneous items, have been moved completely and spotted at the next location in approximately 2½ hrs. This does not include the time consumed in the preparing and breaking-down ready to move. After the drill-pipe is laid down on the rack ordinarily it takes only 2–3 hrs. to disconnect hoses, lay down the travelling block, break out and load-surface mud, water, and fuel lines, and disconnect the units preparatory to moving.

A. H. N.

834.* High-Speed Drilling Chain Paces Deep-Hole Demands. E. Sterrett. *Oil Wkly*, 30.6.41, **102** (4), 35–40.—On the A.P.I.-4 chain the controlling dimension may be taken as the 1¾-in. outside diameter of the roller. Within this limit must be provided metal for the roller, with thickness sufficient to permit heat-treatment and to withstand peening and flattening under service impacts; the bushing, sturdy enough to maintain spacing between side-plates and provide necessary rigidity against twisting or spiraling, and thick enough to permit finishing and hardening against wear on both inside and outside cylindrical surfaces; and the pin, large enough to present adequate bearing surface for its working contact with the bushing, of sufficient diameter to resist shearing at the side-plates, and possessing ample rigidity to maintain true cylindrical form under heaviest loads. In addition to the material or metal requirements for the three working units within this 1¾-in. circle, provision must be included for two clearances—between roller and bushing and between bushing and pin—if the link is to secure the lubrication enabling it to give maximum service life.

With dimensions of stronger chain rigidly circumscribed by specifications and existing clearances in draw-works and rotary drives, chain manufacturers have carried even further their investigations into the suitability of special alloy steels of highest physical properties, and have adapted their designs to utilize the best materials available. That this search has been successful is proved by the ability of a chain weighing

16·5 lb./running ft. to carry an ultimate strength rating of 185,000 lb. with ample safety factor to meet any rig emergency.

How these results were achieved is discussed in some detail and the paper is illustrated by the chief types of chain as marketed by different manufacturers. Methods of handling the chain to ensure maximum utility and minimum cost are also given.

A. H. N.

835.* **Factors to be Considered in Determining Proper Casing Size.** L. E. Porter, *Oil Wkly*, 14.7.41, **102** (6), 81.—After reviewing previous opinions, the author considers the following as essential factors which should be considered in any casing programme: (1) The thickness of oil-zones to be produced should be ascertained, differentiation between wells of, say, 100 ft. or less with those engaging several hundred feet of zone open for oil and gas production. (2) The cost and drilling time for various hole sizes should be ascertained as one of the factors in selecting the primary string (water string). (3) Proper regard to the existence of high-pressure gas horizons between the shoe of the surface string and the shoe of the primary water string, and their respective influence, if any, on hole size, mud weight, etc. (4) Determination of the characteristics of the producing zones, as to whether it is advisable to set the primary strings at the top of the producing horizon prior to drilling into them. In this connection added consideration should also be given to: (*a*) the drilling costs for the size of the hole to be drilled in the producing zone, inclusive of core recovery, if coring is to be done; (*b*) the relative efficiency of the hole to be drilled on the ability to perform future remedial work, deepening, etc., subsequent to the original completion; (*c*) costs with respect to future (*b*) above; (*d*) the influence of drilling fluids on the section of zone to be produced, and whether by setting at the top of the producing zone prior to entering a complete change-over of drilling fluid is warranted, so that a lighter-weight fluid, nearer the hydrostatic pressure of the formation, can be used.

If the zone to be produced is affected by drilling fluids, the time element for keeping the hole open to such fluids should be held to a minimum. This should be axiomatic.

(5) Advantages of larger-hole size (if any, within practical limitation of size) over the small-bore hole in future oil and gas recovery. (6) The mechanical influence of the size of oil-strings and liners on future production methods, particularly with respect to: (*a*) special gas lift and flow devices; (*b*) existing pumping methods for deep-well production; (*c*) size of tubing, etc., under conditions of "waxing," as well as flow friction with long strings.

(7) The mechanical flexibility of various casing combinations which will permit cementing through perforations to exclude certain high-pressure gas zones, retaining them for future production or natural gas-lift purposes when the present zones have been depleted to the point that the oil content can no longer be "flowing" or produced by mechanical means. (8) In "high" gas-oil ratio wells involving several hundred feet of zone, due consideration should be given to casing sizes, so as to permit mechanical flexibility (this problem is related to (6) above for controlling gas-oil ratios by means of: tubing size; packer-type flow devices; bottom-hole beans).

(9) The influence of hole and casing size during the pumping stage of a well, particularly with respect to the operator's ability to clean out sand, bailing operations, etc.; see (4) above. (10) The application of the law of averages of casing failures and the necessity of plugging operations, as may be determined from a study of operating conditions in similar fields at similar depths. A. H. N.

836.* **Speed and Mobility have Lowered Drilling Costs.** Anon. *Oil Wkly*, 14.7.41, **102** (6), 86.—Lower cost of rotary drilling has been achieved without radical technique or machinery changes, but through gradual refinement of methods used previously, that have improved the efficiency of modern rigs many-fold. To make hole the bit must be rotating on bottom. All other rig operations are non-productive. The trend in modern drilling practice and equipment has been to increase the time spent on bottom actually digging hole, to dig more hole/hr., and to provide for faster dismantling, moving, and erection of rigs. Thus non-productive drilling time has been reduced to a minimum and productive time has been boosted to a maximum. Additional savings have been attained through use of fewer and smaller casing strings, longer service life of modern equipment, and many other factors, but all have contributed to improve efficiency. Many of the advancements considered individually have been small, but aggregate effect has been large.

Costs have been reduced in many instances by eliminating some of the "unnecessary" drilling. For example, the Gulf Coast area, once noted for close spacing, has developed many fields on 20- and even 40-acre spacing patterns in recent years; and the State of New Mexico has 3000 wells on 40-acre spacing. Similar trends may be found in many other regions. The drilling of fewer wells/acre lessens the capital investment required to develop a property, and consequently smaller quantities of production are needed to make it a profitable enterprise. However, actual reduction of well costs has been of greater and wider benefit, for it has lessened the investment in those tests that have been drilled.

A detailed review of recent practices is given. A. H. N.

837.* Drilling-Bit Performance in California Operations. W. A. Sawdon. *Petrol. Engr*, May 1941, **12** (8), 23–26.—It would appear from present observation that, everything else being equal, hole below the surface string being drilled with rock-bits will go faster with larger bits (within a range of 10⅝–12¼ in.), and it is safe to say that the driller can run harder on the larger bits. To state this as a rule would be unwise, however, for the personal element enters into the operation.

An instrument of recent use gives on one record sheet the rate of penetration, the weight carried on the bit, the rotating speed, the circulating pressure, and the torque. This instrument has been in service for too short a time to provide adequate data on its application for determination of bit performance, but it appears to offer opportunities for observing the rate of penetration under variations of rotating speed, weight, and pump pressure. As the records are correlated on the one sheet by time intervals, the effect of any change in weight, speed, or pressure should immediately be reflected by the rate of penetration if such changes actually affect the rate. The rate of penetration is affected by the condition of the bit, hence bit wear must be taken into consideration.

Wear of bits in Californian drilling is studied and certain comparisons are made. Co-ordination of rotating speed and weight carried on the bit has probably been the secret of most effective bit performance; yet, although high rotation generally requires a corresponding reduction in weight, there have been numerous cases where the weight carried with speeds of 400 r.p.m. and over has been greater than is generally considered feasible. This has been so while drilling a number of the wells at Rio Bravo, and the mud circulation having been great in such cases, the possibility of the influence of the circulating fluid should not be overlooked. Correlation of rotating speed and weight with circulation pressure and volume should thus possibly be given greater attention for the particular formation being drilled.

The theoretical wear on bearings is proportional to the speed in r.p.m. multiplied by the square root of the weight carried on the bit. The result of this computation is not a figure of measurement, but rather one for the purpose of comparison.

A. H. N.

838.* Three-Cylinder Slush-Pump for Deep-Hole Circulation. W. A. Sawdon. *Petrol. Engr*, May 1941, **12** (8), 38.—The one pump now in service is an 18-in. by 7-in. by 20-in., and although it has been employed for the drilling of only two wells to date, its use has supplied data that indicate the scope of its performance under operating conditions.

The primary objects of the three-cylinder design are to provide for high pressures without compounding and to circulate a large volume of fluid with one pump. By using three cylinders there is also an overlapping of strokes, and this is apparently the reason for the smooth action and elimination of pounding in operation.

Although the pump is rated as having 7-in. cylinders, 7½-in. liners can be used. In the two wells thus far drilled with the pump, however, only 6-in. liners have been employed. With liners of this size, circulating at a pressure of 2500 lb./sq. in. and running at 48 r.p.m. (an r.p.m. being considered as a complete stroke forward and back) the calculated volume of fluid pumped was 640 gal./min., based on operating conditions. When a 7-in. liner is used and the pump run at 50 r.p.m. with 300-lb. steam against a pressure of 2000 lb./sq. in., the rated capacity is 930 gal./min.

After describing certain parts in some detail it is noted that there has been no trouble in maintaining pressure in the boilers. The boiler-plants used have consisted of 350-lb. superheated steam units, but steam at the manifold has usually ranged from 250 to 300 lb. The pump has been able to circulate more fluid than could be used, and the average speed has been approximately 40 r.p.m. At one time it was operated against a pressure of 2800 lb./sq. in. at a speed of 40–45 r.p.m. A. H. N.

839.* Two-Engine Drilling Rig Layout Achieves Flexibility in Streamline Arrangement. H. L. Flood. *Petrol. Engr*, May 1941, **12** (8), 43.—Departing somewhat from usual design, the two engines are mounted side by side just back of the hoist, with the crankshafts at right angles to the drumshaft of the hoist instead of parallel to it.

The drive-shafts on both engines are each equipped with two V-belt pulleys. The pulleys farthest from the engines are joined by V-belts, and serve to compound the engines when this is desired. The other pulley on the shaft of the right engine drives the mud-pump. The pulley on the shaft of the left engine drives the central shaft transmitting power to the draw-works and the rotary table.

On the central shaft a gear-box situated just back of the draw-works serves as a take-off for the shaft on which is attached the sprocket driving the hoist via a chain drive. The central shaft continues through the gear-box and extends under the drum to the front side of the draw-works to serve as a direct drive for the rotary table.

A small d.c. generator mounted on the back member of the transmission framework is driven by V-belt from the right engine shaft. When the engines are not running, lights are supplied by a small-engine light-plant.

The central shaft extends only far enough in front of the draw-works to permit a universal joint to be mounted. On the rotary table shaft another universal joint is mounted, and the removable drive-shaft is flanged between the two universal joints. Mounted in the centre of the drive-shaft is a splined coupling that permits the length of the shaft to be shortened or lengthened approximately 6 in. The two universal joints and the splined coupling provide considerable flexibility in placing the table with respect to the draw-works.

Speed variation, engine characteristics, and arrangement are briefly studied.

A. H. N.

840.* Functional Analysis of the Engineer's Place in the Petroleum Industry. Part 3. E. N. Kemler. *Petrol. Engr*, May 1941, **12** (8), 58.—In this part of the paper the duties of the petroleum engineer—amongst other engineers—are described both in the field of drilling and in that of production. Although the chemist makes recommendations for certain special mud conditioning, the petroleum engineer should follow the mud conditioning in the field and see that it is doing what is required of it. The importance of proper mud conditioning even for routine drilling makes it necessary for the engineers to specify what constitutes proper mud conditioning and to set up control methods.

Core analysis, the correlating of drilling and geological information, and the analysis of electric logs are very important functions of the petroleum engineer. As the proper analysis of this information may mean the difference between a successful completion or a poor well, or, in case of wildcat or semi-wildcat wells, may mean the location of, or passing up of profitable production, it deserves the most intensive study.

The study of reservoir performance as a basis for imparting information on reservoirs, type of reservoir, best method of operating reservoir to obtain most economical recovery, and possible advantage of pressure maintenance is an important function of the petroleum engineer. He should have the responsibility and authority to pass on all these important engineering problems. As the best method may not always be applicable, because of methods used by offset operators, or because of proration or other State regulations, his recommendations necessarily have to be passed on to see that they fit other requirements as well as company policy.

The duties of the chemical, mechanical, and civil engineer are also described.

A. H. N.

841.* Diesel-Electric Rigs in Gulf Coast Service. O. Adams. *Petrol. Engr*, June 1941, **12** (9), 36.—Two diesel-electric rigs (known as No. 1 and No. 6) are described in detail, and these are mounted on barges for operation in the marshy coastal regions in the

Mississippi Delta sections of Louisiana. The original equipment on each rig comprised a total of 400-kw. generating capacity and two diesel engines. The generating unit for rig No. 1 comprised two 200-kw. generators on a common shaft, to which two diesel engines were connected through V-belts. The original generating unit on rig No. 6 was a 400-kw. generator connected by V-belts to two diesel engines. To each of these rigs were later added two diesel-generating sets, the engines being direct-connected to the generators, making four engines on each rig, giving each drilling rig 800-kw. generating capacity.

The practicability of the diesel-electric rig may be credited to two factors : the development of the present-day high-speed diesel engine of adequate size, and the perfection of the variable voltage transmission.

The generators are not only variable-voltage generators, but they also have a characteristic voltage curve that falls to zero at some pre-determined current value. This has for its purpose the following : (1) the peak-generator output, and consequently the peak demand on the engines, is limited to the maximum output of the diesel engine. (2) Once this limit is established the protection of the engine against overload is automatic, regardless of the table, pump, or hook-load. (3) The maximum current when the motor is stalled is limited to that value which is safe for the mechanical and electrical equipment, a limitation that is essential for mud-pump and table-drives.

Characteristics of various parts of the rigs are given in general, and it appears that the operation of these rigs in the Mississippi Delta on barges under conditions that provide a wide range of flexibility and adaptability and performance tests indicate adequacy of this type of equipment. On such locations completely self-contained rigs, having high flexibility and reliability, are a necessity. A. H. N.

842.* Service Record of West Texas Drilling Rig to Date. H. L. Flood. *Petrol. Engr*, June 1941, **12** (9), 46.—Taking the view that during emergency periods essential parts of rigs may be difficult to replace, the author details the actual performance of a particular rig, stressing especially the lack of repair expense and downtime due to mechanical trouble, in order to bring out the durability of modern equipment when properly serviced and operated. The wells drilled to date and the difficulties encountered are described, and it is stated that after severe testing in actual practice measured wear is very small in all parts of the rig. A. H. N.

843.* Piling Substructure for Open-Water Drilling Location in Gulf. I. W. Alcorn. *Petrol. Engr*, Midyear 1941, **12** (10), 29.—Substructures for derrick and machinery are formidable items entering into the cost of drilling operations in open waters of the Gulf of Mexico. As regards the design of such structures, local conditions must be taken into account, but experience is also a very desirable aid in arriving at a suitable and economical design.

Such experience with similar structures was an important factor governing the design of a piling substructure for a well 9000 ft. offshore in about 18 ft. of water (mean low tide) at an open-water location in the Creole Area, Cameron Parish, Louisiana, on the Gulf of Mexico. The entire substructure and the arrangement of all machinery and equipment thereon were developed largely from experience gained on a combination barge and piling substructure used on an inland-water location in the Louisiana Gulf Coast.

For the piling structure under discussion, the design called for the use of a diesel-electric drilling rig, consisting of two 350-h.p. diesel engines connected to a common generator.

The rest of the short paper is a discussion of details of the design. A. H. N.

844.* Hard-Facing Tool-Joints as Practised in Mid-Continent Area. H. L. Flood. *Petrol. Engr*, Midyear 1941, **12** (10), 70.—The application of hard metal to the surface of a tool-joint to resist abrasion is only one of the factors in rebuilding a worn joint. It is usually desirable to regain the original gauge diameter of the joint, even to increase its effective diameter over part or all the length of the joint, and nearly always it is essential to restore the square or tapered elevator shoulder to its original contour.

When the depth of the metal to be deposited exceeds $\frac{1}{8}$–$\frac{3}{16}$ in. it is desirable to use a semi-hard metal. This is not so much to reduce the amount of the more expensive hard metal used, but a composite metal build-up is tougher and less subject to cracking or shattering.

The methods used are many, and only a certain number of these are described.

Some inexplicable actions have been observed as a result of hard-facing in certain ways. When the hard metal has been applied to elevator shoulders, particularly when the joint has been recessed, the surfaces of the joint adjacent to the hard metal will become worn, so that a concave ring or groove is formed. This action is not noted when the hard metal is applied without recessing.

When the weld metal is applied by the arc-welding method, it is highly important to preheat the joint to a minimum temperature of 300° F. This heat can be determined with sufficient accuracy in the field by established methods.

When the weld metal is applied with a welding torch, preheating is not necessary, but it is important to heat the joint uniformly. Beads run circumferentially, with successive beads begun on the opposite side from the one just finished, will aid in uniform heat distribution. A. H. N.

845.* Portable Drilling Equipment—Design Features and Performance Data. W. A. Sawdon. *Petrol. Engr*, Midyear 1941, **12** (10), 92.—Considering the present application of portable rotary drilling rigs, economy of transportation and decrease of rigging-up time are probably the outstanding features. Both new wells and re-drilling or deepening operations are now being done with portable outfits, and the performance possible during the drilling of a new well is indicated by an example given later, that shows the adaptability of a portable rig in meeting a variety of requirements. In drilling new wells a further economy can be obtained by planning the site to take care of production equipment as well as the portable drilling rig. This is true whether a derrick or portable mast is to be used for the drilling operations.

The adaptability of portable equipment both for drilling and repair or clean-out operations is discussed in some detail.

To illustrate the performance of such rigs the drilling of a typical well is studied. Although the total depth was slightly less than 3000 ft., the operation included wall-scraping the hole and gravel-packing the liner by the reverse circulation method after it was run.

A 122-ft. steel derrick was used for the drilling operations. The hoist was of the heavy-duty type and powered by a 220-h.p. gas engine. The draw-works-engine unit was permanently mounted on a truck equipped with self-contained tracks that provided for moving the unit outward a few feet to obtain partial support on the derrick floor, where it was anchored to tie-bolts set in a concrete production mat previously built below the derrick floor. Mud was circulated by a 7½-in. by 12-in. mud-pump driven by a gas-engine.

The well was completed in a total of 14 days with the following time distribution: drilling, 4 days; coring, 2 days; reaming, 1 day; running casing, testing, etc., 3 days; wall scraping, 2 days; gravel packing, washing perforations, 1 day; running tubing, rigging up pump, 1 day; total drilling time on bottom, 46·00 hrs.; total coring time on bottom, 10·75 hrs. (Total, 56·75 hrs.) The well was completed with 3-in. tubing set at 2740 ft.

Other details are given. A. H. N.

846.* Obtaining Subsurface Pressure Records. E. Moore. *Petrol. Engr*, Midyear 1941, **12** (10), 181.—To obtain full value from pressure records, small changes should be readable, and it is seldom that a pressure recorder designed to cover the wide range necessary for all types of jobs will clearly define slight variations at low pressures that are frequently required to disclose the true conditions. A pump gauge has therefore been developed that employs two pen arms actuated by a single pressure element.

By means of this instrument small changes in pressure over a range of from zero to 2000 lb./sq. in. are clearly defined by one pen that travels over the full face of the chart. When the pressure exceeds 2000 lb./sq. in. a second pen takes over and records pressures from 2000 to 6000 lb./sq. in. One instrument can thus be installed on any cementing or acid truck, or otherwise placed in the circulating system to give close readings at lower pressures and then continue to record the higher pressures when the job requires a wide range.

The adaptability of the instrument to cementing, acidizing, and washing jobs is illustrated. A. H. N.

847.* Detailed Knowledge Guide to Drilling Progress. R. W. McIlvain. *World Petrol.*, June 1941, **12** (6), 40–41.—This paper forms the first of a series published as a symposium on drilling in the present issue of *World Petroleum.* The general thesis of the paper is that shallow fields have been exploited. Therefore, in order to meet the ever-increasing demand for current consumption, and to provide an adequate back-log of available reserves to meet all contingencies, it has become necessary to carry exploration to much greater depths. This, of course, means increased development costs. With an unsatisfactory price level for crude oil and its products in effect for most of the last 20 years, with the tremendous tax burden imposed on the industry, and the further complication of increased costs which necessarily result from deeper drilling, the oil producer has, of necessity, had to devote a great amount of time, effort, and money to devising and providing equipment and methods to meet conditions with which he has been confronted. As a result of this effort substantial progress has been made in improving drilling machinery and technique and in effecting a reduction in overall drilling costs. An investigation of the records of a number of wells in the Mid-Continent area shows the distribution of expenses for drilling alone to be approximately as follows: labour, 34%; bits, 20%; supplies and repairs, 19%; fuel, 8%; depreciation, 16·5%; moving 2·5%.

It is evident from the above that drilling costs may be reduced substantially if drilling time can be further decreased. Factors influencing drilling time include hole size, speed of rotation, weight on the bit, physical properties of mud-laden fluid, and the rate of circulation, as well as the use of suitable equipment in the form of mud-pumps, draw-works, and a rig layout.

These several items are discussed generally. A. H. N.

848.* Prime Movers in Economic Drilling. A. H. Bell. *World Petrol.*, June 1941, **12** (6), 42.—This is a short paper pointing out that many operators think of the drilling conditions of the well as causing damage or failure of the drilling equipment, but it is actually the prime movers that cause the damage. The substantial savings in fuel, water, and installation costs that accrue from the use of combustion-engine rigs are fast putting the manufacturers of steam-driven equipment in a precarious position to defend their markets.

It is the opinion of the author that this situation can be reversed if these manufacturers will completely revise their designing policies, and develop equipment having small prime movers with maximum cut-off for economy of steam consumption and horse-power equivalent to the combustion engines now in use. Recent performance comparisons between steam and combustion-engine rigs in the same field have demonstrated that many steam outfits are greatly overpowered. A. H. N.

849.* Preplanning Aids Economical Drilling. L. E. Porter. *World Petrol.*, June 1941, **12** (6), 43–44.—To obtain greater speed in drilling under safe conditions and at less cost it is urged that resort should be made to (*a*) a continued application of the proper design of adequate drilling equipment for the work to be done; (*b*) a continued increase of efficiency through promoting more orderly development; (*c*) a continued application of practical engineering supervision for such phases as machinery design, mud control, and the proper interpretation of the underground physical forces to be overcome.

A recent study made in California showed all sizes and types of casing and hole sizes to reach the same objective. Variations of casing programmes by the same operators were noted from one field to another—in fact, all types of inconsistencies. This brings out the point that too few operators, in selecting the size hole to be drilled and casing size to be set, approach the matter as a programme to be pre-analysed, taking into consideration: (*a*) the long-term economic outlook of the field; (*b*) the sub-surface conditions to be overcome; (*c*) the effects of hole size on the recovery of oil, if any; (*d*) the initial cost; (*e*) the ultimate cost.

In addition to the above, consideration should be given to the ultimate advantage, which, of course, will include the maximum returns for the least expenditure of money and the advantage gained in the production of the well throughout its life, in the movement of production tools in and out of the hole, and in the handling of production-flow devices and adequate-size pumping equipment in and out of the hole. A. H. N.

850.* Deeper Drilling has Encouraged Improved Method. H. M. Staggs. *World Petrol.*, June 1941, **12** (6), 45.—During the past 12 or 15 years drilling speed has been increased by 100%, whilst fishing jobs have been decreased by more than 50%. At the same time, drilling contract prices in deeper drilling have been reduced by 30%, and in the shallower areas by 50% or more. Holes are drilled much straighter, are better cased, and better cemented. Records of all kinds are kept much more accurately, wells are better completed, and accidents connected with drilling operations have been very materially decreased. Problems coming up as deeper drilling has been required have been met and either partly or wholly solved. This has cleared the path for further progress in improved drilling practice.

The trend to-day is towards making a drilling operation, either exploratory or development, a completely planned operation. This planning is done by engineers having knowledge of drilling equipment and the difficulties connected therewith, as well as the timely use of specialized services in logging, mud, cementing, and other such services.

Several improvements and trends in deep drilling are mentioned. Long liners, 3000 ft. or more in length, are being successfully used to reduce casing requirements. These liners are being cemented from the bottom to a short distance above the base of the next larger string of pipe. These liners take the place of string of casing, which necessarily continues all the way to the surface. Deeper drilling has brought about the use of progressively heavier drilling machinery and more power, and drilling speeds far in excess of those of a few years ago. A. H. N.

851.* Economies in Selected Casing. E. A. Jenkins. *World Petrol.*, June 1941, **12** (6), 49.—This short article deals with the choice of casing sizes—especially in mixed strings—to yield most economic conditions. Not only the cost of casing but producing conditions and problems must also be considered in choosing casing sizes. As a further economy, two-zone completions are becoming more common—that is, two separate producing horizons are tapped and produced through a common drill-hole and string of casing. This is accomplished by setting the casing on or through the lowest producing formation, and then perforating or milling out the section of casing adjacent to an upper productive zone. Then by setting a packer between the zones they may be produced ; one through a tubing string, and the other through the annular space, or through two strings of tubing in the same well. A. H. N.

852.* Trends in Deep-Drilling Equipment and Practice. A. G. Levy. *World Petrol.*, June 1941, **12** (6), 50–51.—An extremely concise statement of the trends in all parts of drilling equipment and practice is presented under short and separate sections. Steam remains the most flexible and reliable power available. Internal-combustion power (gas, gasoline, butane, or diesel), whether converted into electric power or not, is definitely indicated where free or very cheap gas is not available, or where water is scarce. The trend in draw-works is towards oil-bath units, completely enclosed—the sprockets forced and precision cut and the chains of the high-precision type. That in swivels and rotaries, as well as crown-blocks and travelling blocks, is towards higher capacities at increasingly high speeds. The trend in mud-pumps is towards greater volumes at higher pressures. In steam-engine design it is towards more power and higher speeds. In internal-combustion engines the trend is definitely towards heavy-duty diesels. In drill-pipe it is towards streamlining, inside and outside, together with the use of higher-yield steels. Pipe-weight indicators are on all rigs. There has been a tendency to try to find a suitable substitute for barytes as a weighting material for drilling muds. Starches are being used experimentally and practically in certain localities as an additive to clay-base muds, partly as a substitute for bentonite in reduction of free water, but more particularly in connection with muds of high saline content.

The trend in chemical treatment is more and more in the direction of the polyphosphates, with sodium-tetraphosphate probably the most generally used. That in cement is towards a retarded setting under conditions of high temperatures and pressures. Preventive squeeze jobs are becoming increasingly common prior to gun-perforating for production wherever water is present close to the objective horizon, and wherever there is reason to believe that the original cementing may be faulty or inadequate. Stage cementing has been advocated, and used more or less for some time. Wall-cleaners are being used more extensively of late, particularly spring-wire contraptions fixed to the outer wall of the casing for the purpose of removing competent filter-cakes and centring prior to the placing of cement. A. H. N.

853.* Trend to Pressure Maintenance. J. H. Abernathy. *World Petrol.*, June 1941, **12** (6), 53.—Although producers are beginning to consider the gas compressor as a conventional equipment item, with a few notable exceptions the general practice is to defer the installation of high-pressure equipment, and await the day when repressuring may be utilized, since pressures are decreased by long production, and equipment can be installed at much lower cost. Many hold the opinion that under present low allowables and long pay-outs it is better to reduce capital investment to a minimum, even at a sacrifice of some efficiency in the distant future. The point made here is that the delay may result in cheaper installation, at great sacrifice to ultimate recovery.

These impressions are current because little information has been available dealing directly with the relative efficiencies of repressuring and pressure maintenance. It can be demonstrated that in many gas-control reservoirs where repressuring will add from 20 to 50% to primary recovery, pressure maintenance will add 75% or more. This means that for an investment of probably not exceeding 10% of well cost, a direct addition to producible reserves of 25–50% is obtained. Pressure maintenance has also an advantage as compared with repressuring in that productive capacities of affected wells are sustained at high levels over much longer periods of time. This may be of greater importance to the country than increasing ultimate recoveries, because it may be necessary to meet war-time demands at short notice. A. H. N.

854.* Facts to Face in Future Drilling. E. K. Parks. *World Petrol.*, June 1941, **12** (6), 57–63.—A statistical study of drilling and its relation to the industry as a whole is made. A special detailed analysis of reducing drilling costs is made and illustrated by typical cases from practice. Comparison of gas, steam, and electric power for drilling is given. The advantages of electric power are listed as : (1) Low operating cost. Records from actual installations show that electric power is much less costly than steam power for a rig of comparable size and drilling under the same conditions. (2) Maintenance costs are extremely low. (3) Moving and set-up time are short, and therefore the cost of moving an electric rig is much lower than that of a steam rig of corresponding size. (4) The life of the equipment is extremely long. There are many electric rigs in operation in California and other fields which are 12–15 years old and are still in daily operation. (5) Capital investments are reasonable, although they may be somewhat higher than in the case of a steam equipment. However, the low cost of maintenance, operating cost, and the saving due to short set-up time, and cost of moving, quickly offset the difference in capital investment. The main reason for the higher cost of a.c. electrical drilling rigs is due to the high cost of power-pumps. It is hoped that recent developments will result in new types of mud-pumps which will materially reduce the cost of power-pumps.

Similarly the advantages of a d.c. drilling equipment are given as : (1) its characteristics are so designed that it is impossible to impose loads on prime movers greater than they can carry, thus definitely preventing their being stalled. (2) It has speed characteristics like the steam engine, thus giving a wide range in speed and torque for the draw-works and a positive indication of any restriction or stoppage in the mud-pump line. (3) It makes available the combined capacity of the mud-pump and draw-works power supply for heavy hoisting duty when coming out of and going into the hole. (4) It provides individual control of drilling and mud-pump operations, centralizing this control at the driller's stand. (5) It readily provides low table speeds, quick reversals, fast or slow pick-up as required on heavy or light loads, and speeds of the empty hook as high as the crew can handle. A. H. N.

855.* Internal-Combustion Drilling Rigs. F. C. Ripley, Jr. *World Petrol.*, June 1941, **12** (6), 76–79.—Generally speaking, there are three classes of internal-combustion drilling machines on the market to-day. These machines in each class are constructed for the lightest to the heaviest work. The three classes are as follows: (1) the converted steam rig; (2) the custom-built machine; and (3) the unit-type power-rig. The converted and custom-built rigs are quite similar in construction, and could probably be considered as being of one class. These machines are doubtless the most versatile now on the market as far as meeting construction demands by the customer is concerned.

The custom-built or the adaptation from steam-rigs has many characteristics in common with the older type of equipment. Vast improvements, however, have been made in both the design and operation of the machine, and the present models are therefore thoroughly up to date for the purpose they are intended to fulfil.

Fundamentally, the machines consist of a standard multiple jaw or friction-clutch draw-works which is usually equipped with double-clutch sprockets on the jackshaft which raises it from the regular three- or four-speed to six- or eight-speed. Behind this draw-works is a master forward friction clutch and reverse-gear driven from a totally enclosed flood-lubricated compound transmission case. Coupled into this case are two or three engines of any aggregate horse-power, limited only by the capacity of the forward clutch.

