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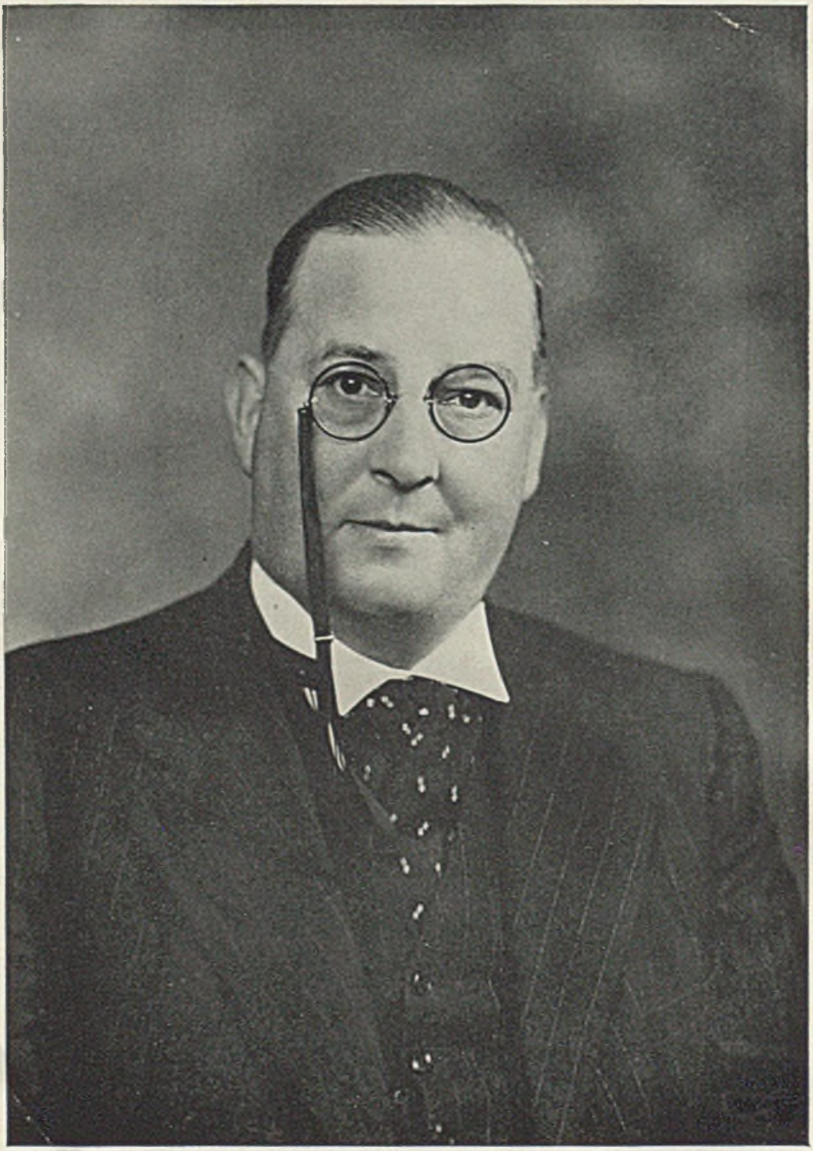

PROF. A. W. NASH, M.Sc.
President, 1939–1941.

[*Frontispiece.*

Vol. 26. No. 195. January 1940.

THE STATIC FRICTION OF LUBRICATED SURFACES *

By A. Fogg, M.Sc., and S. A. Hunwicks, B.Sc. (Eng.).

Introduction.

The primary object of carrying out this investigation was to obtain information on " boundary " friction and the " boundary lubricating " properties or " oiliness " of various substances.

The two chief properties of fluids which determine their lubricating value are viscosity and some other property, independent of viscosity, usually known as " oiliness." Under static conditions any effect due to viscosity must necessarily be absent, since, by definition, viscosity is that property of a fluid which determines the resistance of the relative sliding motion of adjacent layers. The only resistance to the commencement of motion, therefore, is that due to the attractive forces between the solid surfaces as modified by the layer of lubricant between them. The effectiveness of this layer, known as the boundary layer, in reducing the attractive forces becomes a measure of the boundary lubricating properties of the lubricant which must be closely associated with " oiliness."

By means, therefore, of measurements of the resistance to the commencement of motion, *i.e.*, the static friction, a direct measurement of a property associated with oiliness can be made.

The exact mechanism of the boundary layer when motion has begun—for instance, whether it is still due entirely to the attractive forces of the surfaces, or perhaps to bending of the molecules in the boundary layer—is not known, but there is no doubt that the value of the static friction has a direct bearing on the quality of a lubricant.

As a further object, it was hoped that, if the method of test proved successful, it would provide a reliable and simple means of making tests for boundary lubricating properties of oils on a more exact basis than has been possible heretofore.

At the present time the only satisfactory method of test for the quality of a lubricant is a prolonged test under working conditions which is generally fairly costly. In many applications it is known that viscosity is a factor of importance and a flat viscosity–temperature curve is desirable. In some cases chemical stability is important, but in practically all cases, in varying degrees, the property of oiliness plays a vital part.

It appears, therefore, that in order to assess the value of a substance as a lubricant, it is necessary to consider, at least, the following three factors :—

(1) Viscosity–temperature and possibly viscosity–pressure relationships.
(2) Chemical stability.
(3) Lubricating value under boundary conditions.

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* Paper received 22nd June, 1939.

The present investigation deals only with the last of these, and it must be realized, therefore, that if, as a result of this investigation, a substance is found to have good "oiliness" properties, it does not necessarily follow that this substance is a good lubricant for all conditions.

APPARATUS.

Probably the most familiar apparatus used in static friction measurements, and one which is in use in the commercial testing of lubricants, is the Deeley machine. This machine was designed many years ago for the study of "oiliness" characteristics and the variations in frictional resistance produced by different combinations of metallic surfaces. One of these machines was available when the present investigation was begun, and it was decided to explore its possibilities for the work. Many experiments had been carried out at the N.P.L. with this machine by different experimenters, but the machine had never been adopted as a regular testing machine because of the lack of consistency in results obtained under apparently identical conditions. For instance, with given surfaces, lubricant, and a fixed load, consecutive measurements of coefficient of friction have been found to vary by as much as 200 per cent. It is well known that an adsorbed boundary layer adheres strongly to a metal surface, and great difficulty is experienced in removing it. In the operation of the Deeley machine there has always been some uncertainty as to whether or not the adsorbed layers have been removed and the surfaces rendered clean before proceeding to another lubricant.

The arrangement of contact of the two opposing friction surfaces was also considered as a possible explanation of the inconsistency of the results obtained. The friction surfaces consist of three flat pegs, equally spaced on a circle on the underside of a carriage, resting on a disc. With this arrangement it is necessary, for similarity of contact of each of the pegs with the disc, that the flat bearing surfaces of the pegs all lie in one plane, a condition which can never be achieved exactly in practice. (It is not easy to see, however, why variations from the uniplanar condition should influence appreciably observations in the static boundary condition.)

As a result of these considerations, however, it was decided, firstly, to replace the three flat pegs by three balls, so that the condition of each contact should be the same and, because of the high intensity of loading at the contact areas of balls, the separating layer of lubricant should be reduced to the limiting molecular layer, and secondly, to endeavour to develop a technique of cleaning the surfaces which would at least ensure that a standard condition of cleanness is arrived at before a set of measurements is made with any lubricant.

A description of the apparatus with the above modification is as follows. It consists of the two opposing surfaces, one, a disc about 4 inches diameter, and the other, three $\frac{1}{2}$-inch-diameter balls equally spaced round a circle 3 inches diameter on the underside of a circular carriage. (The material used for the friction surfaces throughout this investigation was hard steel.)

The carriage engages with a torque measuring device consisting of a coiled spring with indicating mechanism. The pressure between the surfaces can be varied by loading the carriage with weights. The disc, *i.e.*, the lower friction surface, is carried in a bath which contains the lubricant under test, and a gas ring is provided under the bath for heating the oil, the temperature being measured by a thermocouple in the oil bath.

The machine is operated by slowly rotating the disc by means of an electric motor and gearing, the motor being mounted separately from the machine so as to reduce vibration to a minimum. The frictional resistance between the surfaces causes rotation of the carriage against the action of the spring, and the disc is rotated until slipping of the surfaces occurs, when a pawl-and-ratchet mechanism prevents the spring from unwinding. The torque produced by the spring on the carriage at slip is thus equal to the friction torque and, as the total load is known, the coefficient of friction is easily obtained.

CLEANING THE SURFACES.

Most of the lack of agreement between the results of static friction measurements of various investigators can probably be attributed to failure to remove all traces of contamination from the metal surfaces before introducing another lubricant. The usual method adopted has been to use a solvent, and many such substances have been used with varying degrees of success. It appears, however, that this method is fundamentally unsound, and it is submitted that such a procedure can, at best, only result in the contaminating layers being replaced by an adsorbed layer of the solvent, or some of its more active constituents. Extremely volatile solvents might be expected to give the nearest approach to absolute cleanness, but, if the generally accepted conception of surface forces applies, it would appear that even with such solvents, attachment between surface molecules and solvent molecules would take place.

In view of these considerations it was decided to make a comparison of the static friction of hard steel surfaces when "cleaned" by various solvents or cleaning solutions, and when treated in such a manner that an actual layer of material was removed each time from the surfaces.

For this latter purpose it was decided to rub the friction surfaces with the finest grade of emery paper available "0000 blue back"—first removing surplus oil by means of trichlorethylene vapour—after the surfaces had been contaminated with various substances, and to determine the consistency of the results obtained after this treatment. The disc, *i.e.*, the lower friction surface, was rubbed on a sheet of the abrasive paper placed on a surface plate in order to maintain a flat surface. Measurements of the friction were made as quickly as possible after this treatment, and without handling the surfaces. In all, several hundreds of such observations were made, and the coefficient of friction was always between 0·56 and 0·60, with a mean value of 0·58. On a number of occasions the surfaces were left in the machine and, without contamination except from the atmosphere, the coefficient of friction, μ, measured at short intervals of time up to 1 hour. At the end of this period the value of μ was still above 0·50, showing a very slow rate of contamination.

The first solvent tried was trichlorethylene, both in liquid and vapour form; this substance is marketed commercially as a degreasing agent, and a vapour degreasing plant was used for the vapour-cleaning process. With liquid cleaning the value of μ was 0·33, and with vapour cleaning 0·45.

These values, and those following for other solvents, are the mean of several obtained after cleaning surfaces contaminated with a number of oils chosen at random.

The second solvent used was industrial alcohol (95 per cent.). The mean value of μ obtained was 0·43.

The cleaning process used by Hardy * in certain static friction measurements was then used. This process consisted of removing gross impurities by ordinary benzene or alcohol, rubbing the surfaces on a piece of wet felt sprinkled with chromium sesquioxide, rinsing under the tap to remove finer particles of chromium sesquioxide, drying with clean filter paper, and finally immersing in absolute alcohol just heated to boiling point; whilst still hot the surfaces were removed with clean tongs, rinsed twice with absolute alcohol and dried by draining. Before using this process the surfaces were covered with a light machine oil. After cleaning the mean value of μ was 0·49.

A further cleaning process used by Tomlinson † consisting of rubbing the surfaces, after the removal of surplus oil, with the finest quality cotton wool and a mixture consisting of 8 parts absolute alcohol, 2 parts ether, and 1 part ammonia was next used. The value of μ obtained was rather variable—a new position being used for each observation—ranging from 0·40 to 0·55, with a mean of 0·48.

None of these cleaning methods therefore appears to be as efficacious as the abrasive method. The latter may not, of course, produce a state of absolute cleanness; but since it gives a condition of higher and more consistent friction than any of the other methods, it is obviously a more desirable method to apply.

It might be argued that the abrasive method of cleaning produces a roughening of the surfaces, and thus gives a somewhat artificial value of μ. A number of further observations which were made on the above solvents appear to contradict this, and give further support to the submission that any solvent-cleaning method will leave an adsorbed layer on the surface. Having obtained a number of consistent values of μ of the order of 0·58 for the steel surfaces cleaned by the abrasive method, the above solvents, namely, trichlorethylene, alcohol, and the alcohol–ether–ammonia mixture, were each in turn placed on the clean surfaces, and the coefficient of friction measured. With liquid trichlorethylene the value of μ was 0·33, with alcohol it was 0·43, and with the alcohol–ether–ammonia mixture it was also 0·43; as compared with 0·33, 0·43, and 0·48 for each of these, respectively, when used as cleaning solvents.

In other words, the friction of the surfaces when flooded with the above substances is the same as when the surfaces are cleaned with these substances and the surplus is removed.

The amount of rubbing to produce the clean condition ($\mu = 0{\cdot}58$) was generally very small, except in those cases where there had been obvious chemical action between the lubricant and the surfaces.

An interesting experiment was made to determine the extent of contamination due merely to handling the surfaces after cleaning to the

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* Lubrication Research, Technical Paper No. 1, 2nd Edition, Appendix, p. 52.

† "The Rusting of Steel Surfaces in Contact," G. A. Tomlinson, *Proc. Roy. Soc.*, A, Vol. 115, 1927.

"$\mu = 0{\cdot}58$ condition." The friction disc and the balls were lightly rubbed with the fingers, the hands being in a normal state of cleanliness and having had no contact with oil or grease since washing. The coefficient of friction, measured immediately afterwards, was 0·10. This result demonstrates the ease with which surfaces become contaminated and the enormous effect on the coefficient of friction. As will be seen later, the value of μ is of the same order as was obtained for animal and vegetable oils, and presumably the contamination resulted in an adsorbed layer of similar fat or oil from the human body. When an oil was applied to the clean surfaces, an additional precaution was taken against contamination from any other source. After the friction of the clean surfaces had been measured, they were rubbed with a mixture of emery and the oil to be tested, wiped with a piece of clean dry "Selvyt" to remove loose abrasive particles, and then finally immersed in the oil. This assured that the oil was present on the surface, available for adsorption as soon as the abrasion was finished.*

Effect of Size of Balls.

A number of observations were made at various loads with $\frac{1}{8}$-inch and $\frac{1}{2}$-inch-diameter steel balls using oleic acid as lubricant. Measurements of friction were made at temperatures up to 100° C. with both sets of balls, but there was no appreciable variation with either set at any of the loads or temperatures, the value of the coefficient of friction being in all cases between 0·08 and 0·09.

It was decided to adopt the $\frac{1}{2}$-inch-diameter size for all the work included in this report, but it is intended at a later stage to investigate the effect of curvature more fully.

Temperature and Load.

In all cases where it was safe to raise the temperature of the lubricant without danger of fire or explosion, observations of friction were made up to about 100° C. with temperature rising and falling.

With regard to load, preliminary observations were made with total loads on the carriage (including the weight of the carriage) ranging from 0·738 lb. to 5·904 lb., in order to determine the effect of variations in load. No appreciable variation with load over this range was obtained at any temperature; this independence of coefficient of friction with load is usually taken as evidence of complete boundary conditions. For all subsequent work the load was fixed at 3·690 lb., this being a convenient load for ease of operation of the machine.

The load of 3·690 lb. represents, according to Hertz's theory of elastic

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* A similar method was used by S. Livingston Smith and E. Glaister in experiments on the original form of Deeley machine. In these experiments the lower surface, which was a cast-iron disc, was prepared by washing in benzol and then spraying with hot water to remove all traces of oil. After drying it was lapped with flour carborundum and the oil to be used. (See "The Effect of Use on the Properties of Motor Oils," S. Livingston Smith and E. Glaister. The *Engineer*, 1st May, 1931, p. 476.)

deformation, a mean pressure between the balls and ring of 30·3 tons/sq. in. and a maximum pressure of 45·5 tons/sq. in.

Substances used for Lubricating the Surfaces.

The substances selected were, for the most part, recognized lubricants, but a number of common liquids were also included. A list of the substances used, divided into classes, is given below.

(1) Straight lubricating oils, ranging from fatty oils to highly refined mineral oils. At each end of this range oleic acid and B.P. paraffin were included, the former being typical of the active constituent of fatty oils and the latter as representative of the inactive constituent of mineral oils and the result of ultra-refining.
(2) Extreme-pressure lubricating oils.
(3) Graphited oil and compounded oil.
(4) Common liquids.

When the observations had been completed, no correlation was observable between viscosity characteristics and the friction results. The better known of the substances gave friction characteristics in an order similar to that generally accepted for the " oiliness " value of these substances, for example, all fatty oils were superior to all mineral oils, irrespective of viscosity.

A series of experiments was then carried out to determine the relationship between molecular weight and coefficient of friction. These results proved extremely interesting, and form the subject of a separate Paper.*

Results.

Fatty Oils.

The following vegetable and animal oils were chosen as being representative of the more common fatty oils in use :—

Vegetable Oils.—Castor, rape, olive, coconut.
Animal Oils.—Sperm, pale whale, neatsfoot, lard.

The friction of the steel surfaces when lubricated with each of these was measured at temperatures up to 100° C., the usual cleaning operation being performed at each change over.

Castor Oil.

The coefficient of friction (μ) varied only slightly with temperature, showing a tendency to rise as the temperature increased. At 20° C. $\mu = 0{\cdot}09_5$ and at 100° C. $\mu = 0{\cdot}10_5$. There was no appreciable difference with the temperature rising or falling, and thus no permanent change in the friction as a result of heating in air to 100° C.

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* " A Note on the Mechanism of Boundary Lubrication suggested by the Static Friction of Esters," by A. Fogg, *Proc. Phys. Soc. Lond.*, 1940, Vol. 52.

Rape Oil.

There was no definite variation in friction with temperature, the mean value of μ being about $0{\cdot}10_5$. During the tests with this oil there was evidence of chemical action between the acid and the brass parts of the machine, indicated by a change in the colour of the oil to olive green, and a difference in colour of the brass oil bath above and below oil level.

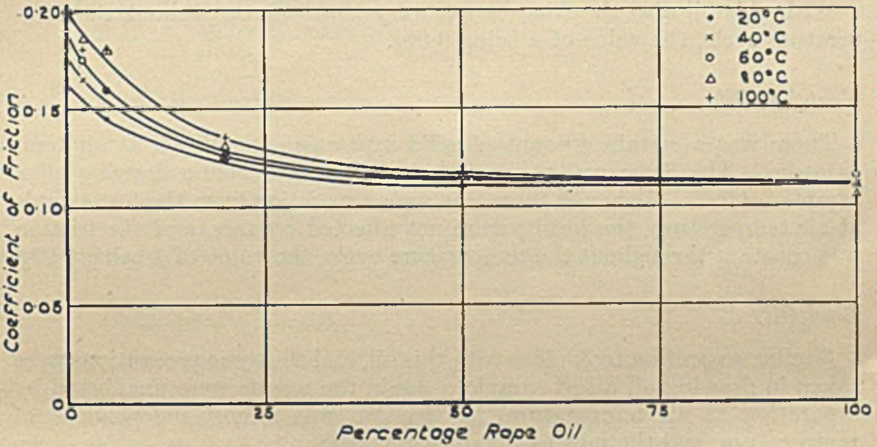

FIG. 1.

EFFECT OF ADDITIONS OF RAPE OIL TO MINERAL OIL.

Olive Oil.

The variation of friction with temperature was almost negligible, the mean value of μ over the temperature range 20–100° C. being $0{\cdot}10_5$.

Coconut Oil.

The coconut oil was a white, greasy solid at air temperature. A small quantity was melted and poured into the oil bath and over the friction surfaces. The oil was allowed to cool before making observations, the first test being made at 20° C., the oil then being solid. The mean value of four observations of coefficient of friction was 0·18, the carriage being moved to a fresh place each time. The temperature was then raised to 100° C. and the oil then allowed to cool, observations being made at intervals of approximately 20° C. From 40° C. to 100° C. and down again to 40° C., μ was very constant, its value being 0·08. It was necessary to wait overnight before the temperature had cooled to 20° C., and the first observation then gave $\mu = 0{\cdot}26$. Without moving to a fresh place, four observations immediately following all gave $\mu = 0{\cdot}08$. The high values at 20° C. are presumably due to the balls and ring becoming " welded " with solid fat; once this " weld " has been broken, the friction is low and independent of the physical state of the oil.

The boundary lubricating properties of this oil, therefore, appear to be the best of the vegetable oils tested.

Sperm Oil.

There was no variation of friction with temperature up to 100° C. either rising or falling, the value of μ being 0·10. There was therefore no effect on the friction as a result of heating in air.

Pale Whale Oil.

With this oil also the friction was very constant throughout the temperature cycle, the value of μ being $0{\cdot}09_5$.

Neatsfoot Oil.

There was a certain amount of solid separation in this oil at air temperature. The drum was warmed and shaken well before drawing off a sample for test. Although there was some separation from the test sample at air temperature, the results were not affected by this, and the friction was constant throughout the temperature cycle, the value of μ being $0{\cdot}09_5$.

Lard Oil.

Similar separation took place with this oil, and the same precautions were taken in drawing off a test sample. Again the results were unaffected by separation at air temperature, the friction was almost independent of temperature, and the mean value of μ was $0{\cdot}08_5$.

This group of oils may be taken as representative of all fatty oils, and it is interesting to note that the variation of friction, due to changes of oils within the group or to temperature, is quite small, the extreme values of the coefficient of friction being 0·08 and $0{\cdot}10_5$. A satisfactory feature of these measurements is that repetition was extremely good, and although mean values have been given, the departure of any one observation from the mean was small (about ± 0·01), being less than is usually encountered in friction measurements in any state except that of complete fluid film lubrication.

These two features, constant friction and consistency, are to be expected, since fatty oils are to a large extent composed of chemical compounds of similar constitution; the surfaces thus become covered with a layer which is, broadly speaking, homogeneous, and whatever relative position is taken up by the opposing surfaces the separating layer is always the same.

Straight Mineral Oils.

In order to cover briefly the normal range of viscosities of commercial straight mineral oils, the following three oils were chosen :—

Oil A—a light machine oil.
Oil B—a motor-car engine oil.
Oil C—a thick gear oil.

The above motor-car engine oil was a sample from a conventionally (acid) refined bulk supply, and a comparison was made with the same brand of oil (Oil D) refined by the solvent extraction process.

A synthetic oil, produced by the Fischer process at the Fuel Research Station, and the following commercial motor-car engine oils were also included, being samples remaining from supplies which had been submitted for other tests :—

Oil E } —extra light motor oils.
Oil F }
Oil G—a heavy motor oil.
Oil H—a medium motor oil.

Oil A. Light Machine Oil.

There was much more variation in the results obtained under constant conditions with this oil than with any of the fatty oils, and a change in friction with temperature.

The mean value of μ at 20° C. was 0·16, and at 100° C. 0·19, the increase being spread gradually over the whole temperature range.

Oil B. Motor-car Engine Oil.

This sample of oil was drawn from a supply refined by the conventional or acid process.

There was a gradual increase in the value of μ with temperature from 0·13 at 20° C. to 0·15 at 100° C., the friction falling to its original value when the oil was cooled to air temperature. Repetition of results was good at the lower temperatures, but there was a variation of about $\pm$ 0·02 in the value of μ at higher temperatures.

Oil C. Thick Gear Oil.

This oil was highly viscous, being in a " semi-solid " condition at air temperature.

The friction was almost identical with that of the previous oil, the value of μ ranging from $0{\cdot}12_5$ at 20° C. to 0·15 at 100° C. Repetition of results again was not so good as with fatty oils.

These results show that, for these three typical mineral oils, there is no definite relation between friction and viscosity. The increase in viscosity from the first to the second is accompanied by a reduction in friction, but the large increase in viscosity from the second to the third does not affect the friction.

To some extent, as viscosity increases molecular size increases and if, as is generally supposed, boundary friction is dependent on molecular length, then an increase in viscosity may, in some cases, cause a reduction in boundary friction. This would account for the reduction in friction as between the first two of these mineral oils.

Another point of interest in these measurements was the greater variation of friction between successive observations under the same conditions than was observed with the fatty oils. This may be due to the fact that mineral oils are composed of a large number of highly complex chemical compounds, some of which are probably adsorbed on different parts of the surfaces; the friction will thus depend on the position of the contacts and whatever layer happens to be there.

Oil D. (Solvent Refined.)

The solvent extraction process results in improvements in viscosity–temperature characteristics and in chemical stability, but there appears to be some doubt as to its value when "oiliness" characteristics have to be considered. There is some reasonable foundation for this doubt, not so much from experimental evidence, but from the fact that solvent extraction is said to remove the more chemically unstable compounds, and it is these compounds, generally, which are the more "active" ones from a boundary lubrication point of view. The results of static friction tests indicate that the "oiliness" value is reduced by solvent extraction.

This particular sample of oil gave an increase in friction with temperature as with other mineral oils, but the value of μ ranged from 0·15 at 20° C. to 0·20 at 100° C. as against 0·13 and 0·15, respectively, for the corresponding conventionally refined oil; the results again were less consistent than with fatty oils.

It must be pointed out, however, that a definite case is not made out against solvent extraction by these results because of the lack of exact knowledge regarding the source and history of the two samples. Opportunity may be taken at this point of directing attention to the difficulty which is constantly arising in lubrication problems—namely, the lack of any means of identifying an oil and the absence of any suitable standards for comparison purposes.

A Synthetic Lubricating Oil.

This oil was produced by the Fischer process at the Fuel Research Station, but the quantity available was insufficient to fill the oil bath of the machine. The friction ring was covered, but it was impossible to make measurements except at air temperature. The friction was rather variable, as with mineral oils, and the value of μ varied between 0·12 and 0·16, with a mean of 0·14.

This result places the oil midway between the oils B and D, one conventionally refined, the other solvent refined. If judged by this test alone, therefore, this synthetic lubricating oil is up to the same standard of "oiliness" as normal motor oils.

Light Motor Oils.

The modern trend in lubrication of internal-combustion engines is towards oils of lower viscosity, the reasons being to decrease the time taken from starting to complete circulation of the oil and to reduce frictional losses in the engine. The latter will be achieved in those parts of an engine where fluid film conditions predominate, provided viscosity does not fall below some limiting value. During some parts of the piston travel, and possibly in other parts of the whole mechanism, however, boundary conditions probably exist, and the "oiliness" value of the lighter oils must therefore be taken into consideration.

Tests were made on oils E and F as being typical of the lighter oils in use.

Oil E.

The friction was almost unaffected by temperature up to 100° C., the mean value of μ over this temperature range being 0·19.

This oil was known to be solvent refined.

Oil F.

This oil behaved almost exactly as Oil E, the mean value of μ being 0·20.

Information regarding the refining process of this oil was not available.

The other two mineral oils tested gave results as follows :—

Oil G. Heavy Motor Oil.

The change of friction with temperature was small, the value of μ being $0{\cdot}19_5$ at 20° C. and $0{\cdot}20_5$ at 100° C.

Oil H. Medium Motor Oil.

There is some doubt about the composition of this oil; it is stated to contain certain inhibitors, and it may also contain a small amount of a vegetable oil. However, since it is used for the same purpose as others in this group, the results have been included here.

There was an increase in the value of μ with temperature from $0{\cdot}17_5$ at 20° C. to $0{\cdot}19_5$ at 100° C.

The results obtained for this group of oils show a fairly wide variation from $\mu = 0{\cdot}12_5$ to $0{\cdot}20_5$, a scale of values sufficiently open to allow the comparative boundary lubricating properties to be fairly easily assessed.

As one of the objects of the investigation was to examine the possibilities of this apparatus as a testing machine, it is obviously desirable that some standard substances should be available as references, and should preferably give results, at each end, at least, of a scale which is large enough to embrace all substances likely to be useful as lubricants.

As a step in this direction it was decided to make measurements with (1) oleic acid, for the lower end of the scale, and (2) B.P. paraffin for the upper end. The reasons for the choice of these two substances have been previously stated on page 6.

Oleic Acid.

The friction observations were very consistent, and independent of temperature, the value of μ under all conditions being 0·08.

This is lower than the value of μ for all other substances examined with the exception of coconut oil, which has the same value.

B.P. Paraffin.

This is not ideal for reference purposes, because it is not a single substance and its composition is unknown and may vary from time to time.

The results obtained were less consistent than with any of the substances so far used. A microscopic examination of the lower friction surface after tests to 100° C. indicated that very small pieces of metal had been torn from the surface. This phenomenon repeated itself after the surfaces had been reconditioned. There was an increase in friction with temperature, and the mean value of μ ranged from 0·18 at 20° C. to 0·22 at 100° C.

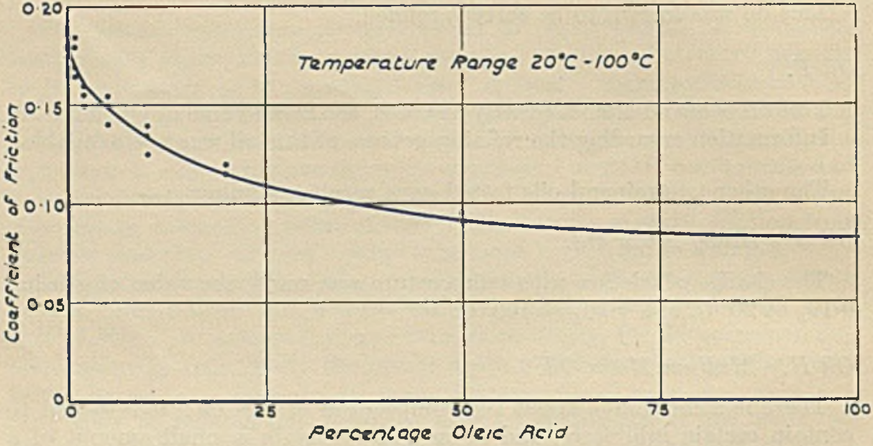

FIG. 2.

EFFECT OF ADDITIONS OF OLEIC ACID TO B.P. PARAFFIN.

These results give B.P. paraffin approximately the same boundary lubricating value as the poorer mineral oils; tearing of the surfaces, however, did not occur with any other of the mineral oils, and it is therefore difficult to understand why this should be exclusive to B.P. paraffin.

Extreme-pressure Lubricants.

The action of extreme-pressure lubricants is not clearly understood, but it is frequently stated that their action is not due to any superior " oiliness " qualities they may possess. Their ability to prevent seizure or breakdown under surprisingly high pressures is generally attributed to a chemical action between the " active " constituents of the lubricant and the metal surfaces, but the nature of the action is still the subject of some controversy.

In view of the controversial nature of the subject, it was considered desirable to measure the static boundary lubricating properties of a group of typical extreme-pressure oils in an attempt to provide additional information on the subject.

Friction measurements were made on each of the following :—

Oil J
Oil K
Oil L
Oil M
Oil N
Oil P
} Commercial E.P. Oils.

JXB oil (an oil obtained for reference purposes for extreme pressure measurements).

All these oils gave very consistent results, repetition being as good, if not better, than with fatty oils. Since the diluent or base oil is probably of mineral origin, and therefore a complex mixture of chemical substances, it appears that this part of the oil plays little or no part in determining the static friction, but that the whole of the surface is covered by the active constituents.

Oil J.

The friction was affected slightly by temperature, the value of μ being 0·11 at 20° C. and 0·12 at 100° C. On cooling, the friction passed through the same values as when the temperature was rising, μ being 0·11 at 20° C., thus showing no permanent effect on the oil by heating to 100° C.

Oil K.

The friction with this oil varied more with temperature, the value of μ rising gradually from 0·09 at 20° C. to $0{\cdot}11_5$ at 100° C. and falling again to its original value on cooling.

Oil L.

There was no variation of friction with temperature, the value of μ remaining at 0·09 from 20° C. to 100° C. with temperature rising and falling.

Oil M.

The friction was independent of temperature up to 100° C. and the value of μ was 0·10.

Oil N.

The friction decreased slightly with increase of temperature from 0·10 at 20° C. to $0{\cdot}08_5$ at 100° C., remaining at the latter value at all temperatures down to 20° C., when the oil was cooled.

Oil P.

The friction was independent of temperature up to 100° C., the value of μ being $0{\cdot}09_5$.

JXB Oil.

There was a small variation of friction with temperature from $0{\cdot}09_5$ at 20° C. to 0·11 at 100° C.

There is remarkably little variation between these oils as regards friction characteristics under static boundary conditions, and as a class they lie between fatty oils and straight mineral oils. They may be regarded, therefore, as having high boundary lubricating properties even up to 100° C., but this cannot be the reason for their extreme pressure properties, since fatty oils, which have higher boundary lubricating properties, have considerably lower extreme-pressure properties.

A short experiment was made to determine whether an extreme-pressure lubricant leaves a surface layer which is, in itself, an effective lubricant.

Clean surfaces were covered with Oil L and left standing overnight to allow ample time for any action which might take place. The following morning the surfaces were degreased in trichlorethylene vapour, which removed all visible oil. The coefficient of friction was then measured at 20° C., and was found to be 0·41, which is of the same order as was obtained by degreasing any contaminated surfaces with trichlorethylene. It appears, therefore, that if any action does take place between an extreme-pressure oil and a metal surface, resulting in a new surface layer, this layer has no separate influence on the friction.

Graphited Oil.

Graphite, in colloidal form, is widely recommended as an additive to mineral oils for the lubrication of many mechanisms. It is fairly obvious that under fluid-film conditions its presence can have no effect, except in so far as it may cause small changes in viscosity. It is, however, claimed that it forms on the metal surface a new surface known as a " graphoid " layer, and that this layer not only reduces the possibility of seizure should lubrication fail, but that it also causes a reduction in friction. This can only mean a reduction in friction under boundary conditions. Tests on the static friction machine would appear, therefore, to be a suitable means of verifying this.

Accordingly, the surfaces were cleaned and covered with Oil D (solvent refined) containing colloidal graphite. Friction measurements were begun immediately, and the first determination at 20° C. gave the same value of μ as for the untreated oil—namely, 0·15. As the temperature was raised, μ increased to 0·18 at 60° C., still behaving as the untreated oil. With further increase of temperature the friction began to fall, the value of μ at 100° C. being 0·16. The oil was then allowed to cool, and the friction gradually fell, the value of μ at 20° C. being $0{\cdot}12_5$, showing a substantial reduction on the value at the start of the temperature cycle. The machine was left untouched overnight, and next day friction measurements were made over the same temperature cycle. At 20° C. the value of μ was $0{\cdot}12_5$, rising to $0{\cdot}14_5$ at 100° C., and falling again to $0{\cdot}12_5$ at 20° C. A repeat of the whole of these measurements gave the same results.

It appears, therefore, that an appreciable reduction in friction is obtained by the addition of colloidal graphite to this mineral oil, the values of μ for the treated and untreated oil being, respectively, $0{\cdot}12_5$ to $0{\cdot}14_5$ and 0·15 to 0·20 over the temperature range 20° C. to 100° C. [The improvement obtained is approximately equal to the difference between the results for Oil B (conventionally refined) and Oil D (solvent refined).]

These results also show that the improvement is not immediate, and that an interval of time (or possibly an increase in temperature) is necessary for the changed conditions to be established.

In order to determine whether the graphited oil had any effect on the surfaces which would persist after removal of the oil, the surfaces were flushed well with benzene to remove all surplus oil.

Measurement of the friction then gave a value of μ of $0{\cdot}12_5$ at 20° C.—*i.e.*, removal of the surplus oil did not affect the friction, indicating that graphite in some form had been left behind on the surfaces. [It is improbable that an effective adsorbed layer of oil was left behind, which might account for low friction, because flushing of the surfaces with benzene when they were covered with untreated oil gave a considerably higher value of μ. See results for benzene given later.]

The surfaces were then covered again, with untreated oil, the value of μ being $0{\cdot}12_5$ at 20° C., which shows that after using graphited oil, the friction of the surfaces remains at the low value obtained with the graphited oil when untreated oil is used afterwards. No attempt was made to determine the duration of this effect.

Compounded Oil.

Rape oil, in various proportions, is commonly used for compounding with mineral oils in order to improve the "oiliness" qualities of the latter. Generally, comparatively small proportions, of the order of 5 per cent., of rape oil are added, and it is generally thought that little, if any, further improvement would be obtained by exceeding this amount. In order to check this belief and the general effect of compounding, observations were made on mixtures of varying proportions of rape oil and the solvent-refined mineral oil, Oil D. The latter was chosen as being representative of the "inactive" or "non-polar" substances, and one, therefore, which would be expected to show the greatest improvement by compounding.

Mixtures containing 2, 5, 20, and 50 per cent. (by weight) of rape oil were made up, and friction measurements obtained up to 100° C. The results are shown in Fig. 1, coefficient of friction being plotted against percentage of rape oil in the mixture. It will be seen that the friction falls fairly rapidly, at all temperatures, with comparatively small additions of rape oil, but the friction at 100 per cent. (rape oil only) is less than for any mixture, the fall in friction being gradual from pure mineral oil to pure rape oil. For practical purposes, however, there appears to be little advantage in increasing beyond 20 per cent. rape oil, approximately three-quarters of the total possible gain being obtained at this mixture strength.

Experiments with another series of mixtures gave similar results. These were mixtures of oleic acid and B.P. paraffin, with amounts of the former of 1, 2, 5, 10, 20, and 50 per cent. (by weight). As mentioned earlier, these two substances are at the extremes of the "scale of oiliness" of the usual lubricating oils, and are therefore particularly suitable for observing the effects of compounding.

The results are shown in Fig. 2, coefficient of friction being plotted against percentage of oleic acid. This curve is similar to the one obtained for rape oil and mineral oil mixtures, the friction falling gradually from pure B.P. paraffin to pure oleic acid, the value of the friction for the latter being lower than for any mixture. The rate of fall of friction at small percentages of the "active" substance, however, was greater than in the previous case.

These results show, therefore, that a considerable gain in the boundary lubricating properties of a mineral oil is obtained by compounding with a fatty oil or a fatty acid, but that in neither case does the friction reach its lowest value before the percentage of the active constituent reaches 100 per cent., which is contrary to general supposition.

Common Liquids.

The substances included in this section are a few common liquids, generally assumed to have no lubricating value. They include some of the solvents previously mentioned as cleaning agents, namely, trichlorethylene, alcohol, and benzene; in addition, water, as being the most common liquid, and glycerin, a liquid with an " oily " appearance, were included.

Trichlorethylene.

This substance was frequently used during the investigation as a solvent for removing surplus oil, and a number of observations were made at different times of its effect on the friction. The results were very consistent, the mean value of μ at 20° C. being 0·33. With the vapour only coming into contact with the surfaces μ varied between 0·41 and 0·45.

