THE EFFECT OF CROOKED WELLS ON EXPLOITATION.*

By H. C. H. Thomas, M.A., A.R.S.M.

The purpose of these notes is to direct attention to the adverse effects of crooked or unintentionally deviated wells on the orderly exploitation of an oil-field.

It is not within the scope of the paper to inquire into methods developed to avoid the drilling of crooked hole. The mechanical disadvantages which may occur during the drilling or producing life of the well are only referred to in so far as they may affect the efficiency of exploitation.

I. Classification of Non-Vertical Wells.

Non-vertical wells can be classified in two main groups :

    A. Wells intentionally drilled with a deviation.
    B. Wells unintentionally drilled with a deviation.

Group A represents a special technique, which is not dealt with here. Group B can be subdivided as follows :

    1. Wells which are crooked, and penetrate the producing horizon in random positions.
    2. Wells which, although crooked, deviate in one direction, and consequently are straight in a plane at right angles to the direction of deviation.
    3. Wells which, although crooked, spiral so that they penetrate the producing horizon vertically below the surface location.
    4. Wells which are straight, although not vertical.

The very great majority of wells fall in groups B 1 and B 2. Broadly speaking, wells in group B 1 are the result of limitations of drilling methods, whilst those in group B 2 have additionally been affected by lithology and structure. Those in B 3 are probably rare, although there is frequently a *tendency* to spiral. Such spiralling tendency may be entirely the result of the rotation of the drill-pipe, and under different conditions seems to appear as a left-handed or right-handed spiral. It may, on the other hand, be an effect of dip, for if the well, owing to mechanical causes, starts to deviate in a direction contrary to that which the dip would impose on it, it may swing left- or right-handed into the imposed direction, rather than change the direction in the plane of the original deviation.

Wells in group B 4 represent a particular variation of those in group B 2, and are probably confined to shallow wells.

At this point it may be well to stress that, without directional surveys,

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it is usually impossible to decide in which sub-group any particular well falls.   The possible exception is where underground structure as derived from well depths is obviously at variance with surface geology.

II. Causes of Crooked Hole.

Nearly all the contributory causes to the drilling of crooked hole can be classified under two broad heads, Drilling and Formation.

Drilling.

It is only necessary to see the sag in a stand of drill-pipe standing in the derrick to realize that a string of drill-pipe is, in effect, a hollow flexible shaft which transmits the power from the rotary table to the bit.

In order to overcome the limitations imposed by the flexible nature of the drill-pipe, heavy and rigid drill-collars of large diameter are used on the bottom of the drilling string.

Two effects are looked for : first, that the concentrated weight of drill-collars at the bottom of the string will give a plumb-bob effect; second, that the rigidity and large diameter of the drill-collars will compel the bit to continue in the direction in which it has been started.

When drilling is in progress some or all of the weight of the drill-collars, and perhaps some of the drill-pipe as well, rests on the bottom of the hole.   This part of the drilling string is in compression, and will tend to bow, causing the bit to wander.   By using a small amount of weight on the bit, we endeavour to make use of the plumb-bob effect, and avoid the bowing of the drill-collar stand.

If a well is not vertical to start with, the plumb-bob effect, if any, should tend to pull it to the vertical, the rigidity and large diameter of the drill-collars would tend to maintain any deviation with which the well is started, and the bowing effect would be to make it deviate further.

Our experience shows that the last effect is the most pronounced.   In fact, the question of starting wells straight is of the utmost importance, more particularly if the maximum size of hole is to be drilled through the conductor.   If a large conductor is set in a crooked hole, and only small hole is to be drilled below it, then, as the bit reaches the bottom of the large hole after drilling out the shoe, some plumb-bob effect can be expected.

Formation.

It was mentioned above that the carrying of the weight of the lower part of the drilling string on the bottom of the hole, as occurs when drilling, will cause a tendency to bow, and crooked hole will result.   In a homogeneous formation the chances of the bit drifting in any direction are equal, subject to any cork-screwing tendency caused by the rotation of the drill-pipe, and it would seem that in any formation lying flat the same would apply.   Even a formation with a pronounced dip, if homogeneous, should theoretically not affect the course of the bit.   Such homogeneous formations are, however, not the rule, and the actual small changes in hardness or drillability, when they occur in a dipping formation, will certainly influence the path of the bit.   The question is, in what direction ?

First, it would seem that the bit will endeavour to orient itself either at right angles to the bedding planes or parallel to them. In other words, the wells in any given area would generally go either up-dip or down-dip, and eventually to an extent where the deviation of the hole from the vertical would be equal to the dip or to the complement of the dip.

Of the factors on which the course taken by the well would depend, two seem to be of primary importance :

> 1. Value of dip.
> 2. Relative hardness of succeeding layers of formation.

1. *Value of Dip.*

From survey results in some Trinidad fields, it appears that when the dip is less than 35°, wells tend to drift up-dip. At greater values of dip they tend to drift down-dip or along strike. On the other hand, we have an insufficient number of surveyed wells in the latter category to generalize with safety. Moreover, except in certain areas, it would not be safe to assume that because the dip is less than the 35° every well which deviates does so in an up-dip direction. I quote here from a paper entitled " Problem of Crooked Holes " by F. H. Lahee : " If the rotating bit, which has been drilling in a soft formation, encounters a hard resistant layer, and if the beds have a moderate dip, the up-dip edge of the bit is checked, while the down-dip edge is still in soft material. If there is any play between the drill stem and the hole, as there generally is, this resistance tends to cause the stem to bend under weight and to bow down-dip, so that the bit is cutting more nearly perpendicular to the bedding. The bigger the hole is in relation to the size of the drill stem, the more opportunity would there be for this effect. On the contrary, if the strata dip steeply, such a hard layer would function like a wedge, forcing the bit to slide down its face while continuing to cut in the soft rock."

2. *Relative Hardness of Succeeding Layers of Formation.*

This is really an effect of dip coupled with the degree of homogeneity of the formation. As stated above, if the formation is completely homogeneous, the effect of dip will be nil. If frequent changes of formation of widely differing hardness occur, any effect of dip will be pronounced. Moreover, it seems probable that the hardness of the formation may influence the critical angle of dip, at which a well drifts up-dip or down-dip.

III. Results of Crooked Hole.

Some of the principal results of crooked holes are listed below, and amplified in succeeding paragraphs.

> 1. Incorrect spacing at the production level or levels, resulting in inefficient drainage.
> 2. Incorrect interpretation of structure.
> 3. Errors in forecasting.
> 4. Failure to complete the well.
> 5. Failure to produce the completed well to exhaustion.

Incorrect Spacing.

It is obvious that crooked hole adversely effects any methodic well-spacing, since, clearly, it is the spacing of the wells on the producing horizon(s) which is of primary importance. The producing horizon must be penetrated at selected regular intervals if it is to yield its greatest ultimate production. It is the usual assumption that a vertical well will be drilled, and appreciable expenditure is therefore incurred in placing the top of the well vertically over the point at which it is intended to pierce the producing horizon. Quoting from Lahee : " In the light of what we now know about the deviation of boreholes, the care with which well locations are measured off and surveyed on the ground becomes almost a joke."

Reference to Table II will show how seriously minor deviations can affect spacing at comparatively shallow depths.

TABLE I.

Table showing Extreme Distances between Two Adjacent Wells.

Depth.	Tolerance.	Surface spacing.					
		300		400	460	800	
		Distance between two adjacent wells.					
1000	1°	Max. :	322	422	482	822	
		Min. :	278	378	438	778	
2000	2°	Max. :	379	479	539	879	
		Min. :	221	321	381	721	
3000	3°	Max. :	470	570	630	970	
		Min. :	130	230	290	630	
4000	4°	Max. :	597	697	757	1097	
		Min. :	3 *	103	163	503	
5000	5°	Max. :	759	859	919	1259	
		Min. :	−159 *	− 59 *	1 *	341	
6000	6°	Max. :	956	1056	1116	1456	
		Min. :	−356 *	−256 *	−196 *	144	

* Wells can meet or cross.

Table I assumes that deviation is consistently in one direction, and the figures given are for two wells which directly approach or directly depart from one another. This is treating the worst extremes, for it is obviously possible for all wells on a structure to drift in the same direction and to approximately the same extent. Further, it is possible that a crooked well may, by cork-screwing, penetrate the producing horizon vertically below its surface position.

Consider an ideal simple case of two wells, spaced on the surface, so that if straight hole is drilled and the wells are produced to exhaustion

the drainage areas will be circles the diameters of which are equal to the spacing between the wells—*e.g.*, 300 ft.

Then assume that while the one well is straight, the other well drifts

THEORETICAL OVERLAP OF ONE DRAINAGE CIRCLE ON ANOTHER EXPRESSED AS % AGE OF ONE DRAINAGE CIRCLE
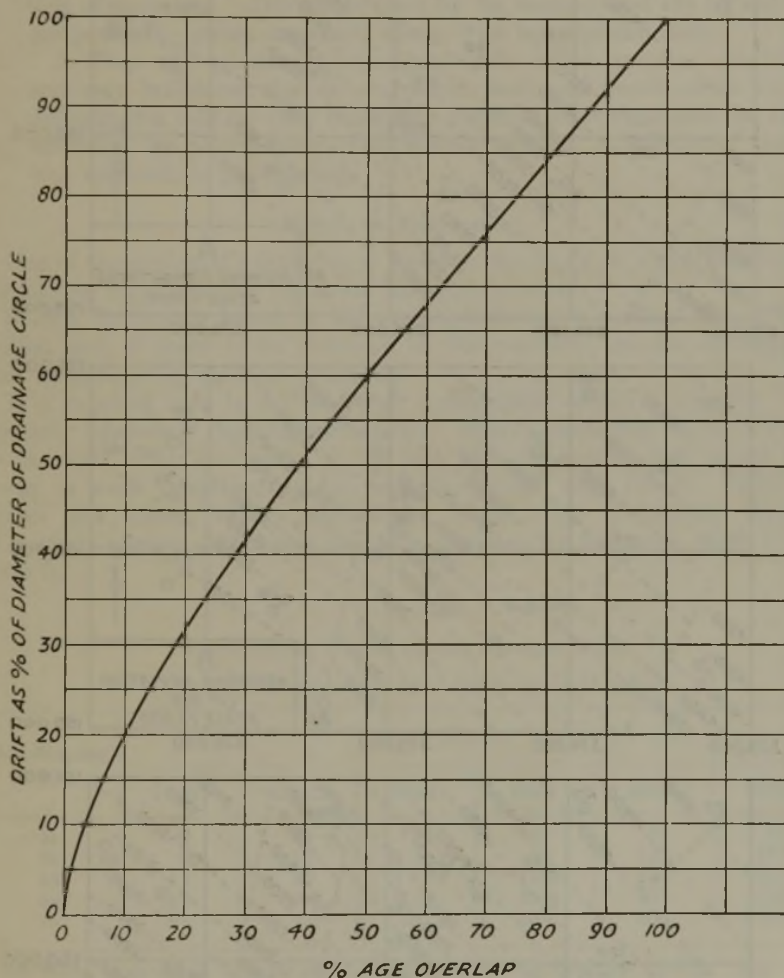

Fig. 1.

towards it. The chart (Fig. 1) shows the percentage overlap of the drainage areas, or the extra undrained area expressed as a percentage of the area theoretically drained by one well.