These machines are called custom-built because with this design it is possible to meet a number of requirements at the customer's suggestion. The draw-works may be raised to as much as 12 ft. above the ground, whilst the engines remain at ground, or low substructure level. Any make of engine desired by the customer can be used with an aggregate horse-power and speed compatible with the capacity of the master clutch and compounds. Many operators prefer to use as much of their steam equipment as possible. In this case a regular four-speed steam draw-works can be cheaply changed over to six- to eight-speed, and can be used with the reverse clutch and compound transmission with complete satisfaction.

For rule-of-thumb comparison of horse-power ratios for depths compatible with steam-drilling time, it might be said that 275 h.p. is sufficient for 3500 ft. of 4½-in drill-pipe; 450 h.p. for 4500–6000 ft.; 600 h.p. for 6000–7500 ft.; 800 h.p. for 7500–8500 ft.; 1000 h.p. for 8500–10,500 ft.

Comparative studies are made of these engines and rigs and of corresponding steam-rigs. A. H. N.

856.* Barge Mounted Diesel Electric Rigs. A. H. Rowan and H. E. Dralle. *World Petrol.*, June 1941, **12** (6), 80–84.—As most commonly used, a variable voltage equipment comprises several direct-current generators of medium capacity, up to 250 k.w., for direct connection or belting to gas or diesel engines, complete with voltage-varying control for supplying power to the operating motors driving the draw-works, table, and mud-pumps on a rotary drilling rig. This form of drive has been time-tested and proved in rotary drilling as one of the most reliable, flexible, and economical in providing a smooth, even flow of power to the operating equipment. To obtain these features there are two methods of operating the generators: series and parallel. These are discussed and compared.

As the number of generating units is increased above two, and on these large rigs there are four generators, the overall advantages considered from the standpoints of practical voltages, generator designs, standardization of parts, simplicity of control, and economics of application are in favour of the parallel system. The conclusions regarding the fields of application of the two systems are borne out by the large number of successfully operating units of both types.

Variable-voltage electric rigs operating on barges in the Mississippi Delta near La Fitte, Louisiana, employ the parallel system of operation and have engine generator capacity of 800 k.w. (1075 h.p.) for the main drives. There are four generators, each rated 200 k.w., 400 volts, 40° C. Two generators operating at 1200 r.p.m. are belted and two generators operating at 600 r.p.m. are directly connected to 8-cylinder 9 × 12, 375-h.p., 600-r.p.m. Cooper-Bessemer engines. The reason for using some belted and some direct-connected generators is purely one of economics. Existing equipment was utilized in making up the barge unit. Mechanically it is preferable to use all generators direct connected to their respective engines.

Details and characteristic data are given. A. H. N.

857. Patents on Drilling. C. A. Rasmussen. U.S.P. 2,241,477, 13.5.41. Appl. 14.8.40. Jar having a tubular body.

F. W. Sharp. U.S.P. 2,241,486, 13.5.41. Appl. 9.10.37. Deflecting tool consisting of a stem, a bit and a deflecting member sliding on the stem.

M. Rosenkranz. U.S.P. 2,241,526, 13.5.41. Appl. 12.9.39. Pipe-joint tester.

J. W. Hatcher. U.S.P. 2,241,549, 13.5.41. Appl. 6.2.40. Rotary bit with disc-cutters on four horizontal axles.

R. E. Hendrickson. U.S.P. 2,241,550, 13.5.41. Appl. 24.7.39. High-angle well-surveying instrument.

J. J. McNamara. U.S.P. 2,241,712, 13.5.41. Appl. 7.2.38. Drill.

G. L. Scott and W. B. Noble. U.S.P. 2,241,746, 13.5.41. Appl. 3.4.39. Directional drilling apparatus.

J. V. Ryan and E. S. Davis. U.S.P. 2,241,926, 13.5.41. Appl. 10.11.38. High-pressure hose coupling.

A. L. Noyer and A. McEachern. U.S.P. 2,241,955, 13.5.41. Appl. 16.7.10. Metallic rope and cable.

L. F. Athy and H. R. Prescott. U.S.P. 2,242,161, 13.5.41. Appl. 2.5.38. Method of logging drill-holes by means of a chemical which induces temperature changes in the hole and measuring these changes.

D. W. Watson. U.S.P. 2,242,602, 20.5.41. Appl. 29.9.39. Double duty fishing-tool.

E. G. Leonardon. U.S.P. 2,242,612, 20.5.41. Appl. 25.5.37. Method for determining the beds traversed by drill-holes.

D. M. Smith and L. Newcomb. U.S.P. 2,243,131, 27.5.41. Appl. 10.1.40. Hold-down bearing for rotary.

F. W. Hild. U.S.P. 2,243,340, 27.5.41. Appl. 23.5.38. Rotary blow-out preventer.

B. J. Festervan and N. F. Henderson. U.S.P. 2,243,419, 27.5.41. Appl. 19.10.38. Fishing-tool for pipe-ends.

A. Pranger and S. A. Guiberson. U.S.P. 2,243,439, 27.5.41. Appl. 18.1.38. Pressure drilling-head.

C. S. Cady. U.S.P. 2,244,674, 10.6.41. Appl. 25.3.40. Expanding drill.

E. A. Hartung. U.S.P. 2,244,693, 10.6.41. Appl. 21.10.38. Pipe and pipe flange-tongs.

E. A. Hartung. U.S.P. 2,244,694, 10.6.41. Appl. 31.3.39. Pipe and pipe flange-tongs.

C. J. Gardner. U.S.P. 2,245,128, 10.6.41. Appl. 2.7.40. Drill-pipe cleaner or drier.

T. T. Nudson and W. A. Abegg. U.S.P. 2,245,221, 10.6.41. Appl. 1.7.40. Device for measuring drill-pipe. A. H. N.

Production.

858.* Reconditioning Procedure for Old Wells. Anon. *Petrol. World*, June 1941, **38** (6), 39.—The first problem of the engineer engaged in reconditioning work is to determine whether or not the wells under consideration can again be made profitably productive. The estimation of costs on work of this sort is by no means simple. It requires an intimate understanding of conditions existing at the time the wells were shut in, and those prevailing at the time the reconditioning is contemplated. A complete examination of each well and all its appurtenances must be made, not only to determine the efficiency of the equipment above ground, but as far as possible to define sub-surface conditions.

When a well has been closed down for any protracted period, many things happen. From disuse, everything mechanical tends to approach nearer and nearer to complete obsolescence. Surface equipment becomes weakened by corrosion and other deleterious influences. Underground, the interstices in the oil-sands are gradually filled with encroaching water, which rises into the casing and tubing, slowly scaling up everything with which it comes in contact, and adding inexorably to the difficulties of reconditioning.

As the period of idleness extends, the disintegration progresses, and it becomes the problem of the reconditioning engineer or agent to determine whether or not it has progressed beyond the point of economical rehabilitation. The paper discusses various methods of such studies and the different steps necessary in reconditioning work.

The whole process of reconditioning has been markedly affected by modern trends in both producing and refining practice. Production research has not only stimulated but has greatly aided the development of satisfactory tools for performing the diverse operations required in the repairing and reconditioning process. Chief of these, perhaps, are the portable servicing hoists and derricks, and shaft-driven centrifugal pumps.

Refinery research has led to a reclassification of the various crudes, and has increased the demand for certain types. The effect of this combination of events is further exaggerated by a world condition that demands the ultimate in production.

A. H. N.

859.* Pumping Equipment and Practices in New Illinois Pools. W. C. White and M. A. Sherwood. *Oil Gas J.*, 24.4.41, **39** (50), 69–70. *Paper Presented before American Petroleum Institute.*—During the past four years approximately 9000 wells have been completed in the Illinois basin. To produce the oil discovered therefrom it has been necessary to modernize central powers and individual pumping units. Modern power installations have been made that pump as many as thirty wells in an area 2 miles long and 1 mile wide. Rod-lines are in use having a length of slightly more than 1 mile. The high efficiency obtained by these powers is a result of improved design.

Actual tests reveal that power consumption during the winter months is as much as 30% higher than in summer months. The use of time-switch control has resulted in lower demand on electric-power systems.

Other subjects discussed in detail are the relative advantages and disadvantages of centralized power systems and of individual pumping units. General principles are laid down for the selection of pumping equipment to give minimum installation cost and realize maximum efficiency, especially in areas like Illinois. A. H. N.

860.* Hydraulic-Pneumatic Pumping Unit Tested on Illinois Well. H. F. Simons. *Oil Gas J.*, 15.5.41, **40** (1), 44.—A new type of pumping unit is being tried in the Illinois field, the usual beam and counterbalance being replaced by a hydraulic cylinder and a radial pump for lifting the rods and oil, and an air-chamber for cushioning the downward stroke. Hydraulic pumping units have been tried on deeper wells in other parts of the country, but the equipment being tested probably marks the first time that such a unit has included air-cushioning and has been used on a well of medium depth.

The unit used in the Illinois fields has a 58-in. stroke and normally operates at

18 s.p.m. However, both the length of the stroke and strokes/min. can be increased if desired. The increased length of the stroke makes it possible to reduce the number of strokes/min. and still handle a large volume of fluid. Reduction in the strokes/min. is very helpful in eliminating sucker-rod breakage, as the number of peak loads and the number of reversals of the load are reduced. In nearly 3 years of operation it is claimed that no sucker-rod breakage has been experienced.

The travelling part of the system, including the cylinder and the rods and pump attached to it, moves at a uniform speed upwards, with the exception of about 10% of the distance, which is used for acceleration and deceleration. The speed on the downward stroke is likewise uniform except for the same factors. However, the upstroke and the downstroke are not at the same speed, the cylinder and rods falling much faster than they are raised. The time required for the upstroke thus becomes greater than the average speed of the travelling cylinder.

The weight of the unit, which is capable of a 16,000-lb. load capacity, is less than 3000 lb. It consists of a 50-h.p. 6-cylinder internal-combustion engine driving a 9-cylinder radial pump through V-belts, the hydraulic cylinder and piston, a chamber for storage of the fluid and the air-cushion, and a frame for supporting the vertical and near-vertical members. The skid on which the equipment is mounted is equipped with a ratchet winch so that the pumper can slide the unit back from the wellhead in case servicing machinery is being moved in. A. H. N.

861.* Core-Analysis Interpretation. N. Johnston. *Oil Gas J.*, 22.5.41, **40** (2), 76. *Paper Presented before American Petroleum Institute.*—Core analysis is an attempt to find the amount of space that is available for oil and gas in a subsurface reservoir, how much of this space is actually occupied with oil and gas, and how much with water, how rapidly this oil and gas will be available, how much of it may be recoverable by various means, and how best to design those means of recovery. These several items are studied and correlated.

A laboratory technique has been adopted for measuring porosity of loose sands. A small amount (2 ml.) of kerosine is pipetted accurately into a 50-ml. graduate, and about an equal volume of dry sand is added. This is tamped into a tight pack with a $\frac{3}{8}$-in. flat-ended rod. The process is continued with about 1 ml. additions of sand and just enough kerosine to fill the sand pores (but no excess), until about 20 ml. of pack has been built. The bulk volume and the kerosine volume allow of a direct calculation of total porosity. By comparison with effective porosity measured by a Kobe porosimeter, this method gives results which must be multiplied by 0·86 to give equivalent effective porosities of very soft but coherent sands.

Porosity and permeability are almost independent physical properties of porous rocks, and are very difficult to estimate visually. Either can change with extreme rapidity along a vertical section, but in general varies less rapidly along the direction of bedding planes. In some uniform sands, correlations may be made between nearby wells by means of either porosity or permeability, the latter being preferred because of the much greater range of values encountered.

Saturation, grain analysis, and chemical tests are briefly discussed.

The bulk of the remainder of the paper deals with the interpretation of these tests to determine the productivity characteristics of sands. The specific productivity index is particularly discussed in detail, and the reasons why theoretical and practical results diverge are analysed, stress being laid on mudding effects, gas-bubble resistance, and resistances caused by interstitial water.

The long paper ends with a discussion of the applicability of the interpretations to completion and production programmes.

It is concluded that core analysis has reached a stage of development in which it is one of the most definite and useful tools we have for the study of reservoir properties. There are many phases of its interpretation which are only semi-quantitative and which definitely merit further intensive study. It is hoped that this discussion may stimulate experimental work along suggested lines, or bring out alternative methods of interpretation which will lead to greater accuracy and a broader usefulness for core analysis. A. H. N.

862.* Pressure-Core Analysis. J. J. Mullane. *Oil Gas J.*, 22.5.41, **40** (2), 118. *Paper Presented before American Petroleum Institute.*—The analytical procedure used to measure the quantities of interest in a pressure-core analysis may be divided into two parts : (1) the operations performed on the derrick floor ; and (2) the operations performed in the laboratory.

When the core-barrel is laid down, it contains the core recovered. All excess volume is filled with drilling mud. The first measurement made is that of the pressure obtained. This pressure should be approximately equal to the hydrostatic head of mud at the coring depth. Its measurement tells whether the barrel has operated properly. Second, the amount of gas contained in the core is measured. This may be free gas, or gas in solution in the oil, or both. A separator and gas-meter are connected to the bleed-off port of the pressure tube. The pressure is then relieved by rupturing a disc, and the gas and liquid are allowed to escape through a valve. The drilling mud and any oil produced are trapped in the separator, and the volume of gas evolved is measured by the meter.

In the laboratory the following quantities are measured : Porosity, permeability, residual oil saturation, residual water saturation, residual salt content of rock as sodium chloride, oil content of drilling mud from core-barrel, salt content of drilling mud from core-barrel, salt content of drilling mud from circulating system, and lump density of dry rock.

In some cases a water-soluble tracer was added to the drilling mud in order to demonstrate the presence of water from the drilling mud in the core and to estimate the amount of such water. Dextrose, a sugar compound, was used for this purpose.

It is shown that a more complete analysis of the core can now be obtained, and that the usefulness of core analysis has been considerably extended. Gas–oil ratio data obtained with the pressure core-barrel have been shown to be in agreement with the production gas–oil ratio as determined in the field.

It has been found that, in addition to gas, both oil and water are contained in cores, even though taken from wells that produce no water. A correlation has been observed between the oil produced from cores taken in a given horizon and the initial potential of the well. At least part of the water produced has been shown to be connate water. With the more complete data obtained with the pressure-core barrel it is believed that more reliable estimates of reserves can now be made from core data. Information as to the mechanism by which cores are polluted by water from the drilling mud is given. Evidence is given to show that two types of invasion are operative. These are : a vertical invasion ahead of the bit, and a radial invasion of the core. A. H. N.

863.* Use of Depth-Pressure Data in the Determination of Well Potentials in California. R. W. French, M. W. Morris, E. G. Trostel, and J. C. Young. *Oil Gas J.*, 22.5.41, **40** (2), 150. *Paper Presented before American Petroleum Institute.*—The paper discusses the operations of depth-pressure since its final approval in November 1939. Data are presented to show the relative accuracy of the test methods, their economic value to the industry, and the degree of their acceptance by operators. Specific problems of an engineering nature have arisen from the interpretation of depth-pressure data ; these are discussed, together with the methods of approach used in attempting their solution.

It is shown that well potentials for use as the primary factor in allocation under the California "uniform method" are being successfully established by depth-pressure means in flowing, gas-lift, and pumping wells. Hazards of extrapolating the mean producing pressure-rate curve are discussed, and minimum practicable mean producing pressures are calculated within conservative limits. Present status of special studies is given, covering such topics as critical sand entry, pump capacity *v.* depth, sonic-method tests, hydraulic unit tests, and gradient determination and estimation, both in tubing and in the annulus. Acceptance of the depth-pressure method is general, but there is no evidence of a sudden swing towards it as an alternate to open-flow tests, nor is there any tendency for it to cause inflation of state potential. Incidental value of this work is great in widening the circle of operators familiar with this analytical method and in promoting more general acceptance of reservoir behaviour concepts.

It is concluded that the comprehensive background of carefully compiled data gathered from most fields in the state in connection with the depth-pressure-potential method should prove valuable if it is systematically reviewed, correctly analysed, and properly applied. A. H. N.

864.* Producing Practices at Red Fish Reef Lessen Offshore Hazards. N. Williams. *Oil Gas J.*, 12.6.41, **40** (5), 36–37.—The project calls for concentration of oil-production handling and flow control through a central separator station. The station is located on a piling-supported structure, the height of which is sufficient to place the separator and operating platform out of reach of the highest tides and waves. No individual separators are placed at any of the wells, and production of all oil-wells is flowed directly to this station.

Sufficient separator capacity for all oil-well production will be provided at this central station, including separators for testing of wells and for regular production. Requirements of the field for the time are being taken care of with one testing separator, two separators for regular production, and one separator for final scrubbing of the gas. A 250-brl. field-tank has been provided for use in cleaning of wells during completion and for emergency storage, but regular production is normally run directly from separators to barges for movement to Cedar Point, at the north end of Galveston Bay, where the company has storage facilities and pipe-line connections. Flow control and manifolding are described.

Each well is equipped with a velocity valve or storm-choke as the first control precaution. This valve protects a well behind the surface chokes and is operative in the event of the Christmas tree proper being broken off or any leaks occurring below the surface chokes. A velocity valve (storm-choke), set in the tubing string at a level usually below the point where there is any likelihood of paraffin formation, functions on a pressure differential principle. The valve is kept open only by the maintenance of a set-back pressure above the choke in relationship to the pressure below the valve. When the pressure above the valve falls below the set minimum, as would occur with a break in surface connection behind the surface choke, the pressure differential would be disturbed and the valve would close. Other precautions are similarly described. A. H. N.

865.* Air-Drive Experiments as Related to Secondary-Recovery Operations. H. Krutter. *Oil Gas J.*, 12.6.41, **40** (5), 49.—Besides porosity and permeability, many other factors enter into the problem of petroleum production. Some of the factors which are important in the secondary-recovery process are the original condition of the field, the depletion of the field during flush production, the rock pressure, the oil saturation, the connate water content, the surface and interfacial forces, the viscosity of the oil, the gas in solution in the oil, the pore pattern in the sand, the horizontal and vertical variation of permeability, the chemical and physical nature of the material coating the sand-grains, and arrangement and spacing of the input and producing wells, the pressures applied and their method of application, and the secondary-drive medium.

The relative permeability to air, $K(s)/K$, is defined as the ratio of the effective permeability to air when the saturation of the core is (s) to the specific permeability (K) to air of the completely extracted core. It is shown that the variation in relative permeability is a function of oil saturation for four runs at inlet pressures varying from about 5 to 30 cm. of Hg. The points all lie within a narrow band. Therefore, within this pressure range the relative permeability–saturation relationship is independent of the pressure applied. The relative permeability for oil saturations up to 20% is essentially equal to 1. This indicates that oil left in the pores of the sand-body is retained in the sharp angles between the sand-grains, and that 20% of the pore volume is comparatively dead space and, therefore, has a negligible effect on the permeability of the sand. The removal of this 20% of oil is essentially an evaporation and entrainment process. These experiments lead to the conclusion that the relative permeability has a definite meaning for a given core, and that this relationship between relative permeability and oil-saturation is independent of the pressure gradients applied and the viscosity of the oil used between the saturation range 0–70% (pressure gradients from 5 cm. of Hg/in. to 30 cm. of Hg/in. and viscosities from 2 to 100 centipoises). At higher oil saturations this relation may break down.

A " threshold pressure " was observed in driving oil by air, below which the oil did not flow. This pressure decreased with an increase in permeability of rock according to

$$P = 18{\cdot}2K^{-0{\cdot}313}$$

Experiments were also performed on oil recovery by air from 100% oil-saturated cores and from cores partly saturated with water and partly with oil. It is concluded that connate water concentration and its distribution in the pores play a controlling part in the amount of oil recovered. A core can produce oil even though the oil saturation is as low as 30%, if connate water is present. This is due to the fact that, although there is only 30% oil, it is contained in the larger-size capillaries, and the connate water is in the smaller capillaries. Consequently, the factor that determines oil recovery to a large degree is the connate-water concentration. It is therefore very important in a core analysis to determine the connate-water content as well as oil saturation for recovery estimates. A. H. N.

866.* New Opelika Recycling Plant Provides Flexible Operation. G. Weber. *Oil Gas J.*, 26.6.41, **40** (7), 46.—The recycling operation at Opelika combines the advantages of exclusive pressure maintenance in the entire field and early operation, begun before reservoir pressure has declined appreciably. The first condition allows operators to carry out an efficient field-injection programme without competition from other similar projects. By providing pressure maintenance early in the field's production history, subsurface condensation is minimized, and a maximum recovery of liquid hydrocarbons will result.

Opelika operations will be of particular interest to recycling engineers. Since the plan incorporates an entire field, the study of residue-gas migration from the injection point will contribute to information on subsurface gas displacement during recycling. The project is the first major operation of its type in a lime reservoir, and as such will furnish important data on recycling to porous lime.

The field development up to date is summarized. Current recycling-plant operation results in a total daily production of 75,000,000–80,000,000 cu. ft. of gas. Shrinkage due to processing and plant use and outside gas sales result in a net withdrawal of 22,000,000–22,000,000 cu. ft. daily. The current withdrawal rate as compared with known reserves of high-pressure gas indicates a long-term plant operation.

A relatively high yield of condensate promises ample return on plant and field investment. In addition, the advantage of early pressure maintenance guarantees maximum recovery of condensate. Field development for recycling under a unitized programme requires far fewer wells than under ordinary well-spacing programmes.

Without recycling it is improbable that the field would justify full development for several years, due to the lack of gas demand in East Texas. Therefore incorporation of the field into a single recycling programme has resulted in greater returns to operators, royalty owners, and tax recipients at a much shorter payout period.

The recycling plant operates at two pressures. About 20,000,000 cu. ft. of the daily intake of 80,000,000 cu. ft. is flashed to a low pressure, and the residue gas is sold to the Loan Star Gas Co. The remaining 60,000,000 cu. ft. is held at high pressure through the absorption process and recompressed for injection. The rest of the paper details the operations. A. H. N.

867.* Increased Recovery by Pressure Maintenance. J. H. Abernathy. *Oil Gas J.*, 26.6.41, **40** (7), 53.—Laboratory data and field operations indicate that the average recovery from a gas-drive reservoir by conventional production methods is in the order of 25% of oil in place (corrected for shrinkage). The balance of the oil is left in the reservoir largely because at about 25% void space the relative permeability of the formation to gas becomes high. Gas–oil ratios go up ; the gas is exhausted and the field is considered depleted, although the pay usually retains a quantity of oil substantially in excess of that required to wet the reservoir rock, which is true depletion saturation. Since void space is the controlling factor determining apparent depletion, any operation which reduced the quantity of void left by the production of a barrel of oil adds proportionately to the producible reserves. This is true though the recovery factor may be other than 25%. A sample calculation is presented indicating the magnitude of the void space " saved " by pressure maintenance. For a hypothetical 4000 ft. Permian Lime reservoir, assuming no free gas, indicated additional recovery by complete pressure maintenance is about 78% of recovery by primary means. It is shown that no part of this 78% can be produced by repressuring. Further calculations have been made, and are presented graphically, showing the additional recovery by pressure maintenance for recovery factors varying from 20% to 40% of oil in place.

Expressed algebraically, the calculations take the following form :

$$Q = \frac{(1 - R) - \left(\frac{1 - R}{S}\right)}{R}$$

R = recovery factor, by primary means. S = shrinkage factor. Q — extra oil to be recovered by pressure maintenance, in per cent. of primary recovery.

Some of the factors which might affect recovery by pressure maintenance are : (1) viscosity ; (2) surface tension ; (3) quantity of free gas in the reservoir ; (4) percentage of connate water ; (5) porosity of the formation ; (6) permeability of the formation ; (7) wettability of the reservoir rock ; (8) bottom-hole pressure ; (9) temperature ; and (10) water drive, if any.

An examination of these items discloses that most of them alter the primary recovery factor and affect pressure maintenance recoveries only indirectly, as calculated. However, the quantity of free gas, the water drive, and the wettability of the reservoir rock should be given special consideration. A. H. N.

868.* Correlation of Field and Laboratory Research in Secondary Oil Recovery. H. R. Pierce. *Oil Gas J.*, 3.7.41, **40** (8), 37.—Some of the research carried out that has resulted in enabling us to prove or disprove some of the most popular conceptions of proper or improper operating technique is as follows :

The most popular fallacy is that in most fields producing efficiency can be increased by back-pressure application. Although many worth-while pools can be made more lucrative, and in many cases more efficient, by designed manipulation, in most pools the recovery efficiencies are irreparably damaged by back-pressuring. Certain types of reservoirs are permanently impaired in efficiency by any method of back-pressuring.

A generally accepted fallacy of secondary recovery application is that most sands are by-passed by having applied to them too much differential from pressure-well to producer. Admitting that this condition can, and sometimes does, exist, simple laboratory technique proves that there have been more sands by-passed and irreparably damaged by starting recovery operations with too low a differential between pressure wells and producers than by starting with too high a differential.

There is continually cropping up the fallacy that a synthetic representation of a sand-body can be reproduced. This is impossible, however, without understanding the wide variation in unit pore-channel permeabilities.

Results prove that more harm is done by copying a neighbour's technique than by any other procedure. Using actual sand-cores, it can be proved in the laboratory that the number and location of wells drilled in any pool are vital to the efficiency and economy of oil and monetary recovery.

By field and laboratory tests, practically accurate saturation of oil-producing reservoirs can be estimated, but there is no method whereby direct readings of sand saturation can be made from core analysis.

By combined field and laboratory tests, sand-pressure gradients, and efficient directional recovery, operations can be established taking into account : (*a*) gas-cap repressuring ; (*b*) natural water drives ; (*c*) stratified permeability arrangements ; (*d*) directional permeability variations ; (*e*) directional and accumulative shale or lime sealing effects ; (*f*) sand thickening ; (*g*) cumulative sealing.

It can be demonstrated conclusively in the laboratory that there is no means of choosing core samples to be tested as representative of the whole section. By simple demonstration on actual cores it can be shown that the so-called differential shooting applied extensively in recovery is inefficient and damaging to the ultimate recovery of oil.

Laboratory tests, when combined with properly conducted field tests, have been devised which give fairly definite indications of the recovery medium which should be used in planned recovery operations and at what time in the life of the pool recovery operations should be applied to get the greatest dollar return.

The recovery of oil by gas recycling combined with limited quantities of water injections is a feasible procedure in some sands, and if properly applied will yield startlingly high dollar recoveries over a long period of application. The method of applying solvents commercially, successfully, and economically to actual sand-bodies in connection with gas-recycling recovery operations has been worked out, and offers many possibilities. A. H. N.

869.* Cotton Valley Section—Recycling in Louisiana. G. Weber. *Oil Gas J.*, 10.7.41, **40** (9), 56.—This is an extensive paper giving details of the field, recycling project, and equipment and operations involved. The following extract from the foreword to the " Cotton Valley Section " explains the principles and reasons for the project:

" The benefits to be derived from recycling gas in reservoirs for the purpose of maintaining pressure and recovering distillate, and other hydrocarbons, may be summarized as follows: (1) pressure is maintained in the reservoirs, thereby reducing condensation of the hydrocarbons in the sand, which normally occurs when pressures are reduced. If this condensation should occur in the sand instead of above the ground, a considerable amount of fluid would become trapped in the sand and could never be recovered by ordinary producing methods. (2) By pressure maintenance, the waste of gas during production is eliminated, especially in areas where a gas market is not immediately available for all the gas produced. In this way the gas can be held in the reservoir until a market is available. (3) Where porosity and permeability are satisfactory, a wider spacing programme for the drilling of wells can be employed, thus eliminating the drilling of unnecessary wells which causes a serious economic burden on the industry. (4) Recycling results in a larger recovery of hydrocarbons/acre, thereby benefiting not only the operator and his investment, but also the land and royalty owner and the public generally because of the additional revenue accruing to the State in taxes.

" The above conclusions have been reached by the Louisiana Department of Minerals as a result of expert testimony given at the various hearings on this subject, and also as a result of observations made of the operation of plants that have already been constructed.

" Louisiana's first effort at recycling is in the Cotton Valley field, Webster Parish, where unitization has been completed on approximately 12,000 acres of gas-condensate producing land. In this field a large majority of the operators and royalty owners voluntarily pooled their interests. Unanimous approval was not obtained to the agreement, however, and the Department of Minerals was petitioned to issue an order which would make the plan 100% effective. Authority was granted to the Department to issue such orders after hearings by Act 157 of the 1940 legislature. After proper hearings such an order was issued, the plan became effective, and the recycling plant has been constructed and has recently begun operation." A. H. N.

870.* Core Analysis Presents Inclusive Formation Data. Anon. *Oil Wkly*, 31.3.41, **101** (4), 59.—Given proper supervision, core-recovery percentages will run sufficiently high to present necessary geological data and enable representative analyses to be made. In 1940, out of 54,789 ft. of hole-cores by a number of operators and appearing in the records of one laboratory firm, 40,718 ft. of core were recovered, or 74·7% recovery. These results were obtained with wire line, conventional and pressure-type core-carrels, in all diameters. The percentage of core recovery appears directly as a function of the service, attention, and interest which the cores received from the operator.

To yield best results in the core laboratory the cores should be of as large diameter as compatible with drilling practice at the well where they are secured. They should be subjected to a minimum of flushing with the mud stream, or, if cut " dry," should be drilled out at such a rate as to preserve within them the maximum percentages of oil, gas, and connate water, so as to present at the surface as close a reproduction of the reservoir *in situ* as possible. Lest any of the *in situ* characteristics be lost or altered, such cores should be examined and analysed promptly on being brought to the surface.

Analyses from adjacent core samples, a portion checked with adequate apparatus at the derrick and others packed with utmost care, including waxing or paraffin coating to prevent evaporation, and then analysed at distant laboratories, show that the more representative and commercially significant values of all desired factors may be secured by immediate analysis. Such prompt determinations present a more representative picture of true reservoir conditions. Derrick-floor analyses, made promptly, also enable drilling changes to be made even within limits of comparatively thin strata while the bit is still in the formation being cored.

The use of the data is illustrated by actual core-graphs showing oil–gas and water–gas contact planes and other pertinent data. The work of many recent investigators is referred to and quoted to elucidate certain points. A. H. N.

871.* Factors Affecting the Use of Gravel in Oil Wells. K. E. Hill. *Oil Wkly*, 26.5.41, **101** (12), 13. *Paper Presented before American Petroleum Institute.*—The placing of a screen of gravel about the liner of a well is essentially a process designed to increase the permeability and porosity of the material adjacent to the well. By means of this process two fundamental benefits should result : (1) a decrease in the amount of sand migrating into the well-bore ; (2) an increase in the production rate due to increasing the effective well diameter.

Therefore, a gravel screen should provide less resistance to flow, after equilibrium has been established, than would the liner and formation without the gravel. At the same time sand must be prevented from migrating into the well-bore. The work is discussed from the two viewpoints of the essential benefits outlined above.