Benzene.

This liquid gave the highest friction of all those used in this investigation, the mean value of μ at 20° C. being 0·48; the results were rather variable.

Alcohol.

The mean value of μ at 20° C. was 0·43; the variation from the mean was $\pm$ 0·02.

Distilled Water.

The results were very widely scattered, the value of μ ranging from 0·20 to 0·40 over the temperature range 20° C. to 60° C. At this stage, owing to the wide scatter, it was decided to examine the surfaces. They were found to be covered with rust and excessively corroded and, as the results were probably meaningless, the tests were discontinued. The rust was removed using various grades of emery paper, and the surfaces were then cleaned in the usual way before proceeding with tests.

Glycerin.

The friction showed a small increase with increase of temperature, but repetition at any one temperature was good. The value of μ increased from 0·20 at 20° C. to 0·25 at 100° C., and decreased to 0·20 at 20° C. when the surfaces cooled.

These results show that glycerin has slightly less boundary lubricating value than the poorest of the mineral oils tested.

The static boundary lubricating properties at 20° C. of all the substances used in this investigation are summarized in Fig. 3, where they are tabulated in the form of a scale. The coefficient of friction of clean steel on steel is shown as corresponding to minimum " oiliness," *i.e.*, the highest possible friction, whilst maximum " oiliness," as revealed by this investigation, corresponds with the coefficient of friction of oleic acid.

It appears from this diagram that a suitable scale of " oiliness " for those substances generally considered to be lubricants would have as its extremities coefficients of friction of 0·20 and 0·08.

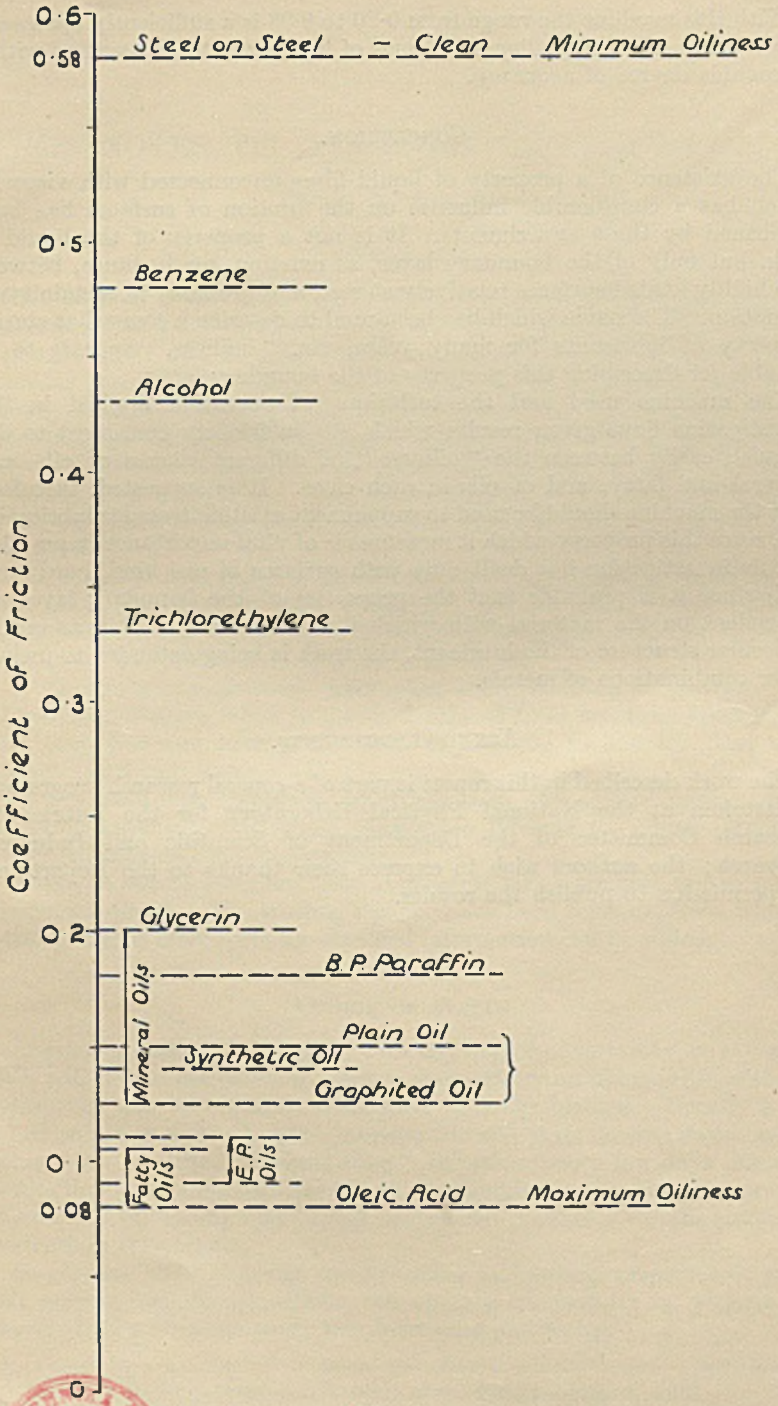

FIG. 3.

SCALE OF OILINESS AT 20° C. (STEEL SURFACES).

With this machine the range from 0·20 to 0·08 is a sufficiently open scale to allow the relative "oiliness" values of lubricants to be assessed with a reasonable degree of accuracy.

CONCLUSION.

The existence of a property of liquid films unconnected with viscosity which has a considerable influence on the friction of surfaces has been confirmed by these experiments. It is not a property of the liquid in bulk, but only of the boundary layer, as existing, for instance, between two highly loaded surfaces relatively at rest, and probably in certain types of motion. The name which has been used to describe a somewhat elusive property of lubricants for many years, viz. "oiliness," appears to be suitable for describing this property of the boundary layer.

The machine used and the technique of operation applied in this investigation have given results which are sufficiently consistent to distinguish easily between the "oiliness" of different classes of oils, *e.g.*, mineral and fatty, and of oils in each class. It is suggested, therefore, that the machine should be used to supplement existing tests for lubricating oils, since this property which it measures is of vital importance in practice.

This investigation has dealt only with surfaces of one kind, hard steel, and, since it is probable that the properties of the boundary layer are dependent on the material with which it is in contact as well as on the molecular structure of the lubricant, the work is being extended to include other combinations of metals.

ACKNOWLEDGEMENTS.

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SOME NOTES ON PLUNGER LIFT OPERATION.*

By F. R. Wellings.

Introduction.

The purpose of this paper is to put forward a few of the major problems encountered in the operation of the method of oil production known as "plunger lift," and to offer some suggestions for overcoming them. A previous paper, read before this meeting by Mr. G. A. Walling in 1935, has already dealt with the economic considerations of plunger lift and given a description of equipment used, and these points are consequently omitted here. Since 1935, apart from one or two simplifications, there have been no essential changes in the design of equipment, but increased knowledge of the operation of plunger-lift wells has enabled their performance to be improved.

The scope of this paper is limited to actual experience of wells on one field only, but as the wells considered possess such widely differing characteristics, it is hoped that a few of the general principles laid down will be applicable to wells on other fields in Trinidad.

In the author's experience, wells have been produced successfully with oil gravities of from 0·868 to 0·945, depths of from less than 1000 feet to over 4000 feet and with productions of from 20 to 350 brl./day, using 2½-inch and 3-inch units.

In the main, the equipment used has been of standard design, unless otherwise specified, and where chokes are referred to, ¾-inch maximum orifice, adjustable ones are implied.

Although overlapping has been avoided as far as possible, one or two of the points raised in Mr. Walling's paper have been repeated here, where it is thought that more recently obtained information can be added.

Choice of Wells.

At present it seems impossible, with any degree of certainty, to say which wells will or will not prove to operate successfully on plunger lift, although indications can be obtained from their previous history. Usually a well is put on plunger lift when it is nearing the end of its flowing days, or after it has been gas lifted for some time. In either case a few days' record of production characteristics, obtained by hooking up a two-pen pressure recorder to the casing and tubing heads, will provide a certain amount of evidence of suitability.

In general, wells showing steady casing and tubing pressures or gentle and regular heading conditions will operate successfully on plunger lift, provided they are reasonably free from sand and water.

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* Paper read before a Meeting of the Trinidad Branch, 1939.

Wells with irregularly variable pressures, indicative of uneven flow of fluid into the hole or the presence of free water, are likely to be troublesome. The same applies to wells heading violently with big changes in casing pressure. This condition may be indicative of high critical back pressure and locking of oil in the formation.

Other things being equal, wells with a low fluid level are more likely to cause damage to plungers than those with a high one.

Wells making sand can be produced on plunger lift, but unless the percentage is small, it would seem that they are best left for some other method of production.

Apart from wearing the plunger excessively, sand can also cause it to stick up in the tubing or prevent the valve from falling off its seat at the top of the stroke. Sticking in the tubing can sometimes be overcome by choosing a plunger the diameter of which has already been reduced by wear, although it has been found in a few cases that a brand-new plunger will give an even better performance in a sandy well. As would be expected, the grain size of the sand seems to be a deciding factor.

With regard to sand jamming the valve, it was suggested in Mr. Walling's paper that cutting small grooves in the valve face would prevent it. The author has had no personal experience of this method, but has found that the trouble can be eliminated to a certain extent by having a suitable clearance between the valve stem and guide, in the cage. About $\frac{1}{32}$ inch on the valve diameter seems to give the best results. Greater clearances sometimes allow of the valve being forced on to its seat by the pressure of gas or oil underneath it while falling. Furthermore, valve stems with large clearances show a greater tendency to become distorted.

Water in a well, unless in the form of a homogeneous suspension or emulsion, can cause uneven stroking, probably due to varying proportions of oil and water entering the footpiece. In a well with a high fluid level, uneven stroking may be no great disadvantage, but in one with a low fluid level, a short stroke may result in a damaged plunger valve.

As an indication of what sort of results may be expected when putting wells on plunger lift, out of forty-five wells with which the author has come in contact during the last two years, twenty-two gave very little or no trouble at all, eleven operated successfully for a time until either sand, mud or water entering the hole, or the fluid level falling too low, rendered their further production by this form of lift, uneconomical. The remaining twelve proved unsuitable from the start, the causes of failure being classified as follows :—

Seven—excessive quantities of sand, mud or water.
Four—fluctuating flow of fluid into the hole and locking of oil in the sand.
One—low fluid level and high gas–oil ratio.

The number of failures is not truly representative of the effectiveness of using previous flowing and gas-lift records in deciding the suitability of wells for plunger lift. In some cases the indications were unfavourable, and had another method of production been readily available, plunger lift would not have been tried.

RUNNING IN AND TESTING TUBING.

The position at which the tubing footpiece is to be set can be estimated approximately from a consideration of previous gas-lift or flowing data. As a rule it is advisable to set on the high side, as it is usually rather difficult to get a plunger to operate with too low a tubing submergence. Once operation has begun, the correct submergence can be decided on. It need scarcely be said that the tubing should be set finally as low as possible consistent with steady operation.

Wells with tubing set to give an operating casing pressure of over 175 lb./sq. in. frequently give trouble through the fluid column being high enough for gas lifting to take place while the plunger is falling.

Wells with a casing pressure below 30 lb./sq. in. are often difficult to start up without damaging a plunger.

A point concerning the actual running of the tubing might be mentioned here. Plunger-lift tubing being manufactured to such fine limits, any slight distortion is sufficient to prevent the free fall of the plunger; hence it is essential to test each joint while running. A broach may be suitable for this, but it has been found that, in many instances, a broach will pass a tight spot where an unworn plunger will not. It is therefore advisable to lower a new plunger on a rope through each joint *after* screwing in. Any joints with tight spots or crooked threads should be rejected. Broaching, though useful in removing scale, etc., will seldom free a tight spot effectively.

The use of another set of elevators in place of slips is recommended while running in. With the latter there is always a tendency to squeeze the tubing, and when supporting several stands, the distortion, though not necessarily permanent, may be enough to prevent the test plunger from entering.

The bottom bumper should be inspected, before running in, for sand cutting directly underneath the mushroom head of the cushion seat; that is, assuming the footpiece has previously been in use.

SIGNIFICANCE OF WELL-HEAD PRESSURES.

Before considering the practical details of getting a plunger to function, it may be as well to emphasize the significance of the pressures at the casing and tubing heads. For noting these a 0–300 lb./sq. in. two-pen pressure recorder is most desirable, though indicating gauges are suitable.

When a well is in a condition of gas lifting, the fluid level in the casing will be at the tubing footpiece. Thus :—

Recorded casing pressure $\simeq$ Recorded tubing pressure $+$ Head of fluid in the tubing $+$ Friction pressure drop.

By closing the well for a few moments, eliminating friction pressure drop, the difference in casing and tubing pressures will indicate the head of fluid in the tubing.

It is not so important to know the actual height of the fluid column as to be able to tell whether there is any column there at all. This is usually possible even when the outlet choke is open.

STARTING UP.

This operation calls for considerable care, as a plunger can receive more damage in its first few strokes than in several months of steady operation, particularly in wells with low fluid level and high gas–oil ratio. The usual procedure is as follows :—

After the tubing has been landed, the well is brought into a straight lifting condition either by swabbing or, if the fluid level is low enough, by applying gas. In cases where the tubing footpiece is set below the top of the perforations, the application of gas to the casing head may be rendered ineffective through the input gas entering the upper part of the sand. As soon as the well kicks off, the casing pressure begins to fall back, and the plunger can then be dropped, and, under certain conditions, will continue operating without further attention. Occasionally, if large quantities of fluid are being produced while the casing pressure is falling, the upward flow will hold the plunger up or will close the valve before the plunger reaches bottom, and cause it to return almost empty. Either trouble can usually be avoided by waiting until the casing pressure has fallen back more.

So long as oil is being produced while the plunger is dropping, this method is satisfactory, as there is sufficient differential between the formation and tubing footpiece to raise the plunger and oil slug to the surface when the flow is temporarily stopped, without forcing oil back into the sand. When the plunger falls back, the release of the gas in the tubing will allow enough oil to enter to reduce the plunger's speed before again hitting the cushion seat.

However, in wells in which conditions are such that efficient straight lifting will not take place, but where only gas or oily mist will reach the tubing head, the situation is very different. Provided a large quantity of formation gas is not being produced, the column of oil and gas in the tubing will be practically in equilibrium with the sand face pressure and the column of oil between the footpiece and the sand face. Hence, when the plunger reaches the footpiece, an increased pressure will be required underneath it in order to raise it again. This will be obtained by the applied gas or formation gas forcing the fluid level in the casing below the footpiece, causing oil to run back into the sand. As the plunger falls again, the pressure is released and the fluid level rises, but usually not fast enough to get to the footpiece before the plunger hits the cushion seat, travelling at a high velocity. One such impact as this may be sufficient to bend or upset the valve enough to prevent its functioning. Furthermore, on the return trip the empty plunger will damage the rubber bumper at the surface, unless the outlet choke is throttled immediately.

This trouble can be avoided if the plunger is trapped in the stack after the first trip, and the tubing pressure allowed to blow down until the oil level has risen again. While the tubing pressure is bleeding off, the two recorder pens will mark out almost parallel lines on the chart, until oil starts to enter the tubing, at which point the tubing pen will commence to move more quickly towards zero. As soon as this change in direction is noticeable, the plunger should be released.

The method the author has found to give the best results in nearly all cases is the following.

Any time after the well is brought into a straight lifting condition both inlet and outlet chokes are closed in, allowing the oil to fall back to form a column in the tubing. When this is done, if both tubing and casing pressures are the same, all the oil will have been forced down below the footpiece, in which case the outlet choke is opened slightly and gas bled off until the oil has once more returned. Except in wells with a high formational gas–oil ratio or low fluid level this is seldom necessary.

The plunger is released, both chokes being kept closed until bottom is reached. The outlet choke is then given a suitable opening, and the release in pressure allows the plunger to rise and deliver its load. At no time during the procedure has the casing pressure been raised sufficiently to force oil away from the footpiece, and so there is no fear of the plunger falling back in empty tubing.

The maximum tubing pressure reached during the first head can be used as an indication of approximate choke settings. If this pressure reaches to within about three-quarters of the casing pressure, the plunger will probably continue to operate on the original setting, for a time at any rate. If it reaches to within less than half, input gas should be applied, or the outlet choke throttled immediately the plunger starts to fall back.

In low-fluid-level wells this method of starting is particularly useful, as with a small slug of oil it is not always possible to trap the plunger after the first stroke. Even with the main-flow arm closed and the bypass open, the retarding force on the rapidly moving plunger is sufficiently great to push the valve off its seat, allowing the plunger to fall back too soon.

Setting of Chokes.

From what has been said under a previous heading, it will be seen that the size of the slug of oil delivered by the plunger on each trip will depend on the difference between the tubing and casing pressures at the moment the plunger touches bottom. A small opening on the outlet choke will allow the gas to escape slowly while the plunger is falling, and the pressure will therefore be fairly high at the moment of impact, and the head of oil correspondingly small. A large choke opening will give the opposite effect. A large enough opening to allow the tubing pressure to fall almost to zero before the moment of impact will obviously be undesirable, as the fluid level in the casing will have to be forced below the footpiece in order for the column to be lifted. On the other hand, too small a choke opening will not allow sufficient oil to enter the tubing. Furthermore, the upward velocity of the plunger may be so reduced that gas will bypass it and allow it to fall back.

The correct pressure at impact—somewhere between these extremes—will be different for each well, but in general it is found that best results are obtained when it is such that the pressure of the gas above the oil slug will fall to zero just before the top of the slug reaches the outlet choke. In other words, the curves on the recorder chart for each head should have a fairly sharp point touching the zero line. If a gas separator is used, the points will touch the separator pressure line.

Some wells can function steadily with flat-bottomed curves (indicative of tubing pressure being low at the moment of impact), but frequently wells operating in this way have a tendency to produce alternate large and small heads.

With a well operating on formation gas alone, unless gas is bled from the casing, the shape of the curves will be decided by the setting of the outlet choke alone. If, however, gas is being applied to the casing, it will be seen that any change in the gas-choke opening will have the same effect on regulating the tubing pressure at the moment of impact as an opposite change in the outlet choke. It therefore follows that in order to reduce the input gas to a minimum, the outlet choke should be throttled in as much as possible

Since most plungers operate below the critical back pressure at which maximum production can be obtained, alterations of the outlet choke setting over quite a large range does not appreciably affect the quantity of oil produced. The limit of throttling is reached when :—

(*a*) The energy required to lift the plunger itself a greater number of times balances out the energy conserved by throttling.

(*b*) The time of discharge of the oil slug through the restricted opening takes up too large a portion of the time of each cycle.

The effect of the limiting factor (*b*) can be reduced to a minimum by the adoption of some form of " surge chamber." This consists of a chamber placed between the tubing outlet and the choke, of sufficient capacity to hold the greater part of each slug of oil. Its use was suggested in Mr. Walling's paper as a means of preventing B.S. from settling back into the plunger on the upward trip, but it has the further advantage that it will allow of oil passing through the choke while the plunger is falling, thus reducing the time taken during the cycle for the oil slug to be discharged from the tubing. With this arrangement the outlet and inlet chokes can be closed in still further without any decrease in production, but with a decrease in input gas. For example, on one well which the author has operated the installation of a choke box enabled the input gas to be reduced by about 30 per cent. and the oil production to be increased from 200 to 220 brl./day.

On wells with a high formational gas–oil ratio it may be necessary, for maximum production, to open the outlet choke as wide as possible, or even to remove it altogether. Another trouble may be experienced by doing this, however. The velocity of the plunger through the fluid at the bottom of the tubing will depend largely on the quantity of free gas present. A fluid containing a large quantity of free gas, approaching to the consistency of froth, may have insufficient retarding effect on the plunger, and the impact on the cushion seat will be heavy. A back pressure maintained on the tubing increases the " viscosity "—if that term may be used—of the gas–oil mixture, by reducing the gas volume. Although the author has never tried it, it seems reasonable to assume that bleeding gas from the casing could have the same effect as throttling in this particular form of trouble.

TREATMENT OF WORN PLUNGERS.

Plunger wear varies greatly from well to well. In some wells a few weeks' operation is sufficient to reduce the plunger diameter by as much as 0·080 inch, whereas in others, plungers have operated a matter of years with scarcely any appreciable wear. How much a plunger can wear before requiring rebuilding or scrapping seems to be open to some doubt. In two particular instances, to the author's knowledge, plungers have operated when the rings have been worn completely off one side and the threads on the cage exposed. Generally about 0·080 inch reduction in diameter is considered to be the economic limit.

A plunger usually wears on a taper, the greatest diameter being across the top, and the least across the cage. If sand is present in the tubing, this taper seems to increase the tendency to stick up, by the wedging action on the sand. In one well with which the author has come in contact the sand conditions were such that new and very much worn plungers stuck in the tubing on the downward trip with equal regularity. A slightly worn plunger with the taper skimmed off in the lathe functioned perfectly satisfactorily.

In Mr. Walling's paper it was suggested that worn plunger barrels could be built up by the deposition of metal with a welding torch. Another method, which has been successful, consists of skimming off the worn rings completely and turning down the barrel to such a diameter that detachable rings, made of special abrasion-resisting steel, can be slipped on. These are held apart by spacers and kept in position with a locking ring, screwed and spot welded on the base of the barrel. After the initial lathe work the rings can be replaced speedily and easily when worn. The cages, of course, have to be built up with a torch.

Probably the commonest source of trouble encountered in plunger lift is the upsetting or bending of the valve stems. Heating, then straightening or forging down, is usually necessary, with suitable tempering afterwards. It is advisable in all cases to give a fairly fine lathe finish to a treated valve stem, since the slightest roughness seems to provide a " tooth " for sand to pack and jam the valve on its seat.

Valve guides receive a fair amount of wear. Fitting replaceable steel bushings has been found to be a satisfactory cure for this.

Two-Piece Plungers.

In an attempt to reduce the number of temporary shut downs through bending or upsetting of the valve stems, a cageless, two-piece plunger was evolved. The lower part consisted of a reinforced valve, fitted with guides to maintain it in a vertical position, and the upper part was the plunger barrel, with its lower end machined to form a seat for the valve. The internal cross-sectional area was arranged so that the barrel should have a slightly lower falling velocity than the valve.

Satisfactory operation has been obtained with this plunger in one or two cases, for short periods. Due to the relatively small surface in contact with the tubing, however, wear on the valve guides was excessive.

Fishing a sanded-up plunger of this type is a longer job than fishing a standard plunger. Either the barrel has to be recovered first and then dropped back again to recover the valve, or two separate runs have to be made with different fishing tools.

A simpler type of two-piece plunger which has been in use in this island for some time employs a loose steel ball to act as a valve. This has also given satisfactory operation for short periods, and in two cases known to the author wells have operated with a plunger of this type when sand conditions were too severe for a standard plunger to function at all. The chief drawback was the difficulty of maintaining the ball in a central position when the barrel landed on it. Even with a concave cushion seat, the flow of gas and oil continually forced the ball out of centre, to the detriment of the ball seat and the lower end of the barrel.

All things considered, it seems that at present the disadvantages of two-piece plungers outweigh the advantages, although it is hoped that a slight modification in the design of the lower component in the former type described will make it a practicable proposition.

CONCLUSION.

The author would like to express his thanks to the management of Apex (Trinidad) Oilfields, Ltd.,for permission to present this paper, and to Mr. Fullerton for advice and criticism.

DISCUSSION.

MR. HARRIS (Chairman) : In opening the paper for discussion, I take the opportunity of congratulating the author on the very lucid way in which he has put the problems before us. I am proposing that comments on the paper should be replied to by the author directly after the comments have been made by each speaker.

MR. WALLING : I should like, first of all, to congratulate the author on his very interesting paper. I would like to know what experience the author has had in "parachuting" plungers—that is, in reducing the falling velocity by means of an orifice in the centre of the plunger. When my company first started plunger lift, many wells turned up in which the plunger hit bottom hard, due to too little fluid. On the advice of the manufacturers of the equipment, we introduced the system of placing an orifice in the plunger, and found that falling velocity could be controlled by the size of the orifice. This completely reversed our ideas about the system. In a well 1800 feet deep, producing at the rate of 2 brl./day, with the plunger making three to four strokes an hour, the overall cost was equal to 17 c. per brl. We were not interested in the shape of the pressure curves we obtained, provided the well operated without damage to equipment.

With regard to plunger lift, I would like to know what the author considers as a failure. Was his statement based on the study of charts, or was it a complete failure that could not be operated by any manner of means ?

There is no doubt that the introduction of parachuting made a big difference, as far as our experience goes in defining the limit to which we can go. We have thirty wells producing an average yield of 10 brl./day each at an economic cost. I should like to know the cost of production as far as the author's experience goes. It is a fundamental point as to the value of the system in producing oil.

MR. WELLINGS : I am afraid my experience as far as parachuting goes is rather limited, as in this field we seldom come across wells that require it. In one well where it was tried the results were not encouraging, as the decreased velocity tended to cause the plunger to stick. In another case of a low-fluid-level well, bleeding gas from the casing overcame the difficulty of the plunger hitting bottom hard. As mentioned in the paper, the consistency of the fluid at the bottom of the tubing is of first importance, and as removal of gas from the casing can affect this, it would seem that use of standard type plungers could be extended to many wells of low fluid level merely by bleeding off gas. It apparently requires very little fluid of the consistency of dead oil to slow down the plunger above the foot-piece.

As to what I call a failure, in this field we consider a plunger-lift well a success so long as it does not require too frequent attention or too many replacements. In some sandy wells the plunger will seldom make two successive strokes without sticking up, and in wells with an erratic flow of fluid into the hole a plunger may be hammered up after an hour's operation. There is usually very little doubt whether a plunger-lift well is an economical proposition or not.

As far as production costs go, I am afraid I have not any exact figures to hand at the moment.

Mr. Paterson : If you have a large-scale operation, some sort of organization is necessary for continuous working. In my experience, causes which affect the operation of plunger lift are accumulation of paraffin, crooked holes, wear of plunger, too much gas, too much back pressure on well head, in some cases muddy and sandy wells, sticking of valve due to bending of spindle, and shortage of fluid in the hole. We have all these problems to face, and it is very evident that staff cannot attend to these all the time. We have had to develop an organization of local operators. We cannot pay too much attention to chart characteristics.

We have classified wells into certain groups, according to the trouble they give. The plungers have to stand up to heavy usage, but there is a definite limit to parachuting, depending on sand, mud, etc. All our wells are economically produced. In cases of small producers, the charts show that they are sometimes one or two hours off production, but are automatically brought back. Occasionally we have had to attend to wells continuously for a week before we could get steady operation.

In the case of erratic influx into the hole, there is nothing to be done to get continuous operation. As the fluid comes into the hole, the heads become larger and larger and then die down again. We operate such wells with the maximum amount of gas all the time, controlling the plunger speed during the time there is no fluid in the hole by parachuting.

Mr. Wellings : As the number of wells with which I come in contact is small, it is quite possible for one staff engineer to control them all with the assistance of only one native operator per tour. We do not look upon plunger lift as our main method of producing non-flowing wells, and any well that continues to be excessively troublesome is put on to some other means of production.

Mr. Castle : Mr. Walling has mentioned the economic side of plunger lift. I should like to know what changes there are in gas-oil ratio and production when a well is changed over from gas lift to plunger lift. Also I should be interested to hear whether anybody in the meeting has had any experience with improvements in the types of fishing tools used for fishing plungers.

Mr. Wellings : With regard to your first query, the changes in gas-oil ratio and production vary enormously from well to well, when changing over to plunger lift. There is nearly always an improvement in gas-oil ratio, as would be expected, since plunger lift can be considered as gas lift without slippage. If a well on gas lift has been producing below its critical back pressure, there will be very little or no change in production when put on plunger lift. We have known wells which would not produce a barrel a day on gas lift without excessive quantities of input gas, yet turned out to be quite large producers on plunger lift.

Mr. Paterson : I should like to hear some of the author's experience of paraffin wells.

Mr. Wellings : Here again I am afraid my experience has been rather limited, as we get very little trouble from paraffin on this field in any wells. Paraffinous wells that have been put on plunger lift here have turned out to be wells with erratic influx of fluid characteristics, so that they have scarcely had a fair test. In the few cases met with, however, it was found that the paraffin gave no trouble so long as the plunger was operating continuously. If for any reason the plunger was taken out of the hole and the well allowed to straight lift for a day or so, a thin paraffin scale forming on the walls of the tubing would prevent the plunger from falling when dropped again.

Mr. Thomas : On page 19, concerning the suitability of wells for plunger lift operation, the author states that, in general, wells with a steady tubing and casing pressure are suitable for plunger lift. Would not wells with such characteristics operate equally well without a plunger ?

On page 25 two cases are quoted where plungers continued to operate even when the rings had been worn off completely. Would not the wells have gone on producing if the plungers had been taken out altogether ?

MR. WELLINGS : Plunger lift is introduced near the end of a well's flowing days to increase the efficiency of production. As previously mentioned, there is usually quite a large increase in production when such a well is put on plunger lift.

In the cases quoted where plungers continued to operate in a very worn condition, neither well would flow unassisted, and only gave a small production when straight lifting. It seems that the turbulence caused by the plunger's rings is capable of maintaining a seal of considerable cross-sectional area.

MR. WALLING : I would like to know whether the author has studied the question of running plunger lift tubing on the completion of wells, thus avoiding the necessity of having to pull the original flow string.

MR. WELLINGS : The question has been studied. Cost is usually the deciding factor. Since plunger lift tubing is considerably more expensive than ordinary tubing, it is not economic to tie it up in a well that is likely to flow for any length of time. Furthermore, unless the tubing happens to be set at the correct depth at the start, the services of a pulling crew are required anyway.

MR. PATERSON : On page 19, the author states : "In general, wells showing steady casing and tubing pressures . . . will operate successfully on plunger lift, provided they are reasonably free from sand and water." I would like to know something about this, as I have a case of a well producing 64 brl. of oil and 240 brl. of water per day.

MR. WELLINGS : My experience has tended to show that wells producing anything above about 5 per cent. of water are likely to give trouble sooner or later, especially in the case of low fluid levels. This need not apply if the proportion of oil and water flowing into the hole remains constant. If the proportion varies, short stroking will result, but, as already stated, this need not cause trouble in a well with a high fluid level.

PHYSICAL CONSTANTS OF ASPHALTIC BITUMENS. PART I.*

By Dr. R. N. J. Saal, W. Heukelom and Dr. P. C. Blokker.

Summary.

This paper gives a survey of the following physical properties of asphaltic bitumens: specific gravity, coefficient of cubical expansion, specific heat, thermal conductivity, permeability to water vapour, surface tension and total surface energy.

The methods by which these properties have been determined are described in detail.

Introduction.

Although the well-known tabulated surveys of the physical properties of materials, such as the American International Critical Tables, the German Tables of Landolt-Börnstein, and the French Tables of Abraham-Sacerdote, contain numerous data from literature on the physical properties of the most widely differing materials and compounds, they give practically no information about asphaltic bitumens.

This is partly due to the large number of asphaltic bitumens obtainable. Thus, in addition to the wide range of products differing chiefly in consistency which may be obtained from a single source, the number of bitumens is considerably increased by the fact that the physical properties may differ according to the method of preparation and the source of the starting material.

A second cause is the fact that data concerning particular properties such as consistency (penetration, softening point, brittleness, ductility, viscosity at fairly high temperatures) and temperature susceptibility are of greater importance for road building (formerly almost the only outlet for bitumens) than information about the normal physical constants.

As asphaltic bitumens are now more and more used for various industrial purposes, a knowledge of the physical constants that are of value for their various applications has become increasingly important. This applies in particular to the bitumens used for electrical and thermal insulation purposes.

We thought it desirable, therefore, to extend our knowledge of the principal data collected by us in the course of years by making further investigations, and to publish the results obtained.

It may be observed that the physical constants in question are in general only slightly affected by the consistency and origin of the bitumen—in other words, they are characteristic of fairly large groups of bitumens. For this reason it is sufficient to discuss the physical properties of only a few bitumens belonging to different groups.

The following physical properties will be considered:

specific gravity,
coefficient of cubical expansion,
specific heat,

---

* Paper received 25th April, 1939.

thermal conductivity,
surface tension and
total surface energy,
permeability to water vapour.

The electrical properties will be dealt with in a second publication.

Specific Gravity.

The specific gravity of bitumens having a penetration at 25° C. greater than 5 was determined by means of a pyknometer, that of harder bitumens by means of a hydrostatic balance.

In the determination with the pyknometer, this was partly filled with bitumen and partly with water.

Before the determination was carried out, the bitumen was heated for half an hour in the pyknometer at about 100° C. above its softening point R. & B., in order to remove any occluded air.

The figures obtained in these determinations are given in Table I.

Table I.

Specific Gravity of Asphaltic Bitumens.

Asphaltic bitumen.	Specific gravity at 25° C.
Pen. 100 g./5 sec./25° C. = 300	1·01 ± 0·02
,, ,, = 200	1·02 ± 0·02
,, ,, = 100	1·02 ± 0·02
,, ,, = 50	1·03 ± 0·02
,, ,, = 25	1·04 ± 0·02
,, ,, = 15	1·04 ± 0·02
,, ,, = 10	1·05 ± 0·02
,, ,, = 5	1·07 ± 0·03
,, ,, =< 5	1·07 ± 0·03

The specific gravities of bitumens partly depend on the origin of the crude oil from which they have been prepared, but in general they lie between the limits indicated in Table I.

For the rest, the specific gravity is only dependent on the penetration, and is therefore practically the same for bitumens of the pitch type, the normal type, and the blown type of the same penetration.

However, bitumens prepared from cracked residues are generally of higher specific gravity; bitumens from heavily cracked residues, for instance, yielded the following values :—

Pen. 100 g./5 sec./25° C. =	100	1·13 ± 0·02
,, ,, =	50	1·13 ± 0·02
,, ,, =	25	1·13 ± 0·02
,, ,, =	15	1·14 ± 0·02
,, ,, =	5	1·15 ± 0·02
,, ,, =<	5	1·16 ± 0·02

Coefficient of Cubical Expansion.

A knowledge of the cubical expansion especially at high temperatures, is necessary for the calculation of tank-capacity in the case of bitumen delivered hot in tank-cars, as well as for the selection of coating materials for objects to be exposed to considerable temperature variation. In the case of pothead compounds, where shrinkage on cooling is an important factor, cubical expansion of asphaltic bitumens is also of value.

In the bitumen laboratory of the Rhenania-Ossag Mineralölwerke investigations were made as early as 1929 in order to determine the coefficients of expansion of various bitumens.[1]

For the measurements at low temperatures (15–50° C.) a pyknometer was used, which was partly filled with bitumen and partly with water.

The determinations at high temperatures (120–200° C.) were made with a Mohr balance. With this instrument a sinker is lowered into the bitumen and the upward pressure exerted on the sinker determined.

The measurements made with Mexican distilled bitumens (pen./25° C. = 23 to pen./25° C = 196) showed that the coefficient of expansion is practically constant in the temperature range concerned, and almost identical for all bitumens. The coefficient of expansion seems to increase somewhat with the hardness of the bitumen (Table II); for further particulars see [1].

TABLE II.

Coefficients of Cubical Expansion of Asphaltic Bitumens.

Straight-run bitumens.	Coefficient of cubical expansion (a) for the temperature range 15–200° C.
Pen. 100 g./5 sec./25° C. = 196	0·00060
„ „ = 65	0·00061
„ „ = 50	0·00061
„ „ = 45	0·00061
„ „ = 23	0·00062

As may be seen from the following survey, the values given in the literature are in fairly good agreement with those listed above :—

Bureau of Standards, Washington [2]	between 15° and 65° C. = 0·00063.
American Standards Association [3]	„ 15° „ 230° C. = 0·00068.
(See also [4])	
H. Rossbacher [5]	„ 25° „ 70° C. = 0·00058.
H. Mallison [6]	„ 15° „ 60° C. = 0·00062.
H. Mallison, F. Jacobsohn, and K. Sarre [7]	

SPECIFIC HEAT.

The apparatus illustrated in Fig. 1 was used for the determination of specific heat. It consists of two parts : a calorimeter, and a device which serves to bring the bitumen to a predetermined temperature and to drop it into the calorimeter. Tube B is completely surrounded by the vapours from a boiling liquid which is heated in space A. In the top of this tube hangs a bucket-like container (C) covered with a lid, and containing the bitumen (about 10 gm.), which is maintained at a constant temperature. The copper block D serves to conduct the heat rapidly from the vapour to the bitumen. The temperature is measured by means of a thermo-element. The calorimeter, consisting of a double-walled vessel provided with water circulation, is under this heating device. The calorimeter contains a copper block F (the size of which depends on the temperature range covered by the determination), having a hole in which the receiver

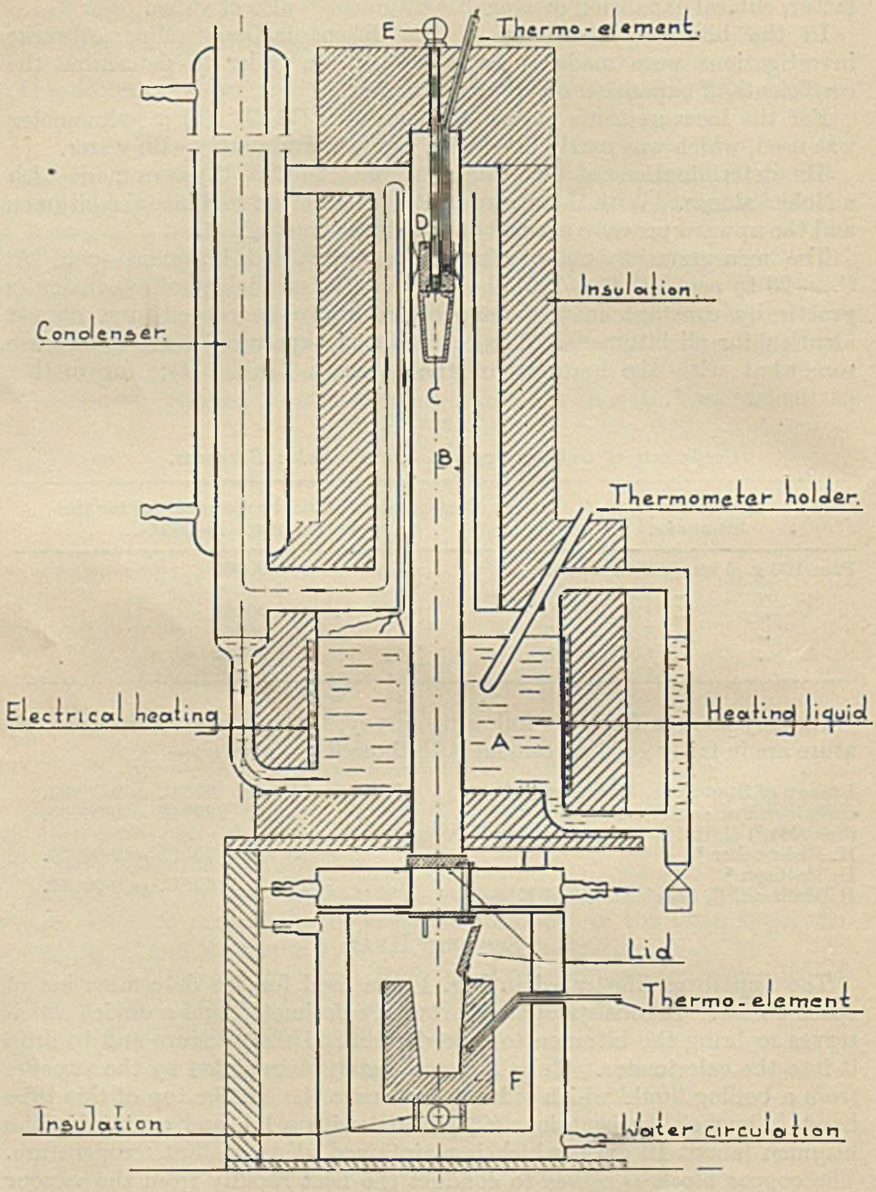

FIG. 1.