It is not proposed to enter here into the complex question of how such overlap will affect the ultimate extraction from the reservoir.

Incorrect Interpretation of Structure.

The effect of crooked hole on structural interpretation is illustrated by the three contour plans. It may be mentioned that these represent an actual case in a Trinidad field. Plan A (Fig. 2) is drawn on the assumption
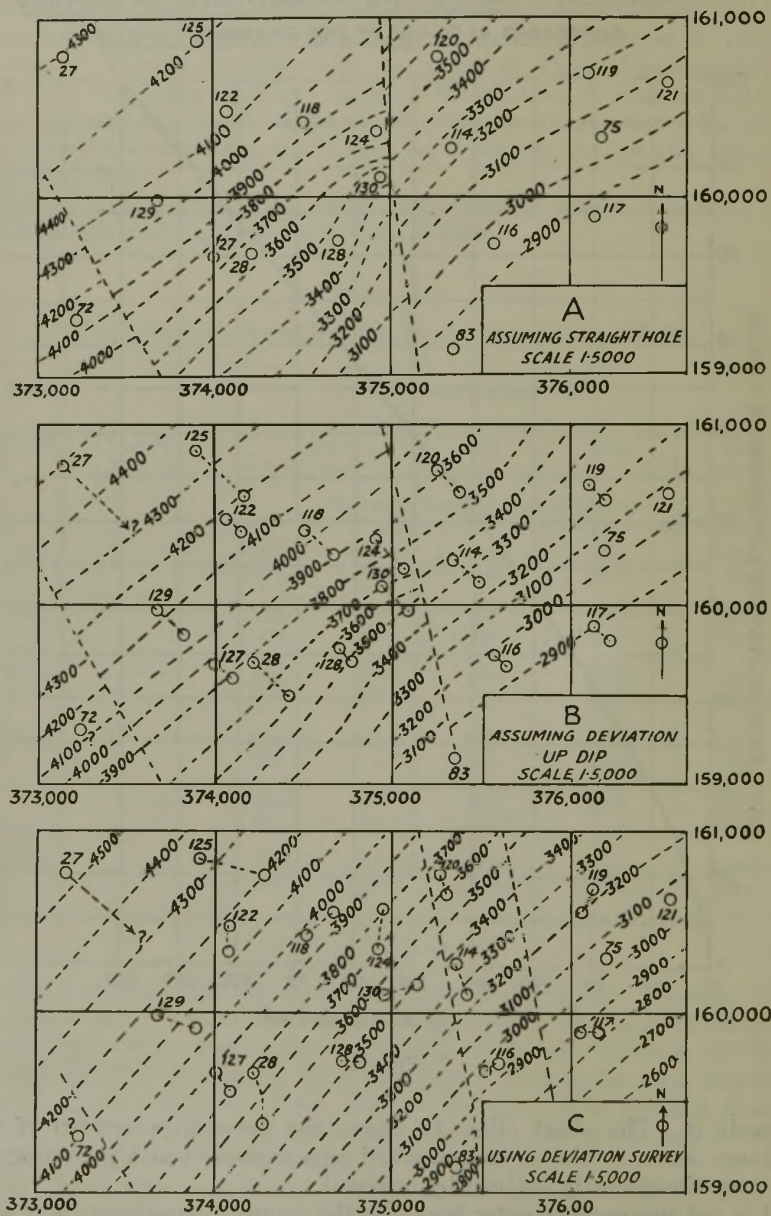
Fig. 2.

that the wells are straight.   Plan B is based on the results of non-directional surveys, and it has been assumed that wells deviate up-dip.   Plan C is based on directional surveys.   In some recent wells in this area it has even been possible to estimate the deviation of the well from the difference between the forecast and the logged depth of a marker.

Two points of interest may be noted :

1. That in this field there seems to be no rule governing the direction of deviation.   Dip varies from 35° to vertical, and the formations are generally partly cemented sands, with interbedded silts.

2. That the position of the oil–water or oil–gas line might be seriously misplaced due to a crooked well, and result either in the drilling of a well or wells below the water or above gas line, or, alternatively, the abandoning of a productive area, in the belief that it was watered, or gas-bearing.

Errors in Forecasting.

One of the geologist's duties is to forecast the depth at which formations containing high-pressure fluids are likely to be met.

Such a forecast is based on the assumption that a vertical hole will be drilled and, if there is no evidence to the contrary, on the assumption that neighbouring wells are vertical.

If a crooked hole is drilled, very considerable errors can occur, particularly in steeply dipping formations.   Heavy mud may be introduced to the well either too early or too late.   In the latter case, which will occur in wells deviating up-dip, serious trouble may result.   Table II shows the minus errors which can occur with formations dipping at various angles, and where the hole deviates by not more than 1° per 1000 ft.

TABLE II.

Minus Errors in Feet against Forecast Depth.

(Table showing possible error due to crooked hole.)

Bed dipping at	Depth.					
	1000.	2000.	3000.	4000.	5000.	6000.
15°	3	10	23	40	61	88
30°	6	22	49	85	132	189
45°	11	39	85	148	229	328
60°	19	68	147	256	387	568
75°	41	145	317	553	854	1225

(a) Note that these figures are for wells deviating directly up-dip.   For wells deviating down-dip errors are very considerably greater than those shown.

(b) Note that in a 4000-ft. well the deviation of which has increased steadily from 0° at surface to 4° at 4000 ft. a minus error of 85 ft. can occur in the forecast if the formation is dipping at 30°.

Failure to Complete the Well.

It is not intended to fully develop this aspect of crooked hole.   Failure may result from mechanical breakdown, or simply because the well drifts

from productive into unproductive territory and cannot be brought back.

High power consumption, twist-offs, and stuck drill-pipe or casing are some of the more usual results of excessively crooked hole, and may result in the loss of the well.

An interesting case was reported recently in which, due to crooked hole, a rig was unable to reach its objective. This objective, a fault, was forecast at 6100 ft. At 4000 ft. the well had deviated 7°, and assuming no further deviation, the objective was re-forecast at 6750 ft., and this was beyond the capacity of the rig. (Note the 650 ft. of unnecessary drilling required.)

Failure to Produce the Completed Well to Exhaustion.

This may be due to collapse of the casing at a dog leg, or the loss of production equipment in the well due to excessive wear. Even if mechanical failure of the well does not occur, lifting the production from a crooked well may prove uneconomical in the later stages.

Thus it is seen that crooked hole affects every stage of exploitation. It may be mechanically impossible to drill straight holes in every type of formation, or the cost of doing so may be prohibitive. Nevertheless it is always possible to start a well straight, and to make some endeavour to keep it straight. A directional survey of every well drilled is not only of considerable value to the exploitation geologist, it is the only way in which we can assess the progress which is being made towards the drilling of straighter holes.

EXTREME-PRESSURE ADDITION AGENTS.*

By E. A. Evans and J. S. Elliott.

Byers (*National Petroleum News*, December 16th, 1936) gave a comprehensive list of patents relating to extreme-pressure lubricants. Van Voorhis brought the list up to date in a paper published in the *National Petroleum News*, March 6th, 1940. Both these publications must have been of the utmost value to those who are interested in extreme-pressure addition agents. The reader of these two articles might very well feel perplexed at the variety of materials patented, and the thoughts which drifted the chemist to those particular things. A little more light is shed upon the list if it is segregated, even roughly, into groups. Apart from a few miscellaneous materials, the additives may be classed generally as sulphur, chlorine, phosphorus, and nitrogen compounds. The sulphur compounds may be sub-divided into derivatives of mineral oils, fatty oils, organic acids, esters, polymers, and a variety of specific aliphatic and aromatic compounds. This simple classification does not lend itself quite so simply to the chlorine and phosphorus compounds.

It may be that the use of sulphur dates back to the time when flowers of sulphur were used in cutting oils. No one knew how it functioned, but the results were there. Logically, the sulphur dispersion was increased by the use of colloidal sulphur, and finally by sulphur in solution. Abrams, in U.S.P. 1,913,300, used dispersed particles intermediate in size between flowers of sulphur and the colloidal variety. He suspended free sulphur particles in oil by means of a mass of freely mobile gel particles of soap. Churchill disclosed in U.S.P. 1,974,299 (assigned to the Tidewater Oil Company) lubricants containing sulphurized fatty and mineral oils, and thereby advanced development a stage farther. U.S.P. 2,142,916 (Standard Oil Company, Ind.) introduced a refinement, by disclosing solvent-treatment of the sulphurized oil, presumably to remove the undesirable sulphur constituents which might be present.

When it had once been established that fatty oils could be sulphurized there was apparently little incentive to seek patent protection for the use of individual oils and fats; in any event, there are very few patents in this category. Cotton-seed and sperm oils have, however, been singled out for attention. The Gulf Research and Development Company has given consideration to the blending of sulphurized sperm oil with esters in conjunction with tricresyl phosphate (U.S.P. 2,179,067).