A *résumé* of the various phases of the problem is given, and field, laboratory, and theoretical considerations lead to the following conclusions :

The use of gravel adjacent to the liners of oil-wells is intended to decrease sand production and increase the oil-production rate. Theoretically and practically both these purposes can be attained by the use of gravel which has a size ratio of 8 when compared to the diameter of the sand at the 10-percentile point on the cumulative screen analysis. However, due recognition must be given to the fundamental laws underlying the use of the frequency cumulative curves in the choice of gravel size for screening unconsolidated sand. The thickness of gravel should be at least five gravel-grain diameters.

Preliminary field results indicate that, after initial flush production, gravel-pack wells have higher production rates, better-sustained rates, and result in greater cumulative production than conventionally completed offset wells. This is a result of the ability to produce the gravel-pack wells at a greater percentage of their true potential capacity. Productivity indices which are lower for gravel-pack wells than for conventional wells are thought to be due to the use of mud instead of oils as the circulating medium.

Decreased sand production and an increased production rate should be obtained from the use of gravel in oil-wells, if a uniformly packed, closely sized gravel, with a gravel–sand size ratio of not more than 8 and a thickness of at least 5 gravel grain diameters, is placed in the well using oil as the circulating medium. A. H. N.

872.* Treatment of Oil-Sands with Surface-Active Chemicals. C. F. Bonnet. *Oil Wkly*, 26.5.41, **101** (12), 21. *Paper Presented before American Petroleum Institute.*—What is known about the flow of fluids in sand reservoir may be summarized thus :

Oil production from an oil-sand is proportional to the porosity, oil saturation, and the permeability of the sand. Oil-sands usually contain water, which is considered to surround the sand-grains so that the water lies between the oil in the pore-spaces and the sand-grain surfaces that form the walls of the pores. When water saturation exceeds 15%, the water interferes with the flow of oil and, if enough water saturation exists, water and oil will be produced together. When water saturation of the sand exceeds 80%, it is probable that the flow will be entirely water, and no significant volume of oil will be produced. The ratio of water production to oil and gas production is not necessarily the same as the ratio of water saturation to oil and gas saturation of a producing-sand section, but saturation and production tend to reach an equilibrium. Sands deposited in nature are seldom uniform, and usually consist of alternate layers that vary in porosity, permeability, and water and oil saturation.

Oil-sands may be treated with surface-active chemicals in order to reduce to a minimum any harmful effects on oil production caused by excess water in the area surrounding a well-bore. In planning this treatment, consideration should be given to the physical characteristics of the sand and the effect of pressure differentials on the flow of the fluids in the sand.

Due to their unique effects on the interfacial relationships between water and sand and water and oil, surface-active chemicals may prove to be valuable tools for correcting abnormally poor production from oil-wells.

Composition and structure of surface-active agents greatly influence their effectiveness for various uses. Selection of effective surface-active chemicals requires correct analysis of conditions that prevail in practical use.

Field tests have been conducted under a variety of conditions. Results show that clear-cut benefits from the use of surface-active chemicals can be obtained only if the method of field application and the objectives of treatment are selected properly in relation to the importance of surface and mechanical forces in the reservoir.

Recognized limitations and benefits that can reasonably be expected from the use of surface-active chemicals in oil wells are discussed. A. H. N.

873.* Engine Heat Used Advantageously on Hydraulic-Pumped Lease. G. M. Wilson. *Oil Wkly*, 16.6.41, **102** (2), 17–18.—Usually wasted radiator-water heat, as well as heat obtained from the engine-exhaust pipes, is being utilized to good advantage by a company operating a number of hydraulic-pump-equipped wells in one of the California fields from two central locations.

The cost of the installation of a combined radiator-water and engine-exhaust-heat exchanger system has proved small compared with the savings being realized in boiler fuel, power-oil heating, and the elimination of extra handling of crude oil in lease-tanks.

The heat-exchange system consists of two independent parts: (1) a unit that derives heat from the hot engine-water from the two engines, and which heats all the oil, including power-oil, coming from the wells, and (2) a unit that absorbs heat from the exhausts from the two engines to heat the fluid produced by any single well that may be on special gauge, the heat aiding in dropping out the water in the gauge-tank. The two units are detailed and illustrated. A. H. N.

874.* Sand Tapping Improving Stripper Well Operations. F. R. Cozzens. *Oil Wkly*, 16.6.41, **102** (2), 20.—The water-control method is known as "sand-tapping," and differs radically from the old-timer's practice of drilling through the entire sand-body and shooting with as much nitroglycerine as the bore-face would hold. Such a practice generally brought the desired flow of oil, but in breaking up the low portions of sand it likewise brought in a deluge of salt water which flooded the well. Final results were usually determined by the amount of water and the operator's ability to exhaust it.

The modern method, instead, is to proceed with caution the moment the pay-sand is reached in a newly drilled well. From records of previous drillings in his district, the operator can estimate with considerable accuracy the thickness of the sand-body. After first measurements are taken, he cores the sand to an estimated depth of one-third its thickness. In most districts the average penetration is 4 or 5 ft. into the pay. In this penetration originates the reservoir which is prepared by lowering into the core three 4- by 16-in. cartridges of gelatin (about 30 lb.), 90% strength, straight N.G. grade. The charge is exploded by electric blasting cap and line, and it is seldom necessary to lift the casing. After the spoil has been stirred and removed by drill and bailer, the cavity is usually of sufficient size to hold 100–200 lb. of gelatin of the same grade and strength. About 100 lb. of sand or earth for anchor is poured down on this charge, and it is necessary to lift out the casing to prevent damage. This charge is also fired by electric cap and line. The results are good yield of oil and low salt-water production. A. H. N.

875.* Economic Selection of Oil-Field Equipment. Part 3. E. N. Kemler. *Oil Wkly*, 16.6.41, **102** (2), 34.—When bottom-hole pressure data are available from pumping or flowing tests the behaviour of the well will be found to follow the relation $Q = c(P_m - P)$, where Q is the production in brl./day, c (the productivity index factor) is a constant for any well, P_m is the static reservoir pressure, and P is the pressure at the formation when the well is producing at a rate Q. If c and P_m are known, Q can be found for any value of P, or P can be found for any value of Q. If several values of Q and P are known, c can be calculated.

The method of calculating the well characteristic or productivity index factor from build-up data offers a simple and easy method, and does not require any production data to make the required analysis. The basis of arriving at this method is such as to make it as accurate as others. Further information on the limitations of each of these methods is necessary, but at present they offer the only basis for the prediction of well performance.

Both methods of determining c are given in detail in the body of the paper, and graphs from field tests are reproduced to illustrate the methods of calculations used.

A. H. N.

876.* Economic Selection of Oil-Field Equipment. Part 4. E. N. Kemler. *Oil Wkly*, 23.6.41, **102** (3), 35–42.—In this part of the paper horse-power requirements for the prime mover of a pumping well are studied. For simplicity, the oil is presumed to be free from gas. The lift is first calculated, and from that the formula for horse-power used is:

$$\text{H.P.} = \frac{350QSD}{33{,}000 \times 24 \times 60} = 0{\cdot}0000073SQD$$

where S = specific gravity; Q = brl./day (42 gal.); and D = net lift in feet. Charts are presented.

The theoretical horse-power requirements for pumping equipment are in general lower than would be normally expected, the overall efficiency of the pumping system being in many cases very low. The efficiency of the modern pumping units of all types is probably very high, and the efficiency from the reduction unit to the polished rod for well-designed equipment would be expected to be more than 90%. The largest loss will therefore result from sucker-rod friction, fluid friction, and pump friction. Of these the sucker-rod friction is undoubtedly the largest factor, and is, of course, subject to little if any control except in extreme conditions.

The lift efficiency (ratio of hydraulic horse-power to polished-rod horse-power) to be expected from sucker-rod type of pumping equipment is quite variable. Even under the best of operating conditions where producing considerable quantities of fluid it is doubtful if this efficiency can safely be taken as greater than 50%.

In the case where a well makes gas with the oil, the calculation of the required horse-power is quite difficult. In the case of a pumping well it is assumed that the free gas will be separated from the oil by the gas anchor, so that the only energy supplied by the gas will come from that gas which comes out of solution after the oil gets in the tubing string. Formulæ can be derived to give the theoretical amount of work which can be obtained from gas coming out of solution. The application of such formulæ is, however, very difficult, because the gas energy is normally used very inefficiently in the tubing string. Even when used at efficiencies of the order of 10-15% it will supply a considerable amount of energy for lifting purposes. A. H. N.

877.* Fault Shearing Off Oil Wells Presents Unusual Problems. G. M. Wilson. *Oil Wkly*, 30.6.41, **102** (4), 17.—Proving that the geologic forces and earth movements that accompany the forming of oil-bearing structures or entrapments are by no means static, an investigation into the cause of the collapse and shearing off of oil-well casings below the surface in a California oil-field has disclosed the existence of an active thrust fault, the over-riding portion of which is moving at the average rate of approximately 1–1½ in./yr. Between twenty-five and thirty pumping wells, within the past approximately 10 or 15 years, have been affected, damaged, and many even abandoned prematurely because of the relatively rapid movement of this thrust-fault.

The most serious damage to well casings appears to be confined primarily to wells that intersect the fault at depths shallower than 800 or 900 ft.

While several methods have been used in coping with this problem, the most successful form of relief used thus far consists of sinking a shaft around the casing of wells the points of contact of which with the fault are not greater than approximately 200 ft. in depth. The shafts are dug by hand, and are carried down a short distance below the fault intersection, after which the damaged casing is removed. The shafts are lined with either 2 by 6-in. plank lagging or 72-in. welded stove-pipe, and then covered with a metal hood. The offset position of the shaft provides for a maximum amount of the movement of the moving upper portion of the thrust-fault before the casing would again be damaged or sheared off.

The new section of casing used to replace the sheared and bent section extending from just below the fault to the surface is not landed in a head, but is centred below the derrick floor by means of $\frac{7}{8}$-in. tie rods and turn-buckles anchored radially to the derrick substructure.

Details of the method as applied in typical wells are given. A. H. N.

878.* Practical Hints for Care of Multi-Cylinder Pumping Engines. F. Swindell. *Oil Wkly*, 30.6.41, **102** (4), 23.—Assuming that the pumping equipment originally purchased was properly selected and installed on a correctly designed foundation, a pumper need follow only a few simple rules materially to extend the economic life of multi-cylinder high-speed gas engines.

Generally speaking, these rules are: (1) an ample supply of good gas at proper pressure in the case of natural-gas operation, and a supply of good-quality gasoline where this fuel is used. (2) Good circulating water, or, if the water supply is bad, the proper treatment of it to avoid harmful effects. (3) Proper lubrication. (4) Proper attention to mechanical adjustment. (5) Proper engine speeds with regard to minimum speed fluctuation and to position on torque curve. (6) Proper maintenance of equipment that is being driven.

In enumerating these rules no attempt has been made to arrange them in the order of their importance, since it is doubtful if one takes precedence over the others. If these suggestions are placed in execution, it is safe to predict a satisfactory economic performance from any well-designed multi-cylinder engine. However, it must be remembered that unless the proper engine for the particular job to be performed is selected initially, it will be exceedingly difficult, if not entirely impossible, for the pumper to obtain satisfactory performance from the equipment. Each of the six items is discussed in detail.

Balancing wells are studied, and it is pointed out that there are wells that cannot be kept in proper balance, due to changing well conditions. Some wells produce slugs of gas that may continue for only a few minutes or they may last several hours. If the well has been balanced for the non-gaseous period, it will be out of balance while the well is producing gas. To meet this problem it is probably best to determine which of the two sets of conditions persist for the greater part of the well's daily pumping period, and balance for that condition. The well will then be out of balance for the other condition, and usually it will not be practical to try to change counterbalance as the well condition changes over short periods. However, the well condition as a whole will be better than had no attempt been made to balance for any part of the pumping period. A. H. N.

879.* Economic Selection of Oil-Field Equipment. Part 5. E. N. Kemler. *Oil Wkly*, 30.6.41, **102** (4), 28.—Of the items in equipment operation which are important, none is easier to control, and yet probably so neglected, as the question of counterbalancing. As a rough approximation it can be said that a well operating without proper counterbalance will impose in the equipment a peak torque which is at least twice the value with proper counterbalance, and for light loads may be several times this minimum value.

The determination of the proper counterbalance by calculation is for all practical purposes impossible. The calculation of the peak torque requires that the load-displacement or dynamometer card be known. The equation for such a card would be difficult to work with if it were known. Since no one has worked out a simple formula for such cases, the complete analytical treatment is obviously impossible. The next method would be to obtain a dynamometer card and from it work out the proper amount of counterbalance. Here again some difficulties arise. The work of determining the proper amount of counterbalance takes considerable time, and involves the time element of several days' waiting under normal conditions.

The maximum well load as it influences torque as given by the Slonneger formula is : $P = (Wo + Wr)\left(l + \frac{LN}{5400}\right)$, where P = polished rod load; Wo = weight of oil column on plunger = $0{\cdot}34\ Sd^2l$; Wr = weight of sucker rod = kl; L = length of stroke in inches; N = number of strokes/minute; l = well depth in feet; d = plunger diameter in inches; K = constant depending on sucker-rod string; S = specific gravity of fluid.

If the weights of the sucker rods are assumed to be counterbalanced, the net or unbalanced load P_u will be given by the formula :

$$P_u = (Wo + Wr)\left(l + \frac{LN}{5400}\right) - Wr$$

$$= Wo\left(l + \frac{LN}{5400}\right) + \frac{WrLN}{5400}.$$

$\frac{LN}{5400} = \frac{Q}{630ed^2}$, where Q = production in brl./day, e = volume efficiency of pump. $Wo = 0{\cdot}34Sd^2l$; $P_u = 0{\cdot}34Sd^2l\left(l + \frac{Q}{639ed^2} + \frac{KlQ}{630ed^2}\right)$. If e is assumed as being 70% and $S = 1{\cdot}0$, and, further, if $d = \left(\frac{KQ}{126}\right)^{\frac{1}{2}}$, the above equation will reduce to :

$$P_u = (0{\cdot}055\sqrt{KQ} + 0{\cdot}0075Q)l.$$

The peak torque will be given by

$$T = P_u \times \frac{L}{2} = (0{\cdot}055\sqrt{KQ} + 0{\cdot}00075Q)l\,\frac{L}{2}.$$

Charts are given and further approximations in the equations are made. The effects of the length of the stroke are clearly indicated with the aid of a chart. The remarks given have been inferred as applying to gear or chain-reduction units. They will apply equally well to a belt-driven countershaft-type rig-front. In this case the results of keeping the length of stroke down will be to give a lower belt-pull requirement. In general, a reduction in length of stroke will require an increase in speed, which will mean in turn an increase in belt speed (ft./min.) and a decrease in effective belt tension. For drives giving belt trouble a careful check should be made on the length of stroke, to see if conditions would permit a shortening of the stroke length.

A. H. N.

880.* Economic Selection of Oil-field Equipment. Part 6. E. N. Kemler. *Oil Wkly*, 7.7.41, **102** (5), 31.—To illustrate the method of selecting a most economical size of equipment to install in water-drive fields a specific example is discussed in detail. Two units are proposed after the characteristics of the field and wells are detailed and a comparative study of the two units is presented. Salt-water disposal is also considered in the problem.

When taking into account all the factors involved with equipment size it can be seen that a substantial saving can be effected by using the smaller equipment. It might appear that the larger unit has been unduly penalized by the higher operating and salt-water-disposal costs. The reverse is, however, probably true. This is because the operating costs will probably increase considerably owing to the production of large amounts of water, which is normally accompanied by considerable corrosion. The salt-water-disposal cost is variable and will depend on the manner and cost of disposal facilities. In some cases it may be only a fraction of a cent, whereas in case a deep-disposal well must be drilled, the cost, including its share of capital charges to repay the investment in the well and system, may be several cents/brl. While this example is not necessarily typical of all wells, it would be representative of some wells, and shows that considerable sums are saveable under many conditions.

A. H. N.

881.* Summary of Recent Opinions on Well-Spacing Problems. T. U. Ju and R. L. Huntington. *Oil Wkly*, 7.7.41, **102** (5), 36.—The main conclusion of the paper appears to be that whilst engineering principles of drainage are important in deciding on the well-spacing programme, economic considerations are often the controlling factors. The conclusions of the A.P.I. report on well-spacing are summarized as: (1) the rate of withdrawal materially affects the drainage area of the well. Given the former, engineers may, within reasonable limits, determine the latter. Under restricted withdrawal, regional reservoir drainage results and the drainage area of a well becomes indeterminate, reaching in some cases to remote points in the reservoir. Under such conditions effective drainage of a well becomes the size of uniform geometrical pattern which will insure adequate wells for reservoir drainage and rateable withdrawal. (2) The same or greater efficiency of recovery can be obtained by wider spacing at lower rates of flow/acre than by close spacing at excessive rates of flow. (3) Well density, within reasonable limits, is not a factor affecting ultimate recovery, when rateable withdrawal by owners of the oil in place is observed in a pool. Where the allocation does not recognize the basis of recoverable oil in place, uniform spacing units are necessary for the procuring of rateable withdrawals.

The strict economic phases of well-spacing have been discussed repeatedly by the Committee on Unnecessary and Unprofitable Drilling of the Independent Petroleum Association of America. In its latest report this group asserts that drilling excessive wells, which can be cured only by wider well-spacing, causes: (1) a large and unnecessary increase in development costs, which could be reduced by drilling of fewer wells/acre. (2) A steady decrease in per-well allowables, resulting in a long-delayed pay-out of investments. Curtailment of drilling rates would relieve this situation. (3) A curtailment in discovery and development of new reserves, occasioned by dissipation in drilling of unnecessary wells of the fund which would otherwise be available for that purpose. (4) Unnecessary consumption of steel and other materials needed in other industries during the current national defence emergency.

Whilst the majority of opinion is towards wide well-spacing, certain opinions are summarized which are against it, such as Clark's contention that the time factor in the rate of development sometimes dictates close spacing. A. H. N.

882.* Dual, Gathering, and Input Lines Mark Big Co-operative Cotton Valley Cycling System. E. Sterrett. *Oil Wkly*, 14.7.41, **102** (6), 61.—The agreement under which all sands lying below the base of the Travis Peak formation in the Cotton Valley field are unitized and are to be exploited by a committee from former individual producers in that area is sponsored by State conservation authorities and legalized by their action in declaring the return of lean gas to the sands a conservation necessity.

On this basis an operators' committee, representing either individually or by proxy every producer from the " D " and Bodcaw sands, planned the plant, the two gathering systems, and the straight-line top-of-structure input system, and worked out an equitable distribution of revenue whereby all operators would be compensated for wells already drilled, whether or not these were to be continued active either as gas sources or as input wells.

In listing the advantages to be derived from the accomplishment of unitization and cycling in the Cotton Valley field, the Louisiana Department of Conservation set up the following benefits :

The project will return to the State of Louisiana in taxes over $2,000,000 at the current rate of taxation from Bodcaw and " D " sands alone. It will increase ultimate distillate recovery by 50% by halting retrograde condensation in the formation, with accompanying increase of surface tension in the sands and resistance to all pressures. It will more than double the lift of the field as compared with former operating conditions. It will retard encroachment of edge and bottom water. It will prevent waste of gas in recovering distillate. It will eliminate drilling of unnecessary wells under offset requirements, effecting a saving estimated at $10,500,000. It will make possible economic recovery of gasoline and other hydrocarbon content from gas from Bodcaw and " D " sand-wells being blown to air under individual production. It will permit the recovery of stock-tank vapour loss at distillate wells, this loss being checked at from 15% to 20% of fluids produced under individual operation with usual lease-tank system. It will prevent the selling of dry gas at distress prices. It will assist in maintaining a balanced oil and gas reserve within the sands at low relative cost.

The paper describes in detail, with many photographic illustrations of the various components, the gathering and input systems used. A. H. N.

883.* Modern Completion Practices. Anon. *Oil Wkly*, 14.7.41, **102** (6), 100.—A comprehensive review is given of recent methods used in completions of wells. The methods of obtaining and utilizing basic data to determine the exact depth and characteristics of producing sands—both in newly drilled and older wells—are detailed.

Multiple-zone completions and progressive completions up the hole are being expedited and assured through running drillable or acid-soluble alloy sections in the completion strings opposite known producing strata, with perforating, wall-scrapers, or nitro-shots to open the sheath behind such sections and permit exploitation of the pay. Where steel casing has been placed opposite an upper zone, improved cut-out tools are permitting economic removal.

In the proper conditioning of the producing sand-face it is now considered advisable to remove the mud-sheaths, and there have been many advancements in this direction. Included in these are acids for removing mud-sheaths, new casing-shoes that direct circulation fluid against the sand-face, jet-guns to scrub walls clear of mud, employment of scratchers or brushes mounted on the casing to break down the cake and permit its circulation out of the hole, and use of wall-scrapers and under-reamers to a larger extent. All these aid in procuring full productive capacity of the bore-hole exposure and increase yield of the wells.

There has been a growing use of gravel-packing as a means of protecting screens against clogging, crushing, or excessive cutting action. Gravel-packing is applicable either through perforated casing, in conventional manner, or by pre-packed liners.

Oil-base muds have been used, outstanding advantages of which are said to be: (1) minimize the possibility of impairing the natural-flow potentialities of the producing horizon such as that resulting from infiltration of water from water-base muds. (2) Permit smaller clearances for setting liners, since the mud-sheath has no appreciable thickness. (3) Eliminate the possibility of clogging the perforations of the liner with thick mud-sheath. (4) Facilitate the removal of the mud-sheath from the walls of the hole, for its mud-sheath has no appreciable strength. (5) Assist in drilling through formations such as heaving shale where water-wetting appears to be a source of difficulty. (6) Permit cores to be drilled and obtained without contamination from drilling water. A. H. N.

884.* Probability Theory Applied to Oil-Exploitation Ventures. Part 4. S. J. Pirson. *Petrol. Engr*, May 1941, **12** (8), 53.—This part of the Paper deals more particularly with producing than with unexplored properties. Principles are laid down and problems solved to illustrate the methods.

In general, the problem of applying the theory of probability to the business of discovering new fields has been reviewed, as well as the method of giving weight to possible hazards in the valuation of producing oil properties. An application of the theory of probability in order to calculate the odds against discovering oil by geochemical prospecting has also been made and the problem approached from various angles. The problem of the reliability of a discovered structure is also treated, and examples of calculations are given. A. H. N.

885.* Reconditioning Oil Wells in the Greater Seminole Area of Oklahoma. Part 1. J. I. Laudermilk. *Petrol. Engr*, May 1941, **12** (8), 114.—The main item discussed in reconditioning oil wells is shooting. As a preliminary step to shooting, the individual well should be studied on its own merits if the necessary data are available. In general, the factors affecting the shooting of the Upper Wilcox Sand in the Greater Seminole Area of Oklahoma include the items discussed below as to use and importance.

Date of initial completion is of value, inasmuch as this factor will materially affect the amount of oil yet to be recovered. The size of most oil-strings of casing in the Greater Seminole Area is ample to permit the use of any reasonable-size torpedo shell in placing the explosive at the desired depth. In some cases, however, this is not true, for the size of the shell is restricted by the casing, and thus to some degree the amount of concentration of the shot possible is limited when torpedo shells are used to place the explosive, for a minimum annular space of ½ in. is required between the shell and the casing-string through which it is run.

The length of the casing-string is of even greater importance than the size, for the explosive must be placed at a sufficient depth below the casing-seat to prevent damage to the casing. The type and grade of casing used in the oil-well have a very definite influence on the possibility of the detonation of the explosive causing damage to the casing-string. The mechanics involved in the collapse of damage of casing due to shooting are not clearly understood, and become very involved when approached from a theoretical standpoint.

The total depth of the well ls important for several reasons. Insufficient total depth will limit the size of shot that can be used without damaging the casing. In some instances, comparatively rare in the Greater Seminole Area, this feature will entirely eliminate the possibility of shooting the producing formation. The total depth of the well may also be used, together with the surface elevation and vertical correction, to determine the location of the shot in the formation so as to reduce the danger of shooting too close to the oil-water contact, and thus causing premature water encroachment or an increase in the existing water–oil ratio of production. Another use is for geologic correlation with other wells that have been similarly reconditioned in the past.

The importance of surface elevations in reconditioning work lies in the fact that variations in the ground surface are reflected in the depths necessary to reach a given geological marker or horizon in different wells.

Vertical and horizontal corrections for depths must be known and applied. Further, data on the producing formation itself, such as the top of the formation, the amount of penetration, and which portion is the best saturated part of the formation, should be known, in order to locate the shot and determine its size and concentration.

A. H. N.

886.* Estimation of Underground Reserves of Petroleum. Part 1. B. B. Bilibin. *Petrol. Engr*, May 1941, **12** (8), 141–143.—Methods of classifying oil-fields according to potentialities, and whether they are proved or unproved areas, are given, together with systems of map-colouring. The following methods are used to estimate reserves : (1) proved (A_1) and semi-proved (A_2) reserves : future yield of oil is determined by means of production-decline curves. (2) Probable (B) reserves : the quantity of oil to be recovered is estimated from production-decline curves based on the producing performance of wells in nearby similar oil-producing areas, or by the volumetric method. (3) Possible (C_1) and prospective (C_2) reserves are calculated by the volumetric method.

Part 1 of the paper deals only with types A_1 and A_2 reserves. The production-decline-curve method of estimating the future production of wells is based on well-performance data on individual wells or groups of wells producing oil from the areas under consideration. Production-decline curves are established from initial (30-day) production data, and the subsequent rate of decline of oil production projected into the future to the limit of the economic rate of yield. The initial yields and the rates of decline of oil production of wells depend on the characteristics of the oil-bearing formations, the manner in which the wells are operated, the rate of field development, and the spacing of the wells. Consequently, initial yields and rates of production decline are seldom the same for all wells in a group, even when the oil-producing formation is regular and uniform throughout an area.

As it may be necessary to calculate the quantity of oil remaining to a partly developed reservoir at any time during its exploitation, the initial yields of wells yet to be drilled and their rates of production decline are calculated by a special method based on the relationship between the initial yields of producing wells, their production-decline rates, the rate of development of the reservoir, and the natural characteristics of the oil-bearing formation. The method is known as the Method of Curves of Dependency and is based on actual well-production data, characteristics of the oil-bearing formations (reservoir pressure, permeability, etc.), and the field exploitation programme (rate of development, spacing of wells, etc.). Some discussion of these curves of dependency is included.

A. H. N.

887.* Functional Analysis of the Engineer's Place in the Petroleum Industry. Part 4. E. N. Kemler. *Petrol. Engr*, June 1941, **12** (9), 56.—The engineering functions of an oil-producing company are involved and technical in nature and are many in number. Because of this the supervision of the engineers must be by someone with technical training and ability. Maximum benefits cannot be obtained by placing them under someone without this training and ability. If proper attention be given to engineering matters, the engineering department can probably function to maximum advantage with a minimum of inter-departmental troubles if placed under the production superintendent. This will be true if engineering is made of sufficient importance so that the higher engineering positions offer opportunity and pay equal to equivalent operating positions. A careful setting out of the duties and responsibilities of the various departments is necessary to obtain best results. Furthermore, engineering departments should limit their activities to engineering functions, thereby keeping their number to a minimum, which will ultimately increase their general standing and importance and make possible a higher salary scale. A. H. N.

888.* Estimation of Underground Reserves of Petroleum. Part 2. B. B. Bilibin. *Petrol. Engr*, June 1941, **12** (9), 72.—The methods of constructing curves of the relationship between the initial yield of oil wells and other factors are detailed, with methods for calculating the probable rate of decline of an oil well.

For calculating oil reserves by the volumetric method, the formula used is: $S = Vdabc$, where S = total oil, in tons, that may be recovered from a pool; V = volume of the oil-bearing reservoir, area times thickness; d = density (sp. gr.) of the oil; a = coefficient of porosity; b = coefficient of saturation; c = coefficient of recovery.

By submitting actual figures (based on records of depleted reservoirs) for V, d, and a, which are known, the value of bc may be determined by using the following transformed form of the above equation:—

$$bc = \frac{S}{Vda}$$

Inasmuch as b and c cannot be calculated separately from field data, it is assumed in the calculation of oil reserves by the volumetric method that $bc = x$, the coefficient of utilization. The equation may then be written: $S = Vdax$.

When this equation is used in the calculation of reserves, each factor in the equation cannot be set down as having a definite value, but must be defined between maximum and minimum limits. Because of this fact, reserves estimates will then be calculated as being between certain limits, such as, say, 2–3 million tons, or as being a reserve of 30—40 million tons—a difference that may be considerable, but nevertheless within the limits of accuracy of the calculation.

The most difficult step in the calculation of underground oil reserves by the volumetric method is the determination of the coefficient of utilization (coefficient of saturation times the coefficient of recovery). Theoretical methods for arriving at a representative coefficient of utilization do not yield dependable results, and the best method is to base the coefficient on the production history of reservoirs that have been depleted of their recoverable oil. A coefficient of utilization so determined can be used with reasonable assurance of accuracy in the calculations of reserves in new areas.

In the calculation of prospective reserves it will be necessary to assume an average coefficient of utilization based on that determined for similar reservoirs. Under those conditions the coefficient of utilization should not be an arithmetic average value, but preferably one based on the most frequently repeated or most characteristic coefficients. Typical coefficients ranging from 0·9 to 0·2 are tabulated. A. H. N.

889.* Reconditioning Oil Wells in the Greater Seminole Area of Oklahoma. Part 2. J. J. Laudermilk. *Petrol. Engr*, June 1941, **12** (9), 86.—Further to the requirements detailed in Part 1, the following studies should be made before a reconditioning programme is applied: local subsurface conditions may be such that no inducement for reconditioning exists in certain areas. Due to localized geological features, it may be impossible for a given well to have any appreciable radius of drainage, or for there to be any considerable amount of physical reserves of oil in the vicinity of the area drained by the well. Information concerning the probable size of the reservoir tapped by the well is very desirable, therefore, as is also knowledge of local subsurface conditions existing in the reservoir, which will affect the probable drainage radius of a given well.

The oil–water contact in the Upper Wilcox Sand in the immediate vicinity of the well in question is a factor of extreme importance. This knowledge allows the engineer to estimate the size of shot he can use without undue danger of increasing the rate of water encroachment.

Information on the total thickness of the Upper Wilcox Sand is very valuable, as it is indicative of local geological structures. It is also desirable in order that the efficiency of production and recovery with partial penetration can be estimated.

The production history has quite a distinct and important bearing on the possibilities and inducements for reconditioning work. If the decline in rate of production has been gradual, the present rate of production may be all that can reasonably be expected, in which case the shooting of the well would be merely a waste of money. If, however, abrupt declines have occurred in the production rate, the possibilities of the well in question should be thoroughly investigated. Even if no abrupt decline has occurred, however, it is advisable in many cases to study the comparative production histories of several wells in a given region, to determine whether the possibility of increasing the rate of production exists.