APPARATUS FOR DETERMINATION OF SPECIFIC HEAT OF ASPHALTIC BITUMEN.

(*C*) fits perfectly; this hole can be closed with a cover. By means of the rod *E* the bitumen container *C* can be loosened, so that it falls into the hole in the copper block; immediately afterwards both the cover of the copper block and the lid of the calorimeter opening are closed. Next, the rise in the temperature of the copper block *F* is measured with a thermo-element (and a mirror galvanometer) with an accuracy of ± 0·02° C. During the measurements both the water circulating in the calorimeter and the mirror galvanometer are maintained at a temperature of 25° C. ± 0·02° C. The temperatures to which the bitumen was heated were about 100, 200 and 300° C., respectively. Water, tetrahydronaphthalene and di-*sec.*-butylnaphthalene, respectively, were used as heating liquids. The calorimeter was calibrated by means of a silver block of the same dimensions as the container *C*, weighing about 130 gm. The following values, calculated from the formula :—

$$c_p = 0{\cdot}055936 + 1{\cdot}05607{\cdot}10^{-5}\,t + 1{\cdot}861510^{-9}\,t^2$$

were assumed for the specific heat of silver :—

0·05663 for the temperature range between 100° C. and 30° C.
0·05721 ,, ,, ,, ,, 207° C. ,, 30° C.
0·05785 ,, ,, ,, ,, 322·4° C. ,, 30° C.
(Landolt–Börnstein's Table.)

Before the determination, the copper block *F* was heated to a few degrees above 25° C. and the decrease in temperature measured over a small period of time. Next, the heated silver block was allowed to fall into the hole of the copper block as described above, and the further change in temperature was recorded. If the temperatures found are plotted against the time, it is possible to determine by extrapolation the temperature rise which would have occurred if no exchange of heat with the surroundings of the calorimeter had taken place. From the known heat capacity of the silver block, the heat capacity of the copper block could thus be determined. The specific heat calculated from these results is in good agreement with the values for copper given in the literature, as will be seen from the following table.

Temp. of silver block (Wt. 130 gm.).	Copper block No.	Weight copper block.	Heat capacity copper block in cal./° C.	Specific heat of copper.	
				Found (at *ca.* 30° C.).	Literature (Landolt-Börnstein's Tables).
100° C.	1	883 gm.	81·77–81·84	0·0927	
207° C.	2	1965 ,,	181·2–182·0– 181·2–180·9	0·0923	0·09185 (25·8° C.) 0·09244 (38·1° C.)
322·4° C.	3	3432 ,,	316·7–319·4– 318·2–319·1	0·0928	

The reproducibility of the results was about 0·5 per cent.

By means of the determined heat capacity of the copper blocks the specific heats of a number of bitumens were measured, taking into account the heat capacity of the container *C*, which almost corresponded to the heat capacity of the bitumen.

TABLE III.

Specific Heats of Asphaltic Bitumens.

Bitumen.	Pen./25° C. IPT.–A. 18.	Soft. pt. R. & B. IPT.–A. 20.	Specific heat in cal./gm./° C. at				Change of specific heat per 1° C. (*a*).
			0° C.	100° C.	200° C.	300° C.	
Venezuelan distilled bitumen . .	177	39½° C.	0·425	0·472	0·520	0·567	0·00047
Ditto . . .	23	62½	0·409	0·463	0·518	0·572	0·00054
Ditto . . .	7	96½	0·382	0·455	0·527	0·600	0·00073
Mexican distilled bitumen . .	22½	65	0·429	0·464	0·499	0·534	0·00035
Ditto blown bitumen . .	39	84½	0·430	0·462	0·494	0·526	0·00032
Ditto . . .	25	86½	0·402	0·458	0·514	0·570	0·00056
Bitumen from cracked residues .	2	73	0·419	0·459	0·499	0·538	0·00040
Light-coloured bitumen . . .	25	53	0·378	0·456	0·534	0·612	0·00078

The specific heat was determined in the temperature ranges of 100 to 30° C., 207 to 30° C. and 322 to 30° C. The figures obtained, calculated from the mean of three determinations, showed that the specific heat is a linear function of the temperature.

From this linear relation between specific heat and temperature, also at fairly low temperatures, it follows that a transition point, and consequently a definite melting point, does not occur.

The specific heats at convenient temperatures (see Table III) were calculated from the linear relation thus found, which may be indicated by the following equation :—

$$\text{specific heat} = \text{specific heat}_{0^\circ\text{C}} + at \quad (t = \text{temp. in } ^\circ\text{ C.}).$$

If it is desired to measure the specific heat in the temperature range of t_1 to t_2, the average temperature t_m should be taken. Then the specific heat may be deduced from the values given in Table III with reference to the following equation :—

$$\text{specific heat}_{t_2-t_1} = \text{specific heat}_{0^\circ\text{C}} + at_m.$$

According to the literature [2] the equation found for the specific heat of mineral oils :—

$$\text{specific heat} = \frac{1}{\sqrt{d}}(0{\cdot}388 + 0{\cdot}00081t)$$

$$(t = \text{temp. in } ^\circ\text{ C.})$$
$$(d = \text{spec. grav. at } 15^\circ\text{ C.})$$

may also be used for asphaltic bitumens (cf. also [8]).

However, our measurements show that in most cases the temperature coefficient of the specific heat is smaller than follows from the equation.

THERMAL CONDUCTIVITY.

To determine the thermal conductivity of asphaltic bitumens, the apparatus illustrated in Fig. 2 was used. This apparatus consists of a spherical copper vessel *A*, in the middle of which is a solid copper sphere *B*, in which are two holes, one of which serves to contain the heating element *C*, the other to contain the thermo-element. The space between the solid sphere and the wall of the larger sphere *A* was filled with bitumen, and the whole placed in a water-bath at constant temperature, so that water flows through the holes *D* into *A* and covers the bitumen.

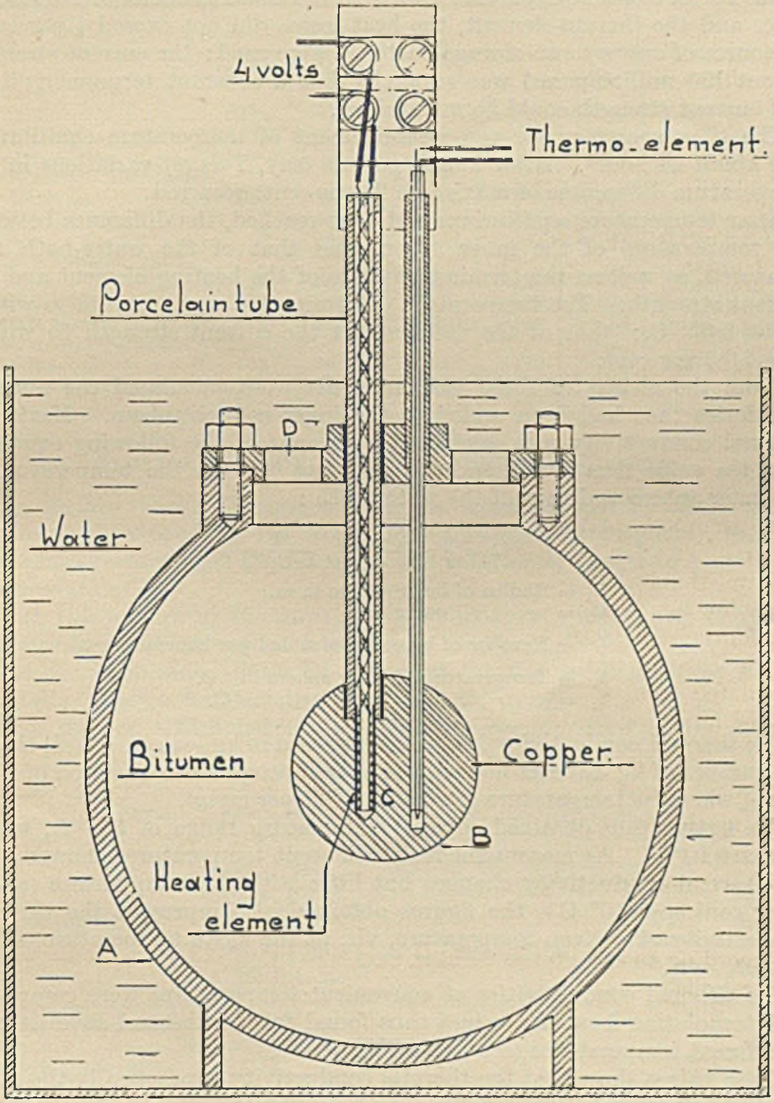

FIG. 2.

APPARATUS FOR DETERMINATION OF THERMAL CONDUCTIVITY OF ASPHALTIC BITUMENS.

The heating element was so adjusted that at a tension of 4 volts, and under conditions of temperature equilibrium, a temperature difference of about 10° C. could be expected; owing to the small diameter of the lead-in wires and the thermo-element, the heat losses did not exceed ½ per cent. As source of current two storage batteries were used; the current strength (about 130 milliamperes) was so slight that a constant terminal voltage and current strength could be maintained.

The time necessary for the establishment of temperature equilibrium was about 24 hours. After longer periods (say, 7 days) variations in the temperature differences of maximum 2½ per cent. occurred.

After temperature equilibrium had been reached, the difference between the temperature of the inner sphere and that of the water-bath was measured, as well as the terminal voltage of the heating element and the current strength. The temperature determination was accurate to within about 0·02° C.; that of the voltage and the current strength to within about 0·5 per cent.

From the results of these measurements were calculated the number of calories that had been added to the inner copper sphere. Next, the thermal conductivity was calculated by means of the following equation from the value thus found, and the difference between the temperature of the inner sphere and that of the water-bath :

$$\lambda = \frac{\phi}{t} \cdot \frac{R_2 - R_1}{\delta_1 - \delta_2} \cdot \frac{1}{4\pi R_1 R_2}.$$

R_1 = Radius of inner sphere in m.
R_2 = „ outer „ „
$\frac{\phi}{t}$ = Number of kg.-calories added per hour.
δ_1 = Temperature of inner sphere in ° C.
δ_2 = „ water-bath in ° C.

The thermal conductivity has been expressed in kg.-cal./m./°C./*h*, that is the number of kg.-calories flowing per hour through a cross-section of 1 sq. metre, when the temperature gradient is 1° C. per metre.

The figures thus obtained cover a temperature range of $t_1 - t_2$, which is about 10° C. As measurements at different temperatures showed that the thermal conductivity changes but little with the temperature (about 1 per cent. per 10° C.), the figures obtained also represent the thermal conductivity at a given temperature, viz. at the mean temperature of the range $t_1 - t_2$.

The thermal conductivities at convenient temperatures were computed by interpolation from the values thus found for the thermal conductivity at different temperatures (see Table IV).

These values show that the thermal conductivity is practically the same for all bitumens.

These values for the thermal conductivity expressed in kg.-cal./m./°C./h (this manner of recording is the most suitable for technical use) may be converted into g.-cal./cm./°C./sec. units by multiplication by the factor 0·00278.

M. Jacob[9] (see also [2] and [4]) found a thermal conductivity of 0·14 kg.-cal./m. /°C./h between 0° C. and the softening point R. & B.; this value is thus in good agreement with our values.

TABLE IV.

Thermal Conductivity of Asphaltic Bitumens.

Bitumen.	Pen. at 25° C. IPT.–A. 18.	Soft. pt. R. & B. IPT.–A. 20.	Thermal conductivity in kg.-cal./m./° C./h.				
			0° C.	20° C.	40° C.	60° C.	70° C.
Venezuelan distilled bitumen . .	177	39½° C.	0·136	0·133	0·130	—	—
Ditto . . .	23	62½	0·141	0·137	0·133	0·129	0·125
Ditto . . .	7	96½	0·144	0·137	0·130	0·124	0·127
Mexican distilled bitumen . . .	22½	65	0·137	0·135	0·133	0·131	—
Ditto, blown . .	39	84½	0·141	0·139	0·138	0·136	0·134
Ditto, blown . .	25	86½	0·150	0·146	0·143	0·140	0·136
Bitumen from cracked residue . .	2	73	—	0·129	0·126	0·124	0·121
Light-coloured bitumen	25	53	0·120	0·117	0·115	—	—

SURFACE TENSION AND TOTAL SURFACE ENERGY.

The surface tension of various bitumens was measured by means of the apparatus developed by Du Nouy (in a hydrogen atmosphere), at such high temperatures that the bitumen was sufficiently liquid to permit the determinations.[10]

With this apparatus the force necessary to draw a metal ring of known diameter from the bitumen is determined.

The value obtained must be corrected for the peculiar shape of the liquid film which is formed when the ring is drawn up.

As a method which permits of reliable determinations of the surface

TABLE V.

Surface Tension and Total Surface Energy of Bitumens.

Bitumen.	Penetration at 25° C. IPT.–A. 18.	Soft. pt. R. & B. IPT.–A. 20.	Surface tension in dynes/cm.				Total surface energy ergs/sq. cm.
			150° C.	120° C.	100° C.	25° C. (obtained by extrapolation).	
Distilled Indian bitumen . . .	250	33° C.	26·9	28·8	30·0	34·4	51
Distilled Venezuelan bitumen . .	200	39° C.	26·0	27·7	28·8	33·0	50
Distilled Mexican bitumen . .	190	42° C.	25·5	—	28·7	33·5	51
Ditto . . .	50	58° C.	26·2	28·1	29·4	34·2	52
Blown Mexican bitumen . . .	190	—	24·8	—	28·1	33·0	50
Ditto . . .	34	85° C.	24·1	26·1	—	32·1	52

The values found by Dr. Nellensteyn [11] at higher temperatures (above 140° C.), determined by Jaeger's bubble pressure method, are in good agreement with our figures.

tension of bitumens at room temperature has not yet been developed, the surface tension at 25° C. had to be computed by extrapolation.

The total surface energy E_s was calculated from the following equation:

$$E_s = \sigma - T\frac{d\sigma}{dT}$$

E_s = total surface energy,
σ = surface tension,
T = absolute temperature.

Table V gives a summary of the surface tension at different temperatures and of the total surface energy of different grades of bitumen. The surface tension values obtained in these measurements are accurate to within about 0·5.

The difference between the values obtained by linear extrapolation and the true values will be very slight, as the value for the total surface energy would fall outside the limits of 50–70 ergs/sq. cm. (between which lie the total surface energies of all hydrocarbons), even in the event of a slight deviation from the linear relation between surface tension and temperature.

PERMEABILITY TO WATER VAPOUR.

The permeability to water vapour is an important factor in several applications of asphaltic bitumens, in particular as insulating material in the electric industry.

We have not made any measurements of this property. Taylor, Herrmann, and Kemp, however, have determined this property on various materials, including a bitumen sealing compound (presumably a blown asphaltic bitumen)[12]; see also.[4]

For determining the coefficient of diffusion of the water vapour within the material, Fick's diffusion law was used, which is expressed by the following equation:

$$N = \frac{DAt}{x}(p_1 - p_2),$$

where N = the amount of water that will diffuse in time t in the direction x through a cross-section with a surface area A, $p_1 - p_2$ being the difference in the vapour pressure of the water.

This law applies perfectly to materials which absorb practically no water (polystyrene). On the other hand, it cannot be expected that water-absorbing materials obey Fick's law.

In most cases in which water is absorbed, less water passes through the material than in the equilibrium condition. As the above determinations had been carried out under conditions approaching equilibrium, the rate of permeation was constant in the case of a definite thickness of the material and at definite vapour pressures. With water-absorbing materials, however, the rate of permeation, also under equilibrium conditions, generally depends on the values of the vapour pressures and the difference between these, and moreover on the thickness of the material. This is due to the fact that the rate of permeation is in general governed by the amount of water absorbed; the distribution in the material and the amount of this absorbed water are dependent on the values of the vapour pressures, the difference between these and the thickness of the material.

As stated by the authors, the values obtained in the above determinations, some of which are given in Table VI, may, as far as water-absorbing materials are concerned, be considered only as approximate constants; they are therefore only to be considered as exact under the conditions stated above.

TABLE VI.

Permeability to Water Vapour of Various Materials, including Asphaltic Bitumen.

Material.	Temp., ° C.	Thickness of material, *ca.* cm.	Water vapour pressure $p_1 - p_2$ in mm. Hg.*	Coefficient of diffusion D in $g \,.\, h^{-1}$. cm.$^{-1}$ mm. Hg^{-1}.
Paraffin wax	21·1	0·05	18·6 – 0·0	0·06 10^{-8}
Polyethylene tetrasulphide (thiokol)	21·1	0·08	18·0 – 0·0	0·22 ,,
Bitumen sealing compound .	25·0	0·08	22·8 – 0·0	1·15 ,,
Plasticized cellulose acetate .	25·0	0·002	22·8 – 0·0	1·18 ,,
Gutta-percha	25·0	0·03	22·8 – 0·0	1·48 ,,
Ebonite	25·0	0·05	22·8 – 0·0	1·51 ,,
Balata	25·0	0·04	22·8 – 0·0	1·80 ,,
Paragutta	25·0	0·05	22·8 – 0·0	1·89 ,,
Polystyrene	21·1	0·1	18·0 – 0·0	3·9 ,,
Moulded bakelite . . .	25·0	0·05	22·8 – 0·0	4·7 ,,
Phenol fibre	25·0	0·08	22·8 – 0·0	5·0 ,,
Soft vulcanized rubber . .	25·0	0·04	22·8 – 0·0	7·3 ,,
Benzyl cellulose . . .	23·9	0·07	22·8 – 0·0	10·6 ,,
Cellulose acetate . . .	25·0	0·02	22·8 – 0·0	160·0 ,,

* As the above figures show, the relative vapour pressure on the one side is about 1.

The permeability to water vapour has been expressed in the table by the coefficient of diffusion D; this represents the amount of water vapour (in grams) which, at a vapour pressure difference of 1 mm. Hg, would diffuse in one hour through a layer of 1 cm. thickness having a surface area of 1 sq. cm., if Fick's law would hold.

E. Badum [13] also determined the permeability to water vapour of various substances. His figures are in good agreement with those of the authors mentioned before. For asphaltic bitumen he found a diffusion coefficient of

$$1{\cdot}4 \times 10^{-8}\, g \,.\, h^{-1} \,.\, \mathrm{cm.}^{-1} \,.\, \mathrm{mm.\ Hg}^{-1}.$$

Amsterdam Laboratory of the *N.V. de Bataafsche Petroleum Maatschappij.*

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OBITUARY.

DONALD C. BARTON.

Dr. Donald C. Barton, research geologist and geophysicist with the Humble Oil & Refining Company, died in Houston, Texas, 8th July, after a three weeks' illness.

Dr. Barton was known internationally for his work in the interpretation of the physiography of the Gulf Coast region, and for his numerous papers on the geology of salt domes. He was a leader in the use of geophysical methods and their application to petroleum exploration, having begun this study in the early 1920's. Later he used his geological and geophysical knowledge to determine and portray the broad geologic structure of the Gulf Coast region. Out of this study came his recognition of the Gulf Coast geosyncline, sometimes referred to as the Barton geosyncline. While most of Dr. Barton's working life was spent in commercial work, he was a persistent thinker, and found time to carry on an unusual amount of scientific research.

Dr. Barton was born in Stow, Massachusetts, in 1888, and was educated at Harvard University, receiving the degree of Doctor of Philosophy in 1914. He was instructor in geology at Washington University, leaving that position to do geologic work with the Empire Gas & Fuel Company until the World War. He served in France during the War. From 1919 to 1923 he was division geologist at Houston for the Amerada Petroleum Corporation, and was chief geologist for the Rycade Oil Corporation from 1923 to 1927. For the next seven years he worked as a consulting geologist, accepting the position with the Humble Company in 1934.

Dr. Barton was a Member of the Institute of Petroleum since 1926. He was also a member of the Société Géologique de France, the American Association of Petroleum Geologists, of which he was President in 1938–1939, the Geological Society of America, the American Institute of Mining and Metallurgical Engineers, the Society of Economic Geologists, and the American Geophysical Union.

L. T. B.

ABSTRACTS.

AUTHORS INDEX.

The numbers refer to the Abstract Number.

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

Geology.

1.* Structural Geology of Wind River Canyon Area, Wyoming. J. R. Fanshawe. *Bull. Amer. Ass. Petrol. Geol.*, 1939, **23**, 1439–1492.—The Wind River Canyon, which transects the Owl Creek–Bridger uplift, affords good facilities for studying structural basin features of the types common in the Central Rocky Mountain region. The area described is roughly rectangular, about 17 miles long (north to south) and about 8 miles wide.

Stratigraphically, the rocks comprise all formations from Pre-Cambrian to late Eocene in age, except representatives of the Silurian and Devonian. A table and a detailed stratigraphic section includes all the formations present in the Wind River Canyon; these are shown to have an approximate thickness of 15,380 ft. Of this total 2550 ft. is represented by Palæozoic rocks, 1990 ft. by Trias and Jurassic sediments, and the remainder (10,840 ft.) by Cretaceous and Tertiary beds.

Earth movements in the form of Laramide mountain-building forces were responsible for varying results in each part of the area. General outlining of the basin areas occurred with the earlier phases of the regional compression. More intense phases of the Laramide compression followed, and readjustments by warping, folding, and faulting ceased in some areas earlier than they did in others. By mid-Eocene time the formation of basin structures and their peripheral mountain rims had taken place. It is clear that the southern part of the Bighorn Basin has been crowded relatively southward and slightly eastward with respect to the asymmetric Wind River Basin during Laramide time. The relative predominance of one basin over the other has thus led to large-scale movements in the Pre-Cambrian basement complex.

The chief single tectonic feature in the area is the Boysen Fault. This runs nearly east to west for over 10 miles and has a maximum observed stratigraphic displacement of 2500 ft. 3 miles east of Boysen. The fracture dies out gradually at its west end, and is lost in the Pre-Cambrian outcrops of Copper Mountain at the eastern end.

Numerous maps, sections, and photographs accompany the paper. G. S. S.

2.* Geology of Basin Fields in South-eastern Illinois. L. K. Lee. *Bull. Amer. Ass. Petrol. Geol.*, 1939, **23**, 1493–1506.—The area under review includes parts of Wayne, Clay, Richland, and adjacent counties in South-east Illinois, and is approximately 75 miles long and 30 miles wide. As the axis of the Illinois basin passes through these counties, the new fields have consequently become known as Basin Fields.

The axis has a southward plunge, and the deepest part of the basin in Illinois is in northern Hamilton and White counties. The basin is traversed by an anticlinal belt, which has also a southward plunge amounting to about 400 ft. from northern Richland Co. to Southern Wayne Co. The anticline is a simple structural ridge in the north, but towards the south the belt broadens and produces several anticlinal axes with synclines. Along these axes local reversals occur, on which most of the production is located.

The chief rocks of the area include those of the Chester and the Ste. Genevieve (McClosky) formations.

The most important production in the area is obtained from the Ste. Genevieve Limestone, which is persistently of an oolitic character. Porosity, however, occurs in lenses of varying degrees both laterally and vertically; it is more persistent on the structures than in the synclines, and is also considered to be primary in origin.

The Cypress (Weiler) Sandstone (Chester) also produces in the North Noble field. It is thought that Chester Sandstone production will become more important as development extends northwards.

To July (1939) 692 producing wells had been completed, giving 18,159,275 brl. Other production data are given in tabular form. G. S. S.

3.* Goldsmith Field, Ector County, Texas. A. Young, M. David, and E. A. Wahlstrom. *Bull. Amer. Ass. Petrol. Geol.*, 1939, **23**, 1525–1552.—Situated near the centre of the Permian basin of West Texas and South-east New Mexico, the Goldsmith Field is one of the many pools located on or near the eastern flank of the major structure known as the Central Basin platform. The limits of the pool have not been completely defined, although the main ultimate producing area has probably now been outlined.

Rocks of Cretaceous, Triassic, and Permian age occur in the field. The Cretaceous is represented by about 80 ft. coarse brown sands (Basement Sand) which lie unconformably on Triassic sediments. These consist of 1500 ft. of the Dockum Group, the upper 1000 ft. made up of red shale and the remainder of coarse red sands (Santa Rosa), and another red shale zone, the base of the Trias.

The Permian beds are divided into four members: Red Silt (100–150 ft. thick), Upper Evaporite, consisting mainly of salt (1200–1400 ft.), Lower Evaporite, chiefly anhydrite (1000 ft.), and the Dolomite section. The lower part of this member is the reservoir rock of the main accumulation of oil and gas.

Structurally, the field is essentially a flat-topped uplift with comparatively gentle dips. The edge of the structure is very irregular, particularly on the east side. " Noses " of varying size are common. Some of these, together with larger features such as the " South Dome," indicate cross-folding at right angles to the main axis extending north-west to south-east.

Production is from a common reservoir of a two-phase type in which the flood-levels are nearly constant. Present data indicate that water-drive is the controlling factor only in the " South Dome." Other portions of the field are under volumetric control.

It is suggested that the porosity of the reservoir is due to sub-aerial erosion and solution during a break in deposition now marked by an unconformity. G. S. S.

4.* Type Locality of Citronelle Formation, Citronelle, Alabama. C. H. Roy. *Bull. Amer. Ass. Petrol. Geol.*, 1939, **23**, 1553–1559.—The name given to this formation was introduced by Matson in 1916, because of the excellent exposures in the town of Citronelle and, more particularly, because of the presence of plant-bearing clays which he believed to be part of the formation exposed at Lamberts Station, a little south of Citronelle. The fossil plants obtained from these clays were determined by Berry to be of Pliocene age.

Recent work shows that the clays are faulted and overlain unconformably by the sands of the so-called Citronelle formation. There is evidence that the former are at least as old as the Pliocene, and that the sands and gravels which Matson called Citronelle are younger than the clays. It is therefore considered that the so-called Citronelle deposits are Pleistocene in age.

It would seem useless at this time to attempt to give any formational name to these deposits, and the term Citronelle should therefore be dropped. G. S. S.

5.* New Discoveries Stimulate Interest in Ecuador. W. A. Sawdon. *Petrol. Engr*, Oct. 1939, **11** (1), 107.—At present all the oil is produced from the Santa Elena peninsula and 95% of it is obtained from the Ancon field. Recently two 150-brl. wells have been completed in the deeper zone north of the east end of the Ancon field at depths of about 3800 ft.

All the old El Tambo field wells are shallow, except one which was drilled to 4000 ft. The average depth is 1200 ft., and production is from a sand which is probably a continuation of the Socorro sand. The Cautivo field has yielded oil from pits and shallow wells. Again the oil is from the Socorro sand. Similarly, the Carolina field has pits and wells. The wells average 600 ft. in depth.

The Ancon field has been developed in three areas. The shallow wells are 1000–1300 ft. deep, whilst the deep sands are at about 4000 ft. Productivity is erratic and is from fissures in a formation which is about 2000 ft. thick. During 1938 this field gave 2,119,500 brl. of oil. The average gas–oil ratio is seldom less than 500 c. ft./brl. or more than 1000 c. ft./brl. The formations drilled are hard, and details are given of the drilling equipment and methods. The crude is piped to a refinery and loading pier at La Libertad. G. D. H.

6.* Discovery on Inland Slope of Andes Increases Scope of Peru's Activity. W. A. Sawdon. *Petrol Engr*, Oct. 1939, **11** (1), 115.—Practically all the Peruvian oil comes from the coastal fields in the extreme north, but a recent discovery on the eastern slope of the Andes raises hopes of the development of other fields. Last year 83% of the oil came from Negritos, and most of the rest from Lobitos. Negritos gives oil from several areas, and it is piped to Talara. Of the 1842 wells operated in 1938, 92 flowed, 9 were on gas lift, and 34 were used for injection. The rest were pumped. Experimental water-flooding has been tried. Production is from four main Eocene sands: the Verdun, Lomitos, Perinas, and Salinas. In some areas the separation of the last three sands is not always clear. The wells range from a few hundred to 4750 ft. in depth. Information is given regarding the drilling, completion and production methods. The discovery of new productive areas is difficult and geophysics is being used. Block-faulting is common and marks off the various producing areas. Bottom-hole pressures range up to 2700 lb./in.^{2} and the gas–oil ratio is about 350 c. ft./brl.

The operations at Talara are described. Lobitos has seven main horizons, all in the Eocene. The shallower wells were less than 2000 ft. deep, but the new wells are over 4000 ft. The sands are faulted over the whole district and prediction of sub-surface conditions is difficult. Some wells flow, some are pumped, and some are on gas-lift.

Zorritos is the oldest oilfield in South America.

The Aguas Calientes field east of the Andes and at the head-waters of the Amazon has directed attention to vast areas in Eastern Peru and Western Brazil. The first well, 3104 ft. deep, found oil sands at 1021–1262 ft., and the initial production was 750 brl./day on a ½-in. choke. Two wells have been completed, and a third is under way. The area is 2 ml. from the head of the Pachitea River. Accessibility is difficult and equipment has to be taken 3000 ml. up the Amazon. Oil will probably be taken by pipe to Pucallpa on the Ucayali River, 28 ml. from the field.

In areas south and east of Zorritos test wells have had shows in several places. In the south in the Pirin region near Lake Titicaca several wells have been drilled and at least one has given a little oil.

The Aguas Calientes discovery has revived interest in the area round Contamania, near which there are seepages. G. D. H.

7.* Brazilian Government begins Aggressive Exploratory Programme. W. A. Sawdon. *Petrol. Engr*, Oct. 1939, **11** (1), 126, 128.—Three test wells are to be drilled in the coastal region in Bahia north of São Salvador, and a small well with a production of less than 1 brl./day was recently completed near São Salvador. The locations have been made on the results of geological and geophysical work. Virtually all Brazil has been surveyed geologically, and geophysical work has been carried out in the states of Alagoas, Bahia, São Paulo, Parana, and Santa Catharina. During the past 40 years test wells have been drilled in these States, in Rio Grande do Sol, and in Para. The bulk of the work has been in São Paulo, where most of the wells are less than 1000 ft. deep, although one went to 5000 ft.

Attention should also be given to Acré, near the Aguas Calientes field of Peru.

G. D. H.

8.* Recent Developments have Materially Strengthened Eastern Venezuela's Position. Anon. *Petrol. Engr*, Oct. 1939, **11** (1), 130.—Oil is now being shipped from the Quiriquire, Pedernales, and Temblador fields of Eastern Venezuela, and a pipe-line is being built from Oficina to Guanta on the Caribbean. A line is also to be built to Jusepin.

The monoclinal structure of Quiriquire is divided into two segments by a north–south fault. The reservoirs are lenticular and the oil zones 100–1400 ft. thick. Details are given of the drilling and gas-injection practice. About a fifth of the gas production —namely, 5,326,000 cu. ft./day—is returned to the reservoir continuously. It is doubtful whether the gas is moving uniformly in all the lenticular sand bodies in the producing section.

Initial pressures at Pedernales are above hydrostatic, and a number of the wells are off-shore. Temblador is on a long, narrow structure. Gas production and drilling details are given for these two fields.

Oil has been obtained from the Uracoa well and also from the El Tigre wells between Tomblador and Oficina. A small pumper was completed at Merey, south-west of El Tigre, and at Areo a little oil was found. Some oil was obtained in the Yopales well.

The Guanoco and Orocual wells were closed in several years ago, and the area east of Caripito and Maturin has been widely prospected without giving commercial oil production. The results obtained with other wells are given. G. D. H.

9.* Oil and Gas Content of Saratov–Left Volga Bank Region. V. Ya. Avrov. *Neft. Khoz.*, June 1939, **20** (6), 11–13.—So far only near Ozinki has oil been found in commercial quantities. In other parts there are indications—namely, bitumen in certain Carboniferous strata of the northern and north-eastern parts of Rayon, and the mineral-sulphur springs near Chapayevki (former Stolypin mineral springs).

Existence of gas in Saratov–Left Volga Bank rayon has been known since 1906, when the Melnikov gas well was sunk, the gas consisting mainly of methane with a relatively high N and He content. As crude oil has been found in adjacent Kuibyshev, Buguruslan, and Saratov–Right Volga Bank rayons, a survey of Saratov–Left Volga Bank rayon is deemed imperative.

The geological structure of rayon is discussed. Prospects of oil are very good as the structure is similar to that of the Emba field. Confirmations were obtained by exploration wells, but oil strata might be of local character.

As an analogy to Samarskaya Luka it is assumed that in Pugachov and Chapayevki region commercial oil and gas accumulations might be found in the Carboniferous at depths up to 1500 m. The possibility of oil occurrence in the Palæozoic and Devonian and the origin of gas are discussed. Helium seems likely to occur in the Palæozoic, and exploration of these horizons is advocated. L. R.

10.* Combustible Gas Seepages in River Sarbaya Basin. A. K. Banov. *Neft. Khoz.*, June 1939, **20** (6), 18–19.—In Kinel–Cherkassy and Podbyelsk rayons of Kuibyshev district in the basin of the upper part of Sarbaya river many gas exits have been located. The geologic structure of the territory is examined. No striking structure types are found, only widely developed microtectonic phenomena. Gas seepages have been detected over almost all the rayon, but are for the greater part situated in the north-eastern region. Gas yields are insignificant, probably varying up to 5 cu. m./sec. Gas compositions of thirteen locations are tabulated. All are methane gases with a high N content, whilst in one case almost pure N was found. Content of heavy hydrocarbons varied between 0·1 and 0·8%. The nature of the gases is not known, but they undoubtedly come from greater depths, having migrated from gas-carrying strata, possibly together with oil, and permeated a horizon carrying water, with which the gases come to the surface.

It is concluded that the gas leakages in the Sarbaya river basin have a great practical importance and that exploration work should be accelerated. L. R.

11.* Second Conference of Geologists and Geophysicists of the Y.P.F. Anon. *Bol. Inform. Petroleras.*, Aug. 1939, XVI (180), 3–21.—This conference was opened on 17th April, 1939. Fourteen papers were read, and followed by discussions. Diagrams showing the timing and electrical characteristics of two borings at Comodoro Rivadavia, in connection with de Luca Muro's paper, are of particular interest.

H. I. L.

12.* Discovery of Petroleum at Pirin, Peru. Anon. *Bol. Inform. Petroleras*, Aug. 1939, XVI (180), 57–58.—In the course of drilling carried out by the P.W.D. of Peru in the reserved zone of Lake Titicaca, petroleum was obtained from well RH 2, at a depth of 56·48 m. The oil gushed out to a height of 2 m. and the daily output has been 100 brl. This oil-field is the highest in the world, its altitude being between 3800 and 4000 m. The well itself stands at 3920·50 m. H. I. L.

13.* Illinois Reserves Reach Half-Million Barrels. G. Triplett. *Oil Wkly*, 5.6.39, **93** (13), 66.—The author, in discussing Illinois reserves, reports an ultimate yield of 461,810,000 brl. of crude oil, of which 40,112,385 brl. have already been produced.

Reserves of new fields in Illinois are detailed in a table. Kentucky and Indiana are also discussed, but the interest in the latter reserves is not so strong as in that of Illinois. A. H. N.

Geophysics.

14.* Electrical Well-logging. Houston Geological Society Study Group. *Bull. Amer. Ass. Petrol. Geol.*, 1939, **23**, 1287–1313.—This paper is concerned principally with the effects of abnormal conditions on the S.P. and resistivity curves. In the case of the S.P. curve, these may include formation pressures equal to or greater than the hydrostatic head due to the fluid in the well, and drilling fluid with a salinity equal to or greater than the salinity of formation brines. That care must be taken in the interpretation of these curves is emphasized by the fact that it is possible for no anomaly to be shown in front of a porous formation. Resistivity measurements may yield misleading results, on account of penetration of drilling fluid into the strata, abnormal salinity of the drilling fluid, and the presence of relatively large amounts of colloidal matter in the more permeable formations.

Correlation may be attempted in three different ways: short-distance correlation on a field, regional correlation, and structural correlation. The application of electrical logging to structural work in the Gulf Coast has shown that, contrary to previous ideas, the deep structures are reflected in the surface beds.

The typical reaction of fluids in various formations is discussed, and it is shown that it is necessary to distinguish between clean, dirty, and cemented sands. Thin layers of salt have a similar effect to other resistant rocks, but, if the salt is readily dissolved by the mud, enlargement of the diameter of the hole will cause a fall in resistivity.

In addition to correlation, electrical logging is being applied to the determination of the fluid content of sands and to the measurement of permeability. S. E. C.

Drilling.