Exactly what happens when sulphur is heated with fatty oils is difficult to forecast, but when the sulphurizing is done with sulphur chlorides it is almost a hopeless task to sort out the reactions. It was surprising, therefore, that so much time was allocated to sulphurizing oils and organic acids on a commercial scale. Doubtless flexible displacements have served a useful purpose, particularly when standardization was at a lower ebb than it is to-day. For the time being it may be that we can forget the

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* Paper presented to a Meeting of the Institute in London, 5th February, 1941.

undefined compounds obtained from sulphurizing complex mixtures, and turn our attention to sulphur compounds of more exactly defined constitution. Before going over completely it should be borne in mind that there is an intermediate phase manifested in the sulphurized synthetic ester group. This group includes sulphurized esters of mono- and dihydric alcohols of somewhat complex composition; it also embraces the simpler type, of which sulphurized ethyl oleate is an example.

Contemporaneously with the developments above referred to, some attention was being given to the sulphurization of complex polymers which are obtained from cracking petroleum.

An early disclosure of the use of a pure organic compound occurs in U.S.P. 2,147,578, which relates to a simple sulphurized naphthalene. A later patent described the use of a sulphur compound of a dihydronaphthalene dimer.

Prior to these two patent publications one of us had been working on pure organic compounds, and had published the results in the General Discussion on Lubrication, I.M.E., 1937. It would appear, therefore, that this was the first, or at least one of the very early publications on the use of pure compounds for extreme-pressure lubrication. In this paper the film-rupture strength of a number of organic compounds was given, and special reference was made to di(3-carbomethoxy-4-hydroxyphenyl) thio-ether (B.P. 455,235).

$$CH_3COO \underset{HO}{\diagup} \langle\ \rangle -S- \langle\ \rangle \underset{OH}{\diagdown} COOCH_3$$
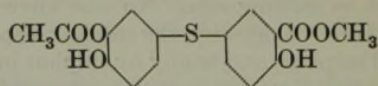
Shortly afterwards (in March 1938) U.S.P. 2,110,281 appeared, claiming the use of alkyl disulphides, aryl thiocyanates, and xanthic disulphides.

$$C_nH_{2n+1}S-S-C_nH_{2n+1}, \qquad R\cdot CNS$$

$$S=C \underset{S-S-C}{\overset{OC_2H_5}{\diagdown}} \underset{S}{\overset{OC_2H_5}{\diagdown}}$$
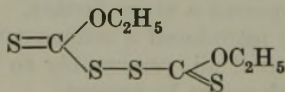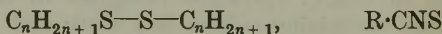
This patent, in the names of Adams and McNulty, was assigned to the Standard Oil Company, Ind.

Sulphonic acid derivatives have not been an area for adventurous exploitation.

Thiocarbonates and allied compounds have been a source of considerable activity. U.S.P. 2,020,021, issued to the Standard Oil Company, Calif., relates to the simple thiocarbonates

$$S=C \underset{S-R}{\overset{OC_2H_5}{\diagdown}}$$
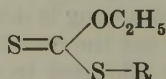
This thought has been extended to alkene trithiocarbonates (B.P. 488,483, N.V. de B.P.M.). Somewhat in the same family are the dialkyl xanthyl ethyl ethers (U.S.P. 2,161,584, Socony Vacuum). The use of xanthogen tetra-sulphides (B.P. 522,189) is of interest to us, and reference will be

made to this later in connection with our own researches on sulphur compounds.

$$R—O—\overset{\displaystyle S}{\underset{\displaystyle S}{\overset{\|}{\underset{\|}{C}}}—S—S—S—\overset{\displaystyle S}{\overset{\|}{C}}—O—R'$$
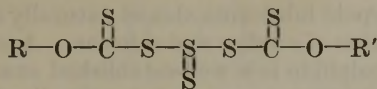
Among the few types of additives containing both sulphur and nitrogen must be mentioned the aromatic compounds comprising divalent sulphur and nitro-groups, also mixtures comprising a divalent sulphur-containing component and a nitro group-containing component (B.P. 455,305).   An example is a thioether containing two nitro groups :

NO₂ ... NO₂ ... —S—
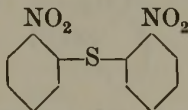
Aliphatic nitriles R·CN, and thioamides, R·CSNH$_2$, have been studied by Armour & Company.

The progress of the hypoid gear brought more and more into prominence mixtures of sulphurized oils and metal soaps.   The principal characteristic of this type of lubricant is that it shall contain " corrosive " or " active " sulphur.   Although several metal soaps have been suggested, a preference has always been exhibited for lead oleate or naphthenate.

CHLORINE.

It is frequently believed that the halogenated compounds cannot maintain as high a load as the sulphur compounds.   Whilst this belief is partly true, no such generalization is permissible.

Concerning the hydrocarbons, there is an array of published patents sufficient to cover almost every type.   B.P. 453,047 suggests that a minimum chlorine content of 55 per cent. is to be aimed at in all halogenated non-oxygenated organic compounds.   This is emphasized by the fact that it succeeds B.P. 452,914 for halogenated non-volatile petroleum products, such as paraffin wax.   This view, however, is not necessarily shared by other investigators, who have patented chlorinated diphenyl, aliphatic, and polyarylalkyl hydrocarbons.

Among oxygenated compounds, apart from sperm oil, carnauba wax, and other naturally occurring esters, interest has been confined to pure compounds.   The range is wide, and extends from alcohols, ketones, esters, ethers to phenols.   Specific application for use in diesel engines has been suggested for metallic salts of halogenated acids.

Halogenated condensation products may have been studied with internal-combustion engines in mind.   Whatever the guiding thought may have been, the goal has been to synthesize a large molecule to combine E.P. properties with oiliness.   Clearly, U.S.P. 1,939,995, which is concerned with the use of waxes condensed with halogenated fatty acids, discloses a step in this direction.

SULPHUR AND CHLORINE.

The call for mild hypoid lubricants almost naturally drifted ideas towards a mixture or combination of sulphur and chlorine. A mixture of chlorinated wax and dibenzyl disulphide is a well-established example (B.P. 454,552). Other patents relate to the presence of " active " sulphur. Perhaps the simplest sulphur-chlorine compound which can be used is perchloromethyl mercaptan, $CSCl_4$. Owing to its character it can be used only under cold conditions. To extend its application Socony-Vacuum (U.S.P. 2,197,781) proposed to react it with unsaturated compounds. Another simple compound suggested is o-toluene sulphochloride (B.P. 449,311).

$$CH_3$$
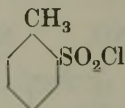
The thiocarbonates reappear in this category as chlorinated alkyl thiocarbonates (B.P. 519,288)
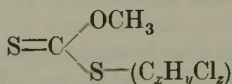
PHOSPHORUS.

The long-known tricresyl phosphate may be regarded as the prototype of the phosphorus group, and tritolyl phosphate as a normal associate (B.P. 446,567). An allied compound is tri-β-naphthyl phosphate
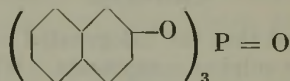
The phosphates and phosphites so far prepared have insufficient E.P. properties to be used in gear oils. They have, however, been tried in I.C. engine oils. In this capacity tributyl phosphite has found favour in prolonging the life of cadmium bearings. Even phosphines
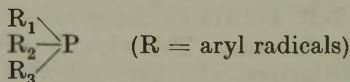
have been suggested (U.S.P. 2,149,271).

PHOSPHORUS WITH SULPHUR OR CHLORINE.

The simplest compounds in this group are the halogenated esters of phosphorus acids (B.P. 448,424). Alkylbenzene dichlorophosphines are also mentioned in U.S.P. 2,190,715.
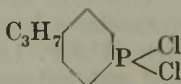

There are several patents for compounds containing both phosphorus

and sulphur, of which triaryltrithiophosphites (U.S.P. 2,188,943) are examples.
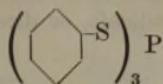
NITROGEN.

Whether nitrogen compounds have been put to practical use by themselves is unknown to us. That they might be useful is evidenced by patents granted to workers in different laboratories. Perhaps they have specific applications. Mention may be made of stearonitrile, $C_{17}H_{35}CN$ (U.S.P. 2,125,851), and alkyl phenyl oxy-ethers of 2 : 4-dinitrobenzene (U.S.P. 2,134,436).
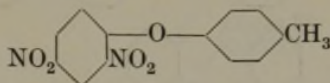

MISCELLANEOUS.

The list can be considerably extended by the inclusion of a variety of organic compounds. Experience may show that a number of them might be better classed as oiliness agents rather than E.P. agents. The division is often difficult, and the overlap extensive.

The compounds to which reference has been made have been selected as representatives in the classification. No marked thresholds divide the patent literature from our own line of attack. All that we claim in this paper is that we have endeavoured to classify other people's published work, and to augment the list of compounds from our own investigations.

EXPERIMENTAL.

As most of the hydrocarbons which might be used in any lubricant can be found within the range of mineral lubricating oils the film-rupture strengths of which lie between 3000 and 4000 lb. per sq. in., it is necessary to examine only a few. Since the Almen machine has been used for a number of years in our investigations on film strength, it is still used to obtain comparative data. Three representative hydrocarbons

Naphthalene   Diphenyl

Diphenylbenzene
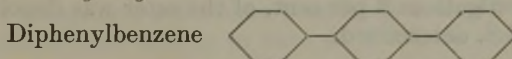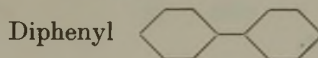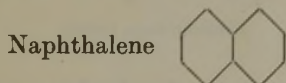
do not increase this strength, when dissolved in oil in concentrations of 1 per cent.