Having obtained all available information, a thorough study of the prior reconditioning work (if any) that has been done on the well should be made, as this will offer the best-known means of estimating the results of prospective work.

In summarizing the factors affecting the shooting of the Upper Wilcox Sand in the Greater Seminole Area of Oklahoma, it should be borne in mind that many minor factors other than those mentioned may be encountered occasionally in individual cases. The above-mentioned factors are of primary importance, however, and a thorough understanding and an appreciation of the importance of each should permit an intelligent approach to the problems of reconditioning oil-wells by shooting the Upper Wilcox Sand. It should especially be emphasized that as far as possible each well must be considered individually on its own merits.

The author then deals with results of shooting, explaining in detail the significance of the terms " initial change in production rate " and " sustained change in production rate." A. H. N.

890.* Planning for Flexibility in Selecting Subsurface Lifting Equipment. P. F. Barnhart. *Petrol. Engr*, Midyear 1941, **12** (10), 25–28.—The Placedo field, Victoria County, Texas, is described, and main characteristics of the sand and the crude oil produced are given. Objective in this field is to progress from (1) flowing to (2) natural intermittent flow to (3) open gas-lift to (4) closed gas-lift operation with minimum equipment and labour. Practices involved are discussed.

In discussing the closed gas-lift operation it is concluded that input gas–fluid ratios vary from 225 to 800 cu. ft./brl., depending on well productivity and whether operating conditions are favourable or unfavourable. The calculated efficiency of lift, when determined, was approximately 22%, which may be considered satisfactory performance. The lift efficiency was calculated by determining the ft.-lb. of work performed in lifting a barrel of fluid, of known specific gravity, a given vertical distance, and dividing by the actual work developed during isothermal expansion of the gas used at given pressure in actually performing this work. A. H. N.

891.* Factors Involved in Pumping Directionally Drilled Wells. W. A. Sawdon. *Petrol. Engr*, Midyear 1941, **12** (10), 46.—After a discussion of the wear and other difficulties encountered in slant-hole pumping the following conclusions are recorded: the lifting costs for pumping slant-drilled wells will probably be somewhat higher over a period of time than for well-drilled vertical wells. Not considering wear on rods and tubing, it is doubtful whether these costs should be much, if any, greater than with other wells, assuming the holes are drilled with careful control of direction and that full advantage is taken of equipment available for checking the performance during production. One company pumping slant-holes drilled during the last two years at Hungtington Beach is reported to have an exceptionally low lifting cost.

It would seem that the proportion of horizontal drift to vertical depth would have a direct bearing on the lifting costs; yet some of those wells with low costs extend more than 3000 ft. below the ocean at measured depths of approximately 5000 ft.

Any conclusions concerning the pumping of slant-holes must be based on the collective experience of many companies. The general opinion of field men in charge of pumping directionally drilled wells appears to be that such wells present no more problems than the average well and that subsurface conditions affect all wells to about the same degree. Tubing and rod wear is encountered in many wells of all classes, and might well be less in a slant-hole carefully drilled than in a vertical well put down with too much latitude for deviation from the vertical. The lubricating property of the crude oil and the effect of sand in wells making an appreciable amount of sand during production are, however, factors of greater importance in a slant-hole from the standpoint of wear on subsurface equipment. A. H. N.

892.* **Economics of Multiple-Zone Completions.** J. O. Lewis. *Petrol. Engr*, Midyear 1941, **12** (10), 52.—So far, four principles have been applied in the development of multi-zone fields: (1) to drill separate wells to each zone. (2) To exhaust one zone and then to re-complete into another. (3) To produce two or more zones together through the same well. (4) To produce two or more zones separately through the same well.

The important factors in exploiting a multi-zone field are costs and conservation. Obviously, it is to the interest of the producer to reduce his costs, but the public also has an interest in low costs, for experience teaches by many examples that any method resulting in a reduction of costs to a considerable portion of the industry leads to reductions in prices to the consumers. Furthermore, such reduced costs make commercially available petroleum supplies that would otherwise not be produced. Experience has shown that economics and conservation are inseparable and complementary.

Examples of multi-completions are given in detail. Although these examples are hypothetical, they illustrate the manner in which double completions operate to reduce costs, increase returns on investments, and make possible the development of leaner sands that might otherwise never be produced. It can therefore be viewed, when properly applied, as tending to conserve oil and gas by making available latent reserves. Moreover, conservation should not be narrowly viewed from the sole standpoint of oil and gas, for other national resources are involved in the recovery of oil and gas—such as man-hours of work, iron, and coal. The conservation of steel supplied at this moment appears more pressing than the conservation of oil and gas, and the industry has been asked to reduce its requirements. Double completions will save from 25% to 40% of pipe and other equipment.

Methods for multi-completion of wells in such manner that production can be carried beyond the flowing stage are a recent development, but so far they have been applied to only a few wells, although covering a wide range in conditions, including shallow-pumping wells in Kansas, gas-condensate wells 6500 ft. deep in Texas, and oil wells 9000 ft. deep in Louisiana. How far it will be practical to extend the use of these devices cannot be foretold at present. It may be expected that difficulties and objections will be encountered, but it is also probable that improvements in methods and devices will be made that will overcome many of the difficulties and objections. The limitations will have to be determined from experience.

A. H. N.

893.* **High-Pressure Acidization of Cores.** P. G. Shelley, J. B. Stone, and L. W. Colburn. *Petrol. Engr*, Midyear 1941, **12** (10), 60.—During the progress of this work approximately eighty cores from three sources were treated: (1) Niagaran dolomite from a quarry near Woodville, Sandusky County, Ohio; (2) oolitic Bedford limestone from a quarry near Bedford, Indiana; and (3) oolitic McCloskey limestone from producing wells in the Clay City and Noble poole of the Southern Illinois basin. These rocks were chosen for their comparative uniformity and availability. Analysis shows the Niagaran to be almost pure limestone.

Cores were treated at gauge pressures of three magnitudes: approximately atmospheric or zero, 1250, and 2500 lb./sq. in. on the downstream end of the core, with pressures from 100 to 200 lb./sq. in. higher on the upstream end to create a treating differential. Data on only about half the cores tested are included in the tables, as difficulties with the apparatus and other factors negated the results obtained on the other half. Data on cores treated at atmospheric pressure are presented for comparison. Although all tests to date have been made at room temperature, provision for temperature control has been incorporated into the apparatus, and controlled temperature tests are contemplated.

The apparatus and technique employed are described in detail and the results are discussed. Perhaps the most important single conclusion that can be derived from a study of the data obtained in this work is that there is less tendency for the acid to channel at high pressures than at low pressures. This phenomenon is apparently due to the fact that at low pressures more of the carbon dioxide evolved by the reaction is present as a gas; consequently, many of the pores are blocked by Jamin action, with the result that the acid channels through the larger pores. In comparing either the pictures of cores or the tabulated data it should be remembered that the results obtained under high pressures probably more nearly approximate actual treating conditions, because at the bottom of a well the acid is always under a pressure greater than atmospheric. A. H. N.

894.* Well-Completion Methods. C. H. Rankin. *Petrol. Engr*, Midyear 1941, **12** (10), 78.—A description is given of the steps taken in completing a particular well in which practically all modern improved methods were employed. Thus is demonstrated the value of newer testing methods over those older methods of testing in which each show required a string of casing, and upper zones that did not appear to have potentialities were cemented-off. By testing in the newly developed manner, ten separate zones were tested individually and the potentialities of each fully explored.

Squeeze cementing, gun-perforating, zone testing, and the development of the devices that have made these methods practical have greatly increased the opportunities for the maximum utilization and development of new wells and the exploitation of undeveloped zones in older fields. A. H. N.

895.* Operating Data on Electrical Oil-Well Pumping. W. C. Lane. *Petrol. Engr*, Midyear 1941, **12** (10), 106.—The electrical pumping equipment used in one particular field is studied from the viewpoint of economics involved and performance data. It is the author's belief that in determining the cost of energy only real items of expense should be included. Not infrequently accounting systems involve practices that cause costs to be substantially higher than they really are, and as a result busy executives have erroneous notions concerning their costs. As a specific illustration a charge is often made for gas for which there is absolutely no market. In other cases the plant is charged a price higher than that received for the same product when it is sold to outsiders. Perhaps the most abused charge is that of overhead expense. It appears to be misleading and unfair to a plant to prorate the item of supervisory expense in proportion to the amount invested in plants, rather than in proportion to the amount of time and expense actually spent in supervising different projects controlled by an organization. In the data presented subsequently in this paper actual costs are used, unless estimates known to be approximately correct were used to eliminate much useless work.

Full details are included, and it appears that low cost energy for pumping and the reduction in field labour made possible by the use of electricity will prolong the profitable life of every well in this field served with electricity. A. H. N.

896.* Electrical Models as an Aid in Visualizing Flow in Condensate Reservoirs. W. Hurst. *Petrol. Engr*, Midyear 1941, **12** (10), 123.—Two methods are available to the engineer for model study: the electrolytic and potentiometric methods. The electrolytic method employs the travel of coloured ions in a medium under the influence of a voltage potential, and the coloured area swept out with time is representative of the area swept out by the dry gas in producing the wet gas of a condensate field. In the potentiometric method, however, the voltage distribution is obtained experimentally between input and output wells in the model, and from these data the history of the movement of gas along streamlines is traced. A brief review is given of the two methods as used by different workers.

The author has employed both the electrolytic and potentiometric methods in electrical model analysis, and it is concluded that each method has its advantages and disadvantages. The electrolytic model is adaptable to showing a wave-front advance in a matter of a few hours, but the results cannot be accepted on a quantitative basis to give the characteristic curves for the instantaneous and overall ratios of wet to total gas production with time, which are important in the determination of the economic life for gas cycling. This is a limitation of the experiments that show a fading-out effect around the boundaries of the coloured ions in the model, and introduces a certain amount of ambiguity as to what does constitute the flooded tracts. This phenomenon occurs early in the test and gets worse with time, but whether it is diffusion, the individual mobility of ions, or even the combination of both, it is difficult to say. The potentiometric method offers a quantitative means for studying gas-cycling, as attested by a sensitivity of 1 mm. change in potential mapping, but, to offset this, the calculations take time in carrying out the necessary steps of the equation. The application, however, of a recent instrumental development of a mechanically linked planimeter and differentiator could reduce this time factor considerably, but, even so, the necessary calculations involved in this method would take a certain amount of time. Other comparisons of the two methods are given.

The study of gas-cycling in parallel sands is given in detail, and a worked-out example illustrates the calculation necessary. Three-dimensional flow is discussed.

It is the author's belief that the dry and wet gases are sharply defined in the formation without the diffusion of one gas into the other. This view is taken from the known fact that the diffusion of one gas into another is an extremely slow process, and the only way it is conceivable for the two gases in the formation to overlap is by a mixing process. Mixing can occur only by turbulent flow, however, and if D'Arcy's law applies, the flow must be streamline. From the knowledge of gas movement in a sand formation, it is concluded that the travel is usually slow enough to satisfy the validity of D'Arcy's law. A. H. N.

897.* Field Study of Valve Cups in Pumping Wells. R. C. Graham. *Petrol. Engr*, Midyear 1941, **12** (10), 138.—The results of observations on more than 600 pumping wells during three years are presented. The method of installing the cups and initial care taken to obviate damage to them are detailed. Results obtained by using improved designs and proper care gave approximately 60% reduction in cup jobs over a 3-year period. This substantial reduction of eighty cups jobs/month was immediately reflected in lower lifting costs and made it possible to continue to produce many wells and leases that would otherwise have been classified as non-commercial. The only additional fact found that has not been previously presented was that tight emulsions caused by fluid by-passing the harder and under-sized cups were greatly reduced and the oil–water separation was effected more readily.

It was found that distinct advantages result from proper cup usage. It is possible to increase oil reserves by eliminating premature abandonment of small producers where excessive cup-jobs or the added cost of high-priced pumps would dictate their abandonment. The elimination of frequent cup replacements permits a reduction in the number of workmen and the amount of equipment required to make the installations, thereby reducing direct expenditures. Finally, production cost while a well stands idle waiting on pulling equipment is reduced to a minimum, and in some cases offset drainage is eliminated.

Based on the results of the tests, the following recommendations are offered: (1) the travelling valve, barrel, and other bottom-hole equipment should be in first-class mechanical condition. (2) Cups should either be soaked in oil before running or allowed to set in the fluid at the bottom of the hole a sufficient length of time to absorb the oil. (3) Records of cup-runs should be available to rod crews so that previous runs may be studied and new installations made in cup sizes indicated by the records. As a general rule, plus 15-thousandths are best adapted to new or semi-new barrels, and plus 30-thousandths to old barrels. (4) Medium hardness cups give much greater service in wells having maximum depths of 2000 ft. The greatest drawback of medium-hardness cups is their tendency to turn when pulled from the well. (5) Stitched cups and cups having reinforced shoulders are recommended. (6) No new design has yet been developed to cause any radical change in the standard make of cups. Deep bevels, inverted bevels, and copper wire between the plies show disadvantageous rather than beneficial results. A. H. N.

898.* Core Analysis Reliable Aid in Determination of Recoverable Oil. J. A. Lewis, W. L. Horner, and M. H. Stekoll. *Petrol. Engr*, Midyear 1941, **12** (10), 165.—The applicability of core-analysis data in estimating recoverable oil depends on several factors. One is that complete analysis of the cores must be made. Partial or incomplete analysis, coring and testing of intermittent sections of the formation are not conducive to accurate and reliable results. In addition, cores require careful analysis immediately on being brought to the surface. Transportation of cores, even in sealed containers, has been found to cause erroneous results with regard to the fluid content of the core. Sweating of the core against the sides of the container apparently occurs during transportation and results in measurements that are not directly comparable with those obtained at the well-site. Once the core analysis has been made, proper understanding, use, and interpretation of the data are necessary to translate the core-analysis results to accurate and reliable estimations of recoverable oil.

An estimation of recovery by water-drive (original bottom-hole pressure maintained) may be made directly from complete core-analysis measurements and calculations. Knowing the residual oil saturation in the cores, the shrinkage or formation volume factor as estimated or obtained from bottom-hole sample analysis, the connate water, and porosity from the core analysis, it is possible to calculate recovery by water-drive with accuracy. The method is detailed and illustrated by tables and charts.

The calculation of recovery by gas-expansion production is based on data similar to those for water-drive, with the major difference that the residual oil left in the formation under gas-expansion is almost invariably higher than that left in the formation after water-drive. Correlation between core-analysis measurements and the recovery obtainable in a gas-expansion field has resulted in accurate relationships being developed. Examples of the accuracy with which recovery by gas-expansion may be calculated is illustrated.

Once the field has been developed and the recovery by primary production obtained, complete information obtained from cores as applied to recoverable oil will indicate possibilities for secondary recovery operation. Secondary recovery operations in such circumstances may be carried out with a surety and an exactness of performance that will enable calculation on return of investment before the investment has been made. For instance, in a gas-expansion field the total recovery possible by artificial water-drive or by gas repressuring compared with that already obtained from the field will indicate the amount of recovery obtainable by either type of secondary recovery procedure. In water-drive fields the knowledge of the permeability profile, the recovery obtained, and the optimum yield will enable computations to be made with regard to the area drained by the water-drive. Determination may then be made with regard to the feasibility of work-overs. A. H. N.

899.* Petroleum Production Engineering Research Responsible for Tangible Advances in Practice. L. C. Uren. *Petrol. Engr*, Midyear 1941, **12** (10), 171.—Professor Uren reviews the major advances made in various fields of production engineering, and 83 references are appended to the paper, listing practically every paper of note published recently. The fields covered are fundamental properties of hydrocarbons and their phase relationships, reservoir conditions and performance, the testing of crude petroleum and formation samples, electrical logging and well surveying, well-spacing problems, studies on drilling fluids and oil-well cements, gravel packing and other well-completion and cleaning methods, flow of gas–liquid mixtures in vertical pipes and of dry gas displacing wet gas in condensate recovery, and researches on materials. The paper is, in fact, an extremely well-balanced *résumé*. A. H. N.

900.* Effectiveness of Gravel-Screens. B. H. Sage and W. N. Lacey. *Petrol. Tech.*, May 1941, A.I.M.M.E. Tech. Pub. No. 1325, 1–18.—Gravel-screens have been placed in water and oil wells for many years to increase the productivity and to decrease the entrance of sand. The results of extensive experimental work on the effectiveness of gravel-screens are described. The factors considered in some detail include gravel-size and condition of packing, sand-size and size distribution, fluid velocity and viscosity, and the thickness and arrangement of gravel-screens. Good agreement was obtained between calculated values based on probability considerations and experimental results relating to the influence of the thickness of the gravel-screen. Graphs present data on the distribution of sand in the gravel-screens, the sand concentration in the oil leaving the screen, the influence of velocity on sand concentration, and other relationships.

The data presented are used to estimate the optimum diameter of gravel to be employed in a particular hypothetical situation, in which an attempt is made to allow for the influence of fluid velocity and viscosity, gas–oil ratio, formation pressure and temperature, size and condition of the gravel-packing, and the nature of the formation-sand. G. D. H.

901.* Mechanism of Fluid Displacement in Sands. S. E. Buckley and M. C. Leverett. *Petrol. Tech.*, May 1941, A.I.M.M.E. Tech. Pub. No. 1337, 1–10.—The production of oil is accomplished as a result of its displacement from the reservoir by either gas or water, and the amount of oil recovered is limited by the extent to which the displacing gas or water accumulates. Production by dissolved gas alone is fundamentally inefficient, and the oil recovery thereby is seriously limited. The displacing oil or gas does not behave purely as a piston ejecting oil, for in all cases the oil and displacing fluid flow together and simultaneously through the same pores. Hence displacement is never complete. The amount of oil displacement during the process depends on the relative ease with which the two fluids can move.

Equations are derived relating the various quantities and are applied to determine qualitatively the course of the displacement. The result is presented graphically.

The viscosities of the fluids, the initial fluid saturation, rates of flow, and capillary and gravitational effects are of varying importance, according to circumstances, and it is shown that the rate of displacement is of great importance in dealing with heterogeneous sands where high rates of flow may reduce the overall recovery.
G. D. H.

902.* Production under Effective Water-Drive as a Standard for Conservation Practice. E. DeGolyer. *Petrol. Tech.*, May 1941, A.I.M.M.E. Tech. Pub. No. 1340, 1–4.—The aim of good engineering practice and good conservation practice in oil production is to keep as much gas as possible in solution. Ideally the gas produced with the oil should be only that dissolved in the oil produced with it. This can best be done by producing a field as a water-drive field. Some degree of water-drive is believed to be present in most fields, but in the past most fields have been produced too rapidly to allow water-drive to be effective. Ultimate recovery by water-drive should be at least 50% greater than for fields produced by gas expansion. Wide spacing will permit fields of low-degree water-drive to be produced effectively as water-drive fields.

The disadvantages of effective water-drive are delayed return on investment and the necessity of grouping small tracts into larger units, but these are probably not insuperable. The standard should be applied to new pools and to the many older pools that have been reasonably well handled up to the present time. The Arkansas Oil and Gas Commission is operating under essentially the proposed standard, and the Railroad Commission of Texas recognizes the standard, even if it does not observe it. G. D. H.

903. Patents on Production. J. D. Ball. U.S.P. 2,241,439, 13.5.41. Appl. 4.5.39. Device for placing gravel in holes.

C. H. Barnes. U.S.P. 2,241,532, 13.5.41. Appl. 22.1.40. Bridging plug-slip means.

L. Spencer. U.S.P. 2,241,561, 13.5.41. Appl. 12.2.40. Bridging plug.

R. E. Millican. U.S.P. 2,241,643, 13.5.41. Appl. 1.4.39. Flow device for gas-lift operations.

C. S. Crickmer. U.S.P. 2,241,656, 13.5.41. Appl. 21.12.36. Means for flowing wells.

E. D. Bennett. U.S.P. 2,242,166, 13.5.41. Appl. 17.10.40. Apparatus for operating oil-wells having two producing horizons.

B. S. Lightfoot. U.S.P. 2,242,252, 20.5.41. Appl. 24.8.39. Pumping unit and power machine for deep wells.

O. Staerker. U.S.P. 2,242,551, 20.5.41. Appl. 17.1.38. Pumping apparatus with two working barrels.

G. D. Johnson. U.S.P. 2,243,099, 27.5.41. Appl. 16.8.38. Tool useful in recovering well-tubing, well-casing, etc.

E. W. Patterson. U.S.P. 2,243,117, 27.5.41. Appl. 19.11.35 and 6.1.39. Counterbalanced pumping unit.

E. E. Stevenson. U.S.P. 2,243,174, 27.5.41. Appl. 10.5.38. Method of and apparatus for heating and quenching sucker-rods.

C. S. Crickmer and H. C. Glitsch. U.S.P. 2,243,308, 27.5.41. Appl. 8.11.37. Flow-valve adapted to be connected into the side of a tubing-string.

M. De Groote and C. M. Blair, Jr. U.S.P. 2,243,329, 27.5.41. Appl. 27.6.40. Process for breaking petroleum emulsions.

M. De Groote and B. Keiser. U.S.P. 2,243,330, 27.5.41. Appl. 27.6.40. Process for breaking petroleum emulsions.

H. V. Flemming and W. R. Barney. U.S.P. 2,243,598, 27.5.41. Appl. 14.10.38. Well-head fitting.

E. V. Foran. U.S.P. 2,244,684, 10.6.41. Appl. 5.7.39. Means for and method of flowing oil- and gas-wells in condensate fields.

R. Livergood. U.S.P. 2,244,714, 10.6.41. Appl. 5.12.38. Releasable sucker-rod connection.

G. W. Taylor, Sr. U.S.P. 2,244,812, 10.6.41. Appl. 4.10.39. Well-pump operating apparatus.

J. D. Dixon. U.S.P. 2,245,002, 10.6.41. Appl. 16.11.39. Means for controlling the flow of fluids in a well.

J. D. Dixon. U.S.P. 2,245,003, 10.6.41. Appl. 3.2.40. Means for lifting fluids from wells.

J. D. Dixon. U.S.P. 2,245,004, 10.6.41. Appl. 4.3.40. Well-fluid controlling device.

J. D. Dixon. U.S.P. 2,245,005, 10.6.41. Appl. 24.5.40. Means for controlling the flow of fluids under pressure.

J. D. Dixon. U.S.P. 2,245,006, 10.6.41. Appl. 9.11.40. System and apparatus for flowing wells.

J. D. Dixon. U.S.P. 2,245,007, 10.6.41. Appl. 14.12.40. Stuffing-box of duplex type.

J. D. Dixon. U.S.P. 2,245,008, 10.6.41. Appl. 30.12.40. Well-fluid flow controlling device.

J. D. Dixon. U.S.P. 2,245,009, 10.6.41. Appl. 6.2.41. Flow-valve.

J. D. Dixon. U.S.P. 2,245,010, 10.6.41. Appl. 10.5.41. System and apparatus for flowing wells.

C. A. Orleans. U.S.P. 2,245,114, 10.6.41. Appl. 6.1.40. Deep-well turbine pump.

J. M. Shimer. U.S.P. 2,245,117, 10.6.41. Appl. 21.4.39. Counterbalancing equipment for deep-well pumping apparatus.

W. E. Gilbert. U.S.P. 2,245,269, 10.6.41. Appl. 4.3.39. Sucker-rod fatigue-testing machine.

W. C. Richardson. U.S.P. 2,245,501, 10.6.41. Appl. 25.9.37. Reciprocating pump for deep-well pumping.
A. H. N.

Transport and Storage.

904. Corrosion of Fuel-Tanks. Anon. *Aircr. Engng*, 1941, **XIII**, 173–174.—Recent investigations into the prevention of corrosion of aluminium and magnesium alloy fuel-tanks for aircraft have shown that not only are the composition and treatment of the metal used of importance, but also that the design of the tank is a factor to be taken into consideration.

The nature of chemical and heavy metal compounds accidentally introduced into the tank, either directly or through the medium of the fuel itself, largely determines, when water is also present, the extent and rate of tank corrosion. Cases of severe corrosion have also been attributed to the use of dissimilar metals in contact with the aluminium alloys used in tank construction.

Numerous methods of preventing tank corrosion are recommended. These include provision for thorough draining, the application of various chemical, anodic, or paint anti-corrosive coatings, and the use of inhibitive capsules which are placed in low spots of the tank where water is likely to collect.

It need scarcely be emphasized that all possible care should be taken to prevent the ingress to fuel tanks of contaminating bodies from any of the many likely sources.
E. F. C.

905.* Method of Designing Cathodic Protection Installations. W. F. Rogers, *Petrol. Engr*, Jan. 1941, 42.—In considering cathodic protection systems two classes of pipe must be recognized : (*a*) well-coated pipe, (*b*) poorly coated or bare pipe.

In the case of (*a*) it is generally accepted that a potential of 0·8 v. will afford protection. This is normally a voltage increase of 0·25 v. in excess of the unprotected potential. Few corrosive soils have a resistance of more than 2000 ohm-cm., and it is calculated that a potential of 0·25 v. will result in a current flow of 0·008 amp./sq.ft. It has been shown that this current flow will give 82·5% protection, and this is the minimum that will be obtained if an impressed voltage of 0·25 v. is maintained on the coated pipe.

The paper shows how it is possible to determine the current source spacing to give protection to the pipe.

In the case of (*b*) design calculations are equally possible. Here current-density values, rather than pipe-soil potentials, are the criterion. The data show that 0·004 amp./sq. ft. will give 75% protection to bare pipe in corrosive soils.

The ground bed exercises a very important place in cathodic-protection schemes, and in general must fill two functions satisfactorily : (1) to dissipate the current properly, without too frequent replacement of the ground-bed material, (2) to have a low electrical resistance.

Junk-steel pipe is the most common form of ground-bed material. The resistance of the bed must be kept as low as possible in order to reduce current costs, and this involves the determining of the best arrangement for the junk-pipe. It is shown that there is an optimum depth for burying the pipe, but varying the spacing is without great effect.

It is necessary that the soil resistivity be less than 1000 ohm-cm. in order that a maximum resistance of the ground-bed of 0·1 ohm can be obtained. If the soil resistance is greater than this it is essential to salt the ground-bed. This is carried out with calcium chloride, which is both highly ionized and very hygroscopic.
D. L. S.

906.* Prevention of Corrosion of Steel Pipe-Lines by Oil-Well Brines. W. Stericker. *Oil Gas J.*, 27.2.41, **39** (42), 72.—Laboratory experiments had shown the efficiency of sodium silicate as an inhibitor in the corrosion of steel pipes carrying oil-well brines. The preventive action is due to the formation of a protective coating on the inside of the pipes, but the concentration needed in laboratory tests was too high to be economical. However, in actual practice the author has used a much lower concentration—40 parts per million of soluble silica—with success. Over a period of 2½ years the number of leaks in such a pipe system have been reduced by 50% and the cost of laying an entirely new pipe system, as was originally intended, has been avoided. Further work is continuing on this method of treatment. H. C.

907.* Develop Interior Coatings for Aviation Fuel-Drums. M. G. Van Voorhis. *Nat. Petrol. News*, 30.4.41, **33** (18), R.130.—The increased use of steel drums for the transportation and storage of aviation gasoline has stimulated the development of anti-corrosion linings for the drums. Galvanizing is not a satisfactory solution to the problem, owing to the formation of loose zinc oxide. Lead coating is said to be more satisfactory. Zinc coatings have been improved by the use, after galvanizing, of solutions of chemicals which produce, on the zinc, coatings somewhat similar to those of anodized aluminium. Varnishes and lacquers are being improved to eliminate the present shortcomings of the materials of those classes now in use. A promising development consists of the addition to the gasoline of lecithin, a soya-bean derivative. H. G.

Gas.

908. First Commercial Liquefaction Plant in Full-Scale Operation. P. A. Condit and W. F. Burgess, *Oil Gas J.*, 1941, **39** (45), 46–48.—A description of the first plant for liquefaction and storage of natural gas for distribution to industrial and domestic users, recently erected for the E. Ohio Gas Co.

Three 57-ft.-diameter Hortonspheres are used, holding 150 million cu. ft. of liquefied gas under a pressure of 25 lb. per sq. in.

The stages of the process are as follows: natural gas—two-stage compression to 615 lb.; removal of moisture and liquid CO_2; chilled (by NH_3) to − 126° F.; removal of liquid N_2; chilled (by ethylene) to − 139° F. (now mostly liquid); pressure released to about 60 lb. at − 218° F., recycle gas removed and liquid reduced to 25 lb. at about − 248° F., then transferred to Hortonspheres. Gas accumulation in the spheres is continuously removed and returned to a flash-gas compressor for re-treatment.

Details of the specialized compressor equipment and of the highly important balancing operations are given. A complete flow-sheet and photographs of the plant are also shown. C. G. G.

909. Natural Gasoline Yields Numerous By-Products. F. H. Dotterweich. *Oil Gas J.*, 24.4.41, **39** (50), 39.—Natural gas consists of the hydrocarbons CH_4–C_7H_{16} and the non-hydrocarbons CO_2, He, N, and H_2S; it is divided into three fractions: dry gas (CH_4–C_3H_8); liquefied (bottle) gas (C_3H_8–C_4H_{10}), and natural gasoline. Except for CO_2, the non-hydrocarbon content is low; H_2S may be removed, as it is corrosive, and marketed for agricultural use.

For the production of raw materials for syntheses, the natural-gas paraffins are rendered reactive by four methods: decomposition, oxidation, halogenation, and nitration. By the first method olefins and hydrogen are obtained for use in the production of plastics, synthetic rubber, motor fuel, explosives, dyestuffs, and for use in hydrogenation. By the second, alcohols, aldehydes, ketones, and ethers are obtained—the raw materials of many modern products. The third method yields parent products of T.E.L., vinyl chloride, and acetate for plastics and sodium polysulphides for the manufacture of thykol. Nitration is the process most recently introduced, and yields nitro-compounds used as organic reagents and in the manufacture of explosives.

Dehydrogenation and polymerization of natural gas leads to the production of high anti-knock fuels such as *neo*hexane, which has O.N. 94 and a high lead susceptibility, making possible the production of 115 O.N. fuels. T. T. D.

910. Annealing Atmospheres from the Combustion Products of Gaseous Fuels. A. G. Hotchkiss. *Industr. Engng Chem.*, 1941, **33**, 32.—The use and cost of natural gas, butane, and propane are compared with that of coke-oven gas and dissociated ammonia for the production of inert annealing atmospheres. The composition of the atmospheres produced from the combustion of these gases at various air–fuel ratios is given. The design of apparatus for the control of combustion is discussed and methods of purification for the removal of H_2O, H_2S, SO_2, and CO_2 are reviewed.
J. W. H.