15.* Determining Sand Thickness in East Texas Wells. H. L. Flood. *Petrol. Engr*, Sept. 1939, **10** (13), 45.—The paper describes the steps taken by one East Texas operator to determine accurately the total thickness of oil-bearing sand in the Woodbine formation in order to provide a formula for production potential. The decision was taken after the rotary equipment was moved away, and as it was not considered economical to use cable tools in the formation, the reversed-oil drilling method was used.

In this method there are two trucks; the first is the hoist truck, and the second is the pump truck. Oil is used as a drilling fluid. An electric motor drives the 2-in. or 2½-in. drilling string, at the end of which is attached a special tubing bit, by means of a hexagonal kelly and a worm drive. A 7½-h. p. electric motor was sufficient to drill at a rate of 5 ft./hr., and provided a safety means, as the motor stalled long before undue stresses developed in the tubings. The ammeter provided a most sensitive torque indicator. Reversed circulation of the oil is used to impart high velocities, and hence high lifting power to the oil.

Electrical logging determined the sand thickness, and a formula for the proration factor was developed based on this and other information. A. H. N.

16.* Proposed Layout for a Four-Engine Rotary Rig Drive. F. E. Bruhn. *Petrol. Engr*, Sept. 1939, **10** (13), 51.—Four Diesel engines are arranged to provide ample flexibility for all combinations of pump and table speeds. The four-engine drive is proposed to eliminate some of the many disadvantages of the two-engine rig, which is the predominating type at the present time. A drawing shows clearly the layout of the unit, with clutches and pulley drives being arranged to connect any or all the engines to any member of the rotary rig.

It is believed that the increased flexibility, increased ease of rigging-up and moving from one location to another, and the high maximum horse-power output available make this drive extremely desirable for drilling to depths of 3000–6000 ft.

A. H. N.

17.* Oil-Well Cements—Chemical Composition and Sensitiveness to Additions of Water. S. L. Meyers. *Petrol. Engr*, Sept. 1939, **10** (13) 100.—Prof. Solacolu has made a study of the effects of adding large quantities of water on the strength of different portland cements, and has thus shown the relationship existing between the chemical composition of the cements and their sensitiveness to large addition of water.

In this report a description is given of the methods adopted in the research, the control steps taken, and the results attained. It appears that high-iron cements are sensitive to increases of water content. High-alumina cements, on the other hand, appear to be relatively insensitive to water changes.

The effects of temperature are also studied, and results of the research are presented in both tabular and graphical forms. A. H. N.

18.* Preliminary Design of Drilling Barge for Deep-Water Prospecting. Part I. R. H. Rogers. *Petrol. Engr*, Oct. 1939, **11** (1) 21.—At the present time under-water drilling is done by equipment mounted on submersible barges or on platforms or decks constructed on pile foundations. This system of drilling from a submersible barge affords a compact, self-contained, mobile drilling unit mounted on a fixed working-platform, a fact which cuts down drilling costs, as it is not necessary to dismantle the rig before moving on to a new location. The disadvantages attending the system are : (1) the limited depth of water in which it can be worked, (2) the necessity of working on a level bottom, with consequent increase in drilling costs.

Drilling from a platform on a pile foundation has exactly the opposite attributes discussed with regard to drilling barges—*i.e.*, high dismantling cost, limit to depth much larger, and no necessity to level the bottom.

It would appear that the ideal drilling rig should combine the advantageous characteristics of both the submersible barge and the pile-founded platform. The author proceeds to design a floating drilling rig with telescopic legs, endeavouring to fulfil the following list of conditions. The rig should :

(1) be capable of drilling in shallow or deep water (9–50 ft.) ;
(2) offer an adequate working-platform having all drilling equipment arranged for efficient drilling ;
(3) be mobile, either self-propelled or not ;
(4) be able to ride out reasonably bad weather ;
(5) have ample storage facilities ;
(6) have adequate transverse stability ;
(7) have adequate longitudinal stability ;
(8) offer a dry working-platform in bad weather ;
(9) be capable of being easily removed after completion of well.

In this part of the paper the author deals with the general description of the equipment and with five items in the design method—*i.e.*, weights, displacement, trim, longitudinal stability, and transverse stability. A. H. N.

19.* Record of Penetration Rate Should Aid in Drilling-Time Studies. H. L. Flood. *Petrol. Engr*, Oct. 1939, **11** (1), 31.—To control and maintain the efficiency of drilling, various instruments have been devised, such as the weight indicator, torque recorder, table-speed tachometer, instruments for measuring deviation of crooked holes, electrical logging, mud analysers, and, more recently, instruments that will warn of the imminence of oil and/or gas in the formation being drilled.

One of the most recent of such instruments is one which records the rate of penetration. The principle of the instrument is to record the weight of the column of liquid of the height of the rotary swivel : as the hole is deepened, this height is recorded on a chart revolving at a known rate, and thereby provides automatically a record of the number of feet of hole drilled per unit time. Thus the instrument consists of a fluid reservoir attached to the swivel, a length of rubber hose, and a special recording low-range pressure gauge. The fluid may be clear water or an anti-freeze solution in cold water. An important accessory is a celluloid template used to analyse the charts and translate the records to rates in terms of feet/min., and feet/hr. A. H. N.

20.* Modified Form of Slim-Hole Drilling for Exploration Wells. M. A. ap Rhys Pryce. *Petrol. Engr*, Nov. 1939, **11** (2), 29—32.—" Slim-hole " drilling describes the drilling of holes to moderate depths to obtain geological information. If the slim-core-hole proves the presence of oil, the operator makes the capital outlay required for the full-size exploitation holes. If, on the other hand, no oil is found, only a minimum amount of capital has to be written off to exploration. The hole is not suitable to be put on production. A method used in South America, however, permits deep tests to be converted into producing wells in the event of oil being found.

The dangers of slim-hole drilling, due to twist-offs, etc., are discussed, and the practices in Trinidad are especially quoted for data on the mud fluid, pressures, velocity of mud, weight on bit, etc.

An analysis is made of the cost of drilling a slim-hole and " streamline drilling " as compared with full-size hole. Approximately 48% less material, principally shale or rock, must be cut and removed from the former than from the latter. Other savings are also given.

A typical well drilled under these " streamline exploration " conditions cost no more than $100,000 at normal rate of exchange, even including transportation. This cost compares favourably with most South American wildcats, which frequently cost a quarter of a million dollars or more, in similar circumstances. A. H. N.

21.* " Slant-Hole " Drilling of Wells Employed in Argentine. Anon. *Petrol. Engr*, Nov. 1939, **11** (2), 80.—A description is given of directional-drilling methods adopted to exploit oil-bearing formations beneath the Gulf of San Jorge. The wells are the first of their kind to be drilled in the Argentine Republic. A. H. N.

22.* Carelessness may be the Cause of Accidents on Drilling Rig. R. G. Bennett. *Petrol. Engr*, Nov. 1939, **11** (2) 140.—The causes of certain accidents in drilling are discussed, chief amongst them being the driller with mania for speed who can endanger the lives of an entire crew by a laxity in safety precautions. Although the paper is written in a rather light vein, it is a serious treatment. It particularly deals with cases, such as exist in South America, where drilling crews are composed of unskilled or semi-skilled labour, trained by a foreign driller in whom they place all confidence. A. H. N.

23.* Deepen Old Producer in North Louisiana Field. G. Weber. *Oil Gas J.*, 7.9.39, **38** (17), 28.—Much of this short article is concerned with the future programme of an interesting well in the Lisbon field. An improved gas-detector will be used to signal the driller at the first indication of an increase in gas content of the mud. It works as follows :—

The instrument consists of a baffle tank held under vacuum by a steam jet. The mud flows over the baffles, and any gas in solution is drawn to the surface and removed, together with air to the electrical-combustion detector. There a hot-wire filament set on a sensitive Wheatstone bridge circuit causes a film combustion, known as the skin effect, immediately around the filament. The increased temperature due to the gas combustion raises the electrical resistance of the filament, throwing the circuit out of balance, and recording the effect in the galvanometer reading and the horn signal. By varying the resistance in the Wheatstone bridge circuit, the instrument can be made to detect gas increase over a wide range. By means of successive readings, the operator can determine whether the gas content in the mud is increasing, remaining constant, or decreasing, and can thus check the walling action of mud after gas horizons have been drilled. A. H. N.

24.* Metals in Drilling—The Rotary Chain. W. L. Nelson. *Oil Gas J.*, 7.9.39, **38** (17), 48.—This is the third article of a series which is designed to cover the industry from oil-sand to filling-station. Recommendations are given in tabular form, and are taken from various metal and equipment manufacturers. A. H. N.

25.* Continental Completes World's Deepest Washing-Over and Cutting-out Job. P. Reed. *Oil Gas J.*, 28.9.39, **38** (20), 34.—The deepest washing-over and cutting-out operation ever undertaken on any test in the world was recently successfully completed at Continental Oil Co.'s No. 1 Well in Western Oklahoma, at a depth of 14,000 ft.

In the method employed, a wash-over string, equipped with a rotary shoe having a slightly larger outside diameter and a slightly smaller inside diameter than the drill-pipe cutter is circulated and rotated over the stuck drill-pipe. After the stuck drill-pipe has been washed over for the desired distance, the wash-over string is withdrawn from the hole and the rotary shoe is replaced by the drill-pipe cutter. The wash-over string is then run back into the hole and the cutter is lowered over the stuck drill-pipe. A cut is made a short distance below a tool joint.

The wash-over operation and cutting procedure adopted in this particular instance are detailed and illustrated in the paper. A. H. N.

26.* Combating Electrolytic Corrosion of Gas-Well Casing by Insulation. W. E. Huddleston. *Oil Gas J.*, 28.9.39, **38** (20), 40.—Leakage of stray electric currents was detected on a large number of wells in the Panhandle area of Texas, and corrosion of the casing from this source has been determined. Elimination of further trouble has been effected by insulating the casing. A diagram depicts the interaction of gas-well casing and lateral lines in the field, and shows surface lines receiving enormous " pick up " in close proximity of the wells.

An outline is given of the methods used in insulation and of detection.

A. H. N.

27.* Metals in Drilling—Rotary Equipment. W. L. Nelson. *Oil Gas J.*, 28.9.39, **38** (20), 58.—This is the fourth short article in the series, and gives the approximate analysis, approximate physical properties, and heat treatment of metals used in the rotary table, pinions, swivels, shaftings, and gears. The steels listed have been recommended by various manufacturers, and a reference list is appended to the article.

A. H. N.

28.* Metals in Drilling—Drilling Hoists. W. L. Nelson. *Oil Gas J.*, 5.10.39. **38** (21), 54.—In this paper specifications and suggestions are taken from current literature and from manufacturing company bulletins. Approximate analysis, approximate physical properties—*i.e.*, yield point, elongation and Brinell hardness, and heat-treatment suggestions are given for catheads, brake-rims, brake- or clurch-bands, drum flanges, sprockets, bearing boxes, shafting and drive bushings for draw-works and drilling hoists are tabulated. A. H. N.

29.* Drilling Equipment Accounts for Illinois Completion Rate. Anon. *Oil Gas J.*, 26.10.39, **38** (24), 62.—Rigs of all types have drilled more than 5,000,000 ft. of hole in the Illinois fields during the past year.

A detailed description is given of many practices and drilling methods employed in the basin.

The paper is one of a series in an " Illinois Basin Section " of the *Oil and Gas J.*

A. H. N.

30.* Hard Formations Increase Well-Drilling Costs. H. F. Simons. *Oil Gas J.*, 26.10.39, **38** (24), 129.—Expense due to unusual wearing of rotary and cable-tool bits is of such importance that the subject of hard formations is reviewed with special attention. The paper deals mainly with conditions encountered in penetrating quartzite and other hard formations which retard drilling operations to an unusual extent.

During the early stages of development in a field, bit costs are often high, but they are reduced as the contractor and drillers become acquainted with the formations and are thus able to obtain the maximum footage per bit. A point is reached, however, where the number of bits cannot be further reduced. Any difference in the number of bits used on the various wells then becomes dependent on the type of surface machinery used and the local variations in geologic conditions. A. H. N.

31.* Metals in Drilling, Part 7, Crown and Travelling Blocks. W. L. Nelson. *Oil Gas J.*, 2.11.39, **38** (25), 49.—Recommendations and specifications are taken from authorities, manufacturers, and fabricators of steels for crown and travelling blocks. The approximate composition, yield point, elongation, Brinell hardness, and suggestions for heat treatments are given for sheaves (six types), bearings and pins (three types), pins (two types), and shafts (three types). The significance of Brinell hardness in terms of machinability is discussed in the paper, which ends with a list of references. A. H. N.

32.* Simultaneous Electrical Logging and Drilling. P. Reed. *Oil Gas J.*, 17.11.39, **38** (27), 93.—Five wells have been drilled with an electrical record of formations being made while the drill stem was making hole. The first four wells were in proven areas, whilst the last one drilled was a wildcat. All wells were re-surveyed after completion by the conventional method.

The equipment consists of specially constructed kelly, drill-pipe, tool-joints, and drill collars. Recording and control equipment is centred to a large extent in a house trailer. Only the front part of the trailer is required for this purpose, the remainder being fitted as living accommodation for the observers. The recording and control equipment in the trailer is connected to associated parts on the derrick floor through a set of electrical weatherproof cables.

The kelly has been constructed to contain an electric cable, which connects to a brush-box mounted at the top immediately below the swivel. The electrical circuit for electrical logging is established through the brush-box to the bit by means of a section of cable built into each joint of drill-pipe. With the exception of the cable, the drill-pipe is entirely standard. Special joints are designed which, when screwed together, the terminals engage and establish contact and insulate the circuit from the mud stream.

To permit the bit to function as an electrode, a specially designed drill-collar insulates it from the drill-pipe. A testing switch of ingenious design is incorporated in the circuit. A. H. N.

33.* Collapsing Pressure of Oil-Country Tubular Goods. W. C. Main. *Oil Gas J.*, 17.11.39, **38** (27), 102. Paper presented before American Petroleum Institute.—This is a new approach, from a theoretical standpoint, to the problem of collapsing pressures of oil-country tubular goods.

The paper points out the limitations of present formulas, and suggests a method whereby the two existing types of rational formulas might be combined to give a result which is also rational, and will apply throughout the entire range of tube proportions regularly used for casing, drill-pipes, and tubing.

Although the equation which is developed by this method is cumbersome, it should aid in clearing up some of the mistaken notions on this problem, and help to straighten out the controversy on safe setting depths of oil-country tubular goods from a collapsing pressure point of view. A. H. N.

34.* The Carter Pressure Core-Barrel. Ben W. Sewell. *Oil Gas J.*, 17.11.39, **38** (27), 140. Paper presented before American Petroleum Institute.—A pressure core-barrel is a coring device which differs from conventional core-barrels in that the core, after having been cut, is sealed within a chamber and brought to the surface under pressure.

The primary purpose of such a core-barrel is to prevent the loss of the contents of the core due to expansion as the pressure surrounding the core is reduced, thus permitting a more accurate determination of its original content.

A discussion of the entire field of pressure-core applications is beyond the scope of this paper ; the more general uses include the following :

1. A more certain determination of reservoir content than is furnished by the conventional non-pressure-type core-barrel.
2. Location of gas-caps and determination of content.
3. Studies of oil, gas, and water gradients through a producing zone.
4. Studies in well spacing.
5. Studies of oil remaining in place in depleted fields by drilling and coring intermediate wells.

6. Studies of various methods and rates of production by working on cores while cores are under pressure.
7. Studies of contamination of cores.

Briefly, the Carter pressure core-barrel may be described as a conventional core-barrel, containing a third tube between the inner and outer barrels. This third tube is provided with valves at both ends and an arrangement for lifting the inner barrel containing the core up into it, after which the valves are closed. All these operations occur at the bottom of the hole. A. H. N.

35.* Porous Formations Sealed by Stage-Cementing Deep Wildcat. H. F. Simons. *Oil Gas J.*, 23.11.39, **38** (28), 38.—The Continental Oil Co.'s No. 1 Proctor, Oklahoma, currently the deepest drilling test in the world, recently began having trouble with caving shale. Circulation could not be maintained with mud heavy enough to stop caving of the shale at the bottom of the well. The fluid was escaping into the formation back of the liner set from 9712 to 14,491 ft. whenever it was " heavied " to stop caving.

The problem was successfully solved by an unusual squeeze-cementing job, which consisted of placing 665 sacks of cement in eleven batches behind the liner, with one setting of a Baker Type K cement retainer at 9708 ft.

Full history of the well and details of the squeeze cementing job are given.
A. H. N.

36.* Drilling to Determine Illinois Daily Output. Anon. *Oil Wkly*, 5.6.39, **93** (13), 53.—It is pointed out that production in Illinois is a function of well completion, as Illinois is a pumping area, and therefore the daily output varies with the number of wells completed. The practices in the Loudon area are described, where wells average 1650 ft. and may be drilled in 100 hr. A. H. N.

37. Oil Possibilities of Deeper Beds in Illinois Basin. A. H. Bell and G. V. Cohee. *Oil Wkly*, 5.6.39, **93** (13), 58.—The authors give the oil possibilities in deeper beds in the Illinois Basin. A table of wildcat wells drilled in the Devonian or deeper sands since 1936, with details of depths, tests, and remarks is given. The Devonian–Silurian limestone appears to have good possibilities of oil production on favourable structures in the Illinois Basin. A. H. N.

38.* Large Oil Volume Found Per Drilling Dollar and Foot. W. H. Strang. *Oil Wkly*, 4.9.39, **94** (13), 16–18.—An analysis of discovery rates and drilling expenditures in the United States during the 4-year period ended 31st December, 1938, reveals that the operator with average success found $3·89 worth of oil for every dollar spent for drilling activities, and 29·8 brl. for every foot drilled.

The difficulty of obtaining accurate information upon the total expenditure of the drilling-producing industry during this or any other period precludes the possibility of an actual profit calculation on finding and producing oil, but it is certain that high production costs, slow rates of investment return, and burdensome taxes whittle the imposing $3·89 figure down to an actual profit in the neighbourhood of a few cents per dollar spent.

Figures in tabular and diagramatic forms are given for the large reserves found per foot drilled.

In two States the return was not sufficient to repay the expenses of drilling alone, production and other costs being entirely a loss. A. H. N.

39.* Derricks Being Assembled Horizontally on Ground and Raised as Unit. F. B. Taylor. *Oil Wkly*, 4.9.39, **94** (13), 24–26).—The new method for assembling steel derricks is given, and records show that in the fields where this method has been used the procedure is another achievement in the saving of drilling time.

The derrick is fabricated in five sections, each bolted and welded as a unit. Assembly bearings joint the sections. When completely erected the derrick has a height of 87 ft., sufficient to care for either regular shallow or slim-hole equipment. When the five sections are assembled on the ground and the work is checked, the derrick is jack-knifed into a vertical position by the draw-works. The joint of the jack-knife which serves as the bearing for the lifting operation is at the front end of the base. To dismantle, preparatory to moving, the process is reversed.

The paper is well illustrated by photographs of the different stages of the operation, and each step is described in detail. A. H. N.

40.* Ideas Used to Solve Field Employee Work Schedules. B. Mills. *Oil Wkly*, 4.9.39, **94** (13), 28.—The paper presents a varied programme of work to meet the provisions of Wages and Hours Act of the U.S.A. The practices of various companies and employees are given as typical examples for provisions both for weekly schedules and for overtime work.

Weekly working schedules for drilling crews are more difficult to make and observe than are those for ordinary field-men. Much of the miscellaneous field work is carried out on a straight eight-hour daylight basis, whilst drilling hours are continuous.

Oil companies and drilling contractors pay exceptionally high wages, the average for each group being above the average for manual labour in any other major industry. A. H. N.

41.* Beware of Derrick Floor—Drilling's Danger Spot. J. I. Powell. *Oil Wkly*, 25.9.39, **95** (3), 30.—While admission must be made that the safety situation in oil-field operations has shown a continued improvement in the past ten years, it is not, however, an indication that the much-desired objective has been reached.

The fact that more than one-third of the accidents occur in the area of the derrick floor indicates the need for greater prevention work. Tables and analyses are given for the frequency of accidents, relative severity of accidents, and the distribution, frequency, and cost of 1000 oil-field accidents. The derrick floor looms on the top in the frequency and total cost of accidents.

It is suggested that oil operators, particularly those who do not have an organized safety programme at this time, should develop a training programme based on the findings of this analysis. A. H. N.

42.* Drilling Gains as Shutdowns and War Strengthen Markets. L. J. Logan. *Oil Wkly*, 16.10.39, **95** (6), 15–17.—Decrease of completions in September reflects the interruption in the starting of new wells by oil-field shut-downs in six Mid-Continent States during the latter half of August.

Data are supplied on the activities of oil-fields in September, and comparisons are made with other periods. A. H. N.

43.* First Mississippi Drilling was Back in 1903. W. H. Strang. *Oil Wkly*, 13.11.39, **95** (10), 56.—An interesting history of wildcat drilling in Mississippi is presented. Although Mississippi did not enter the list of commercial oil-producing States until 5th September, 1939, when the Tinsley dome in Yazoo County was proved productive, exploration for oil and gas within its boundaries began as long ago as 1903. Nevertheless, two-thirds of the 300 wildcat failures drilled in the State have occurred in the past 9 years.

A summary is given of the drilling activity in Mississippi, non-productive wells drilled as well as the productive ones, from 1903 to 1st November, 1939.

The geology of the fields is briefly discussed. A. H. N.

Production.

44.* Mississippi Well is Flowing Oil. N. Williams. *Oil Gas J.*, 7.9.39, **38** (17), 25.—A report on oil well No. 1 Woodruff is given which shows that commercial oil production in Mississippi seems almost a certainty. A. H. N.

45.* Fifteen-Day Shutdown Period used to Good Advantage. Anon. *Oil Gas J.*, 7.9.39, **38** (17), 42.—Production engineers and operators are now able to review field conditions during the 15-day shutdown of all important oil-pools in Texas, Oklahoma, Louisiana, Kansas, New Mexico, and Arkansas. They are also witnessing the first effect of the shutdown on wells that have resumed production. Several months must elapse before it is possible to state accurately the results in all instances, but general observations are summarized in this paper.

The period of the shutdown was from 16th August to 1st September, and was unprecedented—the shutdown was complete with the exceptions of wells which were making abnormally large quantities of water, which might be permanently injured as producers.

Bottom-hole pressures were taken by several companies, and, as may be expected, the pressures increased over the period; but at least two months must pass before definite conclusions can be reached.

The operations in the fields during the shutdown period are summarized.

A. H. N.

46.* Electrically Driven Powers and Central-Generating Unit Feature of Texas Leases. J. C. Slonneger. *Oil Gas J.*, 14.9.39, **38** (18), 42.—The combination of electrically driven geared powers and a central generating plant is unique in the oil industry. In the first installation of this character, which differs from the usual central generating plant for oil-well pumping in general design, an effort has been made to take every advantage offered by central generating-plant pumping and to reduce to a minimum the difficulties arising from oil-well loads..

The problem was to pump seventy-seven wells, 2700–2800 ft. deep, and varying in output from 60 to 200 brl./day, in a field which promises long life, but which may exhaust its gas supply. It was desirable to keep the initial power-plant investment at a minimum and provide for its orderly expansion, so that in the entire life of the field the power-plant would never be out of proportion to the power needed.

The paper gives the solution adopted for this problem and discusses the layout of the equipment and its operation. A. H. N.

47.* Recovery Programme in Naval Reserve Field. H. F. Simons. *Oil Gas J.*, 14.9.39, **38** (18), 56–58.—Taking advantage of the similarity and location of the wells in the Naval Reserve of Oklahoma, owners of these wells have established an unusual community re-pressuring project, with each company in the field sharing ownership and expense. The project started in 1937, 5 years after the discovery.

The operation of, and the results obtained from this enterprise are outlined. Although troubles have been met in the winter, due to gas hydrates freezing and blocking the line, the advantages outweigh the difficulties. Freezing troubles have now been partly eliminated by injecting anhydrous ammonia; methanol has been injected in emergency cases. A. H. N.

48.* Conservation and Proration Analysed. J. E. Pogue. *Oil Gas J.*, 28.9.39, **38** (20), 17.—The paper is a part of a statement by Dr. Pogue concerning the economical aspects of the problems of conservation measures for " maximizing the effective use of reservoir energy in the production of oil, despite the contrary influence of the rule of capture." The rule of capture subjects the industry to activation at the source, and widens the range of production costs, impairs the functional aspect of price, creates instability, and at the same time inhibits maximum recovery.

To counteract these tendencies the reservoir energy should be conserved and most efficiently utilized by regulating the flow of oil-pool to optimum rates, or less, in conformity with engineering principles, even though the pressures of supply may be contrary to this objective.

The conflict between these two rules is analysed. A. H. N.

49.* Re-Cycling Trend Expands with Bigger Gas Reserves. G. Weber. *Oil Gas J.*, 5.10.39, **38** (21), 36–39.—This is the first of a series of papers to appear in the *Oil and Gas J.* which will deal with design, construction, and operation practices, a discussion on gas-testing methods, and vital legal considerations which must be given to the problem of gas condensate fields.

This paper defines the terms employed, discusses plant operations and methods of processing, and presents a survey of gas condensate fields in Texas and Louisiana.

A. H. N.

50.* Injection of Gas into Oil Reservoirs. H. L. Baldwin. *Oil Gas J.*, 5.10.39, 38 (21), 46.—The principles of injection and flow of gas in oil reservoirs are given. The importance of permeability tests is the first point to be stressed.

A general sketch is made of the flow of heterogeneous fluids, gas and oil, in porous media, and the effects of connate waters are taken into account. These principles are applied to secondary recovery methods in a general manner—no complex or detailed formulæ are given.

The practical application of gas injection under three headings—pressure maintenance, gas-drive, and pressure restoration—is discussed. These are distinguished by the relative oil saturation remaining at the time of application and by the method of application. The term re-pressuring is often applied to either or both of the latter two types.

The ideal type of reservoir for pressure maintenance is one with a sand section of high horizontal and vertical permeability, a large structural closure, an initial gas-cap, and an effective water-drive.

Gas-drive is generally applied at a time when reservoir pressures are a low portion of the original and the per cent. liquid saturation has been reduced to values so low that appreciable permeability to gas is present and the oil must be moved more by a viscous drag than by a displacement mechanism.

Among the advantages of pressure restoration as compared with gas drive is a decrease of viscosity of oil through solution of gas, a minimizing of the effects of permeability differences by forcing gas to enter the tighter portions of the sand, and a partial correction of irregular water-encroachment conditions. A. H. N.

51.* Testing and Sampling Methods Used on Condensate Wells. G. Weber. *Oil Gas J.*, 12.10.39, 38 (22), 48.—The lack of sufficient data on the behaviour of gas in the retrograde pressure range prevents accurate calculation of plant-operating conditions and expected yields, which is possible at lower pressures where simple gas laws apply. Until the time when enough is known of the behaviour of gas at higher pressures to support accurate computation, the basic data on re-cycling operations must be obtained from actual well and laboratory tests.

Methods of sampling and testing gas under high pressures are discussed, including Bureau of Mines and Texas Railroad Commission tests. Drawings are given to illustrate the apparatus, and curves are discussed to typify the results obtained.

A. H. N.

52.* Novel Method of Suspending Rod-Lines. Anon. *Oil Gas J.*, 26.10.39, 38 (24), 126.—Both lime- and sand-wells in the Illinois basin decline rapidly to the point where they must be put on the pump soon after completion, and consequently one of the major producing problems in the area is economical lifting of the oil, by mechanical means. The Pure Oil Co., the oldest in experience in the area, has adopted the centrally geared power-and-jack method of obtaining its production.

One of the most unusual features introduced is a new type rod-line carrier which reduces friction losses and increases the efficiency of the pull-lines. The new carriers are constructed from junk sucker rods and hardwood blocks. As the rod-line travels, uprights and a swinging member are made free to travel with it, and a supporting block is forced to move in a straight line, with the rod-line being fully supported throughout its entire travel. The wood is lubricated at first, but a glazed surface develops, which makes an excellent bearing, wears well, and is practically frictionless. These bearings are much more efficient than the sliding of the rod back and forth across the doll-head, and in actual use have required less greasing and care.

A. H. N.

53.* High-Pressure Development in the Bradford Field. J. P. O'Donnell. *Oil Gas J.*, 2.11.39, 38 (25), 50.—While it has been recognized for some time that high pressures result in earlier and greater ultimate recoveries in water-flooding, operators in the

Bradford field of Pennsylvania have shown but little disposition to increase substantially the pressure of their input water. This is due to the fact that practically all properties already under development are equipped to handle comparatively low pressures, and that the water-lines and tubing would not withstand the higher pressures if the plants could supply them.

The author discusses the limits of pressures it is possible to use. Theoretically, pressures in excess of 1 lb. of pressure at the sand face per foot of overburden would lift the overburden and result in entirely by-passing the sand. A. H. N.

54.* Compression Requirements for Re-Cycling. F. W. Laverty. *Oil Gas J.*, 2.11.39, **38** (25), 32.—Recently developed practices in high-pressure gas-fields of processing the gas through the retrograde condensation range to recover a distillate, and then to return the residue to the producing horizons involves boosting gas pressure to something above the formation pressure. Such pressures commonly range up to 5000 lb./sq. in.

The economics of such a process is governed by the power required and its cost. The power required depends on : (1) the volume of gas to be handled ; (2) suction pressure to the compressor ; and (3) discharge pressure from the compressor.

The volume to be handled is a function of field conditions, which can only be determined by field tests. The suction pressure is usually determined by the recovery process. The discharge pressure is determined by the pressure in the sand and the friction losses between the compressor and the sand. The properties of the gas to be handled determine the horse-power required to a limited extent.

The author derives expressions and gives curves for the calculation of horse-power under the extreme conditions obtaining in retrograde condensation range.

A. H. N.

55.* Applied Conservation Assures Magnolia Large Recovery. G. Weber. *Oil Gas J.*, 9.11.39, **38** (26), 12.—The Magnolia field, Arkansas' largest oil reserve, is nearing the completion of its drilling development. Due to compilation of unusually complete engineering data and geologic records, much information regarding its future importance can now be determined.

The field provides an outstanding example of the benefits of strict conservation principles. It is thought that the wide well-spacing, adequate casing programmes, uniform drilling, and completion methods and equitable proration adopted in this field assure maximum recovery over long flow period.

Conservative estimates place the recoverable petroleum reserves from the Magnolia field at 180 million brl., 292,000 million cu. ft. of gas, and 628 million gal. of natural gasoline and butanes. The estimated productive area is only 4000 acres, which fact renders the estimates unusual.

Discussion of the estimated reserve factors and withdrawal rate are given, together with a plot giving production, bottom-hole pressure, and gas/oil ratio. A. H. N.

56.* Acreage Given More Weight in Texas Proration Methods. D. H. Stormont. *Oil Gas J.*, 9.11.39, **38** (26), 20.—Operators in Texas fields are now favouring the trend to wider spacing of wells than was adopted hitherto, and are attaching more importance to acreage in deriving their proration formulas. Increasing numbers of wells and the downward trend in well allowables leave operators but little choice. The generally greater depths that holes must be carried, with the attendant higher cost of drilling, also influence the trend towards larger proration units and wider well spacing.

Figures show that prior to 1929 only about 11% of Texas fields were developed on spacing patterns of 20–40 acres ; during the period between 1929 and 1939 less than 46% of the fields were drilled on this basis ; but so far this year (1939) about 90% of the new field rules called for 20–40-acre spacing pattern.

Spacing patterns and proration units now in general use are discussed.

A. H. N.

57.* Advanced Engineering Ideas Used in High-Pressure Field. N. Williams. *Oil Gas J.*, 9.11.39, **38** (26), 30.—The McFaddin field of Southern Victoria County, South

Texas, offers an example of systematic development where unusually symmetrical and uniform structural conditions make possible an effective oil recovery.

The field is in a general area once notorious for its treacherous, high-pressure gas sands. Recently, however, the danger of major blow-outs appears to have been controlled.

With only one land ownership involved, it was possible to divide the field into 20-acre units of regular and uniform shape, permitting consistent adherence to the spacing pattern adopted. All wells have been located as near as possible to the centres of the units. Absence of competitive drilling has enabled the operators to drill in the order desired, and to their advantage.

A contour map of the field is given with contour lines on top of the sand. The symmetry of the area as shown by the contours is unusual. A geological section of the field is also given and the geology of the area is discussed. A. H. N.

58.* The Case of Unitization in Re-Cycling. G. Weber. *Oil Gas J.*, 9.11.39, **38** (26), 38.—The fundamental conception which re-cycling is based is conservation: the recovery of condensate otherwise lost under pressure-decline production methods and the saving of gas through its return to the reservoir. Conservation, however, is construed to embrace greater recovery at less cost to the operator, and thus re-cycling on a unitized plan is doubly justified by the principle. This enlarged conception of conservation is found in three main factors in the unitized re-cycling plan, namely: (1) wide spacing of wells; (2) centralized operation; (3) maximum recovery.

In considering well spacing, re-cycling on a field plan allows operators to go far beyond the economy of a 40- or 80-acre spacing pattern. The checkerboard system is unnecessary in such a field plan. In anticlinal fields, where sand uniformity will permit, the gas may be withdrawn from a few wells located on the flank of the structure, and the processed gas input at the top of the structure. This will permit stratification of the lean gas downward and outward through the sand to the flanks of the field, replacing the rich gas withdrawn down structure. Water encroachment may require a variation or reverse of this process, and irregularities in the subsurface structure may demand modifications of the rimming method, but the wide spacing allowed by any plan represents a substantial saving in development costs.

Through centralized operation, unitization in many fields is the only justification for re-cycling. Unlike oil properties which can be developed and produced by many individual operators, the gas condensate production must be re-cycled, if not in a field system, at least in large blocks and with some plan between competitive projects to prevent channelling of the gas from input to production wells.

The maximum recovery of condensate can only be realized by so placing input and production wells that the greatest sweep through the sand will be accomplished. A haphazard arrangement of competitive re-cycling systems in the same sand of a field may serve to pay out the installed equipment, but as operations progress, premature channelizing is certain to occur, cutting yields and trapping rich gas in the reservoir.

The case for unitization is further discussed with relation to equity basis, pressure maintenance, and legal viewpoints. A. H. N.

59.* Thickness of Gas Cap in Yates Field Found by Use of Formula. D. H. Stormont. *Oil Gas J.*, 23.11.39, **38** (28), 48.—The use of Gregory's formula for the calculation of the gas–oil contact is illustrated. The formula is $P_D = P_c + G(D - X) + G_1X$,

where P_D = the pressure at the datum line (1300 ft. above sea-level), lb./sq. in.
P_c = the casing pressure, lb./sq. in.
G = static gas-pressure gradient, lb./sq. in. per ft. of gas column at well-head pressure P_c.
G_1 = static oil-pressure gradient, lb./sq. in./ft. of depth.
D = depth to datum line, 1300 ft., ft.
X = distance between datum and oil–gas contact, ft. A. H. N.

60.* Battery of Oil–Gas Separators Provides Flexible Operation for Test Purposes. Anon. *Petrol. Engr*, Sept. 1939, **10** (13), 56.—A new installation in Saudi Arabia is described. This installation includes equipment to measure all gas produced and to test each of 30 wells individually. A. H. N.

61.* Variable Motor Drive and Movable Derrick Provide Economy. R. M. Pyles. *Petrol. Engr*, Sept. 1939, **10** (13), 93–94.—Continuous pumping at any required speed eliminates shut-down periods due to proration. To achieve this purpose an electric motor with a variable speed—the pumping speed being readily changed by means of turning a handwheel below the motor—has been used.

One derrick mounted on rails serves four wells and helps in economically pumping the crude. A. H. N.

62.* Two Wells Pumped by a Single Beam in East Texas Installation. Anon. *Petrol. Engr*, Sept. 1939, **10** (13), 110.—A case of two neighbouring wells having practically identical weights being pumped by a single beam is cited. The power required in this unusual installation is made a minimum by balancing each of the two wells against the other. A. H. N.

63.* Data on Gas-Driven Pool Disclose Characteristics Differing from Water-Driven Reservoirs. A. M. Crowell. *Petrol. Engr*, Oct. 1939, **11** (1), 25.—In a gas-drive reservoir, as the pressure declines the gas comes out of solution and the oil becomes increasingly inert, until eventually it does not contain enough energy to provide for its own movement to the well-bore. Furthermore, the free gas acts to clog the sand pores, and thus hamper the progress of the oil. The importance of pressure control and maintenance becomes obvious.

This article deals with the early history of the Jones pool and its exploitation to date. The study of this pool is of more than local interest, because of the great care taken in its development and the wealth of data supplied.

The structure of the field is anti-clinal, and the Jones pool is one of the few oil and gas reservoirs from which the natural production is being obtained through volumetric control—and on which comprehensive data have been gathered throughout the productive life. The pool is still in its primary development.

Very accurate information on progressive gas/oil ratio, bottom-hole pressure, and producing rates has been kept both for individual wells and for areally weighted averages for the pool as a whole. Data are also extensive on productivity tests, solubility shrinkage information, bottom-hole sample analyses, etc.

Full production data are presented in the paper, together with pressure contour maps and a proration scheme. A. H. N.

64.* Lightweight Pumping Equipment Saves Small Potential Wells from Abandonment. W. H. Stueve. *Petrol. Engr*, Oct. 1939, **11** (1), 46.—Old and heavy equipment had become uneconomical in the Seminole field, Oklahoma. A large number of wells were to be abandoned unless pumping costs could be reduced.

The solution was found in pumping units powered by 3-h.p. motors, and these extended the life of wells, which are producing now from 3–10 brl./day. A. H. N.

65.* Development and Early Exploitation of a Water Driven Oil Pool under Proration. A. M. Crowell. *Petrol. Engr*, Nov. 1939, **11** (2), 21.—Data on Magnolia field, Arkansas, indicate that water-drive may result in reservoir pressure being maintained at near original figure. Tables and graphs are given for a complete set of data.

The development, early exploitation, and indicated future production policy of this pool are pointed towards the realization of conservation and equity along the lines of sound engineering practice.

Wide spacing, sound drilling equipments, the pooling of tracts into units, and a reasonable practicable manner of allocating production should allow, with the co-operation of the industry, the operation of the pool as a single unit.

Although there is a market for 50,000 brl. of oil daily from the Magnolia field at this time, the proration policy is pledged to an optimum rate, which will be far less. Under the optimum-rate concept it is hoped that no reservoir pressure need be spent other than the flush pressure, and that the greatest practicable recovery from the reservoir may be obtained. A. H. N.