Bowden found that oleic acid reduced the coefficient of friction of mineral oils at low temperatures, but increased it at high temperatures. He found (B.P. 484,579) that a reduction of friction independent of temperature can be obtained by replacing the oleic acid with at least 1 per
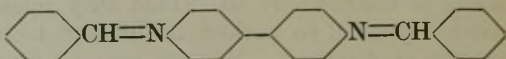
cent. of organic compounds, consisting of at least three substituted and non-substituted rings which are interconnected, either indirectly, preferably by means of aliphatic radicals, or directly.   Examples of such compounds are :—
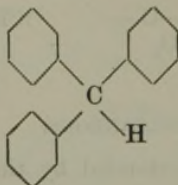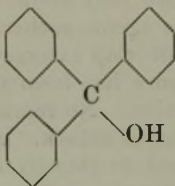

pp'-Dibenzyl diphenyl

Diphenyl benzidine
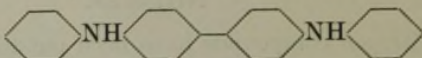
Dibenzylidene benzidine

Dibenzoyl benzidine

Triphenyl methane

Triphenyl carbinol

None of these affects the film-rupture strength (F.R.S.) when in 1 per cent. solution or suspension.   Triphenyl carbinol is not readily soluble in mineral oil, consequently Bowden effected solution by using the mutual solvent methyl*cyclo*hexanol oxalate.

	F.R.S.
1% Triphenyl carbinol 2% Methyl*cyclo*hexanol oxalate 97% Oil	4,000
2% Triphenyl carbinol 4% Methyl*cyclo*hexanol oxalate 94% Oil	15,000

Esters.

In these investigations 3 per cent. of the ester was dissolved in mineral oil and the F.R.S. determined.

		F.R.S.
Amyl acetate	$CH_3 \cdot COOC_5H_{11}$	7,000
Butylene glycol diacetate	$CH_3 \cdot CH \cdot COOCH_3$	6,000
	$CH_2 \cdot CH_2 \cdot COOCH_3$	
Amyl oxalate	$COOC_5H_{11}$	5,000
	$COOC_5H_{11}$	

		F.R.S.
Glyceryl oleate	$CH_2 \cdot COOC_{17}H_{33}$	4,000
	$CHOH$	
	CH_2OH	
Benzyl oleate	$C_{17}H_{33} \cdot COOCH_2 \cdot C_6H_5$	3,000
Ethyl benzoate	$C_6H_5 \cdot COOC_2H_5$	8,000
Amyl benzoate	$C_6H_5 \cdot COOC_5H_{11}$	8,000
Methyl salicylate	$COOCH_3$ OH	11,000
Diethyl phthalate	$COOC_2H_5$ $COOC_2H_5$	10,000
Butyl phthalate	$COOC_4H_9$ $COOH$	5,000
Dibutyl phthalate	$COOC_4H_9$ $COOC_4H_9$	8,000

The wholly aliphatic esters gave low results. Similarly aliphatic acids when esterified with an aromatic alcohol gave low values. Aromatic acids, when linked with either low- or moderately high-molecular-weight aliphatic alcohols, gave somewhat higher results. The effect of very complex esters has not been studied from the point of view of film-rupture strength because of the difficulty in their preparation, and for the reason that they will probably be more useful as oiliness addition agents.

When the molecular weight of the alcoholic part in the molecule greatly exceeds that of the acidic part, or vice versa, the F.R.S. usually tends to be high, whereas a low F.R.S. is obtained when the molecular weights of the two parts of the molecule are of the same order.

The introduction of a nitro- or amino-group into an ester produces little effect, as illustrated by
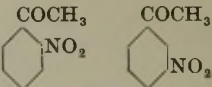
			F.R.S.
	$COOC_2H_5$		
m-Nitroethyl benzoate	NO_2	3%	8000
	$COOC_2H_5$		
Ethyl anthranilate	NH_2	1%	8000

The esters of phosphorus acids have been freely referred to in the patent literature. Most of them appear to have an F.R.S. in the range of 7000–10,000 when used in economic quantities.

Ketones.
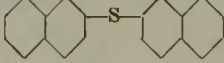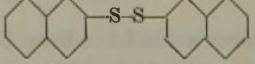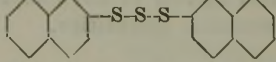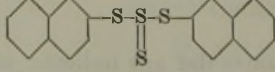
Simple aromatic ketones did not indicate sufficient promise to warrant extensive investigation.

A 1 per cent. solution in mineral oil of each ketone was used.

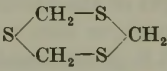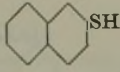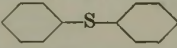|		F.R.S.
Acetophenone	COCH$_3$ (on benzene ring)	4000
o- and m-Nitroacetophenone	COCH$_3$/NO$_2$; COCH$_3$/NO$_2$	7000
o-Aminoacetophenone	COCH$_3$/NH$_2$	4000
m-Aminoacetophenone	COCH$_3$/NH$_2$	4000

Sulphur.

Sulphur compounds offer an enormous and difficult field to survey. Whilst a preliminary search indicated promising avenues of approach, the considerable number of patented sulphur compounds clearly shows the need for a careful sifting of the groupings which build up the F.R.S. Even though thionyl chloride, $SOCl_2$, in as low a concentration as 0·1 per cent. in mineral oil gives a high F.R.S. it is unsuitable, because it is too volatile, and is very easily hydrolysed. It would seem from the following results that when sulphur is firmly held in a molecule, uninteresting results may be anticipated.

			F.R.S.
Carbon disulphide	CS_2	1%	2,000
Sulpho-ricinic acid	(from castor oil)	1%	5,000
Trithioformaldehyde	$S\langle\,^{CH_2-S}_{CH_2-S}\,\rangle CH_2$	1%	4,000
a-Naphthyl mercaptan	SH	1%	3,000
β-Naphthyl mercaptan	SH	1%	4,000
Diphenyl sulphide	—S—	1%	6,000
β-Naphthyl sulphide	—S—	1%	4,000
β-Naphthyl disulphide	—S–S—	1%	5,000
β-Naphthyl trisulphide	—S–S–S—	1%	5,000
β-Naphthyl tetrasulphide	—S–S–S— (with S below)	1%	10,000

No doubt β-naphthyl tetrasulphide owes its increased activity to the sulphur in the iso-position. A similar arrangement of four sulphur atoms

is found in the xanthogen tetrasulphides referred to earlier. The intro-
duction of aliphatic carbon appears to render the sulphur more active.

			F.R.S.
Dibenzyl disulphide	CH_2–S–S–CH_2	1%	8,000
,, ,,		2·5%	15,000
Dibenzoyl disulphide	CO–S–S–CO	1%	9,000

Of the thioethers the examination of which has proved to be an inter-
esting study, diphenyl sulphide is a simple example. Although of no
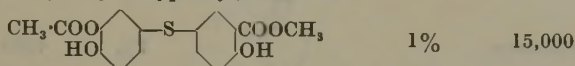value itself, it is the foundation of a valuable E.P. addition agent. Di-
(3-carbomethoxy-4-hydroxyphenyl) thioether

F.R.S.

Di-(3-carbomethoxy-4-hydroxyphenyl) thioether

$CH_3 \cdot COO$ — S — $COOCH_3$ 1%   15,000
  HO   OH

illustrates how substituent groups can materially change the reactivity
of a compound. Hydroxyl and carboxyl groups are of major importance
in lubrication, yet it has still to be established whether they function
independently of, or in conjunction with, the sulphur in this thioether.
  Sulphur in a thiocarbimide might be expected to possess some activity,
but such is not the case. It was not anticipated that the inclusion of one
atom of chlorine would measurably increase the F.R.S. When the chlorine
is placed in the *p*-position, however, a surprising result is attained.

		F.R.S.
p-Tolylthiocarbimide (CH₃ ... N=C=S)	5%	7,000
o-Chlorphenylthiocarbimide (Cl ... N=C=S)	5%	9,000
p-Chlorphenylthiocarbimide (Cl ... N=C=S)	5%	15,000
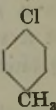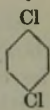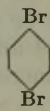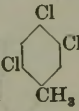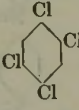
As mercaptobenzothiazole in very small concentrations has considerable
utility in inhibiting corrosion, it is disappointing that it has no influence
on film strength.

Mercaptobenzothiazole	S ... C–SH ... N	1%	5000
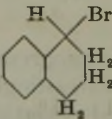
Chlorine.
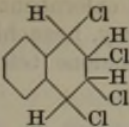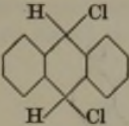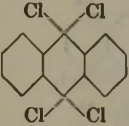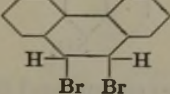
Whilst these investigations were in progress the maintenance of supplies
of Almen pins and bushes became exceedingly difficult ; therefore it was
imperative that an alternative method of test should be found. Brownsdon
(I.M.E. General Discussion on Lubrication, 1937) advocated wear im-

N

pressions as useful criteria in lubricant appraisals. He made no claim that wear impressions could be correlated with film strength, but in many instances the two take a parallel course. It was decided, therefore, that in the exceptional circumstances the Brownsdon machine could be used at least as a guide.

			F.R.S.	Wear.
Oil used			4000	0·415
Chlorbenzene		1%	—	0·430
p-Chlortoluene		2%	—	0·335
o-Dichlorbenzene		1%	4000	0·350
p-Dichlorbenzene		2%	4000	0·410
p-Dibromobenzene		1%	4000	—
2 : 4 : 5-Trichlortoluene		1%	9000	0·215
1 : 2 : 4 : 5-Tetrachlorbenzene		1%	6000	0·280
a-Bromonaphthalene		1%	4000	—
a-Chlornaphthalene		2%	4000	0·425

Less than three chlorine atoms in the benzene and the naphthalene nuclei do not improve the F.R.S. or materially affect the wear. Attention should be directed to the effect of the methyl group.

		F.R.S.	Wear.
5-Bromotetralin	1%	4,000	—
Tetrachlortetrahydro-naphthalene (mixture)	0·5%	8,000	0·305
	1%	8,000	0·300
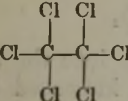
			F.R.S.	Wear.
Naphthalene tetrachloride		0.5%	11,000	0.230
		1%	Over 15,000	0.230
Anthracene dichloride		0.5%	—	0.285
		2%		0.150
		(suspension)		
Anthracene tetrachloride		1%	—	0.220
Phenanthrene dibromide		1%	—	0.350
		2%	—	0.250
Dichlorphenanthrene tetra-chloride	Formula uncertain	2%	—	0.420

It is of interest to note that, as in the case of other substituents conferring E.P. properties, both the position of the halogen atoms in the nucleus and the manner in which they are present affect the improvement obtained.