911. Protective Atmospheres for Hardening Steel. J. R. Gier. *Industr. Engng Chem.*, 1941, **33**, 38.—The composition of a protective atmosphere for hardening steel is the following function of the carbon contents of the steel $(c) = k_2\frac{(CO)^2}{(CO_2)}$, where k is the equilibrium constant in the reaction $2CO = CO_2 + C$. The production of this type of controlled atmosphere is effected by the endothermic combustion of air and hydrocarbon fuel in an electrically heated catalyst furnace. In this process the hydrocarbons are almost completely decomposed into carbon and hydrogen (an endothermic reaction) and the carbon combines with oxygen to form CO (an exothermic reaction). There is an energy deficiency between these two reactions which is supplied by the electric heater.
J. W. H.

912. City Gas for Special Atmospheres. C. R. Cline and C. G. Segeler. *Industr. Engng Chem.*, 1941, **33**, 46.—A composition of gases suitable for metal annealing without scaling or decarburizing, bright hardening, clean heat treatments, carburizing, fire protection, and purging of combustible gases from storage vessels, is presented. The types of equipment required to produce and purify these special atmospheres are discussed. Original data are presented showing the variation in flue-gas composition with combustion air, fuel-gas composition, and combustion wall and flue-gas temperatures. From these data the composition of flue products resulting from the burning of a fuel gas of known analysis with a predetermined air–gas ratio can be accurately estimated.
J. W. H.

913. Gas Carburizing by the Hypercarb Process. W. A. Darrah. *Industr. Engng Chem.*, 1941, **33**, 54.—The hypercarb process supplies a controlled high-carbon case on steel articles by heating in a controlled atmosphere of hydrocarbons and carbon monoxides at 1700° F. The carburizing gas initially contains 70–80% methane and is produced by cracking of natural gas. The gas is recirculated and is stated to become activated during this process. No analyses of the circulating gas are given. Steel articles treated by this process are free from carbon scale and no cleaning is necessary.
J. W. H.

Cracking.

914.* Kinetics and Chemistry of Cracking of Hydrocarbons. Dr. R. Rosen. *Oil Gas J.*, Part 1, 13.2.41, **39** (40), 49–50; Part 2, 20.2.41, **39** (41), 45–46.—Two papers in which the author presents a digest of a series of articles by M. D. Tilicheev of the U.S.S.R. and others dealing with the subject of the kinetics and chemistry of cracking of hydrocarbons. An attempt is made to unify the available data for the various hydrocarbon classes and to present it in tabular form. Most of the studies discussed involve the use of a static method in an iron apparatus, and the sum total of the reactions involved in cracking is dealt with, and not the separate simultaneously occurring reactions of decomposition, polymerization, isomerization, etc. The tables of data consist mainly of cracking-velocity constants at various temperatures for paraffins, olefins, di-olefins, aromatics, naphthenes, and cyclic unsaturated compounds. Conclusions are reached as to the order of the cracking reactions and the variations in cracking-velocity constant with varying molecular weight, whilst additional data included are comparative thermal stabilities of paraffins and olefins and the effect of pressure on polymerization velocity constants. Finally there is a discussion on the relative coking tendencies of the various classes of hydrocarbons, and a comparison is made of the kinetics of " carboid " formation, carboids being defined as substance insoluble in hot benzene. A general outline is given of the chemistry of carboid formation.

The available data, foreign and American, are amplified by interpolation, whilst tentative assumptions and various corrections have been made. Accordingly the data must be regarded as correct only in the first approximation, and are subject to revision as new experimental material is accumulated. J. C.

915.* Control Point Computed for Cracking Furnaces. R. E. Summers. *Nat. Petrol. News*, 30.4.41, **33** (18), R.143.—In controlling the temperature of oil issuing from an oil-heater it is often desirable to locate the control point some distance ahead of the outlet. Temperatures may change by a greater amount or earlier than at the outlet, but if held within narrow limits the control can be made to give uniformity at the outlet. A mathematical method for computing the point in a cracking furnace where average conditions obtain is presented. H. G.

916. Patents on Cracking. A. C. Jessup. E.P. 536,891, 30.5.41. Appl. 30.11.39. A catalyst for the single-stage or closed-vessel process for cracking heavy oils in the liquid phase. It consists of metallic iron and copper. The process may be carried out in a copper vessel, finely divided iron being added. An atmosphere of hydrogen at 10–20 atmos. is maintained in the reaction chamber. About 70% of the sulphur present is obtained as metallic sulphide. The catalyst enables the cracking to be performed at a comparatively low temperature.

P. Mather. U.S.P. 2,242,255, 20.5.41. Appl. 20.10.38. Cracking of hydrocarbons. The oil is heated to cracking temperature under raised pressure. The product is flash-distilled. The vapours are separated, fractionated, and condensed, and the residual oil is subjected to a second flash-distillation, without further cracking. The vapours evolved are condensed and supplied to the cracking step. The residue from the second flash-distillation is mixed with small amounts of a light distillate and heated to a point where the light distillate is vaporized and mild cracking of the residue occurs. These products are removed from the heated zone before deleterious secondary cracking reactions occur, and are passed to a low-pressure distillation zone, where they are reduced to a semi-solid residue. The vapours evolved are condensed.

C. L. Thomas and H. S. Bloch. U.S.P. 2,242,553, 20.5.41. Appl. 30.11.38. Cracking of hydrocarbons. The oil is contacted at cracking temperature with a calcined precipitated silica containing precipitated alumina and thoria.

J. D. Seguy. U.S.P. 2,243,291, 27.5.41. Appl. 31.8.39. The process comprises introducing cracked vapours, and charging oil for the process to a separating and fractionating zone. A product of end-boiling point 600–650° F. is separated, and is further fractionated, giving a light gasoline of high anti-knock value, a heavy gasoline of low anti-knock value, and a heavier reflux condensate. The latter is subjected to a mild vapour-phase cracking (10% decomposition per pass through cracking zone). The resultant products are reintroduced into the separating and fractionating zone. The heavy residue from the fractionating is subjected to a mixed-phase cracking. The vaporous products are introduced into the separating and fractionating zone. The heavy gasoline fraction is cracked under conditions giving the greatest anti-knock value in the product, which is passed to the second fractionating column.

B. L. Kramer. U.S.P. 2,243,315, 27.5.41. Appl. 30.12.37. The oil is cracked under pressure, the resultant products are separated under pressure, and the vaporous phase is fractionated, giving a light distillate and normally gaseous hydrocarbons. The unvaporized oil from the first separation is flash-distilled by pressure reduction, and the vapours are fractionated to give a highly olefinic distillate, containing much gasoline-range oil. The gaseous hydrocarbons formed in the first cracking are scrubbed with an absorber oil consisting essentially of the highly olefinic distillate from the second cracking, to absorb gaseous olefines. H. B. M.

Hydrogenation.

917.* Hydrogenation of Coal—Insurance for the Oil and Automotive Industries. W. L. Nelson. *Oil Gas J.*, 8.5.41, **39** (52), 55.—A general article on the status of the coal-hydrogenation process in the U.S.A. It is suggested that it may become expedient to utilize a combination raw stock of coal and oil in order to stabilize the petroleum industry as a whole and to conserve reserves in face of the growing demands of the motor-transport and aircraft industries. The economics of hydrogenation is discussed in relation to known costs of operation in Great Britain and in Germany. The ease of eliminating S, N, and O from the products is emphasized and also the fact that present commercial practice is a compromise between excessive hydrogenation giving low-octane material and excessive decomposition giving high-octane material but large amounts of coke. The influential factors in the process are stated to be: (1) the vehicle or solvent, (2) the use of agitation, (3) the use of a catalyst, (4) suitable temperatures and pressures; and the importance of these factors is exemplified in short accounts of a British plant of the Low-Temperature Carbonization, Ltd., and an experimental plant of the U.S. Bureau of Mines. A brief survey of the enormous American coal reserves is followed by a description of a method for correlating oil yield against types of coal by means of petrographic examination for the various constituents. The article concludes with some summarized figures of the yields of the various oil-cuts. J. C.

918. Patents on Hydrogenation. Phillips Petroleum Co. E.P. 535,813, 23.4.41. Appl. 11.8.39. Conversion of simple paraffins into saturated hydrocarbons of higher molecular weight by dehydrogenating the paraffin hydrocarbons, thereby forming free hydrocarbons and polymerizable olefins. The latter are subjected to polymerization, and a substantial portion is converted into olefinic polymers of higher molecular weight. The hydrocarbons of lower and higher molecular weight are then separated and those of higher molecular weight passed into contact with a depolymerizing catalyst. The products of depolymerization are passed to a previous separating step, and a portion of the hydrocarbons of lower molecular weight hydrogenated with hydrogen produced in the hydrogenating step. H. B. M.

P. S. Danner. U.S.P. 2,241,393, 13.5.41. Appl. 14.3.38. A heated mixture of naphthenes and olefines is passed over a catalyst in a hydrogenation–dehydrogenation zone. Naphthenes are dehydrogenated to aromatics and olefines are hydrogenated to paraffins. The vapours are quenched by direct contact with a high-boiling organic selective solvent for cyclic hydrocarbons, to stop side reactions and to separate paraffins from cyclic hydrocarbons. H. B. M.

Polymerization.

919.* Isomerization of Feed Stocks Charged to Alkylation Units. L. J. Coulthurst. *Oil Gas J.*, 23.1.41, **39** (37), 37.—The alkylation process, by which a direct combination of butylenes (C_4H_8) with *iso*butane (C_4H_{10}) produces *iso*paraffins, including *iso*-octane, is stated to be an efficient and remunerative method of obtaining high-octane blending stock, to form the main ingredient of 100-octane aviation gasoline. Most refiners have available an ample supply of butane, but not of *iso*butane, and it is now commercially practicable to convert the normal into the *iso*-compound. This conclusion is based on the work of Moldavskii and Nizovkina, *Nat. Petrol. News*, Vol. 32, pp. R.422–428, 27th Nov., 1940. The isomerization process described is available generally for the conversion of straight-chain paraffins into branch-chained *iso*paraffins, but only laboratory results are quoted. In liquid-phase operation a maximum of 74% of *n*-butane may be converted into *iso*butane by isomerization at 158° F. using a mixed catalyst, $CuSO_4.2HCl + AlCl_3$. In vapour-phase operation at a temperature range 158–356° F., $AlCl_3$ alone and gaseous HCl was used as catalyst and a maximum of 67·3% conversion was obtained. J. C.

920. Patents on Polymerization and Alkylation. Standard Oil Development Co. E.P. 536,813, 28.5.41. Appl. 23.10.39. Production of gasolines by a combination of the processes of polymerization and alkylation, from gaseous or lower-boiling olefins and *iso*paraffins. A mixture containing olefins and *iso*paraffins is fed into an activator, where polymerization of the olefins occurs. The resulting hydrocarbon product, preferably fortified by addition of *iso*paraffins, is fed into the same activator at higher concentration, to cause reaction between the *iso*paraffins and the olefins and polymers. Spent activating agent from the alkylation system is fed into the polymerization system, whilst spent activator from the latter is withdrawn for regeneration. Higher-boiling hydrocarbons, predominantly saturated, are recovered from the alkylation process. The product so obtained appears to possess a higher octane number than is obtainable by reaction between *iso*paraffins and unpolymerized olefins. Careful control of polymerization is unnecessary, as the higher polymers are as suitable as the dimer as feed-stock for the alkylation unit.

G. Roberts, Jr., and G. W. Robinson. U.S.P. 2,241,716, 13.5.41. Appl. 15.6.37. The preparation of liquid hydrocarbons from gaseous by treating the latter at high temperature and pressure. The improvement comprises passing the gaseous products of conversion through a liquid absorbent under pressure, so that convertible constituents are recovered by solution. The scrubbing solvent is indirectly cooled by a fluid from an extraneous source. The scrubbed gases are extracted, and their expansion is utilized in pumping the cooling fluid.

G. Roberts, Jr., and G. W. Robinson. U.S.P. 2,241,717, 13.5.41. Appl. 15.6.37. A stream of gaseous hydrocarbons is heated under pressure, thereby forming liquid hydrocarbons. The stream is separated under pressure into a liquid fraction containing the relatively high-boiling normally gaseous hydrocarbons, and a gaseous fraction predominating in the lower-boiling gaseous constituents. The gaseous fraction is passed to a separatory zone, where a fraction predominating in hydrogen and methane is removed. The liquefied, normally gaseous hydrocarbons are withdrawn from the separatory zone, and all or part of them are added to the stream undergoing conversion. The liquid fraction from the conversion is freed of normally gaseous hydrocarbons under reduced pressure. The gaseous fraction predominating in hydrogen and methane from the separatory zone is passed at pressure through a scrubbing zone containing a liquid absorbent medium, which dissolves convertible constituents of the gas. The enriched solvent is freed of the convertible hydrocarbons, which are introduced into the separatory zone. A stream of normally gaseous hydrocarbons is introduced into the system from an extraneous source. The scrubbed gases are expanded, the expansion being utilized to compress the stream of gaseous hydrocarbons entering the system. The compressed stream is cooled, and the liquid fraction so obtained is added to the separatory zone to assist in the separation therein.

M. M. Holm. U.S.P. 2,245,038, 27.5.41. Appl. 14.10.40. A process for the alkylation of *iso*paraffins with olefins, using an acid alkylation catalyst. Two zones of reaction in series are used. The concentration of *iso*paraffin is kept at at least 50% by liquid volume in the first zone, where a high degree of dispersion of the catalyst is maintained. In the second zone the mixture is subject to a force tending to separate catalyst and hydrocarbons, so that part of the reaction mixture becomes richer in catalyst, part poorer. A portion of the part rich in catalyst is recycled to the first reacting zone, and a part poor in catalyst passes to a separating zone, where the acid catalyst is removed. H. B. M.

Synthetic Products.

921.* Cold Resistance of Synthetic Rubber. W. J. McCortney and J. V. Hendrick. *Industr. Engng Chem.*, 1941, **33** (5), 579.—An accurate method for determining the deformation resistance of synthetic rubbers at − 40° C. has been developed. The results show that small variations in compounding greatly affect the stiffening characteristics at low temperatures. J. W. H.

922.* Raw Material Plentiful for Synthetic Rubber. I. E. Lightbown and J. E. Britton, Jr. *Oil Gas J.*, 17.4.41, **39** (49), 174.—The first synthetic rubber was made from *iso*prene, which was originally obtained from turpentine. Later (1900) different and more readily obtainable olefins were studied, and thus Buna—butadiene polymerized in presence of sodium—was developed. At about this time it was realized that the goal to be reached was the production of a synthetic material substantially better in some respects than the natural rubber.

In 1926 Duprene or neoprene was produced from chloroprene, whilst in Germany " Buna S," made from butadiene and styrene, and " Perbunan," made from butadiene and acrylonitrile, were developed. These polymers were found to be little affected by oils, and their production on a commercial scale fundamentally affected the construction of rubber hoses used for conveying materials of petroleum origin.

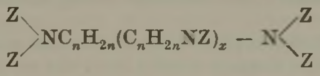
Besides its lack of oil resistance, natural rubber is also prone to deterioration by oxidation, due to the number of double bonds it contains. These double bonds are by no means all satisfied by the process of vulcanization.

The next step in the production of a suitable synthetic was therefore the development of a more saturated rubber, and the material known as " butyl rubber," which had only about one-hundredth the unsaturation of the natural product, was evolved. This used simple olefins as the starting material, only enough diolefines being included to give sufficient unsaturation to the finished rubber for the necessary vulcanization.

At present about 97% of the U.S.A. requirements of rubber are imported from the Far East. If this supply were interrupted, a tremendous expansion of the synthetic industry would be necessary. Fortunately all the basic materials involved are potential petroleum derivatives. Since on a weight basis the U.S.A. annual import of crude rubber is only about one-third of 1% of the crude oil produced, there would appear to be no need for concern over the question of raw material supply for the synthetic rubber industry. D. L. S.

923. Patents on Synthetic Products. A. C. Jessup. E.P. 536,734, 26.5.41. Appl. 30.11.39. Production of *iso*butylene by heating to 300–500° F. either or both straight-chain chlorides of butane in the presence of aluminium chloride. The butylene chloride is formed from butylene and HCl.

M. De Groote and C. M. Blair, Jr. U.S.P. 2,243,329, 27.5.41. Appl. 27.6.40. A process for breaking petroleum emulsions. The demulsifier is for breaking the water-in-oil type of emulsion. It consists of a basic type acylated polyamine of the following formula :—



$$\genfrac{}{}{0pt}{}{Z}{Z}\!>\!NC_nH_{2n}(C_nH_{2n}NZ)_x - N\!<\!\genfrac{}{}{0pt}{}{Z}{Z}$$

n = number from 2 to 10, x = number from 1 to 10, Z is either H, RCO, R′CO, or D, in which RCO represents an acyl radical derived from a higher-weight carboxy-acid; R′CO is an acyl radical derived from a carboxy-acid having 6 carbon atoms or less; D is alkyl, hydroxyalkyl, aminoalkyl, or acyloxyalkylene, in which instance the acyl group is a member of the class consisting of RCO and R′CO. The polyamine is further characterized by the fact that there must be present a member of the class consisting of (*a*) acyloxyalkylene radical, in which the acyl group is RCO, and (*b*) joint occurrence of an amido radical in which the acyl group is RCO and a hydroxyalkyl radical.

M. De Groote and B. Keiser. U.S.P. 2,243,330, 27.5.41. Appl. 27.5.40. Process for breaking petroleum emulsions of the water-in-oil type. The demulsifier consists of a water-soluble polyglycol ether derived by reacting an alkylene oxide with an alkylated monocyclic monohydric, water-insoluble phenol characterized by the fact that the nuclear carbon-atom-alkyl linkage involves a tertiary carbon atom of the alkyl group, and by the fact that the longest alkyl radical carbon atom chain, beginning with the tertiary atom as unity, contains 3 to 5 carbon atoms. H. B. M.

Refining and Refinery Plant.

924.* Stress-Relieving Welded Pressure Vessels in the Field. E. S. Robb. *Refiner*, July 1941, **20** (7), 251–257.—Stress-relieving of existing welded vessels may be necessary, or at least desirable, because of, first, previous operating conditions which set up internal strains in the metal due to sudden temperature changes; second, extensive repairs to welded seams or nozzle connections; third, additional heavy welding occasioned by the addition of new nozzles, manways, or reinforcing pads, and fourth, possible salvaging by major repairs or revisions that can be done in the field.

The necessity or desirability for stress-relieving is a question best answered by the local and manufacturers' engineers. The fact that in many cases stress-relieving may be done without the vessels being moved from their foundations may be the deciding factor, and is therefore of practical and enonomical importance. Not only is there a large saving of direct costs with this method, but several weeks of operating time may be saved, and this is often the most important consideration.

The stress-relieving temperature generally used for low-carbon steel is between 1100° F. and 1200° F. The soaking time required at this temperature is 1 hr./in. of wall thickness as a minimum. Since extra soaking time may be desirable, a more conservative rule is to add the thickness of the heaviest reinforcing plate to the wall thickness and allow 1 hr./in. of total thickness.

The rate of heating above 600° F. should not exceed 400° F./hr. divided by the maximum metal thickness of the shell or head-plate, and it is desirable not to exceed these rates at temperatures below 600° F. The rate of cooling above 600° F. should not exceed 500° F./hr. divided by the maximum metal thickness of the vessel in in. The temperature gradient in the metal of the chamber should not exceed 250° F. within any 15 ft. of lineal distance during the heating period, and the whole vessel should be within 150° F. during the soaking period.

It has been found practical and much more economical to do the work in the field, rather than to dismantle the unit and send the vessel back to the manufacturer. An outline of the equipment and methods used, together with the results obtained, is discussed in this article. A. H. N.

925.* High-Chromium Alloys in the Refinery. W. L. Archer. *Refiner*, July 1941, **20** (7), 262.—Elementary metallurgical terms of steels and their alloys are explained, and the characteristics imparted to steels by incorporating chromium in varying percentages are studied in some detail. Tables and graphs are reproduced for illustrative purposes. Stainless steels—those containing chromium in excess of 11%—are studied, in particular with regard to their strengths, resistance to creep, etc., and corrosion.

Corrosion in the refinery takes place in both the hot and cold phases of operation. In the hot phase most of the damage results from the ravages of sulphur and sulphur compounds, of which there is an almost endless variety. The cold phase brings about corrosion from some sulphur compounds, although the acids are predominantly troublesome here. Among the more common acids encountered are hydrochloric, phosphoric, sulphuric, and sulphurous. In addition, organic acids may be present.

Stainless steels have been applied to many parts of the modern refinery. Among the varied uses for these alloys are bubble-caps, bubble-trays, shell linings, pumps, valves, and vapour lines. Included in the minor applications are gaskets, floats, and thermocouple protection tubes.

Both bubble-caps and bubble-trays present almost identical reasons that promote their acceptance notwithstanding a higher first cost than either cast iron or mild steel. The many operating advantages serve to make the long-term cost less than that of the unalloyed materials formerly tried. Of course the substitution of a tough, ductile material for cast iron eliminates troublesome breakage. Caps need not be replaced because of missing teeth, whilst damaged trays do not occasion costly delays.

Possibly one of the more outstanding features of the chromium alloys is their freedom from coking. The old familiar chipping away of accumulated coke during down-time is banished. In addition, this absence of coking allows longer runs and more efficient operation throughout the run, as trays and caps remain clear. The ease with which these materials may be fabricated leads to a wider variation of design, promoting further operating economies. At the same time the lighter weights of removable trays and caps leads to savings in insurance rates, as the number of accidents to workmen are reduced. Other uses and benefits are discussed.

A. H. N.

926.* On Stream Time Increased by Insulating Headers and Return Bends. B. G. Adams. *Refiner*, July 1941, **20** (7), 269.—By insulating headers and return bends of the cracking-still furnace, on-stream time for the cracking units was increased 25%. A description of the steps taken and an illustration of the method are given.

The insulating material used was of the plastic type. Its cost is negligible, and application and removal are simple. The wet plastic is packed, about 2 in. thick, around each header. The installation is equipped with a hinged-door header-box.

A. H. N.

927.* Tests on Defence Gasoline Containers. M. H. Heeren. *Refiner*, July 1941, **20** (7), 279–280.—The shipment of large quantities of gasoline overseas in face of war dangers is discussed. Handling in drums seems generally indicated. The usual heavy returnable container cannot be economical if it is not re-used, and return shipment of vast numbers of empties can only further tax an already busy transportation system. Furthermore, the substitution of the lighter pressed-steel non-returnable drum should impose less burden in the form of immediate steel demand, and at the same time permit the manufacture of greater total container capacity within a given time.

A container designed with these considerations in mind is described and tests data are given. The closure consists of a threaded flange pressed into a stamped opening in the end or side of the sheet-steel drum. The seal between the two metal surfaces is effected by a natural or synthetic rubber gasket. A threaded plug, also fitted with a gasket, is screwed into the threaded flange to complete the closure. As a further safeguard, a tamper-proof metal seal equipped with a cork ring is formed into place over the entire closure in a single operation by means of a special crimping tool.

The actual testing procedure resolved itself into establishing on a laboratory scale the conditions under which the closures would be used in practice. These conditions included submergence in salt water to a depth of 300 ft. and exposure to exceptionally severe weather conditions.

The general conclusions which can be reached from the results of the above tests are: (1) the closure of the type tested will effectively withstand sea-water pressure of 140 lb./sq. in without leakage or visible corrosion within the test period. (2) No evaporation losses and contamination by water are incurred if gasoline is stored in 18-gauge steel drums equipped with closures of above type, during storage under climatic conditions similar to those artificially produced during the 4-day test period.

A. H. N.

928.* Appraisal of Steels for High-Temperature Refinery Service. Claude L. Clark. *Oil Gas J.*, 27.2.41, **39** (42), 81.—Applications of steel to high-temperature service can be divided into three groups on the basis of the following conditions: (1) permissible deformation during service, (2) constant *versus* varying temperature, and (3) relative importance of strength and surface stability. In order to ascertain the information necessary to ensure a given steel rendering satisfactory service, laboratory tests, of which the author gives a comprehensive list, have been developed to study the physical properties under the combined influence of time, temperature, and stress.

Load-bearing ability, structural stability, and surface stability are the most important characteristics of steel and alloys to be studied, and the author describes in detail the laboratory tests now available, discusses the merits of these tests, and, by the ample use of graphs and photographs, gives interpretation of the results obtained.

H. C.

929.* Metals in Refining (Corrosion Resistance and Strength of Pipe-Still Tubes). W. L. Nelson. *Oil Gas J.*, 17.4.41, **39** (49), 179.—The resistance to sulphur corrosion that various alloys or steels may exhibit cannot be evaluated as directly as most other properties, due to a large extent to (*a*) the varying sulphur content of crude oils, (*b*) the different kinds of sulphur compounds present, and (*c*) to a less extent to differences in the manner of processing. Some effort, however, has been made to correlate sulphur-corrosion data, and it is shown that the inclusion of chromium in steels appears to be the best way for providing immunity to this kind of attack. Silicon and aluminium in small amounts also have a pronounced effect. Calorizing will impart corrosion resistance to a steel surface, but the effect is lasting only for 12–18 months.

Molybdenum, nickel, or manganese in normal amounts have little effect on this type of corrosion, although 3% or more of molybdenum may be of assistance.

The strength of seamless steel tubes in pipe-still service is complicated by a low creep or deformation, which takes place at elevated temperatures, and because local heating effects cause variable tube-wall temperatures. Thus localized hot spots occur and embrittlement follows.

The only element which exerts a definite effect on creep or rupture strength is molybdenum. The maximum useful amount of this metal is 0·5–1·0% for creep strength, but 1·5–2·0% for rupture strength. The effect of Cr, Si, or Al on creep strength is not clear, although in large amounts Cr (plus stabilizing Ni) causes some increase. D. L. S.

930.* Close Fractionation Needed to Recover Isomers from Gas. H. W. Harts. *Oil Gas J.*, 24.4.41, **39** (50), 41.—A description is given of a plant to separate *iso*pentane, with an input of 100,000 gal. daily. Raw product is fed to the grade-gasoline fractionating column at 150 lb. pressure, where butanes and lighter are separated from pentanes and heavier. The 30,500 gal. of the latter are pumped to a second column at 50 lb. pressure to separate the 5350-gal. *iso*pentane (94% pure) as overhead from the *n*-pentane and heavier. To obtain the 99% pure product, the 94% pure *iso*pentane is pumped at 100 lb. pressure to a third tower, where the unwanted butane is removed as overhead and returned to the feed of the grade column.

The conditions and delicacy of control necessary for economic separation of *iso*butane are discussed, with reference to the fact that a *n*-butane fraction boiling 3° F. low contains 10% *iso*butane, and to the tendency of the system to become unstable and work in cycles—during a considerable proportion of which the products will be off-grade—unless the reflux ratio, pressure, and temperatures are very carefully controlled.

A plant for the manufacture of pure propane, *iso*-, and *n*-butane is also described. In this, absorption gasoline is pumped into a column, termed the de-ethanizer (actually up to 50% of the overheads may be propane). The base product of propane and heavier, after sulphur removal, is pumped to the second column, the specified gasoline taken off at the base, and the overhead *iso*- and *n*-butane and propane condensed in the reflux accumulator. Excess reflux is pumped to the de-propanizer, from which excess reflux propane is pumped through dehydrators to storage. The butanes taken off at the base are pumped to the *iso*butane column, whence excess reflux *iso*butane is pumped to storage, whilst normal butane is withdrawn from the base of the tower.

In both cases the description of the plant is accompanied by tables of throughput and composition, together with dimensions of the columns and other working conditions. T. T. D.

931.* Metals in Refining. (Steel Casting and Furnace Auxiliaries.) W. L. Nelson. *Oil Gas J.*, 1.5.41, **39** (51), 39.—The necessary properties of metals used in the various parts of pipe-stills, other than tube materials, are discussed, and tables of chemical and physical properties of suitable alloy steels are presented from which construction materials may be chosen. The tables include properties of bolting steels; casting steels for bodies, housings, and plugs of return bends; materials for tube supports in the radiant sections of stills; and materials for convection-section support of stills. Some more general remarks on corrosion and on scaling by the different types of furnace atmosphere are included. J. C.

932.* Novel Use of Shell Still Raises Kerosine Yield. Victor I. Downey and William H. Humphreys. *Oil Gas J.*, 1941, **40** (1), 52.—To meet an emergency demand for greatly increased quantities of kerosine, a refinery was called upon to process 2000 brl. of crude oil per day in excess of its pipe-still capacity. Shell stills were available, but were not provided with the necessary fractionating equipment.

The additional crude was handled in the Shell stills, and the gasoline, kerosine, and a small fraction of the gas-oil were run to storage as one cut. This cut was then used as intermediate reflux in the pipe-still fractionating column, the top reflux being correspondingly reduced.

The increased output from the column was obtained without technical difficulty or deterioration in fractionation of the products. C. G. G.

933.* Cathodic Protection of Open Tank Condensers. N. A. Miller. *Oil Gas J.*, 22.5.41, **40** (2), 66–68, 75.—Although the merits of cathodic protection against corrosion are well established for certain types of equipment, no published data were found relating to the use of the cathodic system for open-tank condensers. The author has therefore collected information on the results obtained at three large refineries where the system is in operation. In all cases markedly beneficial results were reported.

In addition to protecting the condenser tubes against corrosion, the use of the system affects the form of the material deposited on the tubes from the cooling water. The deposit on cathodic tubes is soft, and may easily be hosed away when the tank is emptied for cleaning, whereas without protection the tubes become covered with a hard scale. This difference in scale formation also appears to result in superior heat exchange with the protected tubes.

For this type of work the anodes usually consist of steel plates submerged vertically in the condenser tanks, although carbon anodes may also be used. The distribution of the anodes to give uniform current over the entire cathode area is of primary importance.

The source of current may be either a d.c. generator or a rectifier of the copper-oxide, selenium, or tube type, rectifiers being preferred for refinery applications. Current requirements are approximately 5–10 amp./1000 sq. ft. of cathode. Anode consumption is about 20 lb./amp./year.

The true criterion for protection appears to be the existence of a definite minimum potential of cathode with respect to electrolyte at all points. The checking of this potential is carried out using submerged test electrodes, or exploratory electrodes of the insulated-button type in conjunction with a (non-polarizing) calomel cell and null-point potentiometer, the apparatus and its application being described.

The article is illustrated with photographs. C. G. G.

934.* Economics of Flue-Gas Recirculation and Economizers in Fired Tubular Heaters for Oil Refineries. C. C. Nelson. *Oil Gas J.*, 22.5.41, **40** (2), 71–72, 75.—Flue-gas re-circulation involves some means of returning a portion of the outgoing flue-gas to an intermediate part of the furnace, with the object of reducing the temperature in the radiant-heat section.

Tests beginning about 1926 have shown that the system as applied to a typical cracking-coil furnace is not economically sound, and it is suggested that in the case of new equipment, suitable temperature distribution can be more advantageously obtained by modification of furnace design.

The economics of air pre-heaters are discussed in detail, and it is concluded that the maintenance and repair costs outweigh the heat savings effected, although local variations in the quality and price of fuel, and in constructional and operating charges, may invalidate this general conclusion for any particular set of conditions.