66.* Bottom-Hole Agitation Removes Solution Gas from Fluid in Pumping Wells. H. L. Flood. *Petrol. Engr*, Nov. 1939, **11** (2) 27.—The new device described in the paper is apparently successful in eliminating gas-lock and in reducing trouble from sanding-up, paraffin deposition, and other difficulties encountered in oil-well pumping.

The apparatus incorporates simple principle and makes use of the slight vibration inherent in tubing string of every pumping well to actuate a series of dashers or agitators, each of which rests on a light coil spring. The resulting agitation in the gas-laden oil simply churns the oil and, assisted by the decreased pressure, hastens the rate at which the gas is liberated. A. H. N.

67.* Application of Displacement Pumping in Peru. J. Henry. *Petrol. Engr*, Nov. 1939, **11** (2), 67.—The author describes a method used to pump a group of wells difficult of access and having low initial production. Twelve small wells located on the steep slopes of a cañon in Peru had to be pumped under the following requirements :—

(1) Control to be sufficiently comprehensive to reduce the input gas–oil ratio to a minimum ;
(2) Unit well control preferable to a central control ;
(3) Equipment to be of sufficiently simple construction to be dealt with by semi-skilled grade of labour ;
(4) Installation cost to be a minimum ;
(5) Sub-surface equipment to be reduced to a minimum ;
(6) Gas input cycles and quantities to be controlled by the surface equipment and quite independently of sub-surface gear.

The solution to this problem is given and diagrams illustrate the method. The description is brief, but the author gives a reference to a comprehensive paper on the subject of displacement pumping which deals with every detail. The paper is by A. Millar, *J. Inst. Petrol. Tech.*, 1932, **18**, 445. A. H. N.

68.* Extensive Gas Conservation Project Underway in Loudon Field. F. B. Taylor, *Oil Wkly*, 5.6.39, **93** (13), 74.—The author describes extensive gas conservation projects under way in the Loudon fields. Excess gas is returned to the strata, which are still at relatively high pressures. The project was designed with the view of future expansion kept in mind. At present five wells are used for gas intake into the formation, injections being effective over 640 acres ; six more wells are to be added shortly to increase the effective injection area. Full details are given of the equipments used and an interesting diagram is furnished for introducing gas into two pay sands simultaneously. A tubing and the casing are used in the well, with the outer pipe perforated against the upper sand, the inner pipe extending to the lower depth, whilst a packer seals the annular space between the inner tubing and the outer casing at a point between the two sands.

Gas hydrate troubles ensued in colder months ; gasoline extraction from the relatively rich gas tended to relieve the trouble, but it was necessary to use alcohol lubrication and ammonia injection before the problem was solved. A. H. N.

69.* Regular Inspections in Pumping Unit Care. J. R. Chambers. *Oil Wkly*, 4.9.39, **94** (13), 19.—Instructions and recommendations are given for the regular inspection of pumping units with a view of maintaining the efficiency and condition of the units at as high a standard as possible. Lubrication duties, the checking of the cooling system, the care of V-belts, and the inspection of air cleaners are typical items in the paper.

Long-period programmes of inspection, as well as weekly and daily routine inspections, are given. A. H. N.

70.* High Rod Stress in Deep Pumping Costly. R. V. James. *Oil Wkly*, 11.9.39, **95** (1), 19–26.—The author believes that high stress is the only important cause of failure, and hence a knowledge of the value of the stress obtained under working conditions is essential to determination of the probable life of a working member. In sucker rods failures have occurred, however, at far lower stresses than the yield stress—the fracture appearance being very different from the ordinary tensile failure. By means of photographs of the cross-sectional views of failures (magnification, × 100), the author analyses fatigue failures and endurance limits, the effects of grain size, of heat treatment, surface finish, and of the surrounding medium, range of loading, and service conditions on the endurance limits.

A study of rod records shows that comparatively short sections of the rod strings are responsible for a large percentage of the breaks. Such being the case, the discovery of the causes of the critical conditions and the elimination of those causes should greatly increase rod performance. The method of discovering such causes followed by the operator is to study the dynamometer charts; that followed by the manufacturer is to study and improve the material. A. H. N.

71.* Importance of Gas in Petroleum Production. C. R. Horn. *Oil Wkly*, 11.9.39, **95** (1), 27.—Gas produced with oil is wasted in enormous quantities. It is estimated that in 1934 alone some 500,000 million cu. ft. of gas were blown to the air and wasted; about sixteen times this quantity was wasted from the beginning of the industry up to 1935. The figures for 1934 mean that approximately one quarter the total gas produced was wasted.

Lack of knowledge of the physical properties and phase relationships of the fluids existing in the oil and gas reservoir has been one of the major handicaps to be overcome by the petroleum industry in its attempt to bring to the surface a greater portion of the oil present in the reservoir rock. The importance of these factors in conservation must not be overlooked.

In this fairly exhaustive paper, the author discusses the forces operating in the production of oil under various conditions, particular attention being paid to the energy of the gas in the reservoir.

The conditions existing in the formations statically are discussed with methods of sampling best suited to study these conditions. Detailed discussion is also given on the two ways in which gas may be liberated from an oil/gas solution: differential and flash liberations; the critical properties of hydrocarbon mixtures with a particular example of 30% methane/70% propane mixture being cited to illustrate retrograde condensation and other interesting points on the phase diagrams; the equilibrium constants and hydrocarbon mixtures; the physical properties of hydrocarbon mixtures, with particular reference to vapour pressure, vapour density, and solubility of gas in oil; the effects of gas in solution on the volume and volume loss on evaporation, the effects on the gravity, the viscosity and surface tension of the crude oil; and finally a study of rates of solution of gas in oil is made.

A bibliography with 61 references is appended. A. H. N.

72.* Oklahoma City Proves Deep Pumping Practical. F. B. Taylor. *Oil Wkly*, 18.9.39, **95** (2), 19–22.—Lifting costs have been steadily reduced in the 6500-ft. field of Oklahoma City until 100,000 brl. are being pumped daily, at a minimum cost of 9 cents per barrel. The paper deals with the history of the field from the days when lifting from such depths was considered impracticable, and, if practicable, unprofitable up to the present time.

Practically every conceivable type of lifting device has been tried in this field at some time in its history. In 1936 a survey showed that the following lifting methods were being used in the field: gas lift (136 wells), gas-lift flow devices (124), electrical centrifugal pumps (54), pneumatic pumping heads (11), walking beam (400), hydraulic submerged pump (1).

With pumping problems overcome in economically producing from the Wilcox, operators of the field are investigating the possibilities of applying secondary recovery measures to the formation. It is believed that if such measures succeed an additional 150 million brl. of crude can be lifted from the Wilcox. A. H. N.

73.* Economic Effects of Recent Oil Discoveries in Illinois. J. E. Pogue. *Oil Wkly*, 18.9.39, **95** (2), 13–15. Paper presented before National Petroleum Association.—The American petroleum industry has been passing through one of its periodic crises, caused by the discovery and rapid development of new flush oil-fields. The patterns of all such crises are remarkably uniform, since the basic form of the problem is that of absorbing large volumes of crude oil from new sources of supply, necessitating rearrangement of existing trade channels.

The problems which the industry has faced during the past year as a result of recent Illinois discoveries are analysed. The conclusion is reached that uncontrolled production in Illinois, as well as in any other area, is a menace to the stability of the American petroleum industry and to the welfare of thousands of people dependent on it for existence. In Illinois the continuance of present practices will result in greatly reduced recoveries and abnormal costs in later stages. Orderly methods of production must be established. A. H. N.

74.* **Properly Conditioned Water Essential to Successful Flooding Operations.** C. L. Pate. *Oil Wkly*, 18.9.39, **95** (2), 28.—The operation of flooding is not merely one of injecting water and displacing the oil from the producing horizon. To increase recovery from old oil-fields by water-flooding three elements are necessary: presence of recoverable oil in the reservoir; an ample supply of suitable or properly treated water; and power to conduct the various phases of the operations. Far too little attention has been accorded to the second condition, with ultimate loss to the operators.

It is very seldom that water sources free from materials that will plug the formation pores are found, consequently chemical treatment becomes essential.

The author urges the following considerations to be taken before attempting water-flooding: (1) Be certain of ample supply of water. (2) Submit sample to chemist for analysis and recommendation. (3) Design water-treating plant most carefully. (4) Remove oil from salt water obtained from oil wells prior to chemical treatment. (5) Kill algae, diatoms, etc., by an algicide where surface is being treated. (6) Supply plant operator with sufficient chemical equipment for making control tests. (7) Pay special attention to operation of the filter.

The paper deals exhaustively with the chemical treatment of water. The chemical reactions attending the addition of various agents to waters of various salt contents are detailed.

The dry compounded type of reagent which is added to the water as it enters the tank is a complete treatment by itself. When the formulæ is added and mixed with the water, it is supposed to bring about the following results :—

(1) Acts as an oxidizing agent to precipitate iron as ferric hydroxide.
(2) Increases the pH value of the water.
(3) Kills or disintegrates live organic matter, such as algæ.
(4) Acts as a coagulant to drag down suspended matter.

The use of aluminium sulphate with muddy waters or waters containing considerable quantities of colloidal material is thoroughly discussed.

The paper ends with a discussion on treating-plant costs and design. The whole discussion is well illustrated in photographs, diagrams, tables, and formulæ.

A. H. N.

75.* **Selective Directional Shooting Pays a Profit.** F. R. Cozzens. *Oil Wkly*, 2.10.39, **95** (4), 19–20.—In shooting newly drilled wells the area of sand which can be drained into the reservoir thus created depends on the length and type of channel, and if the location be in territory where fluid has no driving force behind it, the operator must consider also the fact that the most effective drainage channels are those which reach upwards and outwards into the body of the sand. The making of such channels, known as angle drainage, is becoming of major importance in re-drilling eastern stripper fields, and some very noteworthy results are being obtained by a system of selective directional shooting.

The method is to drill entirely through the pay sand, and in its very lowest portion make a cavity capable of holding 300–500 lb. of nitroglycerine, gelatin, 90% strength, or its equivalent in straight nitroglycerine. The cavity is made by pop-shotting the lowest 6-ft. portion of the sand-face with 25–50 lb. of dynamite or gelatin. The spoil is removed by suction bailing.

Details of the method and its advantages are given. A. H. N.

76.* **Pressure Maintenance Keeps Chalk-Hill Wells Flowing.** J. C. Albright. *Oil Wkly*, 2.10.39, **95** (4), 21–23.—The advantages of pressure maintenance practice in the field may be easily seen from the fact that 40% of the wells in this eight-year-old field are still flowing, whereas nearby districts are dependent on pumping.

The pressure plant was designed for injection for residue and purchased dry gas into the sand, and to extract the desired gasoline fractions from the gas taken into the plant from the oil and gas separators at the lease batteries. A description of the plant is given.

As the wells were completed without shooting, the formation was undisturbed and clean holes were the rule. The wells selected for input of the re-pressuring gas were spotted across the property to provide an even distribution of the input gas, to maintain the reservoir pressure, and to move the oil to the producing wells. A. H. N.

77.* **Simple Re-Cycling Plant Solves Problems in Distillate Field.** B. Mills. *Oil Wkly*, 16.10.39, **95** (6), 18.—The absence of a market outlet for natural gas and the penalties invoked for gas wastage are operating difficulties frequently found in the development of distillate and high gas/oil ratio fields. These conditions applied to the Bammel field, a typical example in Texas Gulf Coast, before a solution was found in a simple efficient re-cycling plant installation.

The present re-cycling effort includes production of the gas under a reduced line pressure from the well, extraction of the distillate with three stages of separation, and return of the dry gas to the formation. The return of the dry gas to the formation meets provisions of the conservation rules, and the market will absorb all distillate produced.

The new plant incorporates several unique operating practices. A remarkable fact about this plant is that it was built entirely by drillers, derrick men and "roughnecks," and without a blue print.

Full details are given of the plant-building and operating conditions. A. H. N.

78.* **Efficiency in Pumping.** F. B. Taylor. *Oil Wkly*, 16.10.39, **95** (6), 24.—The feel of the experienced pumper often spots and prescribes for trouble promptly. His rôle as a diagnostician of production ailments is important.

In this paper, hints and practices are given about the feel of the pump and pull rods. A. H. N.

79.* **Gas Lock and Pumping.** H. Huffman. *Oil Wkly*, 23.10.39, **95** (7), 22.—Most wells, after they cease flowing, will continue to produce large quantities of gas for a long period. This gas will come into the well both as free and as dissolved gas. Under these conditions, unless certain precautions are taken and proven principles followed, the efficiency of the pump will be greatly reduced by either complete or partial gas locking.

The gas laws underlying the evolution of gas from solution and the effects of partial or complete vapour or gas locks on the volumetric efficiency of pumps are discussed, and the remedies indicated. The subject is discussed under the two headings "dissolved gas" and "free gas," and a typical example is worked out numerically to illustrate the text.

It has been found that where facilities are not available for disposing of the casing-head gas, lowering this pressure a few pounds by bleeding it off is frequently enough to increase greatly the output of the pump. A. H. N.

80.* **Secondary Recovery Projects Harmed but Slightly by Production Shut-ins.** F. B. Taylor. *Oil Wkly*, 23.10.39, **95** (7), 28.—The recent Mid-Continent two-week production shut-in apparently had very little detrimental effect on gas re-pressuring or water-flooding operations in most instances.

There were many reasons to anticipate harmful results, largely because of possible trappage of oil and probable loss of pressure through highly permeable streaks.

In isolated cases it appears evident that operations have been injured somewhat seriously, but a majority of the projects have re-established their normal rates of production without difficulty.

In the experience of most of the operators the only previous shut-downs have been very short ones, due to mechanical failures. The review of the results of these extensive shut-downs, however, shows that, on the whole, secondary recovery projects were but slightly harmed. A. H. N.

81.* A.I.M.E. Studies California Economic and Operating Problems. Anon. *Oil Wkly*, 23.10.39, **95** (7), 37.—The possibility of changed economic conditions occurring in the petroleum industry throughout California, particularly in regard to the manner in which oil curtailment is handled, the movement on the part of the Government to acquire certain tideland fields for the exclusive use of the U.S. Navy and to bring about federal control for oil, as well as technical problems and advancements, were studied by the large groups of engineers that attended the two-day session of the Petroleum Division of the A.I.M.E. at Los Angeles.

Abstracts of most of these papers appear in this issue of the *Oil Weekly* under the above headings. Thirteen abstracts appear. A. H. N.

82.* Theft-Proofing Pumping Equipment. Anon. *Oil Wkly*, 30.10.39, **95** (8), 18–20.—Isolated leases, especially when lying in wooded or rolling country, frequently suffer loss of production through pilfrage, such as the stealing of some readily portable and easily removed portion of the pumping equipment which can be junked and sold for a fraction of its replacement value. Since spare parts at lease headquarters or in the Company's tool-house are stocked in proportion to anticipated failure in operation, rather than with regard to portability or pawnability, such petty theft often means the loss of a day's production while replacements are obtained.

The paper illustrates methods and practices followed by various companies to prevent such losses as spark plugs, carburettors, batteries, V-belts, engines, or even complete pumping units—as happened with a particular lease where two units and an engine of a third were stolen. The paper is well illustrated and contains interesting methods. A. H. N.

83.* Much Sand Successfully Separated from Oil. J. C. Albright. *Oil Wkly*, 6.11.39, **95** (9), 32.—Due to the fact that producing formations in the Wilmington field are of an unconsolidated nature and contain only a small amount of calcareous cementing material, sufficient quantities of sand are produced to require each lease, or group of wells, to be provided with an adequate method of sand separation.

In some instances 25% of the total production consists of sand, which is fine enough grained to remain in suspension. The sand also is quite abrasive, cutting flow controls and damaging liners to such an extent that wells must often be reconditioned early in their flowing life, and more or less frequently thereafter.

Methods of separating the sand from the oil include the use of large tanks, where the oil is subjected to a sufficient quiescent zone, to more elaborate equipment, where automatic instruments govern the volume of temperatures and wash-water. Heat exchangers heat the oil and reduce its viscosity so that sand will settle out.

A. H. N.

84.* Pumping Layout Programme Dictates Well Spacing. Anon. *Oil Wkly*, 13.11.39, **95** (10), 88.—The unusual case is cited of drilling four wells to a pattern which was fitted to the type of gear reduction unit selected for purchase and installation when natural flow should fail and mechanical lifting aid be required.

When the wells were drilled in this unusual pattern, the rod-lines tying the odd-numbered wells could be driven in a straight line from one side of the reduction gear, without any part of the drive interfering in any way with the similar type of linkage to the other two wells.

Thus paired, the four wells so nearly balance and approach so closely to the uniform loading of the main shaft of the reduction gear, that none of the usual fluctuation is noted either in the speed or the staccato bark of the exhaust of the four-cylinder gas engine powering the set-up. A. H. N.

85.* Effects of Varying Well Bore Diameters in California Reservoirs. E. K. Parks. *Oil Wkly*, 20.11.39, **95** (11), 24. Paper presented before the American Petroleum Institute.—Present trend towards reduction of well diameter has led to inquiry as to the effects of this practice. The data obtained do not furnish a solution for optimum choice, but are sufficient to indicate that there is doubt whether immediate savings are fully realized. A theoretical discussion accompanies the facts and comments, with the conclusion that further investigations are warranted. Some of the more important conclusions reached by the author are the following :—

(1) There is a strong economic urge to reduce the size of oil-well casing.

(2) Whatever reduction in potential rate accompanies the smaller size is discounted on the basis of present over-production.

(3) There is a definite conviction by some operators that smaller-sized wells do not result in lower drilling costs.

(4) Differences as to the effect of hole size on drilling cost suggest, that if savings are to be made, there must be consideration of the particular formations encountered and the entire drilling-rig assembly.

(5) A detailed study of this problem is associated intimately with well-completion practice generally.

(6) Whatever effort is expended in providing a solution for the optimum hole size will be a direct contribution to genuine conservation of petroleum, material, and manpower, in that the factors involved are, respectively, cumulative production to an economic limit, steel for wells, and drilling time. A. H. N.

86. Flow of Gas–Liquid Mixtures through Consolidated Sand. H. G. Botset. *Petrol. Tech.*, Nov. 1939, A.I.M.M.E. Tech. Pub. No. 1111, 1–13.—Nichols buff sandstone was used in the experiments after leaching with hydrochloric acid to remove iron oxides and calcareous matter. An accurately cut core with metal piezometer rings was set in pitch. Care was taken to fill all the pores with water, and the eight sections of the core were then found to have permeabilities of 0·457–0·531 darcy along the length of about 4·5 ft. Its porosity was 21·8%.

The experiments show that—

1. The mechanism of approach to equilibrium saturation is very little affected by consolidation of the sand.
2. The equilibrium saturation is probably dependent on cementation and grain-size distribution, but it may easily be determined on a small core sample.
3. The ultimate recovery from a consolidated sand will generally be less than that from an unconsolidated sand of the same permeability, the difference in recovery depending on grain-size distribution and degree of cementation.
4. Assuming a uniform sand with no water drive or structure present, the final saturation at the end of the period of natural production is essentially uniform throughout the sand body.
5. Surface tension and interfacial tension, as well as viscosity, must be relatively unimportant (at least over a moderate range of variation), since the results of experiments on the large core with water and CO_2 agree with those for oil and gas on a small core. G. D. H.

Transport.

87.* Modern Tanker Design. N. J. Pluymert. Paper read before the Society of Naval Architects and Marine Engineers, New York. *Motor Ship*, Dec. 1939, 20, 308–309.—Constructional and operating data are given for twelve tankers of the Socony Vacuum fleet, of 15,000–16,000 tons deadweight. The principal dimensions of all the tankers are approximately equal. The dates of construction range from 1930 to 1939. Five tankers are steam driven and seven are equipped with diesel machinery.

The amount of welding has increased with each succeeding design. This has resulted in higher deadweight efficiency and, by the elimination of horizontal surfaces and pockets, tends to reduce corrosion. The machinery and cargo-pump weight of the diesel-engined tankers is 450 tons more than the latest-designed turbine drive. It is considered, however, that the saving in fuel consumption of the motor ship offsets the extra machinery weight, when the time between the usual fuelling ports is 30–35 days or more. S. J. A.

Crude Petroleum.

88.* Deodorization of Irak Crude by Means of Soda. H. Pascal. *IIme Congrès Mond. Pétrole,* 1938, 2, 329–333.—The presence of 1·8% sulphur and 0·11% free hydrogen sulphide in Irak crude introduced difficulties in transporting and refining the crude due to the fumes evolved. These difficulties have now been overcome by the erection of stabilizing plant, but prior to this they were successfully dealt with by injecting a sea-water solution of caustic soda into the crude during pumping operations at the ports of loading. This treatment deodorized the crude, but introduced further difficulties in refining due to (1) persistent emulsions, (2) deposits in pipe stills derived from water-soluble salts, (3) deposits in cracking stills derived from oil-soluble salts. These difficulties were overcome by breaking the emulsions by preheating and washing the crude with fresh water.

A method of estimation of dissolved hydrogen sulphide in crude is given : sweeping the crude with nitrogen and absorbing hydrogen sulphide in zinc or sodium acetate. W. P.

89.* Petroleum Emulsions and their Chemical Resolution. L. T. Monson. *IIme Congrès Mond. Pétrole,* 1938, 2, 335–343.—A survey of the theory and practice of de-emulsification of crude oil. The author discusses various general theories of emulsification in the light of his experience with crude-oil emulsions. Recent developments in the practice of de-emulsification are indicated, plant described, and methods of testing discussed. W. P.

Cracking.

90.* Combination Selective Cracking. E. R. Smoley, W. Meckler, and A. H. Schutte. *IIme Congrès Mond. Pétrole,* 1938, 2, 355–368.—Selection of stocks according to boiling range and according to refractivity (which differentiates virgin from re-cycled stocks) leads to higher efficiency in cracking processes.

Flow-sheets and plant data are given in detail for a number of modern three- and four-coil combination cracking units. The arrangement of equipment is discussed and a new type of heater described, whereby the heating curve is controlled by the use of independently fired heating and soaking sections. W. P.

91.* Selective Cracking and Continuous Coking. J. Grant. *IIme Congrès Mond. Pétrole,* 1938, 2, 369–374.—An account of a reconstruction programme undertaken by Shell Petroleum Corporation at Wood River, whereby the Dubbs fuel-oil cracking plant was modernized by installation of selective cracking and continuous coking equipment. The operation of the new unit is described. The advantages of the new unit are : (1) reduced operating cost, (2) increased " on stream " efficiency, (3) ability to vary production of gasoline and intermediate distillates at will, (4) production of gasolines of 70–72 octane number. W. P.

Hydrogenation.

92.* Hydrogenation of Hydrocarbons in Absence of Catalysts. A. Leopold. *IIme Congrès Mond. Pétrole,* 1937, 2, 217–222.—Hydrogenation in absence of catalysts is discussed and the results of three series of experiments under different conditions are given in detail. It is concluded that the yield of light products obtained by hydrogenation depends not only on the temperature, pressure, and duration, but also on the relative proportions of hydrogen and hydrocarbons. W. P.

93.* Industrial Production of Gasoline by Selective Hydrogenation in Absence of Catalysts. A. Leopold. *IIme Congrès Mond. Pétrole,* 1937, 2, 223–225.—Continuing work already published (see preceding abstract), it is shown that the nature and quantity of products produced by hydrogenation depend on six main factors : pressure ; temperature ; duration ; speed of circulation ; the steel surfaces of the apparatus ;

and the volume of the material processed. The hydrogen consumption depends on the type of hydrocarbon processed and on the method of splitting involved. The reaction can be exothermic or endothermic, according to the relative amounts of hydrogen and hydrocarbons present, and this ratio must be suitably adjusted to achieve economic yields. A modified form of pipe-still has been found more effective and cheaper than autoclaves for carrying out hydrogenation. W. P.

94.* Hydrogenation of Roumanian Petroleum. C. Candea and A. Marschall. *IIme Congrès Mond. Pétrole*, 1937, 2, 227–236.—A study of the hydrogenation of crude oil and of its various fractions using molybdenum sulphide as catalyst. It is concluded that the process depends not only on temperature, pressure, and duration, but also on the chemical composition of the basic material. In the process used, optimum temperature of 300–350° C. and optimum pressure of 200–300 atm. gave yields up to 50% of gasoline. The gasoline has a reduced percentage of unsaturated hydrocarbons and an increased precentage of aromatics and naphthenes. Its sulphur content is low, and it has a low tendency to gum formation. W. P.

95.* Catalytic Hydrogenation of Low-Temperature Tar under High Pressure. S. Ando. *IIme Congrès Mond. Pétrole*, 1937, 2, 237–248.—Low-temperature tar produced from Hokoku coal by the Imperial Fuel Research Institute of Japan was hydrogenated under varying conditions employing a 5-litre revolving autoclave. High pressures and molybdenum catalysts were used. The effects of temperature, time, pressure, and tar–hydrogen ratio were studied in relation to yield and quality of products. Full data are given relating to about thirty tests. In general, higher temperatures gave greater yields of fractions below 200° C. with higher aromatic content; higher pressures gave greater yields of fractions below 200° C., but slightly lower aromatic contents. Increased time of reaction gave lower yields and higher hydrogen consumption. W. P.

96.* Hydrogen of Tars and Tar Oils. J. G. King and C. M. Cawley. *IIme Congrès Mond. Pétrole*, 1937, 2, 249–262.—With a view to utilizing tars produced by low-temperature carbonization, hydrogenation of tars and tar distillates has been studied at the Fuel Research Station, England. The reactions involved and the effects of the various variants are discussed and experimental data presented. The effective production of gasoline from tar requires a two-stage hydrogenation : liquid-phase followed by vapour-phase. Molybdenum catalysts are used, those deposited on alumina being found superior to the pelleted form. Low-temperature tars process better than high-temperature tars; of the latter, vertical retort tars are better than horizontal retort tars. Higher temperatures accelerate hydrogenation, but decrease maximum degree of reaction. The effect of pressure is complex, but in general high pressure improves the yield and there is less deterioration of catalyst. Laboratory and semi-technical plants are described. W. P.

97.* Massive Catalysts in High-Pressure Hydrogenation. M. Pier. *IIme Congrès Mond. Pétrole*, 1937, 2, 263–270.—The use of solid catalyst in massive form is claimed to be superior to their use in a finely divided form. The latter form is limited to liquid-phase reaction and is especially convenient where fresh catalyst must be continuously added. The former method, however, is adapted to both vapour- and liquid-phase reactions.

The influence of temperature, pressure, and type of catalyst is demonstrated in the production of gasoline from coal-tar oils.

The hydrogenation of lubricating oils to improve their viscosity–temperature susceptibility is described. W. P.

98.* Hydrogenation of Cracked Gasoline. K. Kudo and H. Fujimoto. *IIme Congrès Mond. Pétrole*, 1937, 2, 271–275.—Cracked gasolines are not satisfactory as aviation fuels owing to their chemical instability, but suitable fuels can be prepared from them by hydrogenation. Laboratory and semi-technical experiments are described in which cracked gasoline was hydrogenated in the presence of nickel oxide as catalyst. W. P.

99.* Hydrogenation of Residues (Especially Cracked Residues). J. C. Vlugter. *IIme Congrès Mond. Pétrole*, 1937, 2, 277–280.—Two or multiple stage processes are advocated for the catalytic hydrogenation of petroleum residues: a liquid-phase stage followed by vapour-phase stages. Semi-technical plant is described in which Irak residues were first hydrogenated in the liquid-phase to yield mainly gas oil, which was then hydrogenated in the vapour-phase to yield high-quality gasoline. W. P.

100.* Production of Aviation Gasoline by High-Pressure Hydrogenation. C. L. Brown and E. J. Gohr. *IIme Congrès Mond. Pétrole*, 1937, 2, 281–287.—The demand for aviation gasoline of high octane number, volatility, and stability is best met by hydrogenation of petroleum fractions. Three types of process are available:—

(1) Moderate temperature hydrogenation with newly designed catalysts giving high conversion and selective dehydrogenation of cyclic compounds. This process yields gasolines of high volatility, no olefines, low sulphur, stability, and high lead susceptibility, such as are required in the preparation of 100 octane Army fuels.

(2) High-temperature hydrogenation with conventional catalysts yields highly aromatic gasolines. This process gives lower yields but higher octane numbers, albeit less susceptible to lead.

(3) Low-temperature hydrogenation of branched olefine polymers such as di*iso*butylene.

Details of the products produced by processes (1) and (2) are given. Process (3) is discussed in a separate paper (*vide infra*). W. P.

101.* Hydrogenation of Olefine Polymers for Manufacture of High-Octane-Number Fuels. C. L. Brown and E. J. Gohr. *IIme Congrès Mond. Pétrole*, 1937, 2, 289–298.—The third method of production of high-grade aviation gasolines mentioned in the preceding abstract is discussed—*i.e.*, the hydrogenation of *iso*butylene polymers and co-polymers. The properties of blends of hydrogenated products and natural gasolines are listed, as well as those of commercial di- and tri-*iso*butylene, co-polymers, and mixed polymers. The flow diagram of a commercial plant at Baton Rouge is given and parallel laboratory experimental work described.

The lead susceptibility of the hydrogenated fuels is discussed. W. P.

102.* Germany's Coal-Oil Supplies. Anon. *Petroleum Press Service*, 17.xi.39, 6, 44, 529–532.—It is considered that only a portion of Germany's programme for the coal-oil industry has been completed. Many plants were due to come into operation in 1940, whilst some were only scheduled for completion in 1941. There is an extreme paucity of official information on the subject, but it is possible to piece together from various sources an outline of the industry. The various plants known to be operating or in the course of erection are as follows:—

Company.	Estimated Capacity. Tons of motor spirit per annum.
Hydrogenation of Lignite and Coal.	
I.G. Farbenindustrie (Leuna)	350,000
Braunkohlen-Benzin A.G. (4 plants)	500,000
Union Rheinische Braunkohlen-Kraftstoff	150,000
Hydrierwerk Scholven A.G.	150,000
Gelsenberg-Benzin A.G.	300,000
Hydrierwerk Politz (Stettin)	—
Synthetic Processes (Fischer-Tropsch).	
Wintershall A.G. (3 plants)	150,000
Ruhrbenzin A.G.	30,000
Krupp-Treibstoffwerk G.m.b.h.	—
Hoesch-Benzin G.m.b.h.	—
Castellengo-Abwehr Kohleverdelung	—
Graflich Schaffgott'sche Benzin (Deschowitz)	—
Brux (Sudetenland)	Planned for 600,000 tons.
Gutehoffnungshutte	75,000
Extraction Processes (Pott-Broche).	
Ruhrol G.m.b.h.	(Extract hydrogenated.)

It is considered possible that production of light motor fuels will reach 1,800,000 tons in 1939, calling for about 8 million tons of lignite. In the construction of these large units of coal-oil production considerable quantities of special steels are required, which may not be readily available to Germany under war conditions. The possibilities of production of diesel oils and high-octane fuels from coal-oils are considered doubtful. S. J. A.

102*a*.* Production of Aviation Fuels by High-Pressure Hydrogenation. E. V. Murphree, E. J. Gohr, and C. L. Brown. *Industr. Engng Chem.*, 1939, **31**, (9), 1083–1089.—The application of high-pressure hydrogenation to the production of aviation gasolines, blending agents, and 100 octane fuels is discussed. The hydrogen necessary for these various processes is produced in a two-stage operation as follows. In the first stage a mixture of steam and natural gas is passed through a bank of parallel tubes containing catalyst heated to a high temperature. Hydrogen and carbon monoxide are formed in this stage. Additional steam is then added to the mixture, and further reduction is conducted in a second stage at a lower temperature. In this second stage the carbon monoxide and steam react to produce carbon dioxide and more hydrogen.

A typical aviation naphtha hydrogenation plant at conversions of 50–75% per pass yields 80–95% of 75–78 octane hydrogenated naphtha having excellent stability, high lead susceptibility, low sulphur content, and good colour.

Hydrogenation of *iso*butylene dimer and *iso*-normal butylene codimer increases the octane number from 82–84 to 97–100, but this material, on account of its volatility, is only suitable as a blending agent. Various tables are given showing the characteristics of the hydrogenated fuels and polymers, and various high-octane aviation fuels produced by blending hydrogenated products. H. E. T.

Polymerization.

103.* Polymerization and Alkylation of *iso*Butylene for Production of *iso*-Octane Fuels. G. Natta and M. Baccaredda, *Chim. e Industria*, 1939, 7, 393–418.—The continuously increasing importance of processes for polymerization of olefines for production of high-octane gasoline is pointed out, and the necessity of a more careful segregation of cracking and refinery gases is stressed.

In Italy, in particular, where the processing of petroleum products is limited, a separation of the various components of the gaseous blends from cracking should be effected, using, for instance, *iso*butylene and *iso*butane for the synthesis of 100 O.N. fuels, propylene for the production of *iso*propyl alcohol, butadiene together with ethylene for synthetic rubber.

The various chemical procedures proposed for the polymerization and alkylation of olefines are then examined and classified according to the catalyst employed, sulphuric acid, phosphor and arsenic acids, halogenated metals and gaseous catalysts.

A method studied by the authors for the production of *iso*-octane through dimerization of *iso*butylene is described : the method is an eminently selective polymerization, which is effected in presence of two catalysts, gaseous (HCl) and solid (aluminium oxide in most cases). The influence of the various factors, such as temperature, contact time, and concentration of the catalyst, is discussed. It was found that by operating at 200° C. with 1% of HCl and contact times of a few seconds it was possible to obtain yields higher than 80% of transformed *iso*butylene. During this process is formed a small amount of *iso*butyl chloride, which can be easily eliminated by fractionated distillation and then re-cycled as catalyst, though less active than HCl. It was noted that the polymerization leads also to the formation of tri*iso*butylene, transformable by means of appropriate catalysts, almost quantitively to di*iso*- and *iso*-butylene.

It is pointed out that the solid catalyst, aluminium oxide, can easily be regenerated, and that the selective polymerization with hydrochloric acid has the advantage of operation at relatively low temperatures, normal pressure, and in presence of other hydrocarbons. P. G.

Synthetic Products.

104.* Fischer–Tropsch Synthesis of Hydrocarbons and Some Related Reactions. S. R. Craxford. *BrennstChemie,* July 15, 1939, 20 (14), 263–270.—At the temperature of the Fischer synthesis carbon monoxide reacts slowly with the Fischer catalyst, forming cobalt carbide as follows: $2Co + 2CO \longrightarrow Co_2C + CO_2$. This reaction is always slower than the hydrogenation of the carbide by hydrogen at the same temperature. The catalyst reacts at this temperature with carbon monoxide and hydrogen under carbide formation as follows: $2Co + CO + H_2 \longrightarrow Co_2C + H_2O$. This reaction is more rapid than the hydrogenation of the carbide by hydrogen under similar conditions.

Hydrogenation of Co_2C may lead to formation of methane or higher hydrocarbons. Tests have shown that, in the Fischer synthesis, the *ortho-para*-hydrogen transformation is inhibited if oils are produced. This proves that very little adsorbed hydrogen is present at the catalyst surface.

Among the variety of conditions under which methane is formed in place of oil, the *ortho-para*-hydrogen conversion proceeds without difficulty, which shows that in this case adsorbed hydrogen is present.

The water-gas balance reaction proceeds parallel with the *ortho-para*-hydrogen transformation. It starts when methane is formed, and is inhibited during the oil formation of the Fischer synthesis.

The destructive hydrogenation of paraffin hydrocarbons on the Fischer catalyst is inhibited during the Fischer synthesis in a similar way as in the presence of carbide at the catalyst surface. Otherwise it occurs easily at the temperatures encountered.

If ethylene is added to the process gas, it is absorbed by the products, but at the same time causes formation of oxygen-containing organic compounds such as alcohols, acids, etc.

Theoretical conclusions are summarized as follows: the initial stage of the Fischer synthesis is an alternate formation and hydrogenation of cobalt carbide, by which methylene groups are obtained. In the presence of adsorbed hydrogen, the latter are further hydrogenated to methane. If conditions are more in favour of the formation than the reduction of carbide, very little chemically adsorbed hydrogen exists at the surface, and CH_2 groups combine to form long chains. The resulting products are broken from the long chains at the surface by the attack of the adsorbed hydrogen. If the carbon monoxide is adsorbed in the outer adsorption layers and does not come into contact with the catalyst surface, oxygen compounds are likely to be formed.

L. R.

105. Importance of the Fischer–Tropsch Process for German Production of Diesel Oils. H. Koelbel. *Brennstofftechnik.*, 1939, 20, 352, 365.—A high percentage of the oils yielded by the Fischer–Tropsch process is Kogasin II, a diesel fuel with ideal boiling range and a cetene number of 105, compared with 65 for the best natural diesel oils. Analysis of the fuel shows it to have a high hydrogen content and to contain no impurities like sulphur or coke. Engine tests gave good results provided the compression ratio of the engine was lowered to about 12 : 1. A serious drawback of this synthetic fuel, apart from the high cost, is the fact that it solidifies at about 2° C. The author found, however, that a mixture of Kogasin II with a tar oil resulted in a product with pour point-20° C. Tests in ordinary commercial diesel engines with this mixture showed a low consumption and high output of the engines. It is hoped that the new fuel will make Germany more independent of foreign fuels, as even in 1938 90% of the diesel fuels had to be imported. E. W. S.

106.* Synthesis of Gasoline and Oils from Water Gas. F. Martin. *IIme Congrès Mond. Pétrole,* 1937, 2, 299–307.—The historical development of the Fischer–Tropsch process is briefly mentioned and the commercial development from 1933 to 1937 described in more detail. The large-scale industrial plant operated by the Ruhrchemie A.G. is illustrated in numerous photographs, and the properties of the products and heat flow data are given. The development has depended on five major factors;

1. Increase in the life of the catalysts employed.
2. Cheap large-scale contact chambers and sulphur eliminators.
3. Recovery of rare metals and oxides from spent catalyst.

4. Working up the primary product, Kogasin, to improve its anti-knock value.
5. Production of cheap water gas from available materials—*e.g.*, brown coal, peat, coke, etc.

Future possibilities of chemical synthesis by this process are suggested. W. P.