In the foregoing group of compounds, the halogen is additively combined, except in the case of the chlorinated tetralin, and it is evident that such compounds merit special attention as addition agents. Thus, for example, naphthalene tetrachloride, which is the best of the compounds cited from a commercial viewpoint, is more beneficial than the mixture of isomers obtained by chlorinating " tetralin," although such a mixture may itself contain a minor amount of naphthalene tetrachloride.
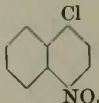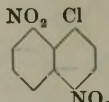
Dichlorphenanthrene tetrachloride presents a curious phenomenon. Although containing four added and two substituted chlorine atoms in the molecule, this substance does not reduce the wear. As it is scarcely likely that it will have a commercial value, it was not given specialized study.

As the aliphatic carbon is important in some sulphur compounds, it was considered advisable to test its influence on chlorine.
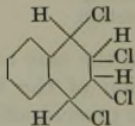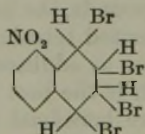
			F.R.S.	Wear.
Benzyl chloride		1%	7,000	0.265
Benzal chloride		1%	14,000	0.215
Hexachlorethane		1%	6,000	0.365

Benzyl chloride is thus superior to chlorobenzene, and benzal chloride to the dichlorbenzene. On the contrary, hexachlorethane does not compare favourably with 1 : 4-dichlornaphthalene tetrachloride, which also contains six chlorine atoms.
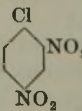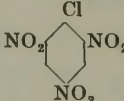
Nitro-chlor compounds.

			F.R.S.	Wear.
1-Chlor naphthalene		2%	—	0·425
1-Chlor-4-nitronaphthalene		2%	—	0·365
4 : 8-Dinitro-1-chlornaphthalene		2%	—	0·320

One nitro-group shows an improvement, and two augment it.

Naphthalene tetrachloride		1%	Over 15,000	0·230
α-Nitronaphthalene tetrabromide		1%	7,000	0·370

The tetrabromide was used because the nitro-tetrachloride is not known.
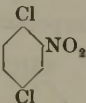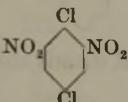
Chlorobenzene		1%	—	0·430
o-Nitro-chlorbenzene		1%	6,000	0·210
2 : 4-Dinitrochlorbenzene		1%	7,000	0·210
Picryl chloride		1%	—	0·330

The introduction of one nitro-group into the benzene nucleus produces an improvement which is somewhat increased by the introduction of a
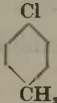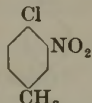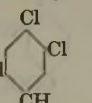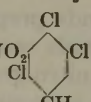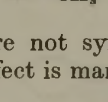
second; a third, however, results in a surprising loss of activity, a feature common to other compounds in which two nitro-groups are in the o-position to the same chlorine atom.

It should be noted that 2 : 4-dinitrochlorbenzene and certain other compounds containing two or more nitro-groups in conjunction with chlorine are powerful irritants, and unpleasant to handle.
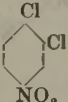
A similar extreme pressure effect is observed with p-dichlorbenzene.
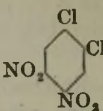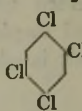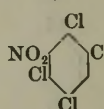
			F.R.S.	Wear
p-Dichlorbenzene	Cl / Cl	2%	4000	0·410
Nitro-p-dichlorbenzene	Cl / NO₂ / Cl	1%	7000	0·210
1 : 4-Dichlor-2 : 6-dinitrobenzene	Cl / NO₂ NO₂ / Cl	1%	—	0·325

The introduction of an alkyl substituent has not a great effect.

p-Chlorotoluene	Cl / CH₃	2%	—	0·335
3-Nitro-4-chlortoluene	Cl / NO₂ / CH₃	1% / 2%	7000 / —	0·230 / 0·210
2 : 4 : 5-Trichlortoluene	Cl / Cl Cl / CH₃	1%	9000	0·215
2 : 4 : 5-Trichlor-3-nitrotoluene	Cl / NO₂ Cl Cl / CH₃	1%	9000	0·160

When the two nitro-groups are not symmetrically disposed about the chlorine then the cumulative effect is manifest.
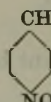
o-Dichlorbenzene	Cl Cl	1%	4000	0·350
1 : 2-Dichlor-4-nitrobenzene	Cl Cl / NO₂	1%	—	0·240

		F.R.S.	Wear.
1 : 2-Dichlor-4 : 5-dinitrobenzene	Cl, Cl, NO$_2$, NO$_2$	1%	—	0·210
1 : 2 : 4 : 5-Tetrachlorbenzene	Cl, Cl, Cl, Cl	1%	6000	0·280
1 : 2 : 4 : 5-Tetrachlor-3-nitro-benzene	Cl, NO$_2$, Cl, Cl, Cl	1%	8000	0·240
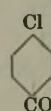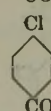
An aliphatic carbon atom is of importance.

		F.R.S.	Wear.
Benzal chloride	CHCl$_2$	1%	14,000	0·215
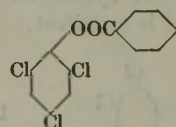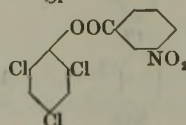
Benzal chloride has physiological disadvantages.

		F.R.S.	Wear.
p-Nitrobenzal chloride	CHCl$_2$, NO$_2$	1%	14,000	0·200

Amongst other compounds which exhibit the same phenomenon are

		F.R.S.	Wear.
Chlorinated ethyl benzoate	Cl, COOC$_2$H$_5$	0·2%	—	0·390
Nitrochlor ethyl benzoate	Cl, NO$_2$, COOC$_2$H$_5$	0·2%	—	0 335

From the many nitro-compounds prepared it seems reasonably safe to assume that all aromatic compounds containing chlorine are improved in film-carrying capacity when a nitro-group is incorporated within the molecule, particularly when the molecule contains at least two halogen atoms.

		F.R.S.	Wear.
2 : 4 : 6-Trichlorphenyl benzoate	OOC, Cl, Cl, Cl	0·5%	—	0·330
2 : 4 : 6-Trichlor-phenyl-m-nitrobenzoate	OOC, NO$_2$, Cl, Cl, Cl	0·5%	—	0·260

		F.R.S.	Wear.
2-Nitro-4-chlorphenol	1%	9000	0·235
Chlor-o-cresol	0·5%	—	0·250
Nitro-chlor-o-cresol	0·5%	8000	0·220
2 : 4 : 6-Trichlorphenol	0·5%	8000	0·260
2 : 4 : 6-Trichlor-3-nitro-phenol	0·5%	9000	0·220
6-Chlorquinoline	2%	—	0·385
5-Nitro-6-chlorquinoline	2%	—	0·200
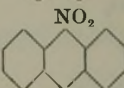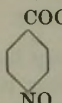
MIXTURES.

So far the electronegative nitro-group has been studied only when it is in the same molecule as chlorine. Now it will be shown that the nitro-group can react when it is in a separate molecule from the chloro-compound, again with advantage accruing from the presence of at least two halogen atoms.

			F.R.S.	Wear.
2% Nitrobenzene	—	0·340	—	0·270
2% Chlorbenzene	—	0·410		
2% Nitrobenzene	5000	0·340	7000	0·280
1% p-Dichlorbenzene	4000	0·410		
1% m-Dinitrobenzene	5000	0·400	7000	0·285
1% p-Dichlorbenzene	4000	0·410		
2% m-Dinitrobenzene	—	0·400	—	0·170
1% Benzal chloride	—	0·215		
2% Nitrobenzene	5000	0·340	8000	0·210
1% Hexachlorethane	6000	0·365		
0·5% Naphthalene tetrachloride	—	0·230	—	0·230
1·0% α-Nitronaphthalene	—	0·420		
1% Hexachlorethane	6000	0·365	6000	0·355
1% α-Nitronaphthalene	4000	0·420		
2% m-Dinitrobenzene	5000	0·400	8000	0·210
2% Dichlordecahydronaphthalene	6000	0·230		
1% Nitrobenzene	5000	0·360	9000	0·210
0·5% 2 : 4 : 6-Trichlorphenol	8000	0·260		

			F.R.S.	Wear.
1% Tetranitromethane in *cyclo*hexanol 1% Chlorbenzene	4000 4000	0·370 ⎫ 0·430 ⎭	4000	0·255
1% Tetranitromethane in *cyclo*hexanol 1% *p*-Dichlorbenzene	— —	0·370 ⎫ 0·410 ⎭	—	0·265
0·5% Nitroform 1·0% Chlorbenzene	— —	0·280 ⎫ 0·430 ⎭	—	0·240
2% Phenylnitromethane 1% Hexachlorethane	— —	0·220 ⎫ 0·365 ⎭	—	0·170

It now only remains to ascertain whether the nitro-group itself is the determining factor in the extreme pressure properties. The following examples show that it is not.

m-Dinitrobenzene		2% suspension	5000	0·400
a-Nitronaphthalene		1%	4000	—
9-Nitroanthracene		2% suspension	—	0·390
Phenylnitromethane		2%	—	0·220
Tetranitromethane	$C(NO_2)_4$	1% in 1% *cyclo*hexanol	4000	0·370
Nitroform	$HC(NO_2)_3$	0·5%	—	0·280
m-Nitro ethyl benzoate		1%	5000	0·410

In passing, it is interesting to note that the effect of an aliphatic carbon is also evident in a nitro-compound as shown in phenylnitromethane.

One may ask how many compounds having E.P. properties are being used commercially. It would be dangerous to hazard a guess, but it would be true to say that if many of them are being used, only a very small number have enjoyed extensive application. It may be that circumstances prejudice progress. Whatever obstacles there may be, the fact remains that film strength and film strengthening is a new phase of lubrication with a great future.