C. G. G.

935.* Corrosion Prevention on Water Side of Refinery Equipment. W. H. Attwill and V. L. Nealy. *Oil Gas J.*, 22.5.41, **40** (2), 81–86, 99.—The subject is dealt with under the headings: (*a*) Chemical Treatment of Water; (*b*) Use of Deaerator; (*c*) Cathodic Protection. The experiences gained by the Texas Co. at their Port Arthur and Houston refineries are reviewed under each heading.

For cooling towers, in which corrosion was initially very serious, the most satisfactory chemical treatment was that of maintaining a concentration of 500 p.p.m. of $Na_2Cr_2O_7,2H_2O$ in the water, with sufficient caustic soda to produce the normal chromate and maintain the p_H at 8·0. The presence of small amounts of phosphate was also found to improve the corrosion resistance of the ch film and to hinder the deposition of mineral scales on the tubes.

Sodium hexametaphosphate is under trial as a corrosion inhib has the advantage of cheapness, but its efficiency is not yet established. So droxide and sodium silicate were not completely satisfactory.

Two years ago a mechanical deaerator was installed in one of th lated cooling-tower systems at Port Arthur, handling 1500 g.p.m. The deae sists of an asphalt-lined tower down which the water flows under high vacuum in. Hg abs.), a system of cypress-wood trays breaking it up into films and sh ch present a large surface area to the vacuum. The dissolved oxygen conte e water is thus reduced from 6–7 p.p. million to 0·2 p.p.m. A test bundle of st denser tubes installed at the same time as the deaerator has now been in op for 26 months without a failure. Previously, the life of such tubes was 5 mont

The application of cathodic protection to condensers of the shell-and-tube ty described, and a diagrammatic layout is shown for handling sixteen condensers a coolers located on a pipe-still. Whilst the system has already proved its valu much work remains to be done in determining the most satisfactory layouts an current densities for widely varying applications. C. G. G.

936.* Continental Adopts Delayed Coking at Oklahoma Plant. W. T. Ziegenhain. *Oil Gas J.*, 29.5.41, **40** (3), 42.—Delayed coking in its modern version represents a distinct improvement over the older procedure of reducing crude residuum in batch-stills to recover gas-oil as a feed for cracking stills. Both, however, recognize time as well as temperature as factors in liberating the gas-oil from the heavy residuum and in causing the deposition of coke during this procedure.

The Continental Oil Co. has converted its original Dubbs plant into a delayed coking installation for providing a desirable feed for its Cross-cracking units. A flow-sheet shows the method of operation of the process.

The raw charge is drawn from two sources: (*a*) reduced crude-gravity 22, distilling 70% to 730° F.—essentially a Kansas crude residuum; (*b*) "extraneous bottoms"—gravity 26, I.B.P. 370° F. distilling 70% to 740° F. This material comes from many sources. Reduced crude is received at a rate of 3700 brl./day and "extraneous bottoms" at 1300 brl./day. These materials are blended, mixed with 1300 brl. of recycle oil and heated to 630° F. before entering the fractionator. The plant operates in duplicate, one unit being on stream, whilst the other is cooled and cleaned out.

An important by-product of the operation is 1,800,000 cub. ft./day of gas, which is fed with the gas-oil into the cracking plant for manufacturing gasoline. In this plant 2900 brl. heavy virgin gas-oil mixed with 4100 brl. coker distillate are processed daily. D. L. S.

937.* Solutizers Improve Treating of Four Types of Gasoline. H. N. La Croix. *Nat. Petrol. News*, 5.3.41, **33** (10), R.72.—The need for developing the maximum possible octane number in gasoline has emphasized the importance of the presence in the gasoline of mercaptans not removed by the normal treating processes. The deleterious effect of these sulphur bodies on lead susceptibility necessitates the improvement of caustic washing. The higher mercaptans are only sparingly soluble in caustic, and greatly improved results have attended the addition of "solutizers" such as sodium or potassium salts of *iso*butyric acid. H. G.

938.* Clad Steels Find Place in Refinery Equipment. Anon. *Nat. Petrol. News*, 19.3.41, **33** (12), R.82.—Considerable advances in the preparation of composite metals have been made whereby it becomes possible to procure big economies in the use of high-priced corrosion-resisting alloys. Several methods are in use: casting-on processes, pressure welding, fusion welding, and electrical resistance welding. Twelve processes that come under these headings are dealt with. In addition to these processes, which produce sheet metal, there are those applicable to prefabricated plant. Anti-corrosion linings are fitted either by welding strips of corrosion-resistant alloys to the surface to be protected, or by coating the surfaces by means of high-pressure spray guns using wire or powdered metal. H. G.

939.* Refinery Uses of Moulded Carbon. M. J. Dorcas. *Nat. Petrol. News*, 30.4.41, **33** (18), R.134.—Moulded carbon articles are now available in a wide range of form, from simple packing rings to plant sections of complex shape. Size-graded carbon, usually ground petroleum coke, is mixed with tar or pitch to a plastic state and moulded under heat and pressure. The articles are then heat-treated in an electric furnace to carbonize the binder. By adjusting the furnace conditions the final product may be of amorphous carbon or graphite. Porosity is adjusted by selection of the particle size of the base material, and complete imperviousness is achieved by impregnating with synthetic resins. The almost total inertness of carbon renders it particularly valuable in many refinery processes. Amorphous carbon has a low thermal conductivity and graphite a high thermal conductivity. Articles of the former may be used for heat insulation, whilst heat exchangers have been constructed from the latter. A complete scrubbing tower weighing 250 tons and Cottrell precipitator towers have been constructed entirely of moulded carbon sections.

H. G.

940.* Alkylation Feed-Stock Produced in Natural Gasoline Plants. H. W. Harts. *Nat. Petrol. News*, 14.5.41, **33** (20), R.153.—The increasing demands for high-octane motor fuels have increased the importance of adequate supplies of *iso*butane and *iso*pentane. Both these raw materials are being isolated from natural gas. The article concerns itself primarily with the economical considerations. Isolation calls for expensive equipment and extremely close plant control, and some doubt is expressed that the procedure is economically justifiable from the point of view of the natural-gas producer.

H. G.

941.* Air Preheaters for Petroleum Heaters. L. A Mekler and H. A. Becker. *Nat. Petrol. News*, 28.5.41, **33** (22), R.162.—The use of air preheaters can, if suitably operated, effect considerable fuel economies. This is an important item when the present trend is to make refinery gases more useful as raw materials for gasoline intermediates than as fuel. The position is discussed largely from the economical standpoint. It is shown that there are optimum conditions for operation, and that operation at temperatures above certain maxima may entail losses. Tables are given showing the economics of preheaters as affected by type and by changes in the preheated air temperature.

H. G.

942.* Regenerative-Type Air Heaters. O. F. Campbell and T. B. Kimball. *Nat. Petrol. News*, 28.5.41, **33** (22), R.168.—The Ljungstrom continuous-counterflow-regenerative air preheater is described and its application to a down-draft de Florez cracking still is discussed. In a table the expected performance of a cracking-still furnace in which the convection bank is substituted by an air preheater is compared with a similar furnace equipped with a convection bank. The use of the preheater is shown to produce some financial saving. Where flue temperatures exceed 1400° F. it is suggested that the use of an air preheater as an addition to the existing plant might prove more economical than the substitution of the convection bank by an air heater calling for the use of expensive high temperature alloys. The advantages and disadvantages of this type are discussed. A disadvantage is its high power requirements; advantages are its small size and the ease with which it is cleaned.

H. G.

943.* Prevention of Fog in Cooler-Condensers. A. P. Colburn and A. G. Edison. *Industr. Engng Chem.*, 1941, **33** (4), 457.—The condensation of a vapour in the presence of an inert gas usually results in some fog being formed. The theoretical mechanism of fog formation under these conditions is discussed, and a solution of the problem is to cause the path of cooling to lie always under the vapour-pressure curve, so that the mixture never becomes supersaturated. The method of eliminating this undesirable condition is to supply a small amount of heat to the vapour–gas mixture during the condensing process. The method was tested experimentally on mixtures of air with steam, butyl alcohol, and trichlorethylene. Details of the experimental technique and methods of industrial application are given.

J. W. H.

944. Elimination of Viscosity Error in Flow Measurement with Rotameters. K. Fischer, S. Blechman, and E. Lipstein. *Instruments*, 1941, **14** (3), 65.—The principal defect of the old-type rotameter with a spheroidal float has been the great variation of the calibration with change in viscosity of the flowing fluid, and the fact that this change was not predictable with sufficient accuracy by the Schoenburn–Colburn equation relating rotameter dimensions with flow velocity and the physical properties of the fluid. A wire-guided disc-type float has been developed in which the disc forming the flow restriction and the body required to give the necessary weight are separated by attachment to opposite ends of a tube of small diameter. The body of the float is located in a pocket of stagnant liquid and is not subject to viscous drag. This type of float indicates flow rates which are independent of viscosity and in agreement with the Schoenburn–Colburn equation. The use of this new type of rotameter in conjunction with a rotameter having a plug-float enables changes in viscosity of the flowing fluid to be continuously recorded, and, if used in conjunction with a very light disc-float rotameter, the latter instrument acts as a continuous indicating pycnometer. J. W. H.

945.* Desulphurizing Properties of Zinc Hydroxide. K. A. Musatov and L. G. Krymova. *J. appl. Chem.* (*U.S.S.R.*), 1940, **13** (12), 1804–1809; translated by A. A. Boehtlingk, *Foreign Petrol. Tech.*, March 1941, **9** (3), 112–121.—It has previously been established (see Abstract 629) that the basic products of the hydrolysis of zinc chloride (ZnO and $Zn(OH)_2$) are of primary importance in the degree of desulphurization of the distillates and for the combination of hydrogen sulphide. Further investigations have now been carried out to support this statement. Zinc hydroxide has been found to desulphurize the distillates more thoroughly than zinc oxide. The temperature of the desulphurization with zinc hydroxide has an optimum which is determined by the degree of the thermal dissociation of the sulphur compounds of the distillate and the pliability of the decomposition of the hydroxide into the oxide and water. For crude-oil distillates the highest desulphurization temperature with zinc oxide at atmospheric pressure lies within 360–370° C. B. M. H. T.

946. Crude Benzole Fractionation. Anon. *Chem. Tr. J.*, 27.6.41, **108**, 379.—A brief account of E.P. No. 536,172, which covers the preparation of pure or nitration grades of benzol, toluol, and xylol by azeotropic distillation of crude benzoles with methanol. C. G. G.

947. Patents on Refining and Refinery Plant. Standard Oil Development Co. E.P. 536,819, 28.5.41. Appl. 21.11.39. A method of separating olefins, having from 2 to 4 carbon atoms per molecule, from saturated gaseous hydrocarbons. The olefins are absorbed in an aqueous ammoniacal solution of cuprous benzine sulphonate at between − 10° and 25° C. Saturated hydrocarbons are only negligibly dissolved. The olefins are recovered by application of heat, or by reducing the pressure. Also, a method of storing such olefins by solution at low temperature and under pressure in the above reagent.

A. L. Snow. U.S.P. 2,241,430, 13.5.41. Appl. 7.2.38. A petroleum fraction is subjected to a plurality of reforming operations, approaching the ultimate end-point of the reforming reaction in a number of steps. The reformed reaction products are selectively dissolved by contacting the hydrocarbons from at least one of the reforming operations with a liquid solvent having a selective solvent action for aromatic and unsaturated hydrocarbons. The mixture of selective solvent and dissolved hydrocarbons is fractionated by intimately mixing with additional vapour-phase hydrocarbons from a reforming operation, separating a vapour-phase raffinate from the selective solvent, and subjecting it to at least one reforming operation.

S. C. Carney. U.S.P. 2,242,110, 13.5.41. Appl. 12.1.38. A method of controlling the evolution of dissolved gases from a continuous stream of hydrocarbon liquid under high pressure. The stream is passed consecutively into a number of vessels. The pressure is gradually reduced in each vessel after the stream has been directed to the next, the reduction in pressure being continuous over a period sufficient to obtain maximum evolution of dissolved gas with minimum loss of the less-volatile components. The rate of pressure reduction is controlled by the amount of vapour evolved. The liquid from each vessel is discharged before the pressure has dropped to a value at which the less volatile constituents are appreciably evolved.

W. A. Schulze and G. H. Short. U.S.P. 2,242,621, 20.5.41. Appl. 28.5.40. In the process of sweetening hydrocarbon oil with copper reagents, stabilization of the sweetened oil to prevent deterioration due to retained oil-soluble copper salts, is achieved by adding a small quantity of dithizone.

W. L. Benedict and J. E. Ahlberg. U.S.P. 2,243,824, 27.5.41. Appl. 22.3.39. Process for refining hydrocarbon distillate consists of sweetening with a copper containing reagent, separating, treating in the presence of a heavy metal sulphosilicate to remove copper, and recovering the sweet gasoline.

T. P. Simpson, J. W. Payne, and P. D. Valas. U.S.P. 2,245,016, 27.5.41. Appl. 25.5.39. An adsorptive material for refining solvent-refined petroleum oils. It consists of a finely divided porous material covered with a layer of activated charcoal derived from petroleum carbonaceous matter.

R. F. Farris. U.S.P. 2,245,028, 27.5.41. Appl. 2.6.39. Liquid hydrocarbons from moisture containing well-fluids. In wells of the distillate type such a fluid is produced at high well-head pressure. It is cooled to a temperature above the maximum for hydrate formation, thus condensing most of the water. The cooled fluid is separated, and water is removed from the system. The gas phase is passed at a pressure greater than 1000 lb./sq. in. into a liquid absorption medium less volatile than the liquid hydrocarbons to be recovered, and separating the enriched absorption medium from residual gas.

C. G. Gerhold. U.S.P. 2,245,143, 27.5.41. Appl. 13.4.39. In order to avoid inactivation by loss of water of hydrated catalysts, sufficient quantities of an aqueous fluid are added to reactant at spaced points in the path of flow to prevent dehydration of catalyst.

F. B. Allen. U.S.P. 2,245,549, 27.5.41. Appl. 17.5.38. Quenching fluid-coked petroleum residue. The material is flowed through a conduit, and discharged in a solid stream. Numerous jets of water are directed downwards and radially inwards, disintegrating the hot fluid material, which falls into a tank of water below in the form of small fragments. H. B. M.

Fire Prevention.

948. Some Information on the Causes and Prevention of Fires and Explosions in the Petroleum Industry. G. M. Kintz. *U.S. Bur. Mines, Information Circular*, 7150, April 1941.—This circular has been written with a view to instructing people how to prevent loss of life and property by fire and explosion due to accidental combustion of natural gas, petrol, and related fuels. It is pointed out that fire or explosion of inflammable gas can occur only when its volume bears a definite relationship to the volume of air present; the mixture must then be in contact with sufficient heat to cause it to ignite. Therefore fire once started can only be put out by removing the fuel, air, or heat. Stress is laid on the danger of using "unapproved" electrical equipment anywhere where inflammable vapours may persist. Fuses, electric-light bulbs, drop-cord attachments, and the like should never be changed or adjusted while the current is on, in any circumstances where inflammable vapours may penetrate. Similarly, the use of petrol as a cleaning agent, as is well known, is, under certain conditions, likely to cause explosion, and should therefore never be allowed.

H. B. M.

949.* Fighting Fires with Carbon Dioxide Extinguishers. P. W. Eberhardt. *Oil Gas J.*, 29.5.41, **40** (3), 48.—The portable carbon-dioxide extinguisher is well known to the oil industry. It consists of a cylinder of the gas at 850-lb. pressure, and is operated by a small hand-wheel. The CO_2 is discharged through a nozzle designed so that the gas hits the fire with a minimum of turbulence.

These units are available in sizes ranging from the small pistol type containing 2 lb. CO_2 to the big, wheeled unit with a capacity of 100 lb. gas. In the early days it was considered that the smothering effect of CO_2 was not effective in the open air, but it is now recognized that many types of out-of-doors fires can be effectively controlled by this means.

These extinguishers are approved for electrical and flammable liquid fires, and, in addition, are unusually effective against running fires. The oil industry is using them in large numbers to protect such hazards as natural gasoline and recycling and repressuring plants, as well as for control-rooms located under stills.

Built-in CO_2 systems are becoming popular in the refining and distributive phases of the industry, and can be operated automatically. D. L. S.

Chemistry and Physics of Petroleum.

950. Densities and Refractive Indices of Liquid Paraffin Hydrocarbon. M. L. Huggins. *J. Amer. chem. Soc.*, 1941, **63**, 116–120.—The relationship between the structures of paraffin hydrocarbons and their densities and refractive indices at 20° C. has been studied in the light of recently published data, and general equations are suggested for molal volumes and refractions. T. C. G. T

951. Common Basis of Intramolecular Rearrangements. VII. Inapplicability of a Free Radical Mechanism. Formation of 1 : 1-Dimethyl*cyclo*propane and Neopentane by the Action of Sodium on Neopentyl Chloride. Relation to the Mechanism of the Wurtz Reaction. F. C. Whitmore, A. H. Popkin, H. I. Bernstein, and J. P. Wilkins. *J. Amer. chem. Soc.*, 1941, **63**, 124–127.—The products of the reaction of 1 mole of neopentyl chloride and 1 mole of sodium were 13% 2 : 2 : 5 : 5-tetramethylhexane, 36% neopentane, 25% 1 : 1-dimethyl*cyclo*propane, and a trace of *iso*butylene. From the reaction of 5 moles of neopentyl chloride and 1 mole of sodium 41% neopentane, 51% 1 : 1-dimethyl*cyclo*propane, a trace only of 2 : 2 : 5 : 5-tetramethylhexane, and no *iso*butylene was yielded.

The bearing of these results on the mechanism of molecular rearrangements and of the Wurtz reaction is discussed. T. C. G. T.

952. Heats of Organic Reactions. X. Heats of Bromination of Cyclic Olefins. M. W. Lister. *J. Amer. chem. Soc.*, 1941, **63**, 143–149.—The heats of hydrogenation and bromination of unsaturated organic compounds in the vapour phase, and which have been published previously, indicated a regular relationship between these properties and the molecular structure. The work has now been extended to the reactions in the liquid state, and the relationship previously noted is confirmed. It is concluded that a theory which assumes repulsive forces between non-bonded adjacent atoms is more consistent with the experimental evidence than one assuming attraction.

A specially designed vacuum calorimeter is described. T. C. G. T.

953. Further Observations on the Absorption Spectra of Derivatives of 1 : 2-Benzanthracene. R. N. Jones. *J. Amer. chem. Soc.*, 1941, **63**, 151–155.—In the course of studies on the carcinogenic properties of hydrocarbons a large number of derivatives of 1 : 2-benzanthracene were prepared. These preparations have now been utilized to determine the effect of a given substituent at a given position of the spectrum of the hydrocarbon.

Observations on the fluorescence of most of the derivatives are also recorded.
T. C. G. T.

954. Synthesis of 4 : 5-Methylenephenanthrene. W. E. Bacmann and J. C. Sheehan. *J. Amer. chem. Soc.*, 1941, **63**, 204–206.—4 : 5-Methylenephenanthrene has been prepared from acenaphthene. T. C. G. T.

955. Preparation of Higher *cis*- and *trans*-Olefins. K. N. Campbell and L. T. Eby. *J. Amer. chem. Soc.*, 1941, **63**, 216–219.—Most methods of preparing olefins yield a mixture of the two geometrical isomers. In the case of the lower members—*e.g.*, 2-butene—these can be separated by fractional distillation, but in the case of higher members the boiling points become so close that fractional distillation as a method of separation is impracticable.

The reduction of dialkylacetylenes can be controlled to yield either *cis*- or *trans*-olefins. *cis*-Olefins are prepared by catalytic hydrogenation in the presence of Raney nickel, and *trans*-olefins by the reduction of dialkylacetylenes with sodium in liquid ammonia.

Four pairs of *cis*- and *trans*-isomers, 5-decene, 4-octene, 3-octene, and 3-hexene are described, and their configuration is established by means of Raman spectra, freezing points, and dielectric constants. T. C. G. T.

956. Action of Anhydrous Ferric Chloride on Alkylbenzenes. D. Nightingale, R. G. Taylor, and H. W. Smelser. *J. Amer. chem. Soc.*, 1941, **63**, 258–261.—When 1 : 3-dimethyl-4-butylbenzenes are warmed with anhydrous ferric chloride the reactions are generally similar to the reaction with anhydrous aluminium chloride.

The 1 : 3-dimethyl-4 : 5-*s*.- and 4-*tert*.-butylbenzenes undergo rearrangement to 1 : 3-dimethyl-5-*tert*.-butylbenzene when warmed with ferric chloride at 80° C. Some 1 : 3-dimethyl-5-*tert*.-butylbenzene is formed from the 4-*iso*butylhydrocarbon, but a higher temperature is required. This is also true of the 4-*s*.-butylhydrocarbon.

Only unchanged 1 : 3 : 4-hydrocarbon was isolated from the two 1 : 3-dimethyl-4-propylbenzenes and 1 : 3-dimethyl-4-ethylbenzene, after warming them with ferric chloride at temperatures up to 150° C. T. C. G. T.

957. Note on the Absorption Spectra of some Alkyl Chrysenes. R. N. Jones. *J. Amer. chem. Soc.*, 1941, **63**, 313–314.—In the course of studies on the carcinogenicity of hydrocarbons the absorption spectra of 5-methyl-, 4 : 5-dimethyl-, 5 : 6-dimethyl-, and 4 : 5-methylene-chrysene have been determined and are recorded.

T. C. G. T.

958. Nitrogen Compounds in Petroleum Distillates. XIX. Isolation from California Petroleum and Synthesis of 2 : 3 : 8-Trimethyl-4-Ethylquinoline. R. A. Glenn and J. R. Bailey. *J. Amer. chem. Soc.*, 1941, **63**, 637–638.—A new $C_{14}H_{17}N$ base, 2 : 3 : 8-trimethyl-4-ethylquinoline (*A*), was isolated from the 308–313° C. fraction of bases obtained from the Edeleanu extract of California petroleum. It was degraded to the hitherto unknown 2 : 3-dimethyl-4-ethylquinoline (*B*).

A is the first quinoline homologue obtained from this source with an alkyl on the Py-nucleus higher than methyl. The structures of *A* and *B* were confirmed by synthesis.

R. D. S.

959. Nitrogen Compounds in Petroleum Distillates. XX. Isolation of 2-Methyl-8-ethylquinoline from California Petroleum and Proof of Structure through Degradation and Synthesis. R. A. Glenn and J. R. Bailey. *J. Amer. chem. Soc.*, 1941, **63**, 639–641.—The isolation of two new $C_{12}H_{13}N$ bases occurring in 258–264° C. fraction from the Edeleanu extract of California petroleum is reported. Proof of the structure of one as 2-methyl-8-ethylquinoline is described. R. D. S.

960. High-Temperature Photolysis of Acetone and the Action of Free Methyl Radicals on Propane. Augustine O. Allen. *J. Amer. chem. Soc.*, 1941, **63**, 708–714.—Acetone illuminated by light of wave-lengths between 2000 and 3000 A. is known to break up cleanly to free methyl and acetyl radicals. Part of this paper includes data on products obtained by the illumination of acetone propane mixtures. The products of reaction were methane, ethane, propane, normal and *iso*butane, pentane (probably from secondary reaction), and carbon monoxide. Hydrogen and unsaturateds were not formed. R. D. S.

961. Synthesis of Multi*cyclo*pentyls. G. E. Goheen. *J. Amer. chem. Soc.*, 1941, **63**, 744–749.—With a view to a possible relationship between the multicyclic five-carbon membered rings and the structure of petroleum products, various multi*cyclo*pentyls were synthesized. The physical properties determined were : boiling point at atmospheric and reduced pressure, refractive index at two temperatures, density at five temperatures, specific dispersion, viscosity at five temperatures, V.I., aniline point. The V.I. was found to decrease as the number of rings increased, but the highest examined, $C_{20}H_{34}$, still had a V.I. of more than 100. R. D. S.

962. Chlorination of Olefins in Reactive Solvents with *tert.*-Butyl Hypochlorite. C. F. Irwin and G. F. Hennion. *J. Amer. chem. Soc.*, 1941, **63**, 858–860.—This paper describes twenty reactions between various olefin hydrocarbons and *tert.*-butyl hypochlorite in the presence of alcohols, phenol, or acetic acid. These solvents take part in the over-all reaction, the products being chlorhydrins or esters. R. D. S.

963. Preparation of 2 : 2- and 3 : 3-Dimethylpentane. H. Soroos and H. B. Willis. *J. Amer. chem. Soc.*, 1941, **63**, 881.—The authors describe how it is possible to prepare these hydrocarbons by the condensation of tertiary alkyl halides with Grignard reagents. R. D. S.

964. Effect of Potassium Oleate on Solubility of Hydrocarbon Vapours in Water. J. W. McBain and J. J. O'Connor. *J. Amer. chem. Soc.*, 1941, **63**, 875–877.—The authors studied the solubilities of the indifferent hydrocarbons, *iso*butane, butadiene, and propylene in water and in solutions of potassium oleate, and found that the presence of the soap enhanced the solubility. R. D. S.

965.* Mechanism of Hydrogenation of Unsaturated Hydrocarbons. Composition of Technical Di*iso*butylene. R. Obolentsov. *J. appl. Chem.* (*U.S.S.R.*), 1940, **13** (2), 198–209; translated by A. A. Boehtlingk, *Foreign Petrol. Tech.*, March 1941, **9** (3), 87–106.—An attempt to identify, from their physical constants, the separated narrow cuts in the fractionation of di*iso*butylene (the raw material for the preparation of *iso*-octane) was unsuccessful, owing to the impossibility of effecting a sufficiently sharp fractionation. The authors therefore applied ozonation, and identified the derivatives of the products of hydrolysis of the ozonides. As a result, eight isomeric octylenes and two isomeric nonylenes were formed in the di*iso*butylene. All the octenes present contain in their hydrocarbon skeleton a tertiary carbon atom with the exception of one (2 : 4-dimethylhexene-5), and they are hydrocarbons with a slightly branched chain. It is considered that further branching is scarcely possible in the hydrogenation of these hydrocarbons and the reversed process is also improbable. B. M. H. T.

966.* Mechanism of Hydrogenation of Unsaturated Hydrocarbons. Composition of the Octylene Fraction of Commercial Di*iso*butylene. R. Obolentsev. *J. appl. Chem.* (*U.S.S.R.*), 1940, **13** (12), 1869–1871; translated by A. A. Boehtlingk, *Foreign Petrol. Tech.*, March 1941, **9** (3), 107–111.—Investigations have been carried out on the structure of the olefin hydrocarbon present in the fraction boiling at 125–126° C. of the polymers obtained in the treatment of unsaturated gases with sulphuric acid. B. M. H. T.

967.* Line Co-ordinate Chart for Vapour Pressures of Organic Solvents. D. S. Davis. *Industr. Engng Chem.*, 1941, **33** (3), 401.—A nomogram is presented which enables the vapour pressures up to the boiling point of the following solvents to be estimated : *iso*-octane, *iso*decane, ethylene glycol monoethyl ether, di*iso*butylene, di*iso*amylene, diacetone alcohol, *n*-butyl acetate, and *n*-amyl acetate. J. W. H.

968. Calculating Beattie–Bridgeman Constants from Critical Data. S. H. Maron and D. Turnbull. *Industr. Engng Chem.*, 1941, **33** (3), 408.—From a general equation for $\log_{10} \gamma$ as a function of reduced temperature and pressure for any gas, expressions are derived relating the Beattie–Bridgeman constants of the gas to the Beattie–Bridgeman constants of a reference gas in terms of critical pressure and temperature only. The Beattie–Bridgeman constants thus calculated for various gases are used to evaluate their compressibilities, and calculated results are compared with observed data and with the van der Waal equation. Compressibilities calculated by the method described agree with the observed data over a wide temperature and pressure range, and are superior to the results of the van der Waal equation at all the temperatures except in the 1·00–1·25 reduced temperature interval. J. W. H.

969.* Role of Diffusion in Engineering Operations. T. K. Sherwood. *Industr. Engng Chem.*, 1941, **33** (4), 424.—This paper is an introduction to a diffusion symposium comprising some 12 papers. The basic principles of diffusion are reviewed and their interpretations emphasized. The application of fundamental diffusion theory to selected examples of absorption, combustion, catalytic hydrogenation and water-cooling tower design is discussed. J. W. H.

970.* Gas Absorption in Bubble-Cap Columns. J. F. Walter and T. K. Sherwood. *Industr. Engng Chem.*, 1941, **33** (4), 493.—Data are presented on the absorption of propylene and *iso*butylene from an inert gas at 3·14 and 4·19 atmospheres in a 2-in. single-plate column fitted with a segment of a 2-in. cap using a heavy naphtha, a gas oil, and a heavy gas oil–lubricating oil mixture. Under various conditions Murphree vapour efficiencies of 4·7–24·0% were obtained. Using the same column for the rectification of alcohol and humidification of air, Murphree vapour efficiencies of 78–92% were obtained. Data on the absorption NH_3 and CO_2 from air by means of water and the desorption of CO_2 from water and aqueous glycerol solution into larger columns are given. For the absorption of NH_3 a Murphree vapour efficiency of 70% was obtained, but for the absorption and desorption of CO_2 the efficiency was 0·65–4·2%. These absorption experiments were carried out over a range of vapour and liquid velocities which corresponded to commercial practice. The results are correlated approximately by an empirical equation relating the Murphree vapour efficiency to the gas solubility, total pressure, liquid viscosity, slot width, and effective depth on the plate. The major variable is the gas solubility and the results indicate that different efficiencies should be used for each component in the design of absorbers for natural and refinery gases. J. W. H.

971.* Relations between Physical Properties of Paraffin Hydrocarbons. A. W. Francis. *Industr. Engng Chem.*, 1941, **33** (4), 554.—Boiling, melting and aniline points, densities, refractive indices, and octane numbers are given for 88 paraffins between C_1 and C_{10}. Equations which are functions of the number of carbon atoms only are derived which reproduce the densities, refractive indices, and boiling points of the normal and other homologous branch chain series. For each isomeric paraffin the aniline point is shown to be a linear function of the density or refractive index and the octane number is a linear function of 1000 times the density minus twice the boiling point. These relations are used to detect errors in the literature, to estimate unknown properties and to predict the properties of unknown isomers. J. W. H.

972.* Free Energies of Formation of Gaseous Hydrocarbons and Related Substances. C. M. Thacker, H. O. Folkins, and E. L. Miller. *Industr. Engng Chem.*, 1941, **33** (5), 584.—The free energies of formation have been calculated for seventy-seven hydrocarbons and eight inorganic compounds in the gaseous state, over the temperature range 298–1200° K. The tables include values for the *n*-paraffins from C_1 to C_{10}, thirty-two branched-chain paraffins between C_4 and C_8, the 1-olefins from C_2 to C_{10}, and twenty-six branched-chain olefins. The experimental values of the entropy, heat of formation, and specific heat–temperature relationship used in the standard free energy of formation equation are given. J. W. H.