107.* Formation of Methane from CO–H_2 Mixtures Using Low-temperature Coke and High Pressures. H. Brueckner. *BrennstChemie*, 1939, **20**, 346–348.—In the reaction of solid fuels with an oxygen–hydrogen mixture, methane is formed in a secondary reaction of the carbon monoxide–hydrogen mixture with the low-temperature coke contained in the producer. According to the result of the tests made at 500–700° C. and up to 1150 lb./sq. in., the synthesis of methane takes place essentially according to the equation: $2CO + 2H_2 = CH_4 + CO_2$. A formation of methane from CO according to $CO + 3H_2 = CH_4$ could not be stated. The methane output rises with temperature, the maximum yields with 40% methane content in the reaction gas being reached with 560 lb./sq. in. and 700° C. E. W. S.

Refining and Refinery Plant.

108.* Electrical Process for Extraction of Salts from Refinery Charging Stock. T. N. St. Hill and H. C. Eddy. *IIme Congrès Mond. Pétrole*, 1938, **2**, 345–350.—The presence of salts in crude oil gives rise to deposits in still-tubes, increased coke formation, and severe corrosion, particularly if hydrogen sulphide is also present. The electrical system of salt removal is claimed to be superior to any washing system. A certain amount of water is added to the crude, which is then circulated between electrodes carrying high potential. Separation takes place without resort to settlement tanks, and although the resulting oil still contains water, the salt content is much reduced. Apparatus is described and costs are analysed. W. P.

109.* Catalytic Purification of Gas Oils. E. Lege. *IIme Congrès mond. Pétrole*, 1938, **2**, 351–354.—Gas oils can be refined by treating them under controlled conditions with sulphuric acid at temperatures from 150° to 250° C. The process is equivalent to a low-temperature cracking process and yields stable oils of naphthenic structure. W. P.

110.* Knowles Coking Process. C. W. Andrews. *IIme Congrès mond. Pétrole*, 1938, **2**, 375–378.—A description of a Knowles Coking Plant at East St. Louis to convert ordinary grades of fuel oil into grades suitable for domestic heating purposes, together with gasoline, gas, and coke. Analyses of the products are given. W. P.

111.* Lachman Process for Refining Cracked Gasoline by means of Zinc Chloride in Vapour Phase. M. Reymonenq. *IIme Congrès mond. Pétrole*, 1938, **2**, 379–388.—The Lachman process as commercially operated in California and in Europe utilizes the catalytic effect of zinc chloride solutions in contact with the vapour phase. Diolefines are polymerized, but olefines and aromatics left unchanged to produce high-grade gasoline of good colour and gum stability. The commercial apparatus and its operation are described and analyses of the products given. W. P.

112.* Clay Treatment of Cracked Gasoline in Liquid Phase. Ancap Refinery. *IIme Congrès mond. Pétrole*, 1938, **2**, 389–393.—A description of plant erected in Uruguay for the distillation, cracking, and subsequent treatment of petroleum fractions. A Dubbs cracking plant is linked with a unit in which the gasoline is treated with clay before re-distillation. This treatment removes gums and gum-forming bodies to yield a gasoline of good gum and colour stability. Ordinary clay is broken down, dried, and screened for use in the plant. W. P.

113.* Use of Copper Salts in the Refining of Kerosine. M. H. Roche. *IIme Congrés mond. Pétrole*, 1938, **2**, 395–398.—Sweetening kerosines by the Doctor Treatment is not always satisfactory and the use of copper chloride is suggested. A process has been developed in which the normal decolourising earth is supplemented by earth previously treated with copper sulphate and sodium chloride. The process is equally applicable to other petroleum fractions. W. P.

114.* **Sweetening Gasolines with Copper Salts.** W. L. Benedict, C. G. Dryer, J. C. Morrell, and G. Egloff. *IIme Congrès mond. Pétrol*, 1938, 2, 399–406.—The use of copper salts in sweetening gasoline is claimed to obviate entirely the known disadvantages of the customary Doctor Treatment. Laboratory and commercial equipment are described for carrying out a process using solid cupric sulphate and ammonium chloride carried by fuller's earth. Intermediate setting is avoided and the process is continuous, yielding a gasoline superior to that obtained by plumbite sweetening. W. P.

115.* **Improved PbS Sweetening Process.** C. W. Stratford and D. B. Nutt. *IIme Congrès mond. Pétrole*, 1938, 2, 407–411.—The disadvantages of the Doctor Treatment are overcome by a process using a suspension of preformed lead sulphide in concentrated caustic soda, the solution being kept continuously in chemical equilibrium by addition of sodium sulphide. This process, the Stracto process, has been in successful operation for several years, and examples are given of its working. W. P.

116.* **Cold Acid Treatment of Cracked Gasoline.** C. W. Stratford, F. G. Graves, and E. S. Brown. *IIme Congrès mond. Pétrole*, 413–419.—In the cold acid treatment of cracked gasoline it is essential to have (*a*) controlled temperature, (*b*) optimum dispersion of acid, (*c*) controlled contact time. There is always a maximum temperature above which the process is less economical; this temperature lies between 20° and 60° F. In the absence of control, acid consumption is excessive, treating and polymerization losses are high, and there is a decrease in octane number of the products. A recent commercial installation for cold acid refining—the Stratcold Plant—is described. W. P.

117.* **Deasphalting and Acid Treating in Propane Solution for Production of Bright Stocks and Cylinder Stocks.** W. H. Bahlke, E. W. Thiele, C. E. Adams, and B. Ginsberg. *IIme Congrès mond. Pétrole*, 1938, 2, 421–433.—An account of experimental investigations on the deasphalting and acid treating of Mid-Continent residuum preparatory to the erection of commercial plant at Whiting, Indiana. The plant is described. Residuum and propane are mixed at 100° F. in the ratio of 1 to 3 by volume and settled in a horizontal drum. The lighter layer is acid treated in vertical drums in a two-stage counter-current operation. After neutralization with weak caustic solution and settlement, propane is distilled and recovered and asphalt is removed by fluxing with light oil. W. P.

118.* **Sulphuric Acid from Refinery Gases.** F. L. Claise and E. S. Brown. *IIme Congrès mond. Pétrole*, 1938, 2, 441–446.—The proximity of the El Segundo refinery to a sulphuric-acid plant working the contact process has enabled the refinery to convert a potential nuisance into an economic proposition. The hydrogen sulphide produced in the cracking of South Californian Crudes is removed from the cracked gases by washing with sodium phenolate. The hydrogen sulphide is recovered, purified, and burnt under controlled conditions to yield sulphur dioxide and oxygen in suitable proportions for catalytic conversion into sulphur trioxide. The hydrogen-sulphide recovery plant is described in detail. W. P.

119.* **Recent Progress in Refinery Acid Recovery.** S. F. Spangler. *IIme Congrès mond. Pétrole*, 1938, 2, 447–449.—A description of the Chemico Sludge Conversion Process, in which acid sludge is decomposed by heating; the sulphur dioxide so produced is purified and catalytically transformed to sulphur trioxide. Thermal decomposition is effected by utilizing the excess coke produced in the reaction as a heat-carrier. Purification entails condensation of water and hydrocarbons by scrubbing, oxidation of non-condensable hydrocarbons by heating in a secondary furnace, cooling by scrubbing, and removal of acid mist by Cottrell precipitation. W. P.

120.* Absorption Process of Natural Gasoline Extraction. R. W. Machen. *Petrol. Engr*, Sept. 1939, 10 (13), 47.—The major portion of natural gasoline is still extracted by the absorption process. An absorption plant consists of three distinct processing units for absorption, distillation, and stabilization, respectively. In older plants absorption columns of the " filled type " are still used. Whilst the initial cost is low, this type of absorber is characterized by a tendency of the oil and gas to channel and a low throughput capacity. The plate tower is more efficient, the simplest form of tray being a perforated plate. A disadvantage of this type is that a fixed gas velocity must be maintained or the oil will fall through the perforations rather than through the overflow pipes. This objection is largely eliminated by fitting a loose rivet into the holes. This rivet rises and falls with increasing and decreasing gas velocity. The " bubble-cap " plate has been developed to overcome the disadvantages of other plate columns. Caps are fitted on to gas chimneys fitted into the plates. The gas passes through the slots in the flange of the cap and bubbles through the oil on the tray.

The absorption oil used is determined by the still, and, generally speaking, a heavy oil, distillation range 475–600° F., is used in old-type steam-still, whilst more efficient modern stills used a narrow kerosine fraction, distillation range 375–500/525° F. Control of the temperature of the absorption oil is an important feature of efficient extraction. In some plants the oil, after dropping through a few plates, is passed through a propane–butane chiller before passing on to the next lower plate. The sludge and residue content of an oil influences the circulation required for efficient extraction, and some plants are provided with a special unit to continuously strip the oil of sludge and residue. R. J. E.

121.* Solvent Refining of Petroleum. B. Kwal. *Petrol. Engr*, Sept. 1939, **10** (13), 66.—Solvent extraction has provided a means of manufacturing a high-viscosity-index lubricating oil from mixed base and naphthenic base stocks. The solvent may either dissolve the high- or the low-viscosity-index components of the base, but good selectivity is an essential feature for economic use. Simple equipment for the process consists of a battery of vertical columns in which the base and the solvent flow countercurrently. The first process was developed by Edeleanu using SO_2 as solvent for the aromatic and unsaturated hydrocarbons. An increase of the solvent power of SO_2 is effected by the addition of benzol. Other solvents used in a similar manner are phenol, nitrobenzene, furfural, and chlorex. Aromatic amines have also been shown to give effective results. Flow diagrams for phenol and chlorex extraction processes are shown and a detailed account of a furfural plant is given. Advantages of using furfural are low cost of solvent and the efficient removal of naphthenic acids, so that further treatment with caustic soda is unnecessary.

Propane differs from the solvents, in that it dissolves the raffinate and precipitates the asphaltic matter and resins of the base material. In the Duo-Sol process both types of solvent are used. Propane dissolves the raffinate, and phenol or cresol dissolves the naphthenic acids and naphthenic hydrocarbons. A feature of this process is excellent selectivity. R. J. E.

122.* Turbidity of Selective Solvent Treated Oils. L. A. Gukhman, I. M. Orudjeva and G. B. Gurvich. *Azerb. neft. Khoz.*, Feb. 1939, 19 (2), 37–39.—Selective solvent-treated oils from Bibi-Eybat and Balakhany crudes, and also Surakhany bright stock, have been found to become turbid during storage owing to the precipitation of solid, apparently naphthenic, hydrocarbons. This turbidity appeared in all cases at comparatively high temperatures—say 10–15° C.—in spite of sufficiently low pour points (below 0° C.). Beginning from the temperature of commencing turbidity, a further fall in temperature caused a rapid increase of viscosity, much in excess of that of non-clouding oils of the same viscosity index.

The only means of safeguarding an oil against clouding was found to be dewaxing. Neither filtration at the clouding temperature nor addition of paraflow was successful. Paraflow addition, however, though not preventing turbidity, considerably improved the viscosity curves of clouded oils, so that they approached those of the dewaxed oils.

It is recommended to examine by means of practical engine tests to what extent the turbidity of the oils affects their performance. L. R.

123.* Production of High-Grade Lubricating Oils from Dossor-Makat Crude by Shapiro Dewaxing Method. G. L. Shapiro and L. G. Zakharenko. *Neft Khoz.*, July 1939, 20 (7), 34–39.—Dossor-Makat crudes are of very distinct paraffinic nature, and their wax content, although very small, tends to separate and to cause trouble at low temperatures, so that it has to be removed. The method, developed by G. L. Shapiro, of simultaneous refining and dewaxing by sulphuric acid application at low temperatures has been investigated. As raw material Dossor-Makat Permo-Trias semi-goudron was used. Compared with the usual pour point of —10° to —12° C., an oil with a pour point between —28° and —30° C. was obtained. A pour point of —28° C. resulted when treating at —40° C., whilst for a pour point between —23° and —24° C. treatment between —30° and —32° C. was sufficient.

In the latter case optimum treating conditions were : consumption of H_2SO_4, 10% of concentrate; consumption of diluents (naphtha and ligroine), 100–120% of concentrate. The resulting oil had a specific gravity of 0·896, a viscosity of 2·95–3·05° E. at 100° C., a viscosity index of about 85, zero Sligh test, and 0·8–0·9% Conradson carbon. A colour of 7½-8 N.P.A. was obtained with about 5% clay.

Oil yield is increased by means of the Shapiro method above the conventional by 63–72%, with 40% less acid and 75% less clay consumption. By combined Shapiro refining and dewaxing with additional selective solvent treatment, the sulphuric acid consumption can be reduced from 10 to 6% if naphthenic acids are used to improve goudron settling.

Refining-dewaxing with 6% acid and subsequent treatment with 350% nitrobenzene produce an oil with 95 viscosity index, 0·4% Conradson carbon, with a yield of about 68% of the dewaxed oil, or 52% of the goudron raw material. Selective solvent treatment with the same quantity of furfurol results in an oil with 94 viscosity index, and 0·6% Conradson carbon, with a yield of 80% of the dewaxed oil or 61% of the original semi-goudron.

During the selective treatment the acid number of the oil, which had been increased by the addition of naphthenic acids, falls to 0·01 SO_3, whilst the pour point rises 5–6° C. L. R.

124.* New Government Refinery at Luján de Cuyo. Anon. *Bol. Inform. Petroleras*, Sept. 1939, XVI (181), 111–122.—Article describing the opening ceremony and technical particulars of a new refinery at Luján de Cuyo in Mendoza, the plant erected being capable of producing annually 90 million litres of petrol of high octane number, 5 million litres of kerosine, 8 million litres of gas oil and about 45,000 m.^{3} of fuel oil. Provision is made for handling 14,000 m.^{3} of crude oil per month. H. I. L.

125*. Filter Rates of Clay–Oil Slurries. H. H. Bible, M. A. Witte, and J. W. Donnell. *Industr. Engng Chem.*, 1939, 31, 1007.—Poiseuille's Law has generally been considered to represent the rate of flow through the filter-cloth and cake, but it is shown by these authors that the flow through the cloth is turbulent, and that in the experiments performed the cloth represented 8–40% of the total pressure fall. It is therefore recommended that in filtration problems the cloth resistance be allowed for independently of the cake resistance.

The data obtained on the oil–clay slurry used have been correlated with respect to the effect of pressure on the filtration rate at constant viscosity, and the effect of viscosity on the filtration rate at constant pressure. J. W. H.

126.* Packing the Centrifugal Pump. F. C. Thorn. *Industr. Engng Chem.*, 1939, 31, 929.—The principles of the design of stuffing-boxes for centrifugal pumps working under various conditions are discussed, and the conclusion is reached that leaking of the fluid being pumped may be reduced to a negligible amount by attention to gland design and selection of the correct type of packing. Gland leakages may even be reduced to zero by the application of liquid seal glands.

The structure, composition, and use of rubber fabric, braided, plastic, and metal foil packings is discussed. J. W. H.

127.* Action of Filter Aids. P. C. Carman. *Industr. Engng Chem.*, 1939, 31, 1047.—The addition of a kieselguhr filter aid to a rigid cake composed of quartz particles, comparable in size to the kieselguhr particles, is shown to increase the permeability of the cake. This increase in permeability is shown to be quantitatively related to the porosity of the cake by means of the direct determinations of the permeability and porosity.

The relationship between percentage filter aid and cake resistance for a non-compressible cake is similar to that obtained for a compressible cake. This substantiates the theory that the main action of a filter aid is to increase the porosity of the cake.
J. W. H.

128.* Separation Processes. Fractionation of Partially Miscible Liquids. M. Randall and B. Longtin. *Industr. Engng Chem.*, 1939, 31 (9), 1181.—The calculation of the number of plates in the fractionation of partly miscible liquids of the minimum boiling point and eutectic vaporization types is discussed. The arrangement of columns necessary to carry out such a fractionation is considered. P. D.

129.* Extraction in Spray and Packed Columns. T. K. Sherwood, J. E. Evans, and J. V. A. Longcor. *Industr. Engng Chem.*, 1939, **31** (9), 1144.—Data were obtained on the extraction of acetic acid dissolved in water by benzene and by methyl *iso*butyl ketone. In the first set of experiments extraction was carried out in an unpacked tube using drops the dimensions of which were measured. In the second set various heights of packing were used. The packing consisted of ½-in. and 1-in. carbon rings, and ½-in. birl saddles. The tower was also operated as a spray tower.

The results indicate that Ka, the product of the extraction coefficient and the interfacial area, depends primarily on a. Ka increases roughly in proportion to the rate of the disperse phase. As the rate of the continuous phase is increased, Ka first rises sharply and then falls, due to coalescence. The drop size depends on the packing rather than on the initial size of the drops fed to the column. P. D.

130.* Counter-current Absorption. H. B. Osborn and C. W. Simmons. *Industr. Engng Chem.*, 1939, **31** (9), 1105.—A large-scale testing unit was constructed with an absorption tower 10 ft. by 1 ft. i.d., packed with 1-in. rings. Experiments were carried out on the absorption of CCl_4 vapour from air by kerosine at approximately room temperature. P. D.

131.* Mass Transfer between Phases : Rôle of Eddy Diffusion. T. K. Sherwood and B. B. Woertz. *Industr. Engng Chem.*, 1939, **31** (8), 1034.—The relative importance of eddy diffusion and film diffusion was investigated experimentally by measuring the water–vapour gradient in a turbulent stream of gas, flowing in a square duct, one side of which was covered with a film of water, whilst the opposite wall was covered with a strong $CaCl_2$ solution.

Air, carbon dioxide, and helium were used. It was found that each film offered 21–36% of the overall diffusional resistance. The Reynolds number was varied from 3600 to 102,000. The product of the diffusional resistance and the gas density was found to vary with Re in the same manner for all three gases. P. D.

132.* Absorption of Gases by Liquid Droplets. H. F. Johnstone and G. C. Williams. *Industr. Engng Chem.*, 1939, **31** (8), 993.—Experiments were made on the absorption of ammonia, hydrogen chloride, carbon dioxide, sulphur dioxide, and hydrogen sulphide from air. Various sized droplets of standard acid or alkaline solutions were used. The results obtained are in agreement with the theory of Johnstone and Kleinschmidt (*Amer. Inst. Chem. Engs*, 1938, **34**, 181). The application of the results to absorption and humidification is illustrated. P. D.

133.* Direct Solution of *iso*Thermal Flow in Pipes. B. F. Ruth. *Industr. Engng Chem.*, 1939, **31** (8), 985.—A method is devised by means of which flow problems may be solved without approximation in the turbulent region. In principle, the value for the unknown quantity which would be obtained if the flow were stream line is first calculated, and is then multiplied by a factor obtained from a chart, in order to give the actual value. P. D.

134.* Separation Processes : Analogy between Absorption, Extraction, Distillation, Heat Exchange, and other Separation Processes. M. Randall and B. Longtin. *Industr. Engng Chem.*, 1939, 31 (10), 1295.—The performance of an absorber may be represented graphically by constructions similar to those used for counter-current extractions (three-component systems). Either the familiar triangular diagram or the diagram drawn on impurity free basis may be used. These may also be transformed to x versus y diagrams.

In the case of heat exchange, an analogy may be drawn between the H *versus* N diagram for partly miscible phases and that in which the phases are immiscible or are made so by mechanical means, as in a heat exchanger. The graphical construction for such a case is indicated, so as to give the number of ideal heat-exchange units required for a given operation. P. D.

See also Abstract No. 203.

Chemistry and Physics of Petroleum.

135.* High-Octane *iso*Paraffinic Fuels. S. F. Birch, A. E. Dunstan, F. A. Fidler, F. B. Pim, and T. Tait. *Industr. Engng Chem.*, 1939, 31 (9), 1079–1083.—Preliminary work indicated the general nature of the sulphuric-acid-catalysed addition of olefines to *iso*paraffins, and was mainly concerned with the addition of butene to *iso*butane, since these hydrocarbons give the most promising results when translated into terms of commercial operation.

In the present paper the authors give the results obtained in several other olefine–*iso*paraffin condensation reactions.

Propylene has been induced to react with *iso*butane at 20° C., the most favourable yield being obtained by employing an *iso*butane–propylene ratio of 4 : 1 in the presence of sulphuric acid of 101·7% strength. Under these reaction conditions a 200% yield of gasoline based on the olefine taken was obtained, of bromine number less than 1, and having an octane number of 89·1. The major portion of the reaction product consisted of *iso*heptanes boiling at 80° and 90°, which from their physical properties appeared to be 2 : 4-dimethyl- and 2 : 3-dimethyl-pentanes, respectively. Definite fractions boiling at 58–61°, 99–100°, and 108–114° C. were also obtained. In the first of these, the *iso*hexane fraction, 2 : 3-dimethylbutane, was identified by formation of its solid dibromo-derivative. The material boiling at 99–100° C. was shown from physical properties to consist mainly of 2 : 2 : 4-trimethylpentane, whilst the less definite fraction (108–114° C.) consisted of other *iso*-octanes.

The addition of propylene to *iso*butane is therefore capable of producing a good yield of *iso*paraffinic hydrocarbons having a high-octane number. Commercial development of the reactions will be concerned, however, with the reduction of the high acid consumption.

Preliminary observations have been made on the condensation of trimethylethylene with *iso*butane.

Condensation of propylene with *iso*pentane proceeds smoothly in presence of excess of the latter to give a good yield of saturated product, consisting largely of *iso*paraffins in the C_8 to C_{10} range. The octane number, 73, of this material was disappointing and indicated the formation of long-chain paraffins. The major portion of the reaction product consisted of *iso*-octanes, probably 2 : 3-, 2 : 4-, and 2 : 5-dimethyl-hexanes. 2 : 3-Dimethylbutane was again identified in the C_6 range, whilst both 2-methyl and 3-methyl-pentane appeared to be present.

The acid consumption in this reaction was also excessive.

Di*iso*butene and *iso*pentane (*iso*paraffin–olefine ratio of 8 : 1) reacted to give a saturated hydrocarbon product of 79·7 octane number. The major portion of the reaction product consisted of hydrocarbons in the C_6 to C_{10} range, and contained a remarkably high *iso*hexane fraction, whilst formation of *iso*octanes was surprisingly small. Both 2 : 3-dimethylbutane and 2 : 2 : 4-trimethylpentane were identified, whilst the following hydrocarbons also appear to be present in the reaction product: 2- and 3-methylpentanes, 2 : 4-dimethylpentane, 3-methylhexane, 2 : 2 : 5-trimethylpentane, and 2 : 2 : 6-trimethylpentane.

2-Butene and *iso*pentane gave a condensation product of 85 octane number, the main fraction of which consisted principally of 2 : 2 : 5-trimethylhexane ; the presence of 2 : 2 : 6-trimethylhexane and 2-methylpentane was indicated, whilst 2 : 3-dimethylbutane was again isolated and identified through its *trans*-derivative.

Of these reactions the most promising from a commercial point of view appear to be the acid condensation of propylene with *iso*butane and of butenes with *iso*pentane. In general, the acid consumption for reactions involving propylene or *iso*pentane are considerably higher than those for butene–*iso*butane additions ; in consequence the technical development of these reactions must await reduction in the acid requirements.
H. E. T.

136.* Catalytic Effect of Metals or Paraffin Hydrocarbons. C. L. Thomas, G. Egloff, and J. C. Morrell. *Industr. Engng Chem.*, 1939, **31** (9), 1090.—This paper presents a comprehensive summary of the catalytic effect of metals on the paraffin hydrocarbons. From considerations of the data presented it is concluded that as catalysts, metals are potentially capable of fostering carbon–carbon scission or cracking, dehydrogenation to form olefines, and complete decomposition to carbon and hydrogen. From the data there appears to be no metal that sponsors catalytic cracking or carbon–carbon scission. There is evidence that both copper and palladium are capable of sponsoring dehydrogenation to produce olefines, although copper is comparatively inert unless specially prepared, whilst palladium has a tendency to promote carbon formation. Iron, nickel, and cobalt are extensively active catalysts in promoting complete decomposition to carbon and hydrogen, but are rapidly poisoned by sulphur compounds.
H. E. T.

137.* Catalytic Hydration of Olefines. W. B. Shimer, M. M. Holm, and L. F. Brooke. *Industr. Engng Chem.*, 1939, **31** (9), 1099.—Sulphuric acid has been shown to be an active catalyst for the hydration of ethylene and propylene to the corresponding alcohols, at relatively low temperatures, where the equilibrium is favourable for high yields of alcohols. Optimum acid concentrations and temperature were 70% and 150° C. for ethylene and 55% and 115° C. for propylene hydration. Under these conditions the equilibrium constants for alcohol formation were $Kp = 0{\cdot}049$ for ethylene hydration and $Kp = 0{\cdot}1$ for propylene hydration, values which agree with published data. Pressure operations increased the rate of alcohol production, and concentration of alcohol in the product, but decreased the amount of water required for maintaining the acid concentration constant. The ratio of ether to alcohol in the product was increased for ethylene hydration, but not for propylene hydration by operating under pressure. H. E. T.

138.* Raoult and Dalton's Laws Demonstrated in Vapour-Pressure Apparatus. J. A. Campbell. *Petrol. Engr*, Sept. 1939, **10** (13), 96.—A complete understanding of Raoult and Dalton's laws is essential to an appreciation of the methods used in the extraction of natural gasoline. A simple demonstration of these two laws using a Reid vapour-pressure apparatus is described. Tests in which the air/liquid ratio is varied show that natural gasoline is a mixture, the changes in pressure experienced being due to changes in the composition of the liquid with evaporation which could not occur with a pure substance. A modification of the Reid apparatus is used to demonstrate the effectiveness of absorption oil as compared with compression alone in condensing natural gasoline and at the same time illustrate Raoult's Law. R. J. E.

139.* Sulphonation of Naphthenic Acids. W. Kisielewicz, S. Pilat, and J. Sereda. *IIme Congrès mond. Pétrole*, 1938, **2**, 435–439.—The author reviews the very contradictory literature relating to the sulphonation of naphthenic acids and describes his experiments using fuming sulphuric acid and naphthenic acids of varying molecular weights. Preparation, purification, and sulphonation are described, and it is shown that (1) the higher the molecular weight, the more easy the sulphonation, (2) for equal molecular weight those acids with higher density and higher refractive index react more easily, (3) the sulphonation does not break down the carboxylic group.
W. P.

140.* New Structural Principles in the Synthesis of Oils. G. Hugel. *IIme Congrès mond. Pétrole*, 1937, **2**, 323–327.—Solutions of substances of high molecular weight, particularly when the concentration is sufficiently high to cause gelling, possess properties which depend entirely on those of the solute. Applying this to viscosity–temperature characteristics of lubricating oils, the author advances a molecular structural theory to account for differences in viscosity index.

It is concluded that high viscosity indices are connected with long-chain structures.

W. P.

141.* Polymerization of Unsaturated Hydrocarbons. H. I. Watermann and J. J. Leeudertse. *IIme Congrès mond. Pétrole*, 1939, 2, 313–322.—An account of research in the Laboratory of Chemical Technology, Delft Technical University, into the effect of structure of basic material and conditions of reaction in the catalytic polymerization of olefines and cyclic unsaturated hydrocarbons.

Polymerization of relatively pure hydrocarbons was effected at low temperatures, mainly with $AlCl_3$ as catalyst, and the products were examined for composition by the specific refraction molecular-weight method. It was shown that $AlCl_3$ is a powerful catalyst giving high yields of high molecular hydrocarbons, but that secondary reactions such as cyclization also occurred even at very low temperatures (—78° C.).

The cyclic character of a hydrocarbon mixture is not the only factor in determining its properties, the degree of branching being especially effective. Since the parachor is also connected with the degree of branching, the authors have compared the molecular composition of their hydrocarbons as determined by specific refraction with that given by the specific parachor. The two methods do not give identical results if the specific parachor of Sugden is used, but show satisfactory similarity if the atomic parachor of Mumford and Phillips is used. The parachor can therefore be used for assessing the apparent total cyclic character of the products of polymerization.

W. P.

142.* Thermal Transformation of Hydrocarbons. A. V. Frost. *IIme Congrès mond. Pétrole*, 1937, 2, 175–182.—An account of the work undertaken in U.S.S.R. to elucidate the mechanism of thermal transformation of hydrocarbons, based on the work of Rice, who showed that cracking is a reaction in chain form in which the radical is an intermediary product.

The kinetics of thermal decomposition of paraffins and of polymerization of olefines are discussed with particular reference to the nature of the radicals involved.

W. P.

143. Viscosity and Its Measurement. Viscosity Index, Rigidity and Thixotropy. J. Suaton. *Bull. Tech. de la Soc. franc. Petrol.* 1939, No. 14, 10–17.—Definition of the absolute units of viscosity, the Poise, and the Stoke are given, and these are followed by brief descriptions of the absolute and commercial viscometers in use at the laboratories of the S.F. des P., together with practical hints on their use. Some notes on the Dean and Davis Viscosity Index System lead to mention of means of improving this property, such as solvent refining and the use of additives. Among considerations of the accurate measurement of viscosity in commercial instruments is the suggested use of standard oils for calibrating the Engler viscometer, in place of water, which gives turbulent flow in this instrument. Limits suggested for the time of flow for the following viscometers are : Engler not to exceed 1 hr. ; Hoppler 30–300 secs. ; Baume capillary tube type 100–300 sec. Discussing the phenomenon of hysteresis, attention is directed to the influence on this property of compounds such as sulphonates. A thixotropic system is defined as one which can pass, as a result of mechanical agitation, from a rigid to a non-rigid state after a period of rest. The principles of Schwedoff's torsion wire method of measuring rigidity are outlined, and the article concludes with Michand's definition of rigid liquids. J. L. T.

144.* Crystal Structure of Hexamethylbenzene and The Length of The Methyl Group Bond to Aromatic Carbon Atoms. L. O. Brockway and J. M. Robertson. *J. chem. Soc.*, Aug. 1939, 1324–1332.—The authors have repeated the determination of the crystal structure of hexamethylbenzene using the double Fourier series method of interpreting the intensity data, with the following results. The distances to the centre of the molecule are 2·92 Å., which, with measurements on the ring, lead to a ring size of 1·39 Å. and a length of 1·53 Å. for the methyl group bond. Thus the methyl group bond attached to a wholly substituted benzene ring has the same length as in a saturated aliphatic hydrocarbon. Between carbon atoms the minimum intermolecular approach distances are 3·70–3·8 Å., and between hydrogen it is 2·0–2·2 Å. The (001) layer is very nearly hexagonal; nevertheless the structure is not monoclinic, but triclinic, since this allows the layer spacing to decrease, corresponding to an increase of about 9% in the density. R. D. S.

145.* Viscosities of Chemically Related Liquids and Their Dependence on Molecular Weight and Molecular Volume. Part II. D. T. Lewis and A. R. Morgan. *J. chem. Soc.*, Aug. 1939, 1341–1345.—The authors reason that even in the liquid state molecular volume and molecular weight exercise a profound influence on viscosity, and should be introduced into any equation intended to represent the variation of viscosity with other physico-chemical constants; and from results of viscosities on series of chemically-related liquids derive an equation combining these fundamental characteristics, showing that when all operative essentials are taken into account, fluorobenzene does not behave anomalously in the halogenobenzene series. Fused silver halides, when plotted according to the equation, give constant slope in the same manner as the homologous liquids, although doubtful parachor values of these salts prevent conclusions as to the effect of molecular volume being reached with certainty. The authors argue that the similar nature of the equations for liquids and gases is to be expected, since in such equations there must be basic dimensional resemblances between liquids and gases. R. D. S.

146.* Kinetics of Bromine Addition to Olefinic Compounds. Part II. The Homogeneous Mechanisms. I. K. Walker and P. W. Robertson. *J. chem. Soc.*, Sept. 1939, 1515–1518.—Bromine is added at a termolecular rate to olefins in acetic acid at 25° at concentrations about M/40, the heat of activation being low, but there is also a bimolecular reaction to a smaller extent. When however, the concentration decreases, the heat of activation increases and the bimolecular mechanism gradually replaces the termolecular, until, at concentrations of M/1000, the change-over is almost complete for allyl derivatives. When about 25% of water is added, the bimolecular reaction again predominates with increased heat of activation, and, similarly, increase in temperature causes the same effect. R. D. S.

147.* Kinetics of Chlorine, Iodine Chloride and Bromine Chloride Addition to Olefinic Compounds. E. P. White and P. W. Robertson. *J. chem. Soc.*, Sept. 1939, 1509–1515.—An account is given of measurements of the rate of addition of chlorine, iodine chloride, and bromine chloride to certain olefins in acetic acid solution and, in some cases, nitrobenzene. While iodine and bromine monochlorides undergo termolecular addition in the same way as do iodine and bromine, the mechanism of chlorine addition was found to be bimolecular in dissociating solvents. Suggested explanations for the termolecular mechanisms are put forward, involving the formation of certain addition compounds, and anomalies in the chlorine addition are considered. R. D. S.

148. Investigations on The Stereoisomerism of Unsaturated Compounds IV. The Identification of *cis-trans* Isomers by Rate Studies. W. G. Young, D. Pressman, and C. D. Coryell. *J. Amer. chem. Soc.*, 1939, **61**, 1640–1644.—In this paper are presented specific reaction rate constants and the heats of activation of the reaction of potassium iodide with several pairs of stereoisomeric alkene dibromides in 99% methanol at 75° and 60°. Acetone was used in place of methanol in the case of the stilbene dibromide isomers owing to the slight solubility of the *trans* form in methanol, which form was found to react over 100 times as rapidly as the *cis* form.

In those derivatives in which the parent unsaturated compounds have two hydrogen atoms adjacent to the double bond and the other two groups are identical or similar, the dibromide from the *trans* compound was found to give a greater rate constant and a smaller heat of activation than the dibromide from the *cis* isomer. The authors therefore suggest that the rate studies of this nature offer a useful means of identifying the isomers of alkene hydrocarbons which cannot be readily identified by the usual methods of ring-splitting, ring-formation, and so on. R. D. S.

149. Investigations on The Stereoisomerism of Unsaturated Compounds V. A Mechanism for The Formation of Butenes from 2 : 3-Dibromobutanes by The Action of Iodide Ion. S. Winstein, D. Pressman, and W. G. Young. *J. Amer. chem. Soc.*, 1939, **61**, 1645–1647.—The removal of bromine from *dl-* and *meso*-2 : 3-dibromobutanes by iodide ions was performed by treatment with sodium iodide in propanol and with potassium iodide in diethylene glycol. The authors found that the removal of the bromine involves almost entirely *trans* elimination at moderate temperatures, and that considerable rearrangement occurs also at a higher temperature.

The mechanism suggested is that the iodide ion attacks one of the (positive) bromine atoms, donating electrons to give iodine bromide, what time the unshared pair of electrons attack the carbon face opposite the remaining bromine atom, liberating bromide ion. A double bond thus being formed, the process is therefore *trans* elimination of bromine. R. D. S.

150. Peroxide Effect in The Addition of Reagents to Unsaturated Compounds. XX. Addition of Hydrogen Bromide to 2-Butyne and 2-Bromo-2-Butene. C. Walling, M. S. Kharasch, and F. R. Mayo. *J. Amer. chem. Soc.*, 1939, **61**, 1711–1713.—2-Butyne treated with hydrogen bromide in certain definite conditions free from oxygen and peroxide gave a normal addition, 2 : 2-dibromobutane being formed, but in conditions of peroxide catalysis racemic 2 : 3-dibromobutane was obtained. The latter product was also obtained when the normal addition was retarded by dilution with an inert solvent (pentane); thus we have a case of abnormal addition to a terminal double bond. (2-Bromo-2-butene is the product of addition of one molecule of hydrogen bromide to 2-butyne under all conditions and, being intermediate, was therefore not isolated in the course of these experiments.) R. D. S.

151. Isomerization of Cyclohexane and Methylcyclopentane. A. L. Glasebrook and W. G. Lovell. *J. Amer. chem. Soc.*, 1939, **61**, 1717–1720.—The isomerization, *cyclo*hexane $\rightleftharpoons$ methyl*cyclo*pentane, having had conflicting reports regarding the nature of the rearrangement and side products, was investigated at temperatures in the liquid phase at 10° intervals from 25° to 77·4° (boiling temperature), the equilibrium being approached from both sides. The investigators found anhydrous aluminium chloride to be inert towards the hydrocarbons, but in the presence of water or hydrochloric acid it brought about a clean reaction with no formation of gas or tar. With aluminium bromide, however, a tarry layer was formed and *iso*butane was evolved. The course of the reaction was followed by refractive index determinations, which indicated only 5% of *cyclo*hexane used in formation of products of side reactions, isomerization thus being almost the sole reaction. Equilibrium constants were measured, and the values of the free energy change, heat of reaction, and entropy change computed therefrom and compared with values calculated from heat-capacity data. R. D. S.

152. Isomerization of Alkenes on Alumina and Thoria. S. Goldwasser and H. S. Taylor. *J. Amer. chem. Soc.*, 1939, **61**, 1762–1765.—The investigators found that isomerization was not affected by the mode of preparation of the catalyst, two different preparations of alumina being shown to have comparable effects. The change in rate of passage of an alcohol over a dehydrating catalyst (vide *J. Amer. chem. Soc.*, 1939, **61**, 1751–1761; *J. Inst. Petrol.* Abstr. No. 1216, 1939) produced a change in distribution of isomers due to isomerization of the products themselves, and not to a change in the mechanism of dehydration. The authors have determined the products of isomerization at 400° for several olefins, and have compared the rates of isomerization on thoria and alumina, postulating a mechanism to account for the products of isomerization, this being based on the formation of an intermediate 3-carbon ring structure similar to that proposed for the catalytic dehydration of alcohols (*loc. cit.*). In addition, comparative stabilities of some olefins at 400° are given. R. D. S.

153. Aromatization of Heptane, Heptene, and Hexene Isomers on Chromic Oxide. S. Goldwasser and H. S. Taylor. *J. Amer. chem. Soc.*, 1939, **61**, 1766–1769.—This investigation presents a study of the effects of structure and rate of passage of hydrocarbons on the reactions occurring in ring-closure and aromatization. The authors have studied the dehydrogenation of *cyclo*hexene and 1 : 3-*cyclo*hexadiene on chromic oxide gel surfaces, and demonstrate the influence of the character of the catalyst on aromatization ; thus, for aromatization of an aliphatic hydrocarbon a dehydrogenating catalyst must be employed. The effect of the structure of an olefin is also shown and discussed. R. D. S.