Our thanks are due to C. C. Wakefield & Co., Ltd., for permission to publish these results.

DISCUSSION

THE CHAIRMAN (DR. A. E. DUNSTAN) congratulated the authors on having produced a comprehensive and thoughtful account of a subject vastly important but empirical to a degree. For some time past emphasis had been laid on the need for some component, added or inherent, which would possess polarity, but on the other hand the refiner had gone to the opposite extreme and by modern processes had provided an almost non-reactive material. Hence the need for additives. In last September's meeting of the American Chemical Society at Detroit, Beeck, Givens, Smith, and Williams contributed a valuable paper on the mechanism of wear prevention by addition agents. They summarised their findings by remarking that their work revealed complex relationships between the chemical and physical aspects of boundary lubrication, but a differentiation could be made between chemical polishing agents and " wedging materials "—the latter effect being a function of surface activity. He (the Chairman) would appreciate the authors' views on this conclusion.

He had been particularly impressed by the careful attempts to give a quantitative significance to the problem. It seemed to him that there remained still to be accomplished the analysis of the numerical results perhaps on the lines indicated above.

COL. S. J. M. AULD said he would like to support the Chairman in his remarks regarding the significance of the presentation of a paper of this nature during the war. It indicated an intention to maintain our equilibrium in scientific as in other matters and was an appreciation of the need, now greater than ever, of pressing on with investigation and technical development. He would also like to record the personal pleasure he had experienced in listening to Mr. Evans' presentation of the paper involving, as it had, so much careful work.

Out of so much material it was not possible even lightly in discussion to consider more than one or two aspects of the subject. The first he would choose was in regard to the actual measurements recorded. The criticism might be levelled against the paper in general that the results were all in terms of one machine. It was well established that no two so-called E.P. machines gave identical results or placed all the substances used as addition agents in the same order of merit as regards their load-carrying capacity. This certainly applied to the Timken, S.A.E., Almen, Cornell, 4-Ball and other machines with which he was acquainted. The conclusion apt to be drawn in some quarters was, therefore, that none of them was any real use in measuring practical values, and that only field tests or tests involving the use of gears such as the 4-Square axle rigs or corresponding observations on cutting surfaces could be of value. Such views would overlook the fact that all laboratory test machines told something in regard to anti-weld or prevention of film rupture. It might be only in relation to their own construction and therefore limited for the purpose of drawing broad conclusions, but nevertheless some information was there. It would not necessarily follow that one could arrive at a complete answer by carrying out similar observations on all known test machines, nor would it be practicable to do so. Many who worked with such kinds of apparatus felt that their results had some relationship with practice in individual cases. A good instance of that was the unquestioned broad relationship between the load carried by leaded greases in the Timken machine and their ability to withstand pressures in the large roller bearings as used in steel mills. He personally had found considerable value in the use of the Falex (Cornell) machine as a means of guiding the choice of materials and giving some comparison of their practical value in regard both to back axle lubricants and cutting oils. He felt, therefore, that there was considerable value to be gained from observations made even on one single machine as long as the observations were under identical conditions. Such a conclusion then permitted Messrs. Evans and Elliott's results to be considered on a far broader basis than they otherwise could.

The second main point which he would like to mention was the fact that this is basically a chemical problem. Whatever the mechanism of the E.P. materials, it was quite clear even from the different behaviour of varying substances that chemical reactions were at the back of it.

As pointed out by the authors all materials fell within certain wide categories, and there seemed little doubt that the thermal stability of the compounds concerned

had some relationship to the conditions under which they became most helpful in promoting the load-carrying capacity of the oils in which they were incorporated. This being the case, it was interesting but immaterial to the discussion what was the *modus operandi*. Reaction might result in (1) the removal of asperities; (2) the successive defoliation of hard structured layers, or (3) the formation of loosely adherent cushions on which the bearing surfaces could ride. It did not follow in his opinion that because the value was some measure of chemical reactivity that the quantities involved would be large. The temporary surfaces produced might only be of molecular dimensions and yet by either of the first two methods prevent welding by ripping off more substantial layers of metal. This, in fact, seemed to take place. On some test pieces the wear was considerable. There did not seem necessarily, therefore, to be any relationship between wear and load-carrying capacity. The former might be a purely mechanical effect, whereas the latter, as he said, was chemical. The dimensional factors of the reactivity were apparently time and temperature. That was why E.P.'s differed so much in their behaviour as between the chief types—lead, sulphur, chlorine, and phosphorus.

It was a big thing that Mr. Evans and his colleagues were attempting in endeavouring to seek some more exact relationship between chemical constitution and extreme pressure characteristics. It might seem so difficult as to be impossible, but it was only by patient and exact working of this kind that one could hope to arrive at general conclusions. There were, of course, certain lines of thought which could come to mind. A good many years ago he had carried out some work on the constitution of the inorganic polysulphides and had shown that those of calcium, for example, consisted of a basic sulphide nucleus to which were attached a chain of sulphur atoms successively more loosely combined. Some similar composition, he felt, might possibly be an explanation of the different reactivity of organic sulphur compounds, and in this respect he drew attention to the β-naphthyl sulphides which the authors had described, and where the F.R.S. had gradually increased until the tetrasulphide gave very substantial figures. He would like to know whether if one took any of these synthetic compounds, particularly the tetrasulphide, it might be possible to attach some more sulphur as a side chain to the existing sulphur and thereby still further increase the film rupture strength.

One point which had occurred to him was that water or material splitting off water should have E.P. characteristics since there was thus open a series of reactions on metals over a range of temperatures. Had Mr. Evans noted anything of this kind?

Dr. E. R. Redgrove said that he had always supposed that the function of these addition agents was to impart to the metal faces in contact, a contaminating film which prevented welding taking place, but in view of some of the examples brought forward by the authors it would appear that he might have to alter or at least to modify his views.

It was very surprising that in some cases an excess of the active principle in the molecule of the addition agent resulted in decreased efficiency and he would like to ask the authors whether they could offer any explanation. Was it due to physical or chemical properties?

Dr. Dunstan had raised a very interesting point. It might be that an excess of the active principle had a solvent effect on the protective or contaminating film, in which case a reduction in the amount of additive compound might be beneficial. Had the authors investigated this possibility?

Mr. J. L. Taylor said: I should first of all like to ask the authors if they have investigated mixtures of sulphur and chlorine compounds, and if so what were the results of their investigations.

The second point I would like to make is regarding wear. If there is anything in the corrosion theory, it seems to me that if an additive is effective in E.P. properties then wear should be large, and I would expect it to be shown up on any wear-measuring machine. The fact that those additives investigated which showed promise gave results indicating reduction of wear in the Brownsdon machine, would seem to indicate that the corrosion theory is untenable.

I should like to ask if the authors have observed a material with good properties in raising the F.R.S. which also gives a higher rate of wear than the mineral oil itself.

In conclusion, I should like to add my congratulations to the authors to those that have been expressed by other speakers, on their imagination in the conception of the work, their industry in carrying it out, and their courage in presenting it at a time like the present.

MR. C. H. BARTON said : It has been shown by Givens, Beeck, and Williams at the Emeryville Laboratory of Shell Development Co. (*Annual Review of Petroleum Technology for* 1939, p. 298, also *Proc. Roy. Soc.*, December 1940) that certain organic compounds of phosphorus and arsenic when dissolved in lubricating oil form phosphides and arsenides with iron or steel bearings under running conditions. The low melting point compounds formed in this way on the surface assist the bearing to run in and reduce the rate of wear. When the bearing is coated with a chemically inactive metal such as gold, the phosphorus and arsenic compounds are ineffective.

MR. N. E. F. HITCHCOCK said : The remarks of the Chairman relating to the mechanism of E.P. additives and his own suggestion that it may be due to liberation of the active element in the nascent form, has led to an interesting discussion. It has been pointed out that this theory would forecast increasing E.P. activity, with increased loading of the molecule with the active atom. The behaviour of dichlorphenanthrene tetrachloride is anomalous to this rule. Might not the explanation of this be due to the juxtaposition of the two equally active chlorine atoms which combine on liberation to form a molecule ? In this case one would expect decreased activity corresponding to the relative reactivity of molecular and nascent chlorine.

MR. J. ROMNEY said : It is as well to emphasize the difficulty of drawing conclusions from work of this type. The authors concentrated on one machine, the Almen, but it is well known, and has, in fact, already been mentioned here, that different film strength testing machines can give quite different results on the same oil. Even the methods of recording results make it difficult to correlate tests on different machines. The Almen records pressures in pounds per square inch, while the Timken records an acutal load in pounds, applied to the lever of the machine. Although attempts have been made to convert Timken loadings to pressures in pounds per square inch, these are not successful because in the Timken test, in which a ring rotates in contact with a stationary block, the area of contact changes during the test, as a wider and wider scar is worn on the block.

The authors recognize these difficulties, and Mr. Elliott has replied to a questioner by pointing out that the authors had to confine themselves largely to one machine because of the work which would be involved in using more than one. It is certainly true that to carry the work to completion it would be necessary to test all the materials on all the available machines, to vary the test temperatures, and to use as test pieces all the metals with which the treated oils might come into contact in service, a very tall order.

However, Mr. Elliott points out that the use of one machine does, at least, give a broad basis for selection, allowing interest to be focussed on those materials giving high film rupture strengths and rejection of those which do not. Even this is risky, since it is very possible that compounds giving low results on the Almen might give quite high results on the other test machines.

The authors mention a very large number of patents taken out for various compounds, and it has always mystified me that so many people rush into patenting materials which are so difficult to find by analysis when present in small proportions in mineral oil. The degree of protection afforded to the patentees must be very small indeed. If it had been possible to obtain master patents covering the use of, say, sulphur compounds or chlorine compounds as extreme pressure additives, there would have been some point in it.

The hypoid gear has, as a previous speaker pointed out, been responsible for all this work on extreme pressure lubrication. The way in which engineers submit such problems to the oil industry with a justified confidence that a solution will be found is a compliment to the industry. I have often thought that it would be a good idea to return the compliment. One of these days I shall hand an engineer a sample of pure water. It is cheap and readily available in quantity, and it will be up to him

to design an engine which will work well with the water as a lubricant.   But I think I'll wait until I have retired from the oil industry.