973.* Liquid-Vapour Equilibrium Relations in the Binary System *n*-Butane.–*n*-Heptane. W. B. Kay. *Industr. Engng Chem.*, 1941, **33** (5), 590.—The P.V.T.-x relationship at the liquid- and vapour-phase boundaries of the system *n*-butane–*n*-heptane have been determined. Comparison of the data obtained on this system is made with that previously published by the author for the system *n*-butane–ethane. Phase equilibria constants for both systems are compared with the values calculated from the fugacities. J. W. H.

974.* Thermal Properties of Pentane. P. R. Konz and G. Granger Brown. *Industr. Engng Chem.*, 1941, **33** (5), 617.—The effect of pressure and temperature on the enthalpy of pentane has been determined by means of the Joule–Thomson expansion for pressures up to 3000 lb./sq. in. and temperatures up to the decomposition point. The specific heat of pentane at atmospheric pressure has been calculated by differentiating the enthalpy–temperature equation, and the results are in good agreement with the experimentally determined specific-heat temperature relationship. J. W. H.

975.* Solubility of Methane in *n*-Hexane. E. P. Schoch, A. E. Hoffmann, and F. D. Mayfield. *Industr. Engng Chem.*, 1941, **33** (5), 688.—The solubility of methane in *n*-hexane over the temperature range 100–220° F. and at pressures up to the critical is reported in the form of bubble-point data. The specific volumes of the liquid phases, together with the compressibilities up to 6000 lb./sq. in. are given. Comparisons of this system with the systems methane–*cyclo*hexane and methane–benzene are made. J. W. H.

976.* Contact Phenomena Changing the Chemical Nature of Hydrocarbons. N. D. Zelinskii. *Refiner*, July 1941, **20** (7), 271–278.—The paper is a translation from the Russian, the introductory part of the original manuscript having been condensed and the remainder literally translated.

Research on catalytic reactions carried out by N. D. Zelinskii and his co-workers is reviewed. Formation of intermediate compounds composed of the reactants and the catalyst is not a necessary pre-requisite for a catalytic reaction. The catalyst changes the dynamic properties and the form of the molecules, and thus accelerates their interaction. The destructive action of nickel catalysts can be prevented by depositing nickel on alumina. *cyclo*Hexanes are distinguished by their selective dehydrogenation to aromatics, which is not observed in the case of other naphthenes. The phenomenon of irreversible catalysis consists in redistribution of the hydrogen of *cyclo*hexenes with formation of naphthenes and aromatics. On bi- and tri-cyclic hydrocarbons five-member rings can withstand hydrogenation and dehydrogenation, whilst three- and four-member rings are decomposed. However, cases are listed in which *cyclo*pentanes also undergo a scission of their ring in hydrogenation over platinum. Cyclization of *iso*paraffins, of a paraffin chain connecting two naphthene rings, and aromatization by conversion of a *cyclo*pentane into a *cyclo*hexane, followed by dehydrogenation of the latter, are cited. Contact with platinum or palladium may effect a shift of the double bond of olefins or stereoisomerization.

There seems to be no basis for an assumption that in all catalytic processes formation of intermediate temporary compounds from the reacting substances and the contact bodies takes place. The author agrees with Mendeleev that a mere contact is sufficient to bring about a dynamic strain in the molecules, which results in some cases in rupture of the ring, its isomerization, or in creation of a new ring from open chains changing the energy level of the valence bonds, whilst in other cases the ring of *cyclo*hexane is completely dehydrogenated to benzene.

All above-mentioned phenomena that change the chemical nature of hydrocarbons depend on simple contact with metal catalysts prepared in a definite way. With regard to decomposition of *cyclo*hexane into hydrogen and benzene, it may be regarded as a dissociation at a considerably lower temperature (beginning with 150° C.) under the action of the contact substances. Out of contact with these metals the stability of the *cyclo*hexane is so high that even at much higher temperatures it does not undergo dehydrogenation.

These studies were started because of their theoretical significance, but the derived conclusions were found to be also of practical use. The contact aromatization of gasoline and ligroin fractions of oil constitutes a method of preparation of large amounts of aromatics. Conversion of *cyclo*pentanes into *iso*paraffins is also of practical importance. A. H. N.

977.* Obtain Up to 37% *iso*-Octane in Catalytic Isomerization. A. P. Sivertsev. *Nat. Petrol. News*, 5.3.41, **33** (10), R.68.—Laboratory experiments on the isomerization of *n*-octane are described. Simple heating yields a maximum of 10% of isomers. In the presence of anhydrous aluminium chloride the maximum yield was 37%, the optimum conditions being 1–2 hrs. heating at 120–140° F. *n*-heptane treated for 5 hrs. at 104° F. yielded 16% of isomers. H. G.

978.* Viscosities of Homologous Series at Equal Temperatures. A. H. Nissan and A. E. Dunstan. *J. Inst. Petrol.*, June 1941, **27** (212), 222.—It appears that log μ is connected more directly with molecular volume than with molecular weight. The formula

$$\log \mu = A \log (\text{molecular volume}) + B$$

applies to a greater extent than the original

$$\log \mu = A\ (\text{molecular weight}) + B.$$

when a wide range of members of homologous series is considered. The molecular volume formula, however, is still far from being comprehensive. B. M. H. T.

979.* Petroleum as a Raw Material. A. W. Nash. *J. Inst. Petrol.*, June 1941, **27** (212), 195.—The subject is treated from the point of view of the isolation of pure chemical entities from or through the intermediary of petroleum. The properties and applications of compounds are considered under six headings : saturated, unsaturated and oxygenated open-chain groups of hydrocarbons, cyclic compounds, sulphur compounds, and nitrogen compounds. B. M. H. T.

980.* Synthesis of Some Diolefin, Olefin, and Other Hydrocarbons and their Polymerization in Electric Discharges. Part I. Synthesis of Unsaturated Alcohols and their Dehydration. K. I. Karasev. *J. gen. Chem. U.S.S.R.*, 1940, **10** (18), 1699–1703; translated by A. A. Boehtlingk. *Foreign Petrol. Tech.*, April 1941, **9** (4), 128–136.—The greatest difficulty experienced in the synthesis of alcohols of the structure of heptene–1–OL–4 consisted in the impossibility of obtaining the Grignard complex in the usual manner from allyl chloride with a more or less satisfactory yield. By means of adding small amounts of aldehyde to the allyl halide in the process of preparing the Grignard complex, the yield of the latter was increased for allyl bromide up to 85% and for allyl chloride up to 70–75% of the theoretical yield. This enabled the yield of alcohols to be increased to 55–65% of the theoretical yield. The most successful method of dehydrating the alcohol was found to be that developed by Chugaev. The sodium alcoholate obtained by refluxing the heptanol with ether and sodium was decanted and treated in the cold with CS_2 and CH_3I. The reaction is exothermic. After further heating, washing, and drying with $CaCl_2$, the remaining ether and CS_2 were distilled off. On further heating the xanthate ether was subjected to the usual decomposition with the formation of the diene hydrocarbon. The hydrocarbon obtained was subjected to a repeated re-distillation, first without sodium and then over sodium for the removal of traces of methyl-mercaptane. The synthesis and dehydration of decene–1–OL–4 were carried out in a similar manner. The constants of the hydrocarbons obtained were determined and the structure proved. B. M. H. T.

981.* Synthesis of Some Diolefin, Olefin, and Aromatic Hydrocarbons and their Polymerization in Electric Discharges. Part 2. K. I. Karasev. *J. gen. Chem. U.S.S.R.*, 1940, **10** (18), 1704–1712; translated by A. A. Boehtlingk. *Foreign Petrol. Tech.*, April 1941, **9** (4), 137–150.—It has been found that in all cases of electric polymerization of hydrocarbons there is a sharp decrease in the iodine numbers, which greatly exceeds the decrease in the hydrogen number. By means of oxidation and other methods, it has been established that the chemical changes of the substance subjected to treatment with a silent discharge take place in the direction of an increase in the molecular weight, a shifting of the double bonds of the salts from position 1 : 4 to position 1 : 3, formation of new double bonds, and evidently cyclization. The migration of olefin bonds into the conjugated position amounts up to 70% of the total double bonds in the case of pure diene hydrocarbons, whilst it is still higher in the case of mixtures with mono-olefins. Chemical changes leading to the formation of conjugated diolefin systems are sharpest during the consumption of the first KWh. of energy. Later, other processes prevail, including cyclization. As a result of this, the percentage of conjugated bonds in comparison with the total number of double bonds does not increase, but, on the contrary, sharply decreases. In the case where the original product is a mixture of mono- and di-olefin hydrocarbons, the process of the formation of conjugated double bonds is not discontinued as rapidly as is the case with pure diolefin hydrocarbons. B. M. H. T.

Analysis and Testing.

982.* Consistency Determinations Improved for Fluid Greases. Anon. *Nat. Petrol. News*, 22.1.41, **33** ((4), R.32.—The S.I.L. Mobilometer is a modification of the Gardner Mobilometer, which is stated to be unreliable when used on very fluid greases. The modified instrument consists of a cone fitted to a shaft and mounted so as to move vertically within a tall water-jacketed cylinder. The cone is pierced by a number of holes with axes parallel to the axis of the shaft. Consistencies are determined by measuring the time taken for the shaft to fall a predetermined distance through the worked grease at 77° F. The " consistency number " is calculated from the formula $C.N = \frac{\sqrt[4]{LT}}{500}$, where L = load on the cone and T = time in seconds. H. G.

983.* Speeds Viscosity Measurement in Capillary Type Viscometer. E. H. Zeitfuchs. *Nat. Petrol. News*, 16.4.41, **33** (16), R.121.—The viscometer described is of the Ostwald type. The trap, in which the correct volume of oil is automatically measured, is situated at the bottom of the tube. Errors due to differences in surface tension are eliminated by so proportioning the tube that liquid in both sides flows in sections of equal diameter. The viscometer is available in four sizes, covering the range 1–1000 c.s. Special sizes appropriate to other viscosity ranges may be made. H. G.

984.* Vapour-Pressure Determinations Affected by Many Variables. F. M. Allen. *Oil Gas J.*, 24.4.41, **39** (50), 50.—This paper reports critically on all the modifications that have been made in the method of determination of Reid vapour-pressures since the introduction of the test. Conclusions are : the volumetric ratio of air- to gasoline-chamber should be as near 4 : 1 as possible. The sample should be properly aerated. When cleaning out the apparatus the rinsing water should be as near air temperature as possible, to ensure a correct value of the " initial air temperature." When determining the latter, the thermometer should be supported by a loosely fitting cork in the neck of the air-chamber to ensure that the air is saturated with water-vapour.

The question of the advisability of avoiding the temperature correction by having an " initial air temperature of 100° F." is gone into in some detail. The errors introduced by this modification are shown to result from the air in the chamber cooling below 100° F., contracting and sucking in more cold air in the interval (up to 10 secs.) elapsing from the time when the chamber is removed from the 100° F. bath until it is connected to the gasoline chamber. The conclusion is that determinations can be simplified by using the 100° F. " initial air temperature," provided that adequate precautions are taken to ensure that the temperature of the saturated air in the chamber is 100° ± 0·5° F. at the instant of final closure. T. T. D.

985.* Revised Charcoal Adsorption Test Adopted by Committee. H. L. Oder. *Oil Gas J.*, 24.4.41, **39** (50), 54.—The principal changes are : the dry, orifice, or wet meter is replaced by a diaphragm meter. A back-pressure regulator is placed on the meter outlet, so that an absolute flowing pressure equal to the required base pressure can be maintained, thus eliminating pressure corrections. The quantity of activated charcoal is changed from 250 c.c. to 130 gm., and grain size 6–14 mesh is tightened to 8–14 mesh, as determined by Tyler screens. The activation period of 40 min. is widened to 40–45 min.

The new activation test for the charcoal is still being worked out.

The charcoal moisture content test is that not less than 5 ml. water shall be recovered when 130 gm. charcoal are distilled with 100 ml. clean kerosine. The charcoal saturation is such that 30 ± 5 ml. net gasoline shall be recovered by distillation with 200 ml. (instead of 150 ml.) glycerol up to a final temperature of 400° F. (instead of 350° F.). The specification of the condenser box is relaxed, and allows of anything that is of convenient shape and ample size.

The new code allows a maximum rate of gas-flow of 40 cu. ft./hr., but stipulates that no adsorption shall be completed in less than 30 min. T. T. D.

986.* Substitution of Gasoline for Ether in Morphine Determination in Opium Dross. Ua Rasmidatta. *Thai Sci. Bull.*, October 1940, **11** (3 & 4), 129.—A new procedure, claiming several advantages over the usual Malay method, is described for the quantitative determination of the morphine content of opium and opium dross. The method comprises the substitution of gasoline for ether and the omission of lead acetate and hydrogen sulphide. The gasoline used in the process had the following specification: at 144° C. the total distillate amounted to 90% by volume. The use of gasoline results in a morphine precipitate whiter in colour than that obtained when ether is employed, and its recovery is simpler and less costly than that of ether.

The substitution of gasoline for ether is not only practical in opium dross analysis, but may be suitable for the extraction of other alkaloids which are now extracted with ether. B. M. H. T.

987.* Revised Standard Method of Test for Distillation of Liquid Asphaltic Bitumen (Tentative) I.P.T. Serial Designation C.B. 3–1941 (T), A.S.T.M. Serial Designation D. 402–36 (T). *J. Inst. Petrol.*, June 1941, **27** (212), 226.—The object of the revision undertaken by the Asphaltic Bitumen Sub-Committee of the Institute of Petroleum was to specify more accurately the procedure to be adopted at the termination of the distillation and during the pouring of the residue, it being considered that this has an effect on the consistency of the results of penetration tests subsequently carried out on the residue. According to the revised test, the residue left in the flask after distillation is allowed to cool to 300° C. before pouring. B. M. H. T.

Motor Fuels.

988.* Methane as a Motor Fuel. Anon. *Engineer*, 1941, **171** (4458), 396–397.—The potential sources of methane are discussed—namely, from coal-mines and sewage gas.

In order that methane may be used as a motor fuel, it must be compressed into cylinders, the cost of compression being given as between 2½*d.* and 3*d.* for the equivalent of 1 gall. of petrol. The total cost is estimated at 10*d.* per equivalent gallon.

It is not essential to alter a petrol engine to operate on methane, but, in order to take advantage of the very high octane number, the compression ratio should be increased to about 15 : 1. The power output is thereby increased by approximately 50%.

Against the advantages of a gaseous fuel for a motor vehicle is the big disadvantage of the extra weight of the storage cylinders, and in some cases it may be considered preferable to convert methane into a liquid product. The various processes for achieving this are briefly described. J. G. W.

989. Liquefied Gas as Engine Fuel. Anon. *Gas and Oil Power*, April 1941, No. 427, p. 77.—An article discussing in general terms the advantages and disadvantages of substituting for all imported petrol indigenous gas fuels, in particular methane. It is argued that a fundamental condition is that the gas must be in a liquefied form, three reasons being given which would cause failure in any attempt to market fuel in a gaseous form—viz., the small mileage per charge, the weight and cost of containers suitable to storage at high pressure, and the cost of compressor plants. Ordinary town gas suffers from the serious disadvantage that when a low enough temperature has been reached to liquefy the hydrogen, other components, such as methane and ethylene, would be frozen solid, and hence would block pipes, valves, and other equipment. Figures are quoted showing the respective advantages as I.C. engine fuels of methane, of ethane, of propane, and of butane over petrol; and the opinion is expressed that it should not be above the capacity of modern industry by means of synthesis and pyrolysis to produce from coal whichever of these hydrocarbons is selected instead of ordinary town gas. J. C.

990.* Octane-Rating Trend Continues Upward. W. T. Ziegenhain. *Oil Gas J.*, 13.2.41, **39** (40), 22–23.—A survey of American motor-fuel quality for the present year, with a tabular comparison of octane ratings, distillation ranges, and vapour pressures for the three standard grades for each year since 1930. Differences in

distillation range between the gasolines of to-day and those of 10 years ago are illustrated graphically. The results show that octane ratings are still increasing, the present figures being 80 for the premium grade, 74 for the regular grade, and 63 for the third grade. Distillation curves have become more uniform and smoother. A note is added on the necessity of production by processes such as cracking, reforming, polymerization, and alkylation, in order to obtain these high-octane rating gasolines.
J. C.

Gas, Diesel, and Fuel Oil.

991.* Cetane Number and Chemical Composition. T. Y. Ju and C. E. Wood. *Oil Gas J.*, 9.1.41, **39** (35), 41–46.—The introductory part of the paper is devoted to a useful recapitulation of the existing knowledge on the combustion of oil in compression-ignition engines. The four phases in the mechanism of combustion are described—viz., (*a*) delay period, (*b*) rapid uncontrolled combustion, (*c*) controlled combustion, (*d*) after burning. Diesel knock and rough running, the ignition quality of fuels, the cetene and the cetane scales, together with the current methods of engine testing of diesel fuels, are all lucidly discussed. Although none of the methods of engine testing developed since 1931 has been standardized, the methods of the ignition-lag test and the throttling test are the tentative standards of the I.P.

The actual research consisted in the determination of the cetane numbers of certain pure hydrocarbons. Alkylated benzenes were considered to have properties intermediate between aromatics and paraffins, and were selected for the investigation. The hydrocarbons were prepared by the reduction of the corresponding alkyl aryl ketones. It was shown that the cetane number of the normal alkylbenzenes increases with increasing number of carbon atoms in the side-chain, owing to a decrease of aromatic simultaneously with an increase of paraffinic character. Amylbenzene is predominately aromatic, whilst *n*-hexylbenzene has properties midway between aromatics and paraffins. In a second part to the investigation the ignition properties were determined of biphenyl, diphenylmethane, and dibenzyl. The anomaly by which the most aromatic compound of these, biphenyl, has the highest cetane number is considered to be related to various factors, such as thermal stability, mechanism of combustion, and molecular configuration. The cetane numbers and other physical properties of bi*cyclo*hexyl and *m*-di*iso*propyl benzene were also determined. J. C.

992. Patents on Gas, Diesel, and Fuel Oil. M. A. Dietrich. U.S.P. 2,243,198, 27.5.41. Appl. 28.1.39. A process for decreasing the pour-point of a hydrocarbon fuel oil. A small amount of a hydrogenated castor-oil derivative is added to the oil. The compound is produced by the reaction of castor oil with an alcohol, aldehyde, *iso*cyanate, or *iso*thiocyanate, and having a softening point of 70°–160° F. It is used in proportions of from 0·1% to about 2%.

F. Martin, O. Roelen, and P. Schaller. U.S.P. 2,243,760, 27.5.41. Appl. 4.3.37. Fuel oil for diesel engines. Carbon monoxide is catalytically reduced giving hydrocarbons of B.P. 200–320° C.
H. B. M.

Lubricants and Lubrication.

993.* Heavy-Duty Lubricating Oils as Measured by Engine Tests. H. C. Mougey. *Oil Gas J.*, 1.5.41, **39** (51), 38.—A general discussion on laboratory engine tests of lubricating oils is presented. It is argued that at the present time the oil is as much a part of the engine as the pistons, valves, etc., and that to-day one of the principal causes of failure in an engine is the effect of lubricating-oil decomposition products on the other engine parts. While the conventional laboratory tests are useful as " identification " tests, experience has shown that only actual engine tests will predict the performance of oils under service conditions. The operating conditions of several engine tests are quoted—viz., the Caterpillar, the Detroit, and the Chevrolet tests—and it is suggested that the Chevrolet test is worthy of development for measuring oxidation resistance, and the Caterpillar test for assessing detergent power. The necessity for correlation work by various laboratories is emphasized, and it is considered that standardized engine tests will be evolved by which it will be possible to (*a*) evaluate oils, (*b*) select oils for different engine and operating conditions, (*c*) develop better oils, (*d*) increase the life and output of engines. J. C.

994.* Modern Trends in Lubrication. W. H. Oldacre. *Oil Gas J.*, 17.4.41, **39** (49), 54.—The modern tendency in lubricating oils is towards the use of additives, the first of which were fatty oils used in steam cylinder and marine oils. There have now been developed a host of dopes for every conceivable purpose, some of which—*e.g.*, pour-point depressants, viscosity index improvers—are in ever-increasing use.

Recently oxidation inhibitors have been engaging attention, since heavily loaded I.C. engines have stressed to the limit the stability of lubricating oils. Deterioration of the oil has led to the corrosion of the new type bearing metals, whilst ring-sticking and lacquer formation have raised fresh problems. To deal with the latter troubles, a new class-detergency additives has arisen. These keep the deteriorated oil products in solution and prevent them from settling out in places where they might cause difficulties. A great many compounds have been used to increase the detergency of oils, including fatty oils, metallic soaps, chlorinated soaps, etc.

Bearing troubles have not been so successfully dealt with as yet, since increased loads and temperatures tend to accelerate the formation of acidic bodies by the oil.

Some sulphur-containing compounds have proved to be effective in inhibiting acid formation, and it has been stated that their action is due to (i) the precipitation of metallic accelerators, (ii) the formation of a metallic sulphide film which affords protection from corrosion.

The author concludes that serious attention should be given to lowering oil temperatures if these troubles are to be overcome. D. L. S.

995. Patents on Lubricants and Lubrication. N.V. de Bataafsche Petroleum Maatschappij. E.P. 536,827, 28.5.41. Appl. 27.11.39. The addition of small quantities of the salts of polyvalent metals and aromatic mono-carboxylic acids, to mineral or other lubricating oils, to avoid the trouble of sticking piston-rings. The above salts, unlike those of polyvalent metals and aliphatic acids, do not break down at the temperatures of operation, nor do they corrode lead-bronze or cadmium alloy bearings. They do not settle out, nor do they cause gelatinization of the lubricant. Some of these salts are moderately soluble in oil—*e.g.*, the zinc salt of *p.-tert.*-butylbenzoic acid is soluble to the extent of 1·5% in Venezuelan lubricating-oil distillate refined with furfural.

Acheson Industries, Inc. E.P. 536,872, 30.5.41. Appl. 31.8.39. Lubricants for bearings which are subject to high temperatures have consisted of graphite or mica suspended in a light petroleum or other volatile solvent, which serves to convey the material to the bearing, then evaporates. It is proposed to use a colloidal graphite, reduced to the colloidal condition in the presence of a polymerized *iso*butylene of molecular weight approximately 7000, suspended in such a solvent, in the presence of a colloid stabilizer. This preparation does not separate out on standing, nor does the graphite flocculate.

Celec. Corp., Ltd. E.P. 537,082, 9.6.41. Appl. 11.12.39. Lubricating oils may be reconditioned and clarified by adding to them a gel obtained by boiling certain plant material—*e.g.*, sisal—in a solution of sodium carbonate. After thorough incorporation in the oil, the gel is flocculated by addition of acid or of a copper or nickel salt in solution. After maintaining at 60° C. for ½ hr., the mixture is filtered. The result is a clean, clear oil of improved viscosity, with no moisture content or acidity.

Armour & Co. E.P. 537,122, 10.6.41. Appl. 7.12.39. The use, as a pour-point depressor, in a lubricating oil or grease, of a substance obtained by reacting a coumarone with a fatty acid chloride having at least 12 carbon atoms—*e.g.*, stearyl chloride—in the presence of an acetylating catalyst. The acylated coumarone is added in the proportion of 0·1–3%, and it is claimed that running friction is reduced by use of these oils.

R. E. Burk. U.S.P. 2,242,174, 13.5.41. Appl. 16.8.38. A lubricating compound comprising an oil of lubricating viscosity having an incorporated sulphur compound and a lead salt the acid component of which results from oxidation of petroleum hydrocarbons of 350–550° F. b.pt.

C. M. Loane and B. H. Shoemaker. U.S.P. 2,242,400, 20.5.41. Appl. 13.9.37. A lubricant containing from 0·01 to 5% of tetrachloropropyl silicate, $Si(OC_3H_6Cl$

K. Frolick. U.S.P. 2,243,420, 27.5.41. Appl. 11.3.39. A small amou[illegible] synthetic ester (b.pt. above 150° C.) of acids formed by the low-temperature o[illegible]on of paraffin wax, is added to a viscous hydrocarbon oil.

J. M. Musselman. U.S.P. 2,243,485, 27.5.41. Appl. 11.3.39. A mineral oil containing a small amount of an arylethyleneamine compound from the group consisting of phenyl and tolyl derivative, with a fatty acid of at least 10 carbon atoms and a naphthenic acid.

B. H. Lincoln and A. Henriksen. U.S.P. 2,244,886, 27.5.41. Appl. 28.8.39. An improved lubricating oil. To a mineral oil is added a small proportion of a sulphur-chloride treated condensation product of a halogenated paraffin and an aromatic hydrocarbon. H. B. M.

Asphalt and Bitumen.

996. Asphalts from Some Wyoming and Other Asphalt-Bearing Crude Oils. K. E. Stanfield. *U.S. Bur. Mines, Report of Investigations*, No. 3568, May 1941.—This report deals with the preparation and properties of several straight-run asphalts of different consistency derived from crude oils of Arkansas, California, Mexico, and Wyoming. It describes the apparatus, technique, and oils actually employed in preparing the asphalts, the procedure being to reduce the crude oils in two steps: (*a*) topping by distillation at atmospheric pressure, and (*b*) removing heavy distillate or lubricating-oil fractions by distillation at decreased pressure.

The test methods employed on the prepared asphalts included determination of bitumen and ash content, solubility in carbon tetrachloride, carbon residue, ductility, flash- and fire-points, loss on heating, penetration, softening-point, specific gravity, sulphur, viscosity, and the Oliensis spot test, much used in America to measure heterogeneity of asphalts.

Full experimental results are given, including distillation temperatures and pressures obtained while preparing the asphalts; also yield and properties of the prepared asphalts, and estimated yield and properties of the 100-penetration asphalts from the various samples investigated, are discussed in detail.

In the third section of the report, temperature susceptibilities of the prepared asphalts are estimated by calculating values for eleven temperature–susceptibility factors hitherto proposed by different investigators. The values obtained for these factors showed different degrees of deviation with change in penetration for asphalts from the same crude oil, and the conclusion is reached that values for viscosity temperature susceptibility coefficient show least deviation with penetration change, whilst values for susceptibility index and fluidity show greatest deviation with penetration change.

It is pointed out that the work involved in these investigations did not include performance or service tests, so that conclusions could not be safely reached as to the suitability of the prepared asphalts for specific purposes; but on chemical and physical grounds, asphalts from Wyoming crudes compare favourably with those from Arkansas, California, and Mexico, and should find similar commercial applications to those for which the latter sources are employed. A bibliography is appended. H. B. M.

997. Asphalt and Related Bitumens. A. H. Redfield. *U.S. Bur. Mines, Minerals Yearbook*, 1940. This report describes the production of asphalt of all kinds in the United States for 1939, when the refineries had to increase output by 10% during that year to meet increases in domestic demands and, to a lesser extent, foreign requirements; they, however, accounted for only 4% of the total output. It is interesting to note that America imports refined asphalt as well as natural asphalt: the amounts increased during this period, being 47,261 and 26,586 short tons, respectively, the former comprising principally Lake asphalt. H. B. M.

998. Significance of Various Methods of Tests Used on Asphaltic Paving Materials. *Technical Advisory Committee, the Asphalt Institute, Research Series*, No. 6, 1941.—This bulletin interprets the various tests applied to asphalt in terms of practice. It stresses the value of truly representative samples. Specific gravity establishes relationship between weight and volume for shipping and costing purposes; in conjunction with [illegible] tests it is used to determine void content in asphalt mixtures, also as a measure [illegible]formity. Ductility is essentially extensibility of asphalt under specified conditions, its presence or absence being more important than the actual degree determined. Softening point is an indirect measure of consistency; it is valuable as a basis of selection of asphalt for a particular purpose; used in conjunction with penetration, it indicates susceptibility. Penetration is the basis on which all solid and semi-solid asphalts are classified, and is a measure of consistency at standard temperature and of susceptibility when other temperatures are employed. Flash-point is indicative of volatility and a guide to the safety temperature when using any particular grade of asphalt; fire-point is of little significance. Solubility in CS_2 and CCl_4 is a quantitative test for bitumen content, generally required by specification. Asphaltene is determined largely for identification purposes; if absent, it denotes lack of binding properties. The Oliensis spot test is mostly used for identifying asphalts manufactured by cracking process; it is not applicable to native asphalts. Distillation is the most useful volatilization test, and results indicate performance and suitability for specific purposes. Loss on heating is regarded as an accelerated volatilization test, giving an indication of volatility under specified conditions. Other tests dealt with include paraffin content, fixed carbon, and ash. H. B. M.

999. Direct Method of Determining Thickness of Asphalt Pavement with Reference to Subgrade Support. P. Hubbard and F. C. Field. *The Asphalt Institute, Research Series*, No. 7, 1941.—The method given in this paper is based on actual tests and observations on behaviour of asphalt pavements laid direct on prepared soils; it does not involve theorizing as to probable behaviour. The unit load-supporting capacity of a soil varies with the area over which such unit load is distributed. The basis of rating load-supporting capacity is " the unit load applied to a circular bearing area of 130 sq. in. required to produce a deflection of 0·5 in." Tests were made on compacted soil samples in a metal box 2 ft. square and 1 ft. deep, using a Southwark–Tate–Emery Universal Testing Machine of 60,000 lb. capacity, equipped with autographic stress–strain recorder. Normal results on the soils alone were obtained when the loaded area did not exceed 58 sq. in.—*i.e.*, that of the tyre contact area of a light truck capable of carrying a 4000-lb. wheel-load. By using three circular load-bearing areas of known diameter, perimeter-area ratios are established which, plotted against loads in lb./sq. in., give the rating of the particular soil under test. Sections of asphalt are then laid on the soil and tested in the same manner; similar load-deflection curves are thus obtained to those developed by the soil alone, from which it is concluded " that under concentrated loading an asphalt pavement resting upon a plastic soil subgrade develops the same type of reaction that governs the behaviour of a soil alone." It is claimed that this method is of great value to the highway engineer; it enables him to determine, among other things, the proper thickness of asphalt required for any rated supporting value of a given soil; relative efficiency of soil-stabilization methods with reference to their load-supporting value; and how thick a stabilized soil should be constructed to support adequately an asphalt pavement of specified thickness. H. B. M.

1000. 1. The Washington National Airport. R. S. Thomas. **2. Choice of Surfacing Types for Airports.** H. H. Houk. *The Asphalt Institute, Construction Series*, No. 54, 1941.—This publication, with a foreword by B. E. Gray, chief engineer, Asphalt Institute, gives an informative account of layout and construction of asphalt runways for municipal airports. The first paper describes location, design, hydraulic fill and grading, paving, and buildings. The second paper deals specifically with surfacing types, the tendency being towards thinner layers of asphalt than in the case of highways, but thicker layers of stabilized soil. Built-in skid-resistance is an important factor, and any design of top dressings and seal coats must bear this in mind; pre-mixed materials are favoured in this connection. Airport surfaces must be smooth

and even to prevent shock, impact damage, etc. Some degree of settlement is inevitable with time, but this is easily corrected by application of "maintenance courses"—*i.e.*, specially designed bituminous materials which fill up any unevenness in the runway surface.
H. B. M.