154. Hydrogen Fluoride as A Condensing Agent. VII. The Acylation of Aromatic Compounds. J. H. Simons, D. I. Randall and S. Archer. *J. Amer. chem. Soc.*, 1939, **61**, 1795–1796.—The authors demonstrate the effectiveness of hydrogen fluoride in the synthesis of ketones from aromatic compounds and carboxylic acids, acid anhydrides and acyl halides by a series of acylating reagents even when ordinary commercial grades of reagents are employed. The yields increase with increasing amounts of hydrogen fluoride. R. D. S.

155. Diphenylmethane as A Thermometric Standard at 25°. T. De Vries and H. A. Strow. *J. Amer. chem. Soc.*, 1939, **61**, 1796–1798.—The authors report a melting point of $25{\cdot}09 \pm 0{\cdot}01°$ C. for pure diphenylmethane, noting that a spontaneous decomposition occurs which is accelerated by light and which results in a progressive depression of the melting point. R. D. S.

156. Relation Between Fluidity, Temperature, and Chemical Constitution of Pure Liquids. E. C. Bingham and S. D. Stookey. *J. Amer. chem. Soc.*, 1939, **61**, 1625–1629.—In this paper is discussed a simple equation $\varnothing/T = a + bT + \ldots$, which is claimed to be accurate, expressing a definite relationship between temperature and viscosity, and affording a well-defined regularity in the viscosity–temperature functions of the successive members of an homologous series up to ten carbon atoms. $\varnothing$ is the fluidity in RHES (reciprocal poise) and T is the temperature in degrees absolute; constant a is a function of the homologous series, and constant b is a function of the molecular weight of the particular member of the series to which the equation is applied. The equation is shown to be valid for a large number of classes of liquids, the only class which the authors found not to fit it being the alcohols. From it a modified equation is derived in which constant a (found to be almost identical for all members of any one non-associated homologous series) is averaged for that series, and constant b is expressed as an exponential function of the molecular weight within the series. Thus it is possible to calculate the viscosity of any member of a non-associated series up to ten carbon atoms at any temperature by means of only four constants. R. D. S.

157. The Viscosity Function. II. Viscosity and Constitution. E. P. Irany. *J. Amer. chem. Soc.*, 1939, **61**, 1734–1739.—The greater number of pure chemical compounds are non-associated in the pure liquid state ; the author therefore reasons that when laws of constitutional additivity such as viscosity are deduced, the inclusion of an association factor to accommodate the facts to such empirical relationships has no meaning, but the intermolecular forces, expressed in some way, must be included in the concept of constitution. By further argument, the author limits to two, as a minimum, the number of material factors which are necessary to postulate a rule of constitutive viscosity, so that single atomic constants are not sufficient for such a rule. However, the simpler the structure of chemical compounds, the more difficult becomes the problem, because among them every structural difference is large enough to obscure all physical relationship. Additive increments occur only in certain series of homologous substances in which the intermolecular forces are either (*a*) negligible, as in non-polar compounds, the paraffins, for example, or (*b*) constant for all members, as in polymer-homologues, composed of a large and variable number of identical polar groupings. In a graphical study on the latter class, the author deduces two parameters, one, constant, expressing the common polar nature of all members of the series, and the other, constitutionally additive, dependent on molecular weights, volumes, chain lengths, and so on. R. D. S.

158.* Fractionation of Mixtures of Hydrocarbons. H. Macura and H. Grosse-Oetringhaus. *Oel u. Kohle*, 1939, **15**, 591–600.—A detailed account is given of the fractionation of mixtures of benzene, toluene, and xylene, using columns of different types and with various packings. Results are quoted to show the effect of different packings on the efficiency of a column, and also the effect of different rates of distillation. Using the final column described, it is claimed that the distillation curve shows quite clearly the presence of the toluene in a mixture of 10% benzene, 0·5% toluene, and 89·5% xylene. T. T. D.

159.* Chlorination of Olefins and Olefin–Paraffin Mixtures. H. P. A. Groll, G. Hearne, F. F. Rust, and W. E. Vaughan. *Industr. Engng Chem.*, 1939, 31, 1239.—From a study of the chlorination of the C_2, C_3, and C_4 olefins under flow conditions, it is concluded that at temperatures below 150° C. in the gas phase the chlorination reaction is extremely slow, but in the presence of the liquid phase the reaction is rapid. Under this latter condition the substitution of chlorine into the saturated addition product or into a concurrently present paraffin is inhibited by the presence of oxygen, the paraffin reaction being more strongly influenced. The quantitative distribution of the chlorination products from the reactions studied are given.

Catalytic vapour phase chlorination of olefins and olefin–paraffin mixtures occurs at moderate temperatures in the absence of liquid, and the concurrent substitution reactions are not inhibited by the presence of oxygen. J. W. H.

160.* Trimethylhydroquinone from a Petroleum Product. W. M. Potts and H. N. Morrow. *Industr. Engng Chem.*, 1939, **31**, 1270.—A description is given of the isolation and identification of trimethylhydroquinone from a spent soda solution that had been used in the treating of the cracked product from a Samfordyce crude oil.

Summarized experimental data and photomicrographs of the identification derivatives are given. J. W. H.

161.* Anti-oxidants for Castor Oil. G. O. Inman. *Industr. Engng Chem.*, 1939, **30**, 1103.—The effect of the addition of anti-oxidants to castor oil has been examined by passing oxygen at 60 c.c./hr. at 125° C. through 25 gm. of castor oil containing 0·1% of the substance under test. The increase in stability conferred upon the oil by the presence of the anti-oxidant was determined by measurement of the acidity after various periods of time.

Of the 21 substances examined, many were shown to be pro-oxidants. The most efficient anti-oxidants were pyrogallol, hydroquinone, and catechol. J. W. H.

162.* Chemical Reactions of Cracked Residues. H. Tropsch, C. L. Thomas, J. C. Morrell, and G. Egloff. *Industr. Engng Chem.*, 1939, **30**, 1112.—The reaction products produced from cracked residues by the processes of oxidation, sulphonation, ethylation, nitration, and condensation are briefly reviewed, and the conclusion is reached that certain of these reactions may offer useful leads for research in the development of products from cracked residues. J. W. H.

163.* Vapour-Liquid Equilibrium in the System Propane-Isobutylene. H. W. Scheeline and E. R. Gilliland. *Industr. Engng Chem.*, 1939, **31**, (8), 1050.—The equilibrium was measured at pressures up to 600 lb. per sq. in. The experimental results are compared with the equilibrium constants calculated from fugacity. Good agreement is found at 400 lb. per sq. in. At lower pressures the polarity of the *iso*butylene, which is responsible for lack of ideality of the solution, results in higher values of K for propane than those calculated. The values of K for *iso*butylene show serious divergences as the critical state is approached. P. D.

164. Motion of Cylindrical Particles in Viscous Flow. R. C. Binder. *J. Appl. Phys.*, 1939, **10** (10), 711.—Experiments were made on the orientation of cylindrical particles in glycerin, using a concentric cylinder viscometer. Two different final orientations of the particle were observed—namely, perpendicular and parallel to the plane of undisturbed flow. The relation between final orientation and length-diameter ratio of the particle was determined for different speeds. The results are considered in the light of theory. P. D.

165. Viscosity of Dilute Solution of Long-chain Molecules. M. L. Huggins. *J. Appl. Phys.*, 1939, **10** (10), 700.—Equations are given for the specific viscosity of dilute solutions of randomly-kinked chain molecules which is of the same form as Staudinger's empirical equation. The equation is tested against experimental determinations on solutions of normal paraffins. The various factors which may be expected to affect the accuracy of the equation are discussed. P. D.

166.* Phase Equilibria in Hydrocarbon Systems: Joule-Thomson Coefficients of Gaseous Mixtures of Methane and Ethane. R. A. Budenholzer, B. H. Sage, and W. N. Lacy. *Industr. Engng Chem.*, 1939, **31** (10), 1298.—Joule-Thomson coefficients were determined at 70°, 100°, 160°, and 220° F., over a pressure range 40–1500 lb. per sq. in. for three CH_4–C_2H_6 mixtures (23·6, 40·0, and 73·3 mol % C_2H_6). The results are presented in tabular and graphical form, and the *iso*baric heat capacity is calculated.
P. D.

Analysis and Testing.

167. A Hydrogen Sulphide Recorder. W. E. Stackhouse. *Instruments*, 1939, **12** (10), 280.—The recorder described works on the principle of determining the H_2S content of a sample of gas by means of a colorimetric reagent, the colour intensity being measured by photocells in conjunction with a potentiometer type recorder. The recorder will respond to changes in concentration of 0·005 grain H_2S in 100 cu. ft. The range can be varied to suit requirements. P. D.

168.* Evaluation of High-Octane-Number Gasolines. L. A. Peletier and S. G. Van Hoogstraten. *Monit. Pétr. roum.*, 15.7.39, **40** (14), 947–950.—This article describes a method of testing the anti-knock properties of fuels of high octane number by the use of which it is claimed that good correlation with results obtained in current aero engines can be obtained. The method is a simplification in some respects of the "Allowable Boost Ratio" method of test described by one of the authors *et. al.* in *Aircraft Engineering* of December 1935. The present method compares the boost pressures permissible at different mixture strengths on the fuel under test at a fixed compression ratio with that obtained on a standard reference fuel such as *iso*-octane to give incipient detonation, the results on the test fuel being expressed as a percentage of the value obtained on the reference fuel at 1·1 times theoretical mixtures strength for complete combustion.

The equipment used is a modified C.F.R. engine coupled to a synchronous motor and a separate unit for the supply of air to the engine at closely controlled pressures.

As regards the engine, the variations from the standard C.F.R.-A.S.T.M. equipment are as follows :—

Aluminium piston (Waukesha No. 105,590) with clearance increased by 0·1 mm. to obviate seizure.

Inlet valve plain in place of A.S.T.M. shrouded valve.

Highlift camshaft (Waukesha No. 23223).

Standard carburettor choke increased from 14 to 23 mm. and variable jets fitted.

Mixture heater (K.L.G. No. 583 ; the heat input being maintained constant and equal to that required to raise the mixture temperature to 90° C. when running on *iso*-octane at 10% rich with no supercharge).

Evaporative cooling using water/glycol mixture boiling at 120° C.

Ignition 30° BTC.

The above test conditions are considered to give the best results, and the reasons for their adoption are discussed. The air-supply apparatus operates from a high-pressure supply and allows of fine adjustments, permitting the boost pressure to be maintained constant to within 1 mm. Hg.

The high-pressure supply can be varied between approximately 28½ and 36 lb. per sq. in. absolute, and the supply to the engine is adjustable between 11½ and 21½ lb. per sq. in. absolute. Details of the air supply equipment are given in an appendix.

This method of test has been found to give results repeatable within very small

limits of experimental error, and in this respect is claimed to be greatly superior to the A.S.T.M. method in the region of 100 octane. In addition, it would be possible to extend the range of the method by the use of reference fuel superior to *iso*-octane.
C. H. S.

169. Trichloroethylene as a Solvent in the Bituminous Laboratory. J. D. Brown. *Proc. Assoc. Asph. Paving Techn.*, 1939, 266–279.—The author points out that although carbon disulphide must be used in the determination of bitumen content in accordance with the definition of bitumen, it is not a satisfactory solvent for routine laboratory use, and it is suggested that for most purposes this solvent could be replaced by trichloroethylene. A comparison is made of the properties of carbon disulphide, carbon tetrachloride, and trichloroethylene and of the behaviour of these solvents when used in various tests on bituminous materials. Solubility tests made in accordance with the A.S.T.M. methods for total bitumen and for solubility in carbon tetrachloride showed no marked difference in the case of road oils, paving bitumens, a blown bitumen, Gilsonite, and three rock asphalts. A very hard bitumen gave similar results with carbon disulphide and trichloroethylene, but showed approximately 8% lower solubility in carbon tetrachloride, whilst coal tars showed slightly lower solubility in trichloroethylene than in carbon disulphide and appreciably lower solubility in carbon tetrachloride. No great difference was found in the rates of solution of bitumens in carbon disulphide and trichloroethylene, but carbon tetrachloride was much slower. The relative rates of evaporation were of the order of 4·1, 1·6, and 1·0 for carbon disulphide, trichloroethylene and carbon tetrachloride. It is pointed out that the flash point of carbon disulphide is very low and that the auto-ignition temperature is about 130° C. In conclusion it is stated that trichloroethylene appears to be a satisfactory substitute for most purposes and worthy of serious consideration as a general bituminous solvent, being superior to carbon tetrachloride in stability, solvent power and rate of solution, less volatile and probably less toxic. A. O.

170. New Methods of Testing Liquid Fuels. F. Seeber. *Luftfahrtforsch.*, 1939 (16), 431–433.—A drawback in the routine testing of motor fuels in the C.F.R. engine is the known fact that spirits giving the same octane number in this engine often show different ratings in the actual aircraft engine. The Deutsche Versuchs Anstalt fuer Luftfahrt (D.V.L.) have developed a new method of knock-rating based on the intake pressure or pressure of the charge at which the first knock is audible, the test being run in a single cylinder of a full scale engine.

With this method it is claimed to be possible to introduce optionally one or more variables during the test—viz., compression ratio, ignition timing, air/fuel ratio, intake air temperature, temperature of the cooling medium, and engine speed, the octane value being made up in the form of curves taken under widely different conditions, but always in the real cylinder. It was possible to solve certain problems of fuels of similar C.F.R. rating but of different chemical structure, as, for instance the different temperature sensitiveness of paraffinic fuels as opposed to aromatic fuels.
E. W. S.

171. Determination of the Mercaptan Sulphur in the Calorimetric Bomb. E. Dittrich. *Brennstofftechnik*, 1939, 20, 348–349.—The lower aliphatic mercaptans present in mineral oils can only be definitely found with the calorimetric bomb if the combustion is effected at a starting pressure of at least 500 lb./sq. in., and if the mercaptans are strongly diluted. On the other hand, exact results can only be established with combustion in the quartz tube according to Grote and Krekeler. E. W. S.

Motor Fuels.

172.* Vapour-lock Properties of Motor Fuels. Th. Hammerich. *Oel u. Kohle*, 1939, **15**, 569–577.—Vapour-lock properties of fuels are controlled, in America, by Reid vapour-pressure measurements and the determination of the 10% recovery point in the A.S.T.M. distillation. These methods have not been adopted generally in Germany, as the results obtained do not accord well with practice. In order to correlate these properties with the constitution of the fuel, the author has worked out a new method of separating the C_3 and C_4 hydrocarbons, using "fractional dephlegmation." The sample is first submitted to a modified A.S.T.M. distillation in which the first 25% is received in a long-necked round-bottom flask, completely immersed in a bath at — 80° C., the condenser tube being fitted through a rubber bung to an adaptor connected to the neck of the receiver by a ground-glass joint. The receiver is then removed from the cooling bath and connected to the bottom of a column packed with aluminium spirals. This column is surrounded by a bath, which is maintained at the desired temperature, thus acting as the dephlegmator, and is connected at the top through a two-way tap to two calibrated tuning-fork shaped receivers immersed in baths at — 80° C.

To separate the C_3 fraction, the temperature of the dephlegmator is adjusted to — 35° C., the tap to one of the tared receivers opened, and the flask heated with a micro-burner. When the volume in the receiver ceases to increase, the receiver is disconnected and weighed. To determine the C_4 fraction, the tap to the second receiver is opened and the temperature of the dephlegmator adjusted to 3° C., until the volume in the receiver ceases to increase, when the latter is disconnected and weighed. As the sample was weighed before the preliminary distillation, the percentage of the C_3 and C_4 hydrocarbons can be calculated. Work on samples of known composition showed that this method gave reliable results, so it was used as the standard method of analysis.

Since the appearance of vapour-lock may depend on factors other than volatility, the author describes a method of determining the lock (Abreisst) temperature. In this the fuel under test is forced, at 10 litres/hour, by means of a membrane pump through a copper spiral immersed in a water-bath. Means are provided for heating the bath, and the temperature of the fuel in the spiral at the moment when a vapour-lock occurs (rate of flow $<$ 1·5 l/hr.), is the lock temperature.

Tables and diagrams are given illustrating the effect of the addition of C_3 and C_4 hydrocarbons on the vapour pressure, A.S.T.M. 10% point and lock temperature of I.G. standard benzine, and the same properties are recorded for mixtures of gasoline, alcohol, and benzene. These figures show that there is an approximately linear relationship between lock temperature and A.S.T.M. 10% point in the case of most gasolines, but this does not hold for benzene or alcohol mixtures, or for gasolines rich in C_3 and C_4 fractions.

On this account, the author proposes, as a more reliable guide to vapour-lock properties, the mean of the recovery to 50° C. and to 70° C., which is reported as the volatility and expressed as a percentage.

When volatility is plotted against lock temperature, straight lines are obtained for fuels of equal vapour pressure. If plotted on one diagram, the lines corresponding to different vapour pressures form a pencil of rays, the slope ($\tan \alpha$) being a function of vapour pressure. The author includes a graph of this relationship, and thus, if the volatility (v) is known, the lock temperature (l) is obtainable from the equation

$$l = \frac{30 - v}{\tan \alpha} + 48$$

Hence, from measurements of Reid vapour pressure and determination of the A.S.T.M. distillation curve, it is possible to calculate the lock temperature, which is a direct measure of the vapour-lock tendencies of the fuel. T. T. D.

173.* Producing High-Octane Aviation Gasolines by Means of Destructive Alkylation. D. L. Goldstein and B. A. Englin. *Neft. Khoz.*, July 1939, **20** (7), 27–34.—In the process of destructive alkylation, with benzole present, the anti-knock properties of low-octane fuels are improved. A liquid residual complex of aluminium chloride with hydrocarbons is formed which flows freely at low temperatures, thus facilitating the technological development of the necessary full-size apparatus. Destructive alkylation in the presence of benzole proceeds under milder temperature conditions than the usual process of treating petroleum products with aluminium chloride to a solid residue. In the present experiments destructive alkylation was carried out between 150° and 200° C.

As raw materials were used : Grosny paraffin-base aviation gasoline, synthin (consisting mainly of normal paraffinic hydrocarbons), and products of Ishimbaevo crude.

It has been found that the heavier the raw material, up to a certain limit, the more intense is the reaction, and the greater the quantity of alkyl benzole formed. For example, optimum anti-knock properties result with a synthin having a f.b.p. of 220° C. In the destructive alkylation of products of Ishimbaevo crude, parallel with the formation of high-octane gasolines, the latter are also desulphurized.

From Grosny gasoline a fuel is produced having 95·5 octane number with 3 cu. cm./kgm. ethyl fluid. From synthin a fuel is obtained which has 85 octane numbers when 2 cu. cm./kgm. ethyl fluid are added, whilst octane numbers of the products of treatment of Ishimbaevo gasoline containing 2 cu. cm./kgm. $PbEt_4$ range between 89·5 and 92 octane.

The anti-knock properties indicated are not the optima obtainable, and the possibility of further improvements is being investigated. L. R.

174.* Production of Anti-Knock Fuels from Oil of Turpentine. G. Hugel. *IIme Congrès mond. Pétrole*, 1937, **2**, 309–312.—The principal constituents of French oil of turpentine are α- and β-pinene. The various known methods of converting pinene into cymene either by dehydrogenation or by oxidation are discussed. The author advocates heating oil of turpentine, with sodium as catalyst, to a temperature of 270° C., when a mixture of about one-third menthane and two-thirds *p*-cymene is produced. This, by nitration and reduction, yields amino-cymene, which has already been noted for anti-knock properties. W. P.

See also Abstract No. 102.

Diesel Oil.

175.* Transformation, Spontaneous Ignition and Cetene Numbers of Diesel Fuels. O. Herstad. *Oel. u. Kohle*, 1939, **15**, 629–631).—" Transformation " curves have been determined for the two reference fuels supplied for cetene number determinations by the A.I.O.C. Whereas in the case of gasolines the maximum transformation occurs between 160° C. and 230° C., for diesel oils the range is from 350° C. to 400° C. Further, whilst in the former case maximum transformation temperature rises with increasing octane number, in the latter case maximum transformation temperature falls with increasing cetene number, and the maximum transformation time (in sec./c.c.) falls from 56 in the case of the high cetene standard to 38 in that of the low cetene standard.

The transformation curves of mixtures of the two fuels were also determined, and it is shown that there is an approximately linear relationship between maximum transformation time and composition, analogous to that between cetene number and composition.

Spontaneous ignition temperatures of mixtures of the two standard fuels were also determined, covering the range 600–560° C., and it is shown that there is a linear relationship with cetene number, which with the mixtures in question varied from 43 to 71. The desirable cetene number range of 51–64 corresponds to S.I.T. of 590–570° C. T. T. D.

Lubricants and Lubrication.

176.* Reclamation of Used Lubricating Oil. S. H. Wilson and M. B. Rands. *New Zealand J. Sci.*, 1939, **21**, 1B–15B.—New Zealand imports all its requirements of lubricating oil, and 68% of the total quantity is used in I.C. engines fitted to land vehicles. It is considered that the better oils demanded by modern engines are produced by solvent refining, and are worth reclaiming. In peace-time, regeneration by methods used in the original refining may not be economical, but in war-time, regeneration may be desirable to conserve supplies. The main benefit to be obtained from the use of reclaiming is thought to be the improved running and longer life of the engine consequent on more frequent draining of the sump oil. The English method of reconditioning by batch methods of washing, heating and settling, chemical treatment for coagulating impurities, pad and edge filtration and centrifuging, are contrasted with German methods of reclaiming using acid and earth treatment. It is pointed out that a strict comparison between new and reclaimed oil is not possible, since in practice fresh oil is always being added. The warning is made that natural inhibitors present in moderately refined oil are removed by further refining, and that more refined oil oxides more rapidly in conseqeunce. The methods of examining used oil adopted in New Zealand are the usual ones, plus the precipitation of suspended inorganic matter by trichlorethylene. Metallic soaps are not precipitated. Analyses are given of used oils from tractors, one oil containing the familiar aluminium soap detergent, and also from trucks using filters packed with cotton waste. It appears that there is no saving in cost of oil, but that the benefit is found in lower wear and better running of the engine. J. L. T.

177.* Comparison of the Low-temperature Behaviour of Petroleum and Synthetic Lubricating Oils. R. Heinze and M. Marder. *Oel u. Kohle*, 1939, **15**, 611–616.—The power required to drive a 10–50-h.p. Mercedes-Benz engine at 40 rev./min. was determined in watts/rev. at temperatures between 0° C. and —20° C., by enclosing the engine and the electric motor required to drive it in a refrigerator. Four petroleum and two synthetic oils were used, and the variation in the power required with temperature was measured in each case.

Viscosities determined directly on the Vogel–Ossag instrument at the temperatures concerned were not in good agreement with those calculated with the help of the Ubbelhode–Walther viscosity-temperature chart, and neither was in quantitative agreement with the actual behaviour of the oil in the engine. Although the extrapolated figure is not completely unreliable regarding the actual behaviour of the petroleum oil, neither is of great significance in forecasting the behaviour of the synthetic oil.

In contrast to this, the figures obtained by means of the Schwaiger rotating cylinder viscometer are in very good agreement with the actual behaviour of the oils over the same low-temperature range. The synthetic oils proved themselves better in the engine and in the Schwaiger viscometer than their behaviour in a capillary viscometer would lead one to expect. On the other hand, the figures obtained on the Vogel–Ossag lead to an over-valuation of the usefulness of petroleum lubricating oils at low temperatures.

The authors emphasize that their results show that the synthetic oils have better low-temperature properties in the engine than do petroleum oils of equal viscosity at 50° C. This behaviour is, apparently, independent of the viscosity pole height, for figures are quoted to show that two oils, one synthetic of viscosity 68 centistokes at 50° C., the other petroleum of viscosity 48 centistokes at 50° C., and of pole height 1·93 and 1·89, respectively, have almost identical curves for performance between 0° and —20° C. Since the synthetic oils have, in general, flat viscosity curves, the authors consider that, for motor lubrication, they are greatly to be preferred to the more usual petroleum lubricants. T. T. D.

178.* Modern Grease-making. F. E. Huggins. *IIme Congrès mond. Pétrole*, 1938, **2**, 451–453.—A description of conventional grease-making plant for saponification in autoclaves under pressure. W. P.

179.* Y.P.F. Lubricating Oil for Aircraft Engines. (Aircraft Lubricating Oil P. 444.) Report by the Director General of Naval Air Force. *Bol. Inform. Petroleras*, Aug. 1939, XVI (180), 39–48.—Full report of the tests carried out with this lubricant in a Wright Cyclone 745-h.p. engine. The results were so satisfactory that the oil has been generally adopted in the Argentine navy for use in its aircraft. H. I. L.

180.* Characteristics of Lubricating Oils. Ing. A. S. Barcelo. *Bol. Inform. Petroleras.*, Aug. 1939, XVI (180), 34–37.—This is a dissertation on the necessary characteristics of lubricating oils, with special reference to the needs of automobiles, which was broadcast by the author at the request of the Y.P.F. H. I. L.

181.* Viscosity-Pressure Characteristics of Lubricating Oils. B. W. Thomas, W. R. Ham, and R. B. Dow. *Industr. Engng Chem.*, 1939, **31** (10), 1267.—Raffinate and extract were prepared from a Pennsylvania 180 neutral oil by acetone extraction, and the viscosity of these and the unextracted oil determined over a pressure range of 1–2820 kg. per sq. cm. The temperatures chosen were 37·78°, 47·94°, 68·33°, and 98·89° C. A rotating cylinder viscometer was used. The results show that the extract has a considerably greater pressure coefficient than either the raffinate or the original oil. P. D.

182.* Effect of Pressure on Viscosity in Relation to Lubrication. J. W. Givens. *Industr. Engng Chem.*, 1939, **31** (9), 135.—The results on bearing temperature rise when using three oils under varying loads published by Everett (*S.A.E. Journal*, 1937, **41**, 531), are correlated by using a mean value of the viscosity under the pressure and temperature conditions of the bearing in calculating ZN/P. It is also shown that the temperature rise in the bearing is proportional to $(\alpha P)^2$, where α is the viscosity pressure coefficient for an oil. It is concluded that effects which might be attributed to " oiliness " are such as would be expected from hydrodynamic theory if the effect of pressure on viscosity is correctly allowed for. P. D.

183. Lubrication of Diesel Engines. H. O. Farmer. *Pwr. and Works Engr*, 1939, **34** (400), 401–403.—The functions of the lubricating oil and the varying conditions of temperature and pressure to which it is subjected are described. The importance of details such as external leaks and adequate crank-case ventilation is stressed. The purpose and significance of the usual laboratory tests, including viscosity, flash point, coke and oxidation tests, are described for the guidance of engineers who wish to purchase to specifications. Recent developments in the direction of solvent refining and the use of addition agents are indicated, and the treatment of the oil during or after use is briefly discussed. K. T. A.

184. Problems of Oil Engine Lubrication. K. Arter. *Pwr. and Works Engr*, 1939, **34** (400), 415–417.—Besides maintaining an adequate film between rubbing surfaces, diesel-engine lubricants have to seal the piston rings against gas leakage and play an important part in removing heat from the bearings and pistons. These arduous duties demand a high degree of stability, and a flat viscosity/temperature curve is usually desirable. It is important to maintain satisfactory lubrication of the piston rings and cylinder walls, at the high temperatures which prevail; even momentary failure may cause lasting damage through scuffing, and this, in turn, permits increased blow-by of hot gases. These gases contain sooty carbon, acidic, and other undesirable constituents. If they are able to pass the piston rings at an abnormal rate, an unsuitable oil will quickly break down, ultimately causing stuck rings.

The removal of contaminants by filtration or centrifuging is good practice; the usual methods of treating used oils are briefly discussed. Water may get into the oil by leakage from the cooling system or through condensation of blow-by gases. In conjunction with other contaminants water can be a prolific source of sludge; good crankcase ventilation and the avoidance of low operating temperatures are therefore important. Recent developments in refining methods and the use of addition agents are outlined, and the operator's problem of balancing lubricant quality against price is discussed. K. T. A.

Asphalt and Bitumen.

185.* Failure of Asphalt Surfacings and Adhesion of Binder and Stone. R. Ariano. *Le Strade*, 1939, **8**, 409–425.—The failures, such as cracking, loss of adhesion, and consequent infiltration of water, often experienced in asphalt surfacings subject to wide temperature variations are considered and the cause of difference in behaviour of surfacings on earth and concrete roads was investigated.

Laboratory findings, subsequently confirmed by actual practice, demonstrated that the concrete, which is permeable, can give rise in certain instances to the failures mentioned in the surface coating; it seems, however, that by a convenient treatment with road oil, this permeability can be at least partly reduced, if not entirely eliminated.

The various methods proposed to determine cohesion and adhesion are then described and it is pointed out that in general they do not correspond to the behaviour of the materials during actual use. Results of adhesion tests on stones made by the Experimental Road Institute are then described, and it is concluded that, unless subjected to the action of water, the adhesion between binder and stone may be even greater than between binder and binder. The importance of the quality of asphalt employed is stressed, and it is stated that results obtained with asphalt from asphaltic rocks are generally better than with the first-grade petroleum asphalt, and that adhesion is greater with increasing hardness for asphalts of the same source. The use of highly porous aggregates should be avoided, as they tend to bring the under-bottom water into contact with the protective coating. The influence of temperature is noted, and it is also pointed out that improvement of adhesion occurs with weathering. P. G.

186.* The Stability of Emulsions. Part I. Soap Stabilised Emulsions. A. King and L. N. Mukherjee. *J. Soc. chem. Ind.*, 1939, **58**, 243–249.—The instability of an emulsion is defined as the rate of decrease of its interfacial area with time, and the difference between this and sedimentation is pointed out. The efficiency of an emulsifying agent is a specific property, and hence comparisons can only be made with two given liquids and various emulsifying agents. The systems examined were kerosene–water and olive oil–water, and the size frequencies were observed after definite time intervals using various emulsifying agents in varying amounts; the emulsions were prepared in an homogenizer or by hand-shaking. In general the globules became coarser with time, and it was provisionally concluded that for homogenized emulsions particles larger than 7·5 μ coalesced to give free oil. For hand-shaken emulsions the particles are much coarser, a large number of particles being greater than 7·5 μ. The difference is considered to be due to the differing amounts of air entrained at the emulsion interface. As a quantitative basis of comparison, the decrease in the total area of interface per gram of oil after given times has been used, and found to decrease linearly with time. The reciprocal of this decrease has been defined as the emulsion stability. The formation of free oil alters the linear relationship, and hence it is advisable to take values before much free oil separates. Comparison of the stability of emulsions can also be made by means of the " time of half-break."

Soaps in general give very fine but relatively unstable emulsions. Sodium and potassium soaps have a very similar emulsifying effect, whilst ammonium soaps are definitely inferior. Oleates are the most efficient emulsifiers, potassium oleate being the best, and palmitates the least, both with kerosene and olive oil.

Finer and more stable homogenized emulsions were obtained when the soap was formed *in situ* than when added as an entity. The specific area of interface obtained with homogenized emulsions was about ten times that obtained by hand-shaking, and the ratio of stabilities about 1·8 : 1 on the average. The presence of calcium ions, hydrochloric acid, or heat accelerates the decrease in stability in all cases.

The paper concludes with experimental details of the preparation of soaps, emulsions, methods of sampling, and of size-frequency analysis. H. G. W.

187.* Emulsions in Industry. Part V. Asphaltic Bitumen Emulsions in Building and Road Construction. H. L. Bennister. *Chem. and Ind.*, 1939, **58**, 758–762.—The author points out that owing to the greater complexity of asphaltic bitumen compared with oils, and hence the complexity of the emulsions obtained, some difficulty is experienced in preparing emulsions of a given specification. The greater ease of handling when cold is a definite advantage of emulsions over other bituminous materials. Methods of manufacture by stirrer or colloid mill are discussed, and it is stated that the particle size usually ranges from 1 to 5 microns, with occasional particles up to 15 microns. The character of the dispersing agents used, which are alkaline bases ranging from sodium hydroxide to pyridine, and of the stabilizing agents, such as soaps, gums, sulphonated fats, etc., has a marked effect on the finished emulsion and on the bitumen obtained on breaking. More stable types of emulsion are obtained by the use of bentonite, etc., or the hydroxides of certain metals, and in general these are acid or neutral and stable to electrolytes, fillers, etc. Mixed emulsions are also used for certain purposes.

For road use emulsions must be stable on storage, yet " break " readily when spread on the road. The use of sodium oxalate, fluoride, glycols, alcohols, etc., is stated to increase the storage stability, whilst the rate of breaking is controlled by the quantity of stabilizing agent used. The waterproofing of cement, concrete, and mortar by the addition of 20–30% of bituminous emulsion is mentioned, as well as the use of a lighter emulsified oil for dust-laying. By the addition of dyestuffs, pigments, and metallic powders are obtained bituminous emulsion paints, used mainly for waterproofing buildings, etc. Emulsions containing only 30% of bitumen are used in soil stabilization, particularly underground, and details of manufacture of such emulsions are given.

An outline of the methods of testing emulsions before use is given, and the difficulty of obtaining entirely satisfactory emulsions is mentioned. Properties generally examined include homogeneity, storage stability, viscosity, water miscibility, resistance to freezing, and rate of breaking in use. By distillation of the emulsion in iron stills the bitumen and dispersing agents used can be examined.

The author points out that "satisfactory all-round fulfilment of the exacting specifications with gradual modification and improvement of products is the keynote of the industry to-day rather than sudden development in specialized fields." H. G. W.

188. Emulsified Asphalts. C. A. Downing. *Proc. Assoc. Asph. Paving Techn.*, 1939, 242–265.—In a paper presented at the 1935 annual meeting of the A.S.T.M., the author described a method of test intended to give information regarding the storage stability of bitumen emulsion in much shorter time than the A.S.T.M. 5-day settling test. The present paper includes a further description of the method, with minor modifications and results of tests on 373 samples of emulsion. The test consists in determining the difference in bitumen content of samples taken 1 cm., 2·5 cm., and 4·6 cm. below the surface of a mixture of 50 ml. emulsion and 350 ml. water, contained in a 400-ml. beaker, which has been allowed to stand for 2 hr. The bitumen content is determined by heating 1-gm. samples in a constant temperature oven at 163° C. for 2 hr. and reweighing. It is stated that the relationship between the settlement test and the modified miscibility test was such that in 1937 the settlement test was replaced in specifications by a clause requiring that the maximum difference in bitumen content of the samples from the various depths should not exceed 4·1% for mixing emulsions. The author is of the opinion that this test, the cement mixing test, and the dehydration test are of greater value in anticipating the service behaviour of emulsion than any other tests. In connection with the cement mixing test it is stated that it is advisable to specify the surface area of the cement, and in future specifications a minimum of 1900 sq. cm. per gm. will be prescribed. A. O.

189. Blistering of Asphalt. A. W. Attwool. *Proc. Assoc. Asph. Paving Techn.*, 1939, 280–309.—An account is given of investigations which were undertaken several years ago in an attempt to determine the cause of blister formation in asphalt surfacings. In one case of extensive blistering in mastic asphalt, examination of the asphalt and aggregate, the concrete, and samples of the subsoil indicated that the materials were normal, and it was thought that the trouble may have been due to the formation of water vapour and possibly other gases from decomposition of coke breeze, used as a bed for the concrete, this causing pressure to be exerted upwards, and resulting in lifting of the surface in weak places when the asphalt softened in warm weather. In another case there were dozens of blisters, ranging up to 6 in. in diameter and about 1 in. in height, on the north side of the road, whilst the south side was free from blisters. Three blisters were removed and samples taken of the asphalt, the underlying concrete, subsoil, and gas from blisters. During removal of the blisters adhesion of the asphalt to the concrete was found not to be very strong in some places, and numerous beads of moisture were present under each blister. The asphalt was found to be normal, and the gas in the blisters consisted of air with a little water-vapour, whereas the gas evolved on heating the asphalt in the laboratory contained a high percentage of carbon dioxide and a relatively high proportion of unsaturated hydrocarbons. Gas evolved on heating the concrete more closely resembled the gas from the blisters, but differed with regard to carbon dioxide and hydrogen, whilst the gas from the soil contained an extremely high percentage of carbon dioxide. Examination of the concrete and sub-soil showed the concrete to be good, but rather porous; the clay sub-soil contained clinker to which was attributed the carbon dioxide evolved on heating the soil. The results of investigation did not support the various theories concerning blister formation, and the author put forward the following explanation: Small " blows " which are produced through moisture, overheating, etc., during laying are sealed in the underside of the asphalt, and when the asphalt is softened by the sun, the trapped air expands and a small blister is formed. When the temperature falls, the asphalt hardens, the air contracts, and a subnormal pressure exists in the blister, with the result that air or moisture is drawn from the concrete. This process continues with alternate heat and cold, and the blister increases in size. Tests made in the laboratory showed that it was possible to lay a surface in such a way as to produce artificial blisters and then to relay the surface so that no blisters can be produced. It was concluded that if potential blisters are avoided in laying, it is impossible to produce blisters; potential blisters are more easily produced if the temperature of the mastic is unduly high, and sun temperatures as low as 45° C. will produce blisters if potential blisters exist under the mastic. These views received support from investigations by other workers. Subsequently, in order to determine whether the bitumen may have indirectly contributed to the tendency to blister, a co-operative investigation was made, samples of mastic from twenty-two streets laid by different contractors being examined. It was found that in most cases where the material was laid directly on the concrete blistering was evident, whereas when separated from the concrete no blistering had occurred. It is stated that of the asphalts in which Venezuelan bitumen was used as flux, 69% had blistered, and that this would seem to indicate some superiority of the Mexican bitumen flux. Analyses of the samples indicated no apparent relationship between bitumen content and blistering. All samples with hardness numbers over 22, blistered, whilst samples with lower hardness numbers were satisfactory. All gravel-gritted mixtures were satisfactory, but granite-gritted mixtures blistered. The relationship between hardness and blistering is believed to indicate that if there is a tendency to blister, it will occur more readily if the asphalt is soft. Surfacings were laid on concrete slabs, so that half of the slab was occupied by one of the asphalts fluxed with Venezuelan bitumen and half with one of the asphalts fluxed with Mexican bitumen. The sides of the slabs were sealed and the slab immersed to a depth of 4 in. in a water-bath and heated from above by means of an artificial sun. A slight blister appeared on the Venezuelan material in about 8 hr., and after further exposure blisters appeared on both sections of the slab, the blisters on the Venezuelan section being larger but less numerous than on the Mexican section. The asphalts were then relaid with a thin layer of sand upon the concrete, when it was impossible to produce a blister on either section. Tests on the two bitumens are said to show that the Mexican bitumen is more stable. Both materials were of the same penetration, but the Mexican bitumen had higher softening point, plasticity, and viscosity, and it is thought that the surface tension of the Mexican bitumen is higher and will cause that bitumen to adhere to the concrete more strongly. A. O.