MR. H. L. WEST said : With regard to the method of action of extreme pressure lubricants, the published work on this subject seemed to indicate that there is a definite reaction between the metals and the lubricant, so that what is suitable for one pair of metals is not necessarily the best for another pair.   Thus with the so-called " active " (to copper) lubricants evidence of sulphides and sulphates has been obtained, and it is concluded that the oxygen which is always present must be taken into account. With the chlorinated lubricants ferric chloride had been found to be present, and, under certain conditions, even ferric oxide.   Some work had also been done on the substituted phosphines, and arsines, which showed that the metalloids present definitely formed alloys with the metal surfaces.   Most of this work is, however, of American origin, and so far has not been substantiated.

It seemed a pity that the authors had not carried out any work on the chlorinated aliphatic compounds, and thus make the picture more complete.   It seemed surprising also that so much work had been done on aromatic compounds with the halogen attached to the nucleus and so little with it in the side chains.   It is well known that, in the nuclear halogen compounds, the halogen atom is very firmly held and cannot be hydrolysed, except in exceptional cases, by caustic soda, whereas the halogen in the side chain behaves more as in an aliphatic compound and is readily hydrolysed by alkali.   It would be interesting to see what happened with longer side chains, and with several side chains attached to the nucleus.

The action of a polar group, such as the nitro grouping, in activating the halogen is well known and usually decreases the further away from the halogen atom the group occurs ; thus the *ortho* nitro compound would be expected to be more reactive than the *meta* or *para*.   In the case of the $1:4$-dichlor-$2:6$-dinitrobenzene it would appear that the two nitro groups are neutralizing one another, and it would be interesting to see the results of the $1:4$-dichlor-$2:5$-dinitrobenzene, that is, with the nitro groups in the *ortho* position to each chlorine atom.

MR. H. D. MANSION wrote : The writer agrees in general with Colonel Auld's remarks that care should be exercised against placing too much reliance in the film strengths given by any one of the various E.P. lubricant testing machines.

In a research on Durability of Gears the I.A.E. Research Department has tested a number of E.P. dopes (a very small number compared with those tested by the authors, it may be noted), under extreme load conditions as the lubricant for spur gears.   Most of the dopes tested showed a film rupture strength of at least 15,000 lb./sq. in. on the authors' Almen machine, this being the limit of load available, and being about four times the value for the base oil.   In the gear testing machine, however, where scuffing (viz., seizure of the tooth profiles above and below the pitch line), was taken as the criterion of failure, these same dopes gave failure loads ranging from 1.64 to 2.80 times that of the base oil.   Another machine known to the writer indicated that a very great increase in load-carrying capacity could be obtained by the use of a certain mild dope.   The gear machine, however, indicated only some 10 per cent. increase in load capacity.

Some of these anomalous results must be accounted for, as mentioned by one speaker, by the fact that, on some machines, only a small increase in Hertz stress is caused by quite a large increase in load, since the wear which occurs in the early part of the test serves to increase greatly the bearing area.   This cannot be said of the Almen machine, but here perhaps one may criticize the inability to go to high enough loads for testing the more powerful dopes, and the uncertainty of the testing temperature when failure is reached.

Whilst it is desirable to test E.P. lubricants under something more approaching service conditions than is offered by most of the so-called E.P. testing machines, it must be understood that the involute gear, in whatever form, is recognized to be far from ideal as a test specimen, since, even by the most accurate gear grinding methods, the reproducibility of form falls far short of what can be achieved on any type of circular specimen.   There is also, of course, the disadvantage of cost.   On the subject of the actual dopes themselves, the writer, not being a chemist, will make no comment, but would like to express, in conclusion, his appreciation of the great service

rendered by the authors in carrying out, and in publishing, their work on so extensive a range of addition agents.

PROF. A. W. NASH wrote : The authors are to be congratulated on the presentation of an important investigation. I have found the paper particularly interesting as very similar work was completed in my own Department about two years ago. Whereas the authors employed the Almen machine for their film strength determinations, our work was carried out with the Shell Four Ball machine. Another point of difference was the concentration of addition agent employed. We used 10 gms. of dope in 200 gms. of mineral oil compared with the 1–3 per cent. concentrations mentioned in the present paper.

It is rather interesting to compare for identical compounds our results with these reported. For example, the authors rate aromatic chloro compounds in increasing efficiency as follows :—chlorobenzene, o-dichlorobenzene, p-dichlorobenzene, benzyl chloride and benzal chloride. Our rating for these compounds is somewhat different, being in order of increasing efficiency—chlorobenzene, o-dichlorobenzene, benzyl chloride, p-dichlorobenzene and benzal chloride.

We have found p-dichlorobenzene to be more effective than o-dichlorobenzene, p-chlorophenol to be better than o-chlorophenol, and p-chloro-nitro benzene to be better than o-chloro-nitro benzene. Similarly the authors found p-chlorphenyl-thiocarbimide to be more effective than o-chlorophenylthiocarbimide.

It is difficult to see why the para-derivative should be more effective than the ortho-. A possible explanation was advanced by Mr. F. G. Howard, who has carried out much of the work on E.P. additives in this Department. He suggested that the " availability " of the active group present in the additive may be an important factor. Whereas o-dichlorbenzene has all its chlorine concentrated on one side of the benzene ring, p-dichlorobenzene has its chlorine divided equally on opposite sides of the ring. If a molecule of each compound was brought towards a metal surface, the probability of a contact between the metal and a chlorine atom would in the case of the para-compound be about twice that in the case of the ortho-form. In this respect the results obtained for chloroform and hexachlorethane were interesting. In both compounds the active component is chlorine and it will be seen from the formulæ :

$$H-C\begin{matrix}Cl\\Cl\\Cl\end{matrix} \qquad \begin{matrix}Cl\\Cl\end{matrix}C-C\begin{matrix}Cl\\Cl\end{matrix}$$
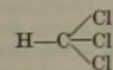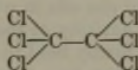
Chloroform   Hexachlorethane

that in the case of hexachlorethane the possibility of a chlorine atom coming into contact with a metal surface is practically twice that in the case of chloroform. Thus the " availability " of chlorine in hexachlorethane is presumably twice that of chlorine in chloroform. As determined in the Four Ball machine hexachlorethane has a $2\frac{1}{2}$ sec. seizure load of 126 kgs. as compared to a $2\frac{1}{2}$ sec. seizure load of 98 kgs. for chloroform. That is, the hexachlorethane is about 1·3 times as effective as chloroform.

In the functioning of an additive many factors undoubtedly play an important part, such as high dipole moment, high chemical reactivity of the additive for metals, condensation of additive and oil to produce compounds chemically reactive to metals, etc. Nevertheless in certain instances the " availability " of the active group would appear to be of primary importance.

Author's Reply to the Discussion.

F. L. Miller of the Esso Laboratories, at the General Discussion on Lubrication, 1937, stated : " To measure load-carrying ability by actual gear or car tests is both tedious and costly, and is rarely feasible. Great impetus has thus been given to the development of simpler and more convenient test machines. Although all the machines purport to measure the same property of lubricants, hardly any two show even reasonable agreement as to the relative order in which they rate the load-carrying abilities of different types of lubricants." By his own showing the S.A.E. machine and the Almen classify the lubricants more or less in the same order, within the limits of the respective machines. It is generally accepted that no laboratory apparatus can take the place of the actual gear, but without laboratory methods, even incom-

plete ones, progress would be exceedingly slow and uneventful. The Almen machine may have limitations, but the charitable will regard it as an anchor in the deep sea of uncertainty. The only method available to satisfy a hopeful thought is to resort to a field test.

So far we have been fed on working hypotheses, to explain the mechanism of E.P. lubricants. There appears to be little experimental evidence to support the suggestion that a film of chloride or sulphide is formed. Finch, using electron diffraction methods, has shown that oxide films are produced, but at what stage they form he has not stated. This discovery is of considerable importance, particularly as we have shown that nitro and hydroxyl groups possess utility. A difficulty might be encountered in the case of phosphites which would ordinarily be regarded as reducing agents. Whether they could still be so regarded at 600° C. in close contact with bare metal under high pressure is open to speculation. Givens and his co-workers suggest that arsenic and phosphorus compounds function by combining with the metal surface, forming lower melting-point alloys. Students of surface phenomena will doubtless come to our aid to unravel the yet unknown reactions.

Even the congratulatory remarks of such deep thinkers as Dr. Dunstan and Col. Auld, which we greatly appreciate, will not draw us to express any opinion how E.P. lubricants perform their duties. We are diffident to accept the working hypotheses upon the scanty evidence, and we do not feel that our investigations go any further than to indicate that certain groups confer properties and certain others do not. "Wedging materials" might well be associated with polar groups and adsorption, but surely E.P. compounds should be inspected from the aspect of chemical activity, or as Col. Auld suggested, thermal stability.

The preparation of organic polysulphides was no easy matter, particularly the β-naphthyl tetrasulphide. Unfortunately the organic monosulphides cannot be induced to add sulphur as is the case with many inorganic sulphides.

Brownsdon showed that some interesting results could be obtained when water is added to wear-reducing agents. It is possible that di (3-carbomethoxy-4-hydroxy-phenyl) thioether may split off water, but we do not know.

The contaminating film to which Dr. Redgrove has alluded is probably an oxide. The belief is borne out by the fact that the majority of E.P. compounds increase the rate of oxidation of the oils in which they are dissolved. There does, however, appear to be an optimum activity of the active principle. In the mono- and di-chlorbenzenes the chlorine is too firmly held to the benzene ring to allow of reaction, whereas in those compounds possessing two nitro-groups *ortho* to the same chlorine atom it would seem possible that the chlorine is lost so readily that only a portion of it can enter into reaction at the metal surface. The case of dichlorphenanthrene tetrachloride appears very exceptional. We have no explanation to offer.