1001. Patents on Asphalt and Bitumen. L. V. Gourlay. E.P. 536,564, 20.5.41. Appl. 26.4.40. Treatment of stone chips for use on roads, by heating a non-absorbent stone, then coating with 1–2% of a primer of 60% coal tar pitch and 40% creosote oil, then, with or without addition of a filler, treating the coated stone with 4–5% of a molten bituminous binder. Finally, 2–5% absorptive sand may be added.

Emile L. Baldeschwieler. U.S.P. 2,243,409, 27.5.41. Appl. 4.9.37. To improve the adhesivity of a bituminous composition, 1–2½% of a lead-soap is added to an asphalt, and the resulting mixture is maintained at 210–350° F. for at least 5 days.
H. B. M.

Special Products.

1002.* The System Nitromethane *n*-Propanol-Water. A. R. Fowler and H. Hunt. *Industr. Engng Chem.*, 1941, **33**, 90.—The ternary phase diagram of nitromethane, *n*-propanol, and water has been determined in order to find a means of separating these three components which occur together during the production of nitromethane by the nitration of natural gas. Refractive indices and densities are given for the binary and ternary mixtures. The vapour–liquid equilibria data for the binary and ternary systems are also given. The ternary mixture forms an azeotrope. A means of recovering nitromethane from the three-component system is suggested.
J. W. H.

1003.* Develop Special Paraffins. Anon. *Nat. Petrol. News*, 19.2.41, **33** (8), R.50.—Two factors are accelerating research in the development of special paraffin waxes. War conditions have hampered the supply of carnauba wax, montan wax, and ozokerite, and new dewaxing processes are producing new types of wax. No satisfactory substitute for carnauba wax has yet been produced, but certain high-melting-point, microcrystalline paraffins give promise as substitutes for ozokerites. The predominating desirable characteristics are high gloss, high tensile strength at low temperature, high melting point, and hardness. Waterproof wrappings, candles, and polishes are the principal markets for wax, but many other outlets for waxes of the right properties are visualized.
H. G.

1004. Patents on Special Products. E. T. Layng. U.S.P. 2,241,708, 13.5.41. Appl. 25.11.38. Treatment of hydrocarbons. Dehydrogenation of a hydrocarbon by use of a catalyst the active ingredient of which is formed by igniting chromic acetate. Preparation of aromatic hydrocarbons by treating aliphatic hydrocarbons having at least six carbon atoms per molecule with a catalyst prepared by igniting chromic acetate.

C. M. Thacker. U.S.P. 2,242,488, 20.5.41. Appl. 10.12.37. Conversion of paraffins into olefines. A catalyst of silica gel impregnated with a solution of copper tungstate, dried by hot air, and reduced with hydrogen, is used in dehydrogenating paraffins of low boiling point.
H. B. M.

Detonation and Engines.

1005.* Theory of the Kadenacy System. E. W. Geyer. *Engineering*, 1941, **151** (3935), 463–464.—A mathematical treatment of the mechanism of the Kadenacy effect is given, and calculations are made from the published experimental data of Professor Davies.

The author concludes that unless the area at outlet is a considerable fraction of the cross-sectional area of the vessel the depressions obtained are negligibly small.
J. G. W.

1006.* Safety Devices for Heavy-Oil Engines. Anon. *Engineering*, 1941, **151**, 497.—A safety device of simple design, made by the National Gas & Oil Engine Co., automatically cuts off the fuel supply should the lubricating-oil pressure fall below a predetermined limit. When the engine is running, the normal lubricating-oil pressure is arranged to lift a double oil-proof diaphragm, and thereby to hold open a spring-loaded mushroom-type valve connected to the suction pipe of the fuel-pump. Failure of the lubricating-oil pressure at once allows the spring-loaded valve to shut off the fuel supply. By making an adjustment of the spring loading and changing the material of the lower diaphragm, the device can be as easily used for the automatic stopping of the engine should the cooling-water supply fail.

To safeguard an engine against too high a cooling-water outlet temperature, an additional device can be used consisting of a simple fuel-valve controlled by a bellows type mercury-in-steel thermometer. E. F. C.

1007.* Evaluation of Diesel Fuels in Full-Scale Engines. Report of Co-operative Fuel Research Committee. W. G. Ainsley. *Refiner*, July 1941, **20** (7), 282. *Paper Presented before American Petroleum Institute.*—The C.F.R. Full-Scale Engine Group was organized by engine-men representing the major classifications of automotive-type diesel engines. This original group, with the co-operation of the representatives of the petroleum industry, the Government agencies, and colleges, has carried on an extensive series of tests on commercial diesel engines.

The purpose of the investigation was to determine the influence of fuel properties, such as cetane number, viscosity, volatility, and gravity on the engine performance.

In summarizing the data from these full-scale diesel-engine tests, it is realized that many of the fuel characteristics are related; and, although engine performance varies with the test values on the fuels used, it may or may not be a direct relation.

The results are given in graphs and tables with the following conclusions: (1) the ignition quality of the fuel (cetane number, A.S.T.M.) affects starting, engine smoothness, exhaust smoke, exhaust odour, and combustion-chamber deposits. (2) The volatility of the fuel (A.S.T.M. distillation) affects smoke and engine deposits. (3) The viscosity (Saybolt Universal seconds) affects smoothness and smoke. The importance of viscosity was recognized in the basic research programme as involving the consideration of ease of circulation, atomization, penetration, injection pump-plunger leakage, lubrication quality, heat content, volatility, and overall power output. The data on power output show a decrease in power with a decrease in viscosity, which may be caused in part by the effect of viscosity. (4) The gravity (A.P.I.) affects smoke, power, and fuel consumption. (5) The carbon residue on 10% bottoms (A.S.T.M.) affects smoke and combustion-chamber deposits.

The paper ends with two appendices dealing with recommendations on required diesel-fuel characteristics and with exhaust odour rating of diesel fuel, respectively. A. H. N.

1008. Annual Report of the Explosives Division, Fiscal Year 1940. W. J. Huff. *United States Bur. Mines, Report of Investigations*, 3537, November 1940.—This report contains a section on the investigation of hazards in using diesel locomotives in confined spaces, such as coal-mines. It is emphasized that the use of petrol engines in similar circumstances is unsafe and should be discouraged. With unprotected diesel engines, apart from hazards to health consequent on discharge of toxic gases, there is always a possibility of explosion when operating in an inflammable atmosphere. Recommendations include engine tests to determine the amount of air required for safe ventilation, examination of the atmosphere in which engines will operate, adjustment of quantity of air to maintain safe conditions, and frequent inspections of engines to maintain normal exhaust. The essence of these investigations is to create conditions under which complete combustion of diesel fuel is obtained. H. B. M.

1009.* Calibration of Tetraethyl Lead in Standard Reference Fuel C 12 by C.F.R. Motor Method. Report of the Institute of Petroleum Knock Rating of Aircraft Fuels Panel Sub-Committee. *J. Inst. Petrol.*, June 1941, **27** (212), 230.—A calibration curve for T.E.L. in C 12 reference fuel has been prepared. Primary reference fuels were not employed, as two accepted sub-reference fuel calibrations—viz. T.E.L. in C 11 and F 3 in C 12—were available for cross checks. Four concentrations of T.E.L. in C 12 were rated in twelve C.F.R. engines, owned by seven laboratories, thus providing twenty-four ratings for each point. B. M. H. T.

1010. Patents on Detonations and Engines. Mathias Pier and Gerhard Free. U.S.P. 2,242,321, 20.5.41. Appl. 24.8.39. A process for the production of non-knocking motor fuels by catalytic cracking of hydrocarbons obtained from $CO + H_2$ reaction, mixed with a paraffin-base petroleum.

W. L. Benedict and J. E. Ahlberg. U.S.P. 2,242,504, 20.5.41. Appl. 29.4.39. Catalytic production of anti-knock gasoline from hydrocarbon oil. Hydrocarbon oil is extracted with a selective solvent. The result is separated into raffinate and extract. The raffinate is dehydrogenated, the extract is hydrogenated, and then both are catalytically cracked. Gasoline is obtained, and also a gas, which is returned to the hydrogenating step. H. B. M.

Economics and Statistics.

1011.* Oil Situation in Russia. Anon. *Engineer*, 1941, **CLXXI**, 413-414.—The total production of crude oil in Russia during 1939 was 30 million tons. Only a slight increase in output is estimated for 1940; this is ascribed to lack of modern drilling equipment with which to develop many potential oil-producing areas.

The author discusses the effective value of Russian oil assets to the German war machine, having in view the inevitable destruction by the Russians of all oil stocks, refinery, and oil-well equipment which threatens to fall into German hands, also the possibilities and limitations of alternative methods of oil transport from each of the main oil-bearing areas should Germany be forced to attempt transport of crude oil to European refineries. E. F. C.

1012.* Natural Gasoline Plants in the United States. Anon. *Oil Gas J.*, 24.4.41, **39** (50), 92.—A list of natural-gas plants is given, by States. The information tabulated is: Company and Plant Address; Field Location; Type of Plant (Absorption, Charcoal, Compression, Vapour Rectification or Compression and Absorption); Daily Capacity (in gallons). T. T. D.

1013.* Validity of Competition in a Natural Resource Industry. J. D. Gill. *Petrol. Tech.*, May 1941, A.I.M.M.E. Tech. Pub. No. 1324, 1–5.—It is assumed that the rate and extent of the economic development of the U.S.A. demonstrate the validity of competition in the non-natural resource industries. There appears to be no condition within the petroleum industry which invalidates the principle of competition as applied to it. Various benefits are pointed out which have been conferred on the oil industry by competition. Whilst in looking backwards weaknesses and sources of waste can be seen, it is doubtful whether they could have been foreseen and prevented under non-competitive development, and whether problems would have been tackled so well and resources discovered so rapidly in the absence of competition. Having regard to the conditions of occurrence of oil, it is not unreasonable to expect some waste.

Competition should continue to keep the petroleum industry virile and progressive in meeting the requirements of future generations for the kind of products natural to it. The affairs of the industry should be considered carefully in relation to the whole economy of the country. G. D. H.

BOOK REVIEW.

Catalysis—Inorganic and Organic. By Sophia Berkman, Jacque Morrell, and Gustav Egloff. Pp. 1130. Reinhold Publishing Corporation, New York, U.S.A. 1940. $18.

This, the latest contribution from the Research Dept. of Universal Oil Products Co., Chicago, is entirely worthy of the reputation of a well-known laboratory and the renown of the authors.

In a general introduction attention is directed to the impossibility of formulating a complete theory of the mechanism of catalysis, but the hope is expressed that a systematic study of the multiplicity of experimental results here gathered together for the first time will help to resolve the complexity of the phenomena associated with surface chemistry, assist in simplifying and facilitating a critical examination of the available facts, and furthermore lead the future investigator towards justified generalizations.

In the early chapters of the monograph are discussed the factors that constitute the phenomenon of catalysis in general, such as the kinetics of intermediate reactions, the energy factor, resonance, electric and magnetic properties of catalysts, and the application of the electronic theory. Adsorption, homogeneous and heterogeneous catalysis, catalytic activity, activation and reactivation, inhibitors, promotors, poisons, and carriers are dealt with in a comprehensive manner.

After the general introduction there follows a very extensive tabular survey of the catalysts appropriate to various types of reaction : inorganic syntheses (*e.g.*, ammonia), organic syntheses (*e.g.*, methanol, and its homologues, aldehydes, acids, ketones, amines, and nitriles), synthetic processes of industrial importance (*e.g.*, lubricants from simple olefines, anthraquinone, esters, and ethers).

A variety of reactions involving catalysis is next summarized. Hydration (*e.g.*, of ethylene) ; dehydration (*e.g.*, of alcohols, glycols, acids, aldehydes, and ketones) ; reduction (*e.g.*, of carbon oxides) ; hydrogenation (*e.g.*, of di*iso*butylene, aromatic hydrocarbons, nitro-derivatives, and fatty oils) ; destructive hydrogenation of coal, tar-oils, and petroleum fractions ; dehydrogenation (*e.g.*, of paraffins, *cyclo*-paraffins, alcohols) ; halogenation (*e.g.*, chlorination of paraffins, unsaturated and aromatic hydrocarbons, acids, alcohols, and ethers) ; alkanation ; condensation ; the application of boron halides and aluminium chloride and phosphates to the condensation of *e.g.*, ethylene with other hydrocarbons, the condensation of cracked benzine with olefines, of alcohols with olefines, of acetylene to vinyl esters, of acetylene to acetaldehyde, and of olefines with aromatic hydrocarbons ; polymerization, covering the building up of complexes, from a large number of unsaturated hydrocarbons, the ketenes, mono- and di-olefines, styrene, vinyl compounds, and the like, and finally catalytic isomerization and cyclization.

Naturally of special interest to members of the Institute of Petroleum is the chapter entitled " Catalysis in the Petroleum Industry."

At the moment the chief concern of the oil industry lies in the production of high-octane fuel for the road and the air, together with the specialized development of high-efficiency lubricants, but, without doubt, in the future individual synthetic entities—" chemical bricks "—will more and more come into the picture. Benzene and its homologues mono- and di-olefines, acetylene, and the like, utilized in the manufacture of explosives, plastics, resins, and solvents, will assume great importance. The incidence of cracking has led to the doubling of the motor-spirit yield from crude, and the annual 400,000,000,000 cu. ft. of cracked gas will eventually be pressed into the service of the new synthetic chemistry of petroleum. Even now, on the very threshold of this startling innovation, can be seen the appearance in commercial quantities of alcohols, glycols, ether, esters, ketones, amines, chloro- and nitro-derivatives, aldehydes, lubricants, resins, and rubber.

The first section in this well-written and inspiring chapter is concerned with the production of high-duty motor spirits.

Pyrolysis, catalytic and acid polymerization, hydrogenation, alkanation, isomerization, catalytic cracking and reforming, dehydrogenation are all dealt with authentically and at considerable length.

There follows a description of the various processes concerned with the hydrogenation of coal, tars, carbon monoxide, and oil. The whole range of these syntheses is clearly set out in two very useful tables on pp. 1048, 1049. Leading on from gasoline there is developed the treatment of individual hydrocarbons and their products. Amongst these are described catalytic cyclization and aromatization; polymer lubricants from (*e.g.*, *iso*butylene); resins and plastics from acetylene and ethylene and other olefines, butadiene, phenols, styrene, vinyl, and acrylic compounds.

Naturally synthetic rubber takes an important place in these developments. Starting-out materials, such as butadiene, isoprene, dimethyl butadiene, chloroprene, styrene, and acrylic nitrile are indicated and mention is made of the Buna rubbers, Perbunan, Neoprene, Koroseal, Thiokol, and Vistanex.

Again, useful tables are given (pp. 1062, 1063) illustrating the derivatives of aromatics, resins (phenolic, thermoplastic, and vinyl), and artificial rubbers.

A short section on anti-oxidants and catalytic refining processes such as the Gray clay treating plant, desulphurization over bauxite, and sweetening by lead and copper compounds, completes the book.

There is an admirable subject and author index extending over forty-one pages. The volume is admirably printed and illustrated. It is unnecessary to add that it should and doubtless will find a place in every laboratory of industries in which catalysis is employed as well as being a valuable reference book for the general chemical practitioner.

A. E. Dunstan.

INSTITUTE NOTES.

OCTOBER, 1941.

Roll of Honour.

The Council deeply regrets to have to record the loss of the following member, who has made the supreme sacrifice whilst serving in His Majesty's Forces :—

Flight-Lieutenant G. L. HOLLOWAY, R.A.F.
(Associate Member)
Killed on active service, June 22nd, 1941.

PRISONER OF WAR.

Lieut. R. H. S. HAYDON (Associate Member) has been reported as Prisoner of War in Germany.

AWARDS.

Flying-Officer R. A. CHISHOLM, R.A.F. (Student) has been awarded the Distinguished Flying Cross for destroying two Heinkel 111's on a night in March, 1941, and for showing the greatest keenness and determination in seeking and destroying the enemy.

MEMBERS SERVING WITH H.M. FORCES

The Institute has received notification of the following members serving with H.M. Forces. This list is additional to the lists published in the Institute Notes of October and December, 1940.

J. G. Annan, Jr., Capt., R.A.S.C.
G. K. Beaumont, R.A.F.
D. H. Bond, Lt.-Col., R.A.S.C.
J. R. T. Bradford, Wing-Cdr., R.A.F.
A. B. Cameron, Lieut., R.E.
P. R. Clark, Major, R.A.O.C.
A. C. Deller, R.A.F.
A. V. Driver, R.A.
B. Gluckman, Lieut., S.A. Army.
E. G. Hannah, Pilot Officer, R.A.F.
J. L. Harris, R.A.F.
G. E. Heish, R.A.
D. G. Hitt, Capt., R.E.
L. J. L. Jeffreys, R.A.C.
J. M. Leitch, Capt., R.A.S.C.
D. S. Paul, Major, R.A.S.C.
W. G. Peacock, R.A.S.C.
S. A. G. Priestley, R.A.A.F.
T. G. Robson, R.E.
D. L. R. Smith, Flying Officer, R.A.F.
E. N. Tiratsoo, R.A.F.
J. de Waele, Lieut., R.E.

INSTITUTE SCHOLARSHIP.

An Institute Scholarship, of the value of £40, has been awarded to E. B. Turner, Stud.Inst.Pet. (Royal School of Mines).

STUDENT'S MEDAL AND PRIZE.

The Student's Medal and Prize for the Session 1940–41 has been awarded to J. G. Perks (Birmingham University) for an essay on "Deep Well Surveying." F. W. Longbottom (Birmingham University) was awarded a prize for an essay on "High Octane Fuels."

Ten essays were submitted for the Prize, and the referees reported that all of them reached a very high standard.

BURGESS PRIZE.

A Burgess Prize to the value of £5 has been divided between A. K. Davis and V. D. Daft, both of Birmingham University.

ANNUAL REVIEWS OF PETROLEUM TECHNOLOGY, VOL. 6.

A copy of Vol. 6 of the *Annual Reviews of Petroleum Technology* is posted with this *Journal* to all members of the Institute entitled to receive the *Journal*, and to current *Journal* subscribers. The *Journal* was not issued in August and September, 1941. Monthly publication is resumed with the present issue.

A limited number of Vols. 3 to 5 of the *Annual Reviews* are available at the Institute offices (price 5*s.* 6*d.* per vol. to members). Vols. 1 and 2 of the Annual Reviews are now out of stock.

NEW MEMBERS.

The following elections have been made by the Council in accordance with the By-Laws, Sect. IV, para. 7.

Elections are subject to confirmation in accordance with the By-Laws, Sect. IV, paras. 9 and 10.

As Fellow.

Bond, Douglas Harry	England.

Transferred to Fellow.

Lessing, Rudolph	England.

As Member.

Kronstein, Joseph Alexander	England.
Leitch, James Morton	,,

Transferred to Associate Member.

Tiratsoo, Eric Neshan	England.

As Students.

Baskin, Leon A.	England.
Frost, James	,,
Garner-Richards, Cecil Pooley	,,
Rankin, Philip Alexander	,,
Wheeler, Roy	,,

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.

Bailey, Darrel Guy Fallen, Student, R.S.M. (*S. E. Coomber ; G. D. Hobson.*)

Brown, Thomas, Ph.D., Research Chemist, Trinidad Leaseholds, Ltd. (*A. W. Nash ; T. G. Hunter.*) (*Application for transfer from Student Member.*)

Cantor, Joseph, B.Sc., A.R.C.S., A.I.C., Chemist, Shell Refining & Marketing Co. (*J. S. Jackson ; J. Parrish.*)

Cowles, Richard Edwin, Analytical Chemist, N.S.W. Govt. Railways. (*O. Colverd ; S. A. G. Priestley.*)

Dartnall, Herbert James Ambrose, A.I.C., Scientific Officer, Ministry of Aircraft Production. (*J. S. Jackson ; A. M. E. Beaven.*)

Don, John Smart Aikman, C.A. (Edin.), Accountant, Lobitos Oilfields, Ltd. (*J. S. Parker ; D. M. Glendinning.*)

Forrest, Archibald John, Major, R.A., Director, British Viscoleum Fuels, Ltd., Liverpool. (*J. S. Parker ; D. M. Glendinning.*)

Gibson, Harold, Chemical Engineer, Foster Wheeler, Ltd. (*R. K. Fischer ; A. S. Bridgewater.*)

Laidlaw, Ian Grant, Chief Drilling Engineer, Trinidad Leaseholds, Ltd. (*F. H. L. Tindall ; H. C. H. Thomas.*)

Linnard, Horace, Chief Laboratory Assistant, Texas Oil Co., Ltd. (*N. L. Anfilogoff ; R. F. Hurt.*)

Morgan, Ralph Victor, Technical Assistant Aviation Dept. Asiatic Petroleum Co. (*E. LeQ. Herbert ; D. A. Yonge.*)

Morten, Denis, Chemical Engineer, Shell Refining & Marketing Co. (*J. S. Jackson ; J. Parrish.*)

Morton, Frank, Ph.D., F.I.C., Research Chemist, Trinidad Leaseholds, Ltd. (*A. G. V. Berry ; B. G. Banks.*)

Sheppard, George, D.Sc., F.R.G.S., Survey Directorate, G.H.Q., Home Forces. (*C. Dalley ; R. R. Tweed.*)

Shiels, Leo Osmonde, Representative, Caltex (Aust.), Ltd. (*A. R. Code ; H. B. Borwick.*)

Stibbs, Edward George, Inspection Engineer, Trinidad Leaseholds, Ltd. (*J. W. Hardy ; H. C. H. Thomas.*) (*Application for transfer from Student Member.*)

de Verteuil, Louis Rene, Assistant Gas Engineer, Apex (Trinidad) Oilfields, Ltd. (*A. H. Richard ; G. H. Scott.*) (*Application for transfer from Student Member.*)

ARTHUR W. EASTLAKE,
Honorary Secretary.

*

BRANCH NOTES.

TRINIDAD BRANCH.

Dr. Gustav Egloff addressed a well-attended meeting of the Trinidad Branch at Point-à-Pierre, Trinidad, on May 8th, 1941.

After referring to previous occasions on which he had addressed the Institute's Branches in Rumania and elsewhere, Dr. Egloff dealt at length with petroleum's contribution to the war effort of the Allies and U.S.A. He first contrasted the position in Germany and German-occupied countries, where various methods of freeing gasoline for military service were enforced. According to his latest information, 14,000 motor vehicles had been converted to wood-burning, and the Germans had planned to produce 40,000 wood-burning vehicles. Compressed gases in steel cylinders were also being distributed through filling stations.

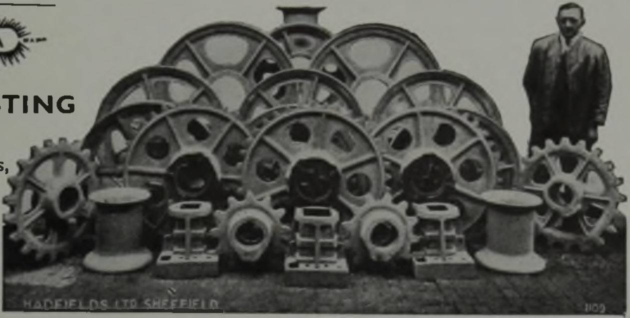
Referring to aeroplane developments Dr. Egloff stated that one model had just come off the lines in U.S.A. with a cruising range of 8000 miles and a bomb load of 18 tons. Although U.S.A. was then producing 35,000 barrels of 100-octane gasoline per day, research was rapidly proceeding to produce new hydrocarbons with 50 per cent. greater power output than 100-octane fuel. Petroleum would also supplement the supplies of toluene from coal carbonization. Toluene supplied could, in fact, easily be increased ten-fold, if the need were there. Phenols and formaldehyde from petroleum were also providing the raw materials for plastics used in aeroplane construction. The petroleum industry had no bottle-necks, and materials for peace and war-time requirements were available in any quantity.

" Our aim," concluded Dr. Egloff, " is one of unity and co-operation ; so that those who come after us may enjoy the privileges of freedom that we have enjoyed up to the present time under the democratic way of life."

" DRILLING MUD : ITS MANUFACTURE AND TESTING." By P. Evans and A. Reid. (1st edn., 1936 ; reprinted January, 1940 ; 263 pp.)

The Institute has now received a further consignment of this book, reprinted by the Mining, Geological, and Metallurgical Institute of India.

Copies are obtainable from the Birmingham office at 21*s*., or $4.25 per copy (including postage).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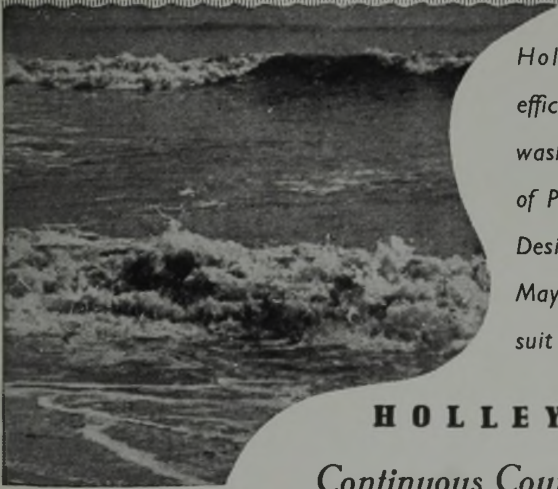

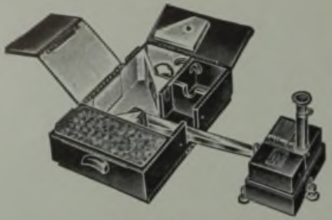

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Institute of Petroleum	vi, x, xii
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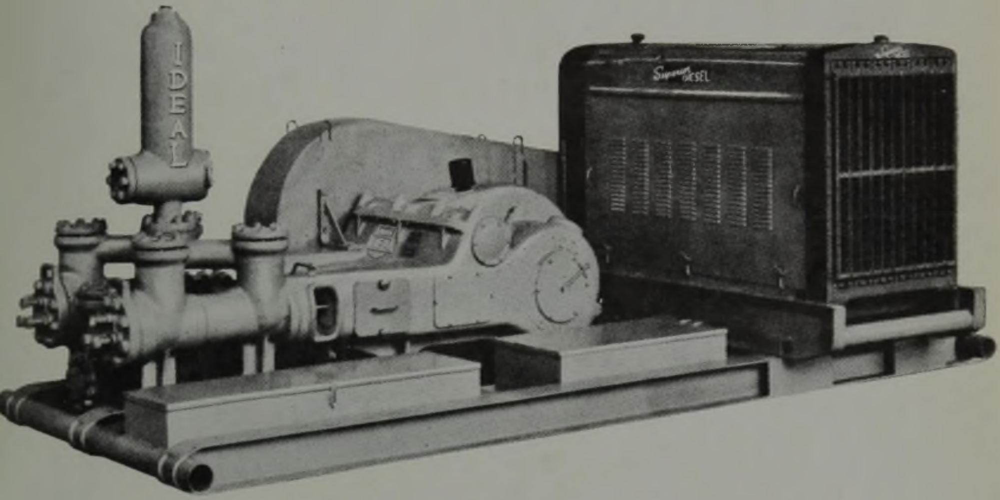
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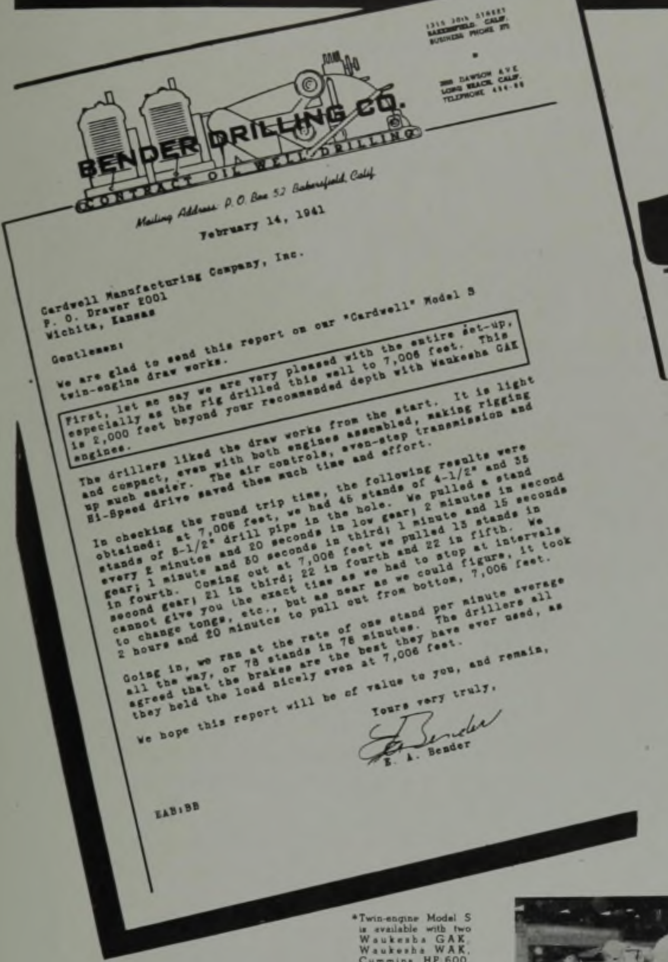

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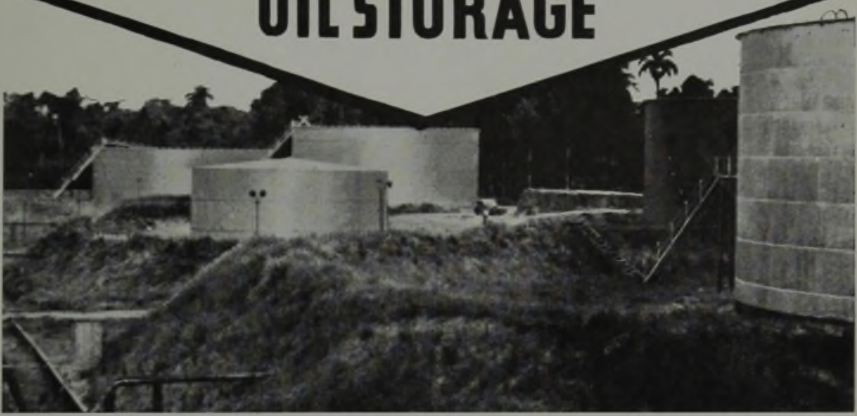


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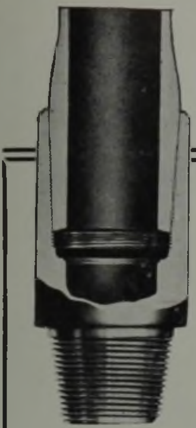

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