190. Correlation of Physical Tests with Service Behaviour of Asphaltic Mixtures. J. S. Miller, H. P. Hayden, and R. Vokac. *Proc. Assoc. Asph. Paving Techn.*, 1939, 310–326.—In a previous paper details were given of an investigation which was undertaken for the purpose of correlating physical tests with service behaviour of asphalt surfacings. Examination was made of a number of pavements at least two years old representing (*a*) cracking type of surface, (*b*) sound type which had neither cracked nor shoved, and (*c*) shoving type. Classification of each pavement was made in the field by inspection of the surface and from service records. Information as to the type, source, and consistency of asphalt cement, gradation of aggregates, and box weights was obtained where possible, and samples were taken of each of the pavements. The present paper discusses the tabulated data concerning composition, density, voids, and characteristics of the original asphalt cement and of the bitumen recovered by the Abson method. It is pointed out that asphalt cements are believed to continue to harden during the life of a pavement, and that pavements which are satisfactory when laid may change to the cracking type as a result of hardening. The data indicate that type " *b* " Trinidad pavements are about three times the age of petroleum bitumen type " *b* " pavements, and that transition to the cracking type has taken twice as long in the case of Trinidad mixtures. Petroleum bitumen pavements which shoved but had not required replacement served longer than the " *a* " and " *b* " types. No definite trend in aggregate grading was found to account for behaviour of the various types. In the petroleum bitumen pavements the average filler content increased from types " *a* " to " *c*," while the average bitumen content was similar for " *a* " and " *b*," but was 1% higher for " *c*," and it is concluded that cracking could only have been due to hardness of the petroleum bitumen. The average filler content of the Trinidad pavements was substantially the same, whilst bitumen content increased from " *a* " to " *c*," and cracking is attributed largely to deficiency of bitumen. Density and voids were determined both on the original pavement and on a sample of the mixture compressed at 325° F. with a load of 5000 lb./sq. in. The Trinidad " *a* " mixtures contained about 1·2% more filler and 0·7% less bitumen than the petroleum bitumen mixtures, but the voids were only 3·1% for Trinidad, as compared with 7·1%. Voids in the original pavement and in the recompressed mixture were similar for Trinidad mixures, whereas the petroleum bitumen mixtures were reduced from 7·1% to 4·3% on re-compression, showing that Trinidad mixtures were more readily compressed on the street. In the " *b* " pavements the voids in the Trinidad mixtures were not altered, and were only slightly reduced on re-compression in the petroleum bitumen mixtures. In the " *c* " type the original condition is disturbed by shoving and a decrease in voids occurs on re-compression. The average ductility of bitumen recovered from " *b* " type pavements was 40 cm. in the case of petroleum bitumen mixtures, as compared with 139 cm. for Trinidad. The consistency of the asphalt cement and of the recovered bitumen becomes harder with the change from the " *c* " to the " *a* " type, and other properties such as penetration and specific gravity change accordingly. Decrease in penetration of the bitumen recovered from " *a* " type Trinidad pavements is believed to be due to overheating in the mixer.

The average penetration of the bitumen from the " *b* " Trinidad mixtures was only 7 points below the original, and since the average age was 28 years, it is thought that the bitumen would have complied with most stringent specifications in its early life. The " *b* " petroleum bitumen mixtures show an average decrease in penetration of 22 points, and it is thought that these pavements, of which the average life is 9 years, will develop cracking within a few years. The average penetration of the bitumen recovered from " *c* " type Trinidad pavements was only 2 points below the original, whereas the petroleum bitumen pavements showed an average decrease of 16 points.

Although the penetration of the bitumen of Trinidad asphalt cement was about 20 points softer and average age of the pavements much greater, the percentage decreases in penetration was slightly lower for Trinidad than for petroleum bitumen pavements. In both cases the penetration range in the three types showed little overlap. The low limit for consistency of petroleum bitumen in type " *b* " pavements was about 24 penetration, which agrees with the mean of Hubbard's range for unsatisfactory performance, the questionable range for Trinidad is thought to be 30/40 penetration. The data are said to indicate that Trinidad bitumen will serve satisfactorily at softer consistencies than petroleum bitumen, and this is attributed to the stabilizing action of the natural filler. A. O.

191. Bituminous Road Materials. G. W. Eckert. *Proc. Assoc. Asph. Paving Techn.*, 1939, 327–386. This paper is a review of patent and periodical literature published in 1938. The patent literature covers preparation of asphaltic bitumen, use of solvents addition agents, emulsions, and bitumen-aggregate systems, whilst the subjects considered in the periodical literature include chemistry, physical properties, cut-backs, emulsions, tars, weathering, adhesion, admixtures, testing of bitumen-aggregate mixtures, surfacing, recovery of bitumen, and soil stabilization. A. O.

See also Abstract No. 169.

Special Products.

192. Coal and Lignite as Basis for Home Production of Solvents and Softeners. O. Horn. *Brennstofftechnik*, 1939, 20, 349–352.—A detailed summary is given of all solvents, including synthetic petrols, spirits, and softeners, as well as synthetic fatty acids, produced in Germany from coal and lignites. The article deals with the production of these materials from coal *via* tar and benzol or phenol, from coal *via* calcium carbide and acetylene, and with hydrogenation of coals and lignites. E. W. S.

Detonation and Engines.

193.* Development of Anti-knock Motor Fuel. A. W. Trusty. *Petr. Engr*, Sept. 1939, **10** (13), 106.—The history of the development of the present-day methods of knock-testing are outlined. Investigation of knock-testing arose from the fact that the "knock" or detonation proved to be the most important factor limiting engine efficiency. Earlier tests were often contradictory, owing to the different conditions and standards used by various workers. The adoption of standard test equipment and precisely defined control has by to-day resulted in the evolution of reproducible methods. Nevertheless comprehensive tests to correlate road performance with laboratory ratings have shown that wide divergences are experienced with different cars, so that it is doubtful whether strict correlation with road performance in a laboratory test can be achieved. The adoption of *n*-heptane and *iso*-octane as primary standards has removed the confusion arising from the use of different standards. The high cost of these primary standards has, however, resulted in the adoption of carefully calibrated secondary reference fuels.

Recent changes in engine design show a considerable increase in efficiency. This was only made possible by a corresponding increase in the anti-knock quality of fuels. The factors affecting detonation are outlined, and the importance of the major ones, such as spark-timing, engine speed, and mixture strength, is discussed. R. J. E.

194. Knocking in the Otto Engine. H. Weinhart. *Luftfahrtforsch.*, 1939 (16), 74–78.—By comparing some observations in a comparatively long bomb in which an actual detonation is induced, with that in a single cylinder, it is possible to show that even with heaviest knocking in the Otto engine no detonation proper is taking place, but a very quick combustion. The ionization method is used for rating the combustion speed. E. W. S.

195.* Engine Flame Researches. T. A. Boyd. *J. Soc. Aut. Engrs*, 1939, **45** (4), 421–432.—This paper is a review of research on engine combustion pursued by General Motors Research Laboratories over many years. Single-cylinder studies were commenced with the Midgley optical indicator, which threw some light on the nature of knock. For the quantitative indication of knock the bouncing-pin was developed. Next, the progress of the combustion reaction was traced by means of a gas-sampling valve; it was shown that the progress of the reaction across the combustion space was continuous and the reaction rate accelerated as engine speed increased. During knocking combustion the gas farthest removed from the plug contained aldehydes, chiefly formaldehyde.

To obtain further information on the nature of detonation, photographs of the flame-front were taken through a quartz slit running the length of the chamber. Under non-detonating conditions the flame advanced at a fairly uniform rate; with the onset of knocking the last part of the charge appeared to burn instantaneously, coinciding with a steep rise in the pressure diagram. During knocking combustion surges or pressure waves are apparent both in flame photographs and indicator diagrams. It has been shown that there is a one-to-one ratio between the frequency of these waves and that of the audible sound of knock. Measurement of the energy radiated during combustion has shown that it is a maximum at the mixture ratio corresponding to maximum power; it is increased when detonation occurs.

The next development was the spectroscopic study of the light passing through the window during combustion. The flame proved to be similar in composition to the inner cone of a gasoline torch, both showing the characteristic bands of CH and C_2. However, these bands were absent from the region *behind* the flame, called the after-glow, indicating that combustion was completed within the flame-front. Ultra-violet spectra revealed the presence of OH radicals both in the flame and the after-glow; bands corresponding to the HCO combination were identified in the flame, but not in the afterglow. When knock was present the CH and C_2 bands in the flame-front were reduced in intensity, and formaldehyde was one of the oxidation products formed ahead of the flame.

Flame temperatures, measured by the sodium–line-reversal method, were between 3700° F. and 4200° F. (4550° F. when knock occurred).

To obtain more detailed information regarding the flame-front, the quartz slit was replaced by a thick plate of fused quartz covering the entire cylinder head, and a special camera enabled thirty consecutive pictures to be taken of one combustion. These clearly showed the uncontrolled nature of combustion in the detonating portion of the charge. Analysis of the flame-pictures in conjunction with accurate pressure diagrams yielded a definite relationship between fraction of the volume inflamed and mass of charge burned. The influence upon combustion rate of changes in ignition timing, air/fuel ratio and throttle opening is illustrated graphically. As a result of these researches it is now possible to calculate the volume of gas inflamed and mass burned at any instant, without the need for flame pictures, provided that accurate pressure cards are available and that allowance is made for piston motion.

K. T. A.

196. Alternative Fuel Engines. Anon. *Pwr. and Works Engr*, 1939, **34** (400), 413–414.—Unlike the gasoline/kerosine unit, the true alternative fuel engine should be able to use either of two fuels to equal advantage. British manufacturers have been developing engines which will run on town or producer gas as well as diesel oil; the change-over can be accomplished while the engine is running. When operating on gas, a small pilot charge of oil is still injected for ignition purposes, and the proportion of oil to gas (measured on a B.Th.U. basis) can be varied between, say, 4% and 100%. Two typical engines described and illustrated are the 130 B.h.p. Crossley and the National. Test results show that, on the basis of B.Th.U./B.h.p./hr., fuel consumption is approximately the same with liquid and gaseous fuel. K. T .A.

197.* Piston Ring Blow-by on High Speed Petrol Engines. C. G. Williams and H. A. Young. *J. Instn Aut. Engrs*, 1939, **7** (9), 30–65.—Three engines have been employed in the investigation of blow-by and several variables have been studied, particular attention being given to blow-by at high speeds. The engines used were :—

(1) An overhead valve single-cylinder water-cooled engine of 500-c.c. capacity, having a maximum speed of 4000 r.p.m.;

(2) A 500-c.c. air-cooled motor-cycle engine of racing type with a maximum speed of 2000 r.p.m.; and

(3) A four-cylinder engine of 1267-c.c. capacity operating up to 5500 r.p.m.

Special precautions were taken to seal the crank-cases from air leakage, the efficiency of the sealing arrangements being checked by noting the rate of pressure drop after the crank-case pressure had been increased to 10 in. of water. The crank-cases were connected to an expansion tank to provide adequate damping of fluctuating pressures, this tank being connected to a calibrated gasometer balanced so as to impose negligible back pressure. The mean radial pressure of piston rings used in the experiments was measured by the flexible band method, in which a band is wrapped round the ring and force applied until the gap is closed.

The variables studied included side clearance; radial pressure; cylinder bore distortion; rate of oilflow; piston-ring width, ring gap; clearance behind rings; B.M.E.P.; number of rings; oil viscosity; and spark advance, and, in addition, the effects of bevelled and wedge-shaped rings were investigated.

The authors' main conclusions show that beneficial results are obtained by increasing the piston-ring radial pressure or engine load, and by reducing ring-side clearance, ring width, or number of rings; and by retarding the spark. These remedies, however, necessitate some compromise. Blow-by was adversely affected by poor cylinder bore condition and insufficient running-in. Taper-turned rings gave high initial blow-by, but reached stability more quickly than plain rings. No effect was noted due to varying oil viscosity or quantity of oil supplied, and no beneficial effect was produced by the use of wedge-shaped rings.

A theory of ring flutter is submitted. It is suggested that at sufficiently high speeds the piston ring moves from the lower to the upper side of the ring groove just after top dead centre, because of frictional drag and inertia. This change in ring position releases pressure at the back of the ring, which is then suddenly subjected to gas pressure from the ring face, which may occur with sufficient violence to cause fracture.

C. H. S.

198.* Air and Air Filters for Diesel Engines. D. Adams. *Petr. Engr*, Sept. 1939, **10** (13), 47.—The general control of air and air filtration for diesel engines is outlined. Filters offered for this purpose are all based on the principle of providing an oil surface on which the air impinges so that dust particles are caught and held by the oil. Usually air-intake filters are placed outside the building, and the design and construction of the intake pipe, together with the provision of suitable housing, are discussed and illustrated. The quantitative air requirements of typical diesel engines are given and the attraction of supercharging exemplified. R. J. E.

199.* Bore Wear from the Viewpoint of Materials.—P. S. Lane. *J. Soc. Aut. Engrs.*, 1939, **45** (4), 413–420.—The nature of wear between various combinations of ring and bore materials has been studied by means of a brake-shoe type of machine, normally run dry. On a weight–loss basis piston-ring irons are not the " best wearing " irons but they have the desirable faculty of freedom from scuffing action. The ability to readily release wear products without surface mutilation is probably at least as important as low weight loss. Gray cast-iron structures which show low weight loss are subject to scuffing and often cause high wear of mating surfaces, even though the latter are much harder.

Variations in the structure and wear of automotive cylinder castings are illustrated, and the balancing of wear through hardness and structural relations is discussed. Relative wear values for various cylinder sleeve materials are presented.

K. T. A.

200. Mixture Strength and Volatility. L. A. Peletier. J. L. Tops, and W. J. Baron van Heeckeren. *Aircr. Engng*, Nov. 1939, XI (129), 407–410.—Tests were carried out on a modern 9-cylinder radial, air-cooled aero-engine supercharged by centrifugal blower to ascertain the effect of fuel volatility on the uniformity of mixture distribution. The tests were made at intake air temperatures of about 15° C. and 50° C. and at lean and rich mixture strengths with fuel–air ratios of approximately 0·073 and 0·096, respectively. The volatility of the seven fuels used as characterized by their 90% distillation points ranged from 101° to 185° C. Nine Cambridge mixture strength indicators were used for measuring the strength of the mixture fed to each individual cylinder.

Contrary to expectations, at low intake air temperature (about 15° C.) with both lean and rich mixtures distribution became more uniform with decreasing volatility. At the higher air intake temperature (about 55° C.) distribution became less uniform with decreasing volatility up to a 90% point of 152° C. The fuel having a 90% point of 185° C., however, then showed the most uniform distribution of the fuels tested. At the higher intake air temperature and at rich mixture distribution appeared to be practically independent of fuel volatility. No significant difference in the evenness of distribution was observed when certain of the tests were repeated with another make of carburettor.

Following up a tentative explanation for certain of their findings, the authors suggest that there would seem to be two conditions at which an ideal distribution could be obtained :—

(*a*) when complete immediate evaporation takes place in the carburettor, and the impeller is being fed with a homogeneous vapour–air mixture ;

(*b*) when an evaporation takes place between the carburettor and the impeller, the latter serving as distributing agent for the liquid.

The deflection of the mixture between carburettor and impeller is, in the authors opinion, the main cause of distribution irregularities when neither of the ideal cases obtains. E. F. C.

See also Abstracts Nos. 168, 183, and 184.

Coal and Shale.

201.* Colloidal Dispersion of Coal. J. M. Pertiewa. *IIme Congrès mond. Pétrole*, 1937, 2, 213–216.—The dispersion of coal in various liquids is studied by measuring the heat of wetting of pulverized coal before and after removal of adsorbed gases.

The important part played by adsorbed gas films is demonstrated, the gas-free coal being more readily and more completed wetted.

The quantity of hydrogen adsorbed by a coal at 100 atmos. pressure and at 16° C. and 100° C. is determined. Although when gas-free coal is placed in contact with liquids such as fuel oil, anthracene oil, molten paraffin wax, greater wetting and greater dispersions are achieved at atmospheric pressure, yet if such a system is hydrogenated at 200–225 atmospheres and 450° C., the amount of coal transformed into liquid and gaseous products diminishes and the rate of adsorption of hydrogen increases as compared with a similar system containing coal which has not been freed from adsorbed gases. W. P.

202.* **Methylation of Inferior Fuels to Produce Aromatics.** F. Michot-Dupont. *IIme Congrès mond. Pétrole*, 1937, 2, 197–212.—A process is described whereby materials such as lignite, peat, schist, cannel-coal, etc., are distilled at low temperatures in the presence of alkali or alkaline-earth salts of fatty acids (calcium acetate), the system being made alkaline by sodium carbonate and activated by iron or iron oxide.

The constitution of the products is shown and the mechanism of the reactions discussed. Commercial production and utilization of the products are described.

It is claimed that the process gives a high yield of primary tars; eliminates phenols with the production of substituted aromatic hydrocarbons (especially toleune and xylenes); reduces the sulphur content of the distillates (the sulphur being recovered from the gases); yields heavy oils which can be readily cracked or hydrogenated, and gives a residual coke of good quality. W. P.

203.* **Fushan Shale Oil.** K. Ishibashi. *IIme Congrès mond. Pétrole*, 1937, 2, 183–196.—A comprehensive account of the refining of Fushan shale oil and of the properties of the crude oil and the various fractions derived from it. W. P.

Economics and Statistics.

204.* **Declaration of Neutrality of the Argentine Republic—Decree.** Anon. *Bol. Inform. Petroleras*, Sept. 1939, XVI (181), 123–127.—Declaration of Neutrality of the Argentine Republic in respect to the state of war existing between France, Great Britain, Poland, and Germany. This is followed by the text of a new law No. 12,591, which is to be promulgated without delay in order to make effective control of prices, etc., in view of the existing emergency. H. I. L.

205.* **Report and Balance Sheet of the Y.P.F. for 1938.** Anon. *Bol. Inform. Petroleras*, Sept. 1939, XVI (181), 1–110.—The report is fully detailed and contains much matter of interest. There are numerous graphs, especially those showing production, which repay examination. Attention is directed to the diagram on page 110 showing the rapid development in Mendoza during the period 1938–39. H. I. L.

206.* **Uruguay—Tax on Refined Fuel Oils.—Decree.** Anon. *Bol. Inform. Petroleras*, Aug. 1939, XVI (180), 59.—This decree regulates the quantities of fuel which may be imported free and those subject to taxation. The figures for the different quotas will be submitted to the Executive in the first fortnight of June and December. The Decree appears to be dated at Montevideo, 18th August, 1939. H. I. L.

207.* **World Legislation affecting Petroleum.** Anon. *Bol. Inform. Petroleras*, Aug. 1939, XVI (180), 53–55.—This is a continuation of a reference index to various laws affecting the petroleum industry, in all countries, contained in No. 174 and subsequent numbers. The present index covers Irak, Italy, Japan, and Liberia. H. I. L.

BOOK REVIEW

Uses and Applications of Chemicals and Related Materials. Compiled and Edited by Thomas C. Gregory. 8vo. Pp. vi + 665. Reinhold Publishing Corporation, New York, 1939. Price 60*s*.

A series of surveys under the title "Where You Can Sell," subsequently changed to "Industrial Uses of Chemicals and Related Materials," has been appearing in the *Oil, Paint and Drug Reporter* since 1922. These surveys were conducted by Ismar Ginsburg until his death in 1933, when they were continued by Thomas C. Gregory. Under the editorship of Mr. Gregory, the material collected in these surveys has been incorporated in book form.

The book deals with the uses, potential applications and sales possibilities of 5167 substances, including petroleum products, greases, animal and vegetable oils, and waxes. The products are dealt with in strict alphabetical order under their common rather than chemical name, and hence the book will be useful to non-technical readers. The name of each item is given not only in all variants commonly encountered in English, but also in the more important foreign languages, while in connection with the uses of many of the substances listed patent references are given. An appendix of nine pages devoted to synonyms and cross-references is also included.

Very comprehensive lists on the uses of many petroleum products are given—for example, two pages are devoted to the use of paraffin wax in thirty-six main connections, including even such minor uses as paraffin wax bath medical treatments. The references to several petroleum products could, however, have been improved, *iso*-octane, for instance, being described as a "compounding agent for aviation gasoline."

The uses of a very large number and variety of substances valuable in petroleum technology have been adequately described in detail, with many patent references. The employment of acetyldiphenylamine as a coal carbonization spent stabilizer and the condensation of *cyclo*hexylphenyl ether with halogenated derivatives of aliphatic hydrocarbons to produce pour-point depressors are typical examples selected at random. The use of substances as catalysts in petroleum refining operations has not been overlooked, although the details pertaining to aluminium chloride in this connection might have been more comprehensive ; nevertheless the main uses have been well covered.

The work is undoubtedly a reference book of considerable value.

T. G. Hunter.

PUBLICATIONS RECEIVED

The Canadian Mineral Industry in 1938. Reviews by the Staff of the Bureau of Mines. Pp. iv + 102. Canada Department of Mines and Resources, Mines and Geology Branch. No. 804. Price 25 cents.

The report is divided into three sections : metals, industrial minerals and fuels, the latter containing an account of Canada's resources of coal, coke, natural gas, oil shale, peat and petroleum. Close to 97% of the total Canadian output of crude petroleum is now being obtained from the Turner Valley field in Alberta. The total production of petroleum in 1938 amounted to 6,956,229 brls. as compared with 2,943,750 brls. in 1937.

A Printing Method of Recording Road Surface Texture. By J. S. Wilson. Road Research Bulletin. No. 3. Pp. 6. Plates 11. H.M. Stationery Office. Price 9*d.*

This pamphlet describes a simple method which has been developed at the Road Research Laboratory, by means of which dangerous surfaces may be detected. A few square inches of the road to be examined are flicked with a cloth to remove dust and then carefully inked over either with an ordinary half-tone black printing ink diluted with paraffin or with a water letter-press ink. A clean rubber roller is run over the inked area and the impression on the roller transferred to a piece of paper. The stones depicted in the prints appear as if in relief, the shading of the ink giving a stereoscopic effect. The method lends itself to the study of the texture changes which a road carpet undergoes during its life, and the progress towards failure of the carpet by becoming slippery or by its disintegration is clearly shown.

Methods for the Detection of Toxic Gases in Industry. Carbon Disulphide Vapour. Department of Scientific and Industrial Research. Leaflet No. 6. Pp. 8. H.M. Stationery Office, 1939. Price 3*d.*

This pamphlet describes the properties, occurrence, poisonous effects and method of detection of carbon bisulphide vapour. The standard method adopted for the detection of low concentrations of the vapour in industry depends on its interaction with diethylamine and copper acetate, to produce a coloured compound, copper diethyldithiocarbamate.

INSTITUTE NOTES.

January 1940.

FORTHCOMING MEETINGS.

Thursday, 22nd February, 1940. At 5.30 p.m. at the Royal Society of Arts, John Adam Street, London, W.C.2. **"The Testing of Greases,"** by M. W. Webber. (Meeting of the Lubrication Group.)

April, 1940. **Annual General Meeting.**

Additional Meetings may be arranged during February and March.

ELECTION OF OFFICERS.

The Council has elected Professor A. W. Nash, M.Sc., M.I.Mech.E. to be President of the Institute for the Session 1940–1941.

The following have been elected Vice-Presidents of the Institute for the Session 1940–1941 :

Ashley Carter, A.M.I.Mech.E.
C. Dalley, M.I.E.E.
F. H. Garner, Ph.D., M.Sc., F.I.C.
J. McConnell Sanders, F.I.C.
F. B. Thole, D.Sc., F.I.C.

ELECTION FOR COUNCIL.

In accordance with the Articles of the Institute, the following members of Council retire at the next Annual General Meeting in April, but offer themselves for re-election : E. A. Evans, W. E. Gooday, C. A. P. Southwell, A. Beeby Thompson and C. W. Wood.

One new nomination has been received on behalf of J. A. Oriel, M.A. (Manager, Shell Refineries, Ltd.).

The Council has decided that, in view of present circumstances, a postal ballot will not be held, and the names of the above six candidates will be submitted to the Annual General Meeting of the Members to fill six vacancies on the Council.

NEW MEMBERS.

The following elections have been made by the Council in accordance with the By-Laws, Section IV, Para 7.

Elections are subject to confirmation in accordance with the By-laws, Section IV, Pars. 9 and 10.

Fellows.

Ivanovszky, Leo	London.
Lytle, John Ebert	New York.

Transfer to Fellow.

Stigand, I. A.	London.

Members.

Dunn, Roland	Belfast.
Dyson, Leonard Anderson Leighton	Belfast.
Farthing, Vernon Lambert	Liverpool.
Hancock, John	Ayrshire.
James, John Edmund	Essex.

Associate Members.

Idyll, Clifton Purvis	Trinidad.
Peacock, William George	Birmingham.

Pomeroy, Ralph Gaisford	Johannesburg.
Smith, C. Gordon	Liverpool.
Warbrook, Reginald Harold	Dublin.

Transfer to Associate Member.

Moore, Philip Harold	Surrey.
Nissan, Alfred Hesket	Birmingham.

Student.

Ijdens, Rente Albert	Delft.

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.

Evans, Frederick Neville Stuart, Divisional Superintendent, c/o Trinidad Leaseholds Ltd., Central Goods Yard, Reading, Berks. (*J. F. F. McQueen ; W. B. Heaton.*)

Holloway, Gilbert Lloyd, Geologist (Anglo-Iranian Oil Co., Ltd.), 22, Hawthorne Road, Birmingham, 30. (*A. W. Nash ; C. E. Wood.*)

Khalili, Jawad, Student, c/o Anglo-Iranian Oil Co., Ltd., P.O. Box 1, Chertsey Road, Sunbury-on-Thames, Middx. (*A. W. Nash ; C. E. Wood.*)

Marshall, John Macintosh, Director (*Valvoline Oil Co.*), 131, Banks Road, West Kirby, Cheshire. (*J. Smith ; N. W. Smith.*)

Park, James Harris, Engineer (*Serck Radiators Ltd.*), 118, Fabian Crescent, Shirley, Birmingham. (*F. Hepworth ; J. Gray.*)

Phipps, Leonard Frederick, Fire Brigade Officer, Central Fire Station, Singapore. (*L. H. Cooper ; A. J. Brown.*)

Roth, Francis, Engineer (*Harold Moore*), Nordstjernan Oljeraffinaderibygget, Nynashamn, Sweden. (*H. Moore ; E. Stokoe.*)

ARTHUR W. EASTLAKE,
Honorary Secretary.

DESPATCH OF JOURNALS.

Owing to the war and the requirements of Censorship examination, members, and particularly those living abroad, are advised that considerable delays may occur in the receipt of their monthly *Journal.*

Journals for members in the United Kingdom are posted about the last day of the month. *Journals* for members overseas may not leave England until two or three weeks later.

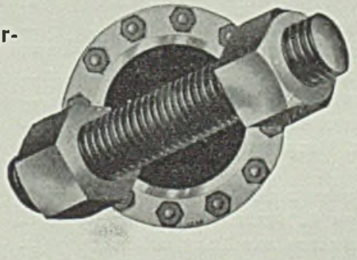
MEETING OF U.S.A. MEMBERS.

A very successful dinner-meeting of members of the Institute of Petroleum residing in the U.S.A. was held at the Stevens Hotel, Chicago, on Wednesday evening, November 15th. Dr. Gustav Egloff presided over an attendance of about 250 members and their guests. Guests of honour included T. A. Boyd, General Motors Research Corporation, E. W. Webb, president, and Thomas Midgley, vice-president of Ethyl Gasoline Corporation.

During the course of the evening, Dr. Graham Edgar, vice-president and director of research, Ethyl Gasoline Corporation, gave an address on "The Manufacture and Use of Tetra-Ethyl Lead." Dr. Edgar predicted spectacular advances in automotive power, foreshadowed by experiments already carried out to determine the possibilities of increasing compression ratio under conditions in which the anti-knock value of the fuel is no longer the limiting factor. Supercharging, generally applied so far only to aircraft, opened up another field of opportunity for utilization of fuels of high anti-knock value by the automobile engine. Tests with an 8-cylinder supercharged engine showed that it delivered a maximum horse-power nearly twice that of the un-supercharged engine. Thus, with 10 or 12 octane numbers improvement in fuel, it was possible almost to double the horse-power by supercharging. Dr. Edgar stated that about 75 per cent. of all motor fuel sold in U.S.A. contained tetra-ethyl lead, and in the aviation field almost all gasoline of 80 octane or over contained tetra-ethyl lead.

Amazing progress, said Dr. Edgar, had been made and was being made in the petroleum industry in modifying the structure of petroleum hydrocarbons to produce gasoline of high anti-knock value. Cracking and reforming, both thermal and catalytic, coupled with isomerization, alkylation, polymerization, aromatization, etc. were developing rapidly and were increasing both yields and quality of motor fuel.

The dinner-meeting was the fifth annual function of this character which the members of the Institute of Petroleum have arranged in U.S.A. The meetings are held during the week of the annual A.P.I. meetings.



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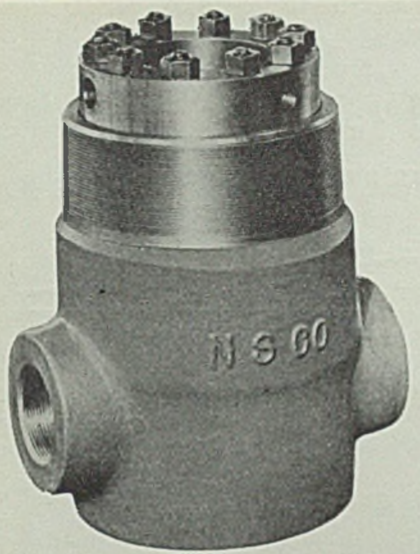
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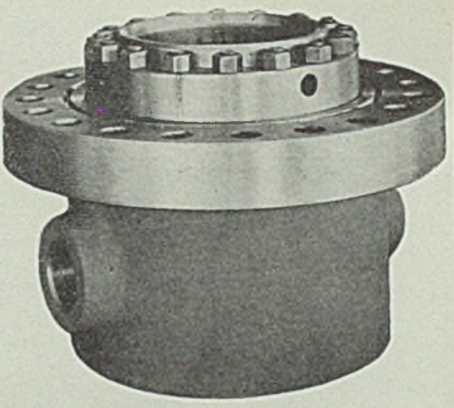

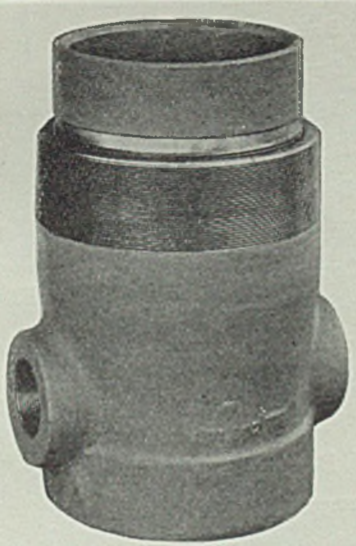

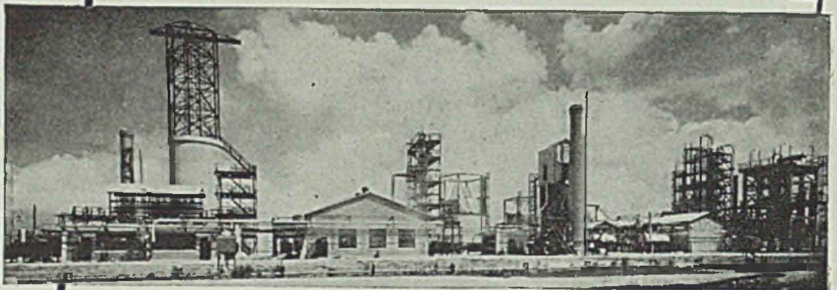

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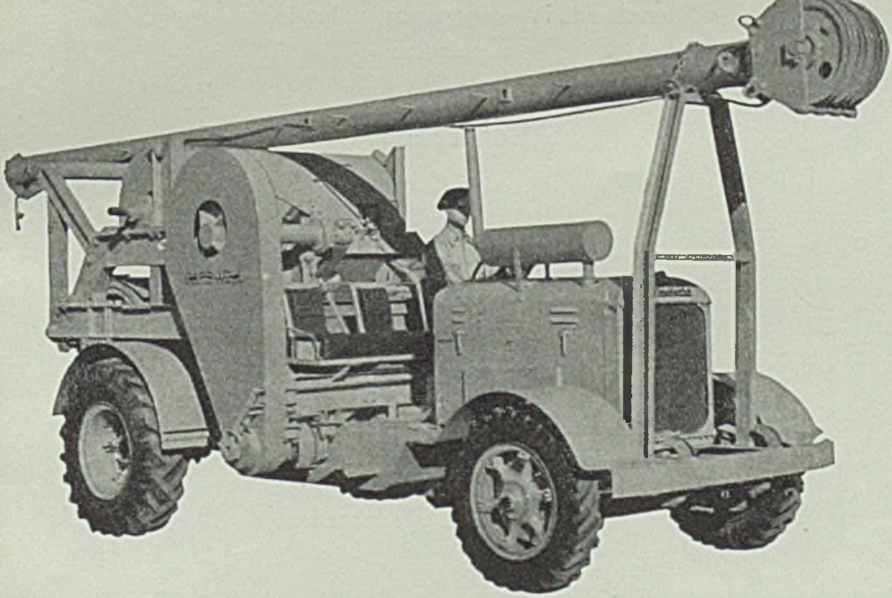

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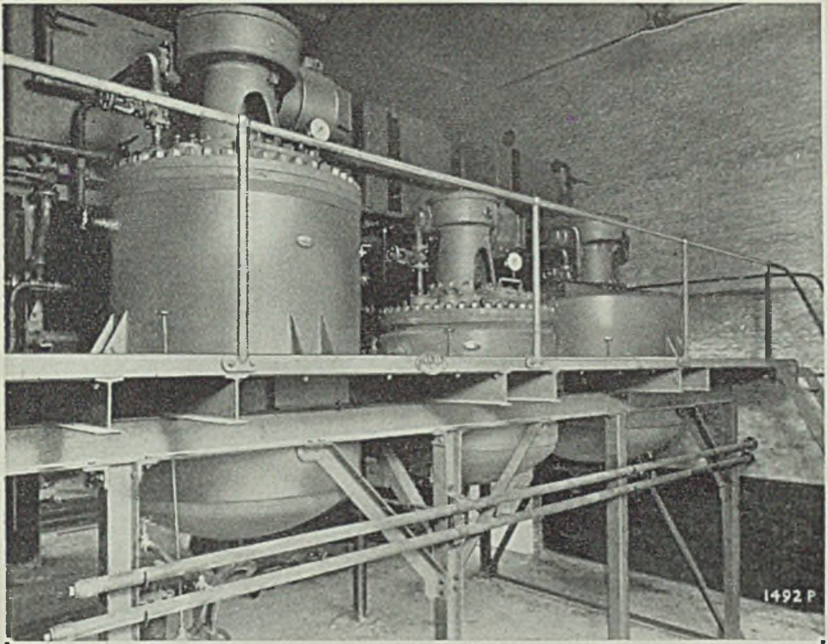

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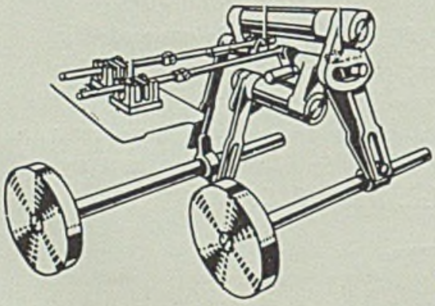

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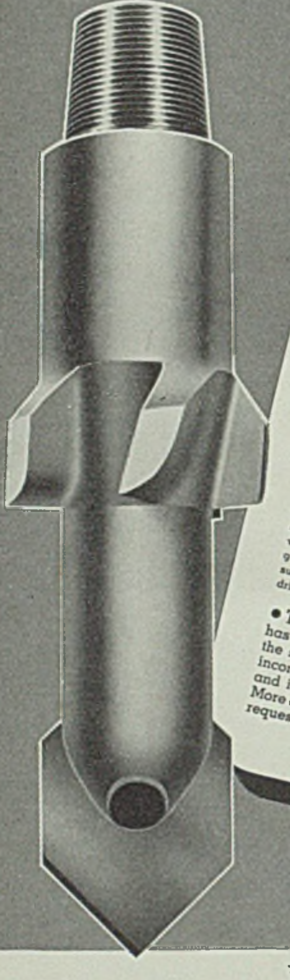

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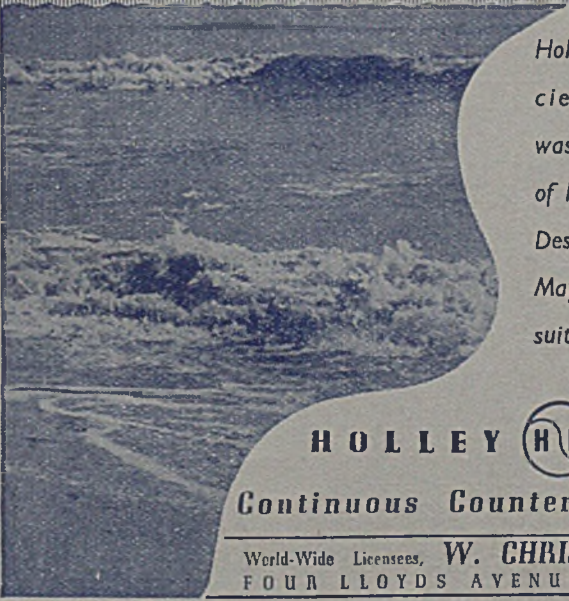

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