Mr. Taylor will be pleased to know that we have considered mixtures of sulphur and chlorine compounds. We felt, however, that they were outside the scope of the paper. Although it might be true that an improvement does occur by their association, no generality can be assumed.

In an investigation of a wide range of compounds we have not found one which increases the wear when tested on the Brownsdon machine. This is not conclusive evidence that wear would not result in practice.

Messrs. Romney and Mansion will be glad to know that certain of our more promising compounds have been tested on the S.A.E. machine. Also we have made tests using the Almen machine at double its normal speed of rotation. The correlation has been reasonably satisfactory.

The work undertaken by Mr. Mansion at the I.A.E. Research Laboratory is very valuable. The investigations are being continued.

Professor Nash has raised exceedingly important points regarding " availability " of active groups. Except in the instance quoted of the chlorphenyl thiocarbimides we have not observed this effect. It will be noticed that p-dichlorbenzene in concentrations up to 2 per cent. has no apparent E.P. properties. It may be, however, that in concentrations as high as 5 per cent. other factors come into play. Perhaps the distribution of molecules of the addition agent and their orientation on the metal surface changes; availability then becomes important. All the results observed by Prof. Nash were obtained with concentrations of 5 per cent. In the only case when we used 5 per cent. we observed a similar effect. Most of our results were

obtained with concentrations of 3 per cent. and under.   In none of these was the effect observed.   From a commercial point of view 3 per cent. is more attractive !

The only excuse we can offer to Mr. West for not investigating the chlorinated aliphatic compounds is that they are referred to reasonably extensively in the patent literature.   Probably after the war, when we have more time at our disposal, we shall be pleased to recall his suggestions.

There does not appear to be any direct evidence in the paper by Givens and his colleagues, in the Proceedings of the Royal Society, in support of the theoretical suggestion that chemical combination takes place between the metal surface and the phosphorus in the addition agent.   It appears to us to be another working hypothesis. Finch has stated that whenever a compound containing sulphur, chlorine, or phosphorus has E.P. properties an amorphous oxide of metal is always formed on the metallic surface.   We imagine this to be a very important discovery.   It enables us to visualize the subsequent formation of a Beilby layer, which really carries the load.   We are quite content to accept the disclosures of the electron camera, together with the idea of an amorphous oxide Beilby layer.

In conclusion we venture to suggest that workers on E.P. compounds might benefit by giving closer consideration to the Beilby layer.

EXTENSION OF THE OCTANE SCALE ABOVE 100 O.N.

REPORT AND RECOMMENDATIONS OF THE INSTITUTE OF PETROLEUM KNOCK-RATING OF AIRCRAFT FUELS PANEL.

(Approved by the Chemical Standardization Committee.)

INTRODUCTION.

As some experimental types of fuel have anti-knock values better than that of pure *iso*-octane, it has been considered desirable to provide an extension of the octane scale. The Sub-Committee of the above Panel recommended the following procedure, which has been approved, and is now recommended by the Chemical Standardization Committee.

METHOD OF TEST.

As no generally acceptable alternative to the A.S.T.M. Motor Method has been produced, it was decided to employ the Motor Method with such modifications as are necessary to obtain reliable ratings of high anti-knock value.

The method recommended is the Motor Method except that (*a*) the spark advance is fixed at 17° early, to reduce unsteady knocking which occurs above 100 O.N., and (*b*) the bouncing-pin lower-leaf spring-tension may have to be increased to prevent the pin from bouncing due to the higher combustion pressures. (Tensions up to 300 gms. have been found satisfactory.)

SCOPE OF THE PROPOSED " 17° MOTOR METHOD ".

The " 17° Motor Method " is primarily intended for testing experimental types of fuel of over 100 O.N. (For the sake of continuity, experimental blends below 100 O.N. may also be tested by this method provided that they are reported suitably, *e.g.*, " 98 O.N. 17° Motor Method ' ".)

Commercial Aviation fuels of nominally 100 O.N. should be tested as heretofore by Motor Method, even if the rating may be above 100 O.N.

REFERENCE FUELS.

In order to obtain continuity of scale, it has been decided to employ the secondary reference fuels recommended by the Institute of Petroleum (*Journal*, February 1939, p. 106) from 92 O.N. up to 102 O.N.—namely, C + 4 mls. T.E.L./Imp. gln. and F + 4 mls. T.E.L./Imp. gln. In order that fresh batches of these secondaries may be calibrated from time to time, it is necessary to have a primary reference. This is achieved by using pure *iso*-octane + 4 mls. T.E.L./Imp. gln. and *n*-heptane + 4 mls. T.E.L./Imp. gln.

SCALE.

The scale recommended extends from the O.N. of reference fuel C + 4 mls. T.E.L./Imp. gln. to that of F + 4 mls. T.E.L./Imp. gln. (C.12 + 4 mls./Imp. gln. = 93 O.N. approximately. F.3 + 4 mls./Imp. gln. = 116 O.N.)

PREPARATION OF PRIMARY SCALE.

Blends of the leaded primary fuels were rated in terms of unleaded primary fuels up to 100 O.N. Above 100 O.N. the scale has been extrapolated and is recommended for adoption as the primary standard. This is presented in Fig. 1 and Table I.

The extrapolation is necessarily of an arbitrary nature, as the form of the calibration curve below 100 O.N. varies. The curve as presented will provide similar octane numbers to those given by the extrapolated secondary reference fuel calibrations referred to in the *Journal* for February 1939.

TABLE I.

Octane Number Calibration Tables for the Extension of the Octane Scale by the C.F.R. Motor Method (I.P.T. G.39 (T)) up to 100 O.N., thence by Extrapolation.

Iso-Octane $+$ 4 mls. T.E.L./Imp. gln. in *n*-heptane $+$ 4 mls. T.E.L./Imp. gln.

% Leaded Octane.	Octane No.	% Leaded Octane.	Octane No.
70	89·9	85	103·2
71	90·6	86	104·2
72	91·4	87	105·2
73	92·2	88	106·3
74	93·0	89	107·4
75	93·9	90	108·5
76	94·8	91	109·6
77	95·7	92	110·7
78	96·6	93	111·8
79	97·5	94	112·9
80	98·4	95	114·0
81	99·3	96	115·2
82	100·2	97	116·4
83	101·2	98	117·6
84	102·2	99	118·8
		100	120·0

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Fig. 1.

CALIBRATION (BY MOTOR METHOD) OF LEADED ISO-OCTANE AND N-HEPTANE AGAINST
ISO-OCTANE AND N-HEPTANE.

TENTATIVE METHOD FOR KNOCK-RATING OF EXPERIMENTAL AVIATION FUELS OF OVER 100 O.N.

"17° MOTOR METHOD."

I.P.T. Serial Designation G.39b—1940 (T).

The apparatus and method shall be as laid down under Serial Designation G.39 (T) (" Standard Methods for Testing Petroleum and its Products," 3rd Edition, 1935, pp. 210–218), except that a fixed ignition setting of 17° early shall be used, and the bouncing-pin lower-leaf spring-tension increased to prevent the pin from bouncing as a result of higher combustion pressures. The spring tension may be increased if necessary for stable working up to a maximum of 300 grams.

The method is primarily intended for testing experimental types of fuel of over 100 O.N.

The primary scale is in terms of pure *iso*-octane and *n*-heptane up to 100 O.N., thence by extrapolation up to 120 O.N.

Leaded secondary reference fuels are calibrated in terms of leaded primary reference fuels which have been calibrated and approved from 90 O.N. to 120 O.N. (see Table I).

TABLE I.

Octane Number Calibration Tables for the Extension of the Octane Scale obtained by the C.F.R. Motor Method (I.P.T. G.39 (T)) up to 100 O.N., thence by Extrapolation.

% Leaded Octane.	Octane No.	% Leaded Octane.	Octane No.
70	89·9	85	103·2
71	90·6	86	104·2
72	91·4	87	105·2
73	92·2	88	106·3
74	93·0	89	107·4
75	93·9	90	108·5
76	94·8	91	109·6
77	95·7	92	110·7
78	96·6	93	111·8
79	97·5	94	112·9
80	98·4	95	114·0
81	99·3	96	115·2
82	100·2	97	116·4
83	101·2	98	117·6
84	102·2	99	118·8
		100	120·0

CALIBRATION OF C.F.R. REFERENCE FUELS.

Calibration of Secondary Reference Fuels F.3 + 4 Mls. T.E.L./Imp. Gln. and C.12 + 4 mls. T.E.L./Imp. Gln. by the C.F.R. Motor Method (I.P.T. G.39 (T) and I.P.T. G.39b (T)).

The calibration of the above reference fuels has been determined and continued up to 116 octane number in accordance with the procedure described in the preceding report. In order to do this, it was necessary to prepare a calibration for leaded secondary reference fuels in terms of leaded primary reference fuels (see Fig. 2). The final calibration (Fig. 3) is arrived at by interpolation from Figs. 1 and 2.

In order to conform with modern practice and to provide an accurate means of interpolating results, Fig. 3 is expressed below in tabular form.

TABLE II.

Octane-number Calibration Tables C.F.R. Motor Method (I.P.T. G.39 (T)) up to 100 O.N., thence by I.P.T. " 17° Motor Method."

F.3 + 4 mls. T.E.L./Imp. gln. in C.12 + 4 mls. T.E.L./Imp. gln.

% F.3 + T.E.L.	O.N.	% F.3 + T.E.L.	O.N.
0	93·3	50	103·0
2	93·7	52	103·4
4	94·0	54	103·9
6	94·4	56	104·4
8	94·8	58	104·8
10	95·2	60	105·2
12	95·6	62	105·7
14	96·0	64	106·2
16	96·4	66	106·6
18	96·8	68	107·0
20	97·2	70	107·5
22	97·5	72	108·0
24	97·9	74	108·5
26	98·3	76	109·0
28	98·7	78	109·5
30	99·1	80	110·0
32	99·4	82	110·5
34	99·8	84	111·0
36	100·2	86	111·5
38	100·6	88	112·1
40	101·0	90	112·7
42	101·4	92	113·3
44	101·8	94	114·0
46	102·2	96	114·6
48	102·6	98	115·3
		100	116·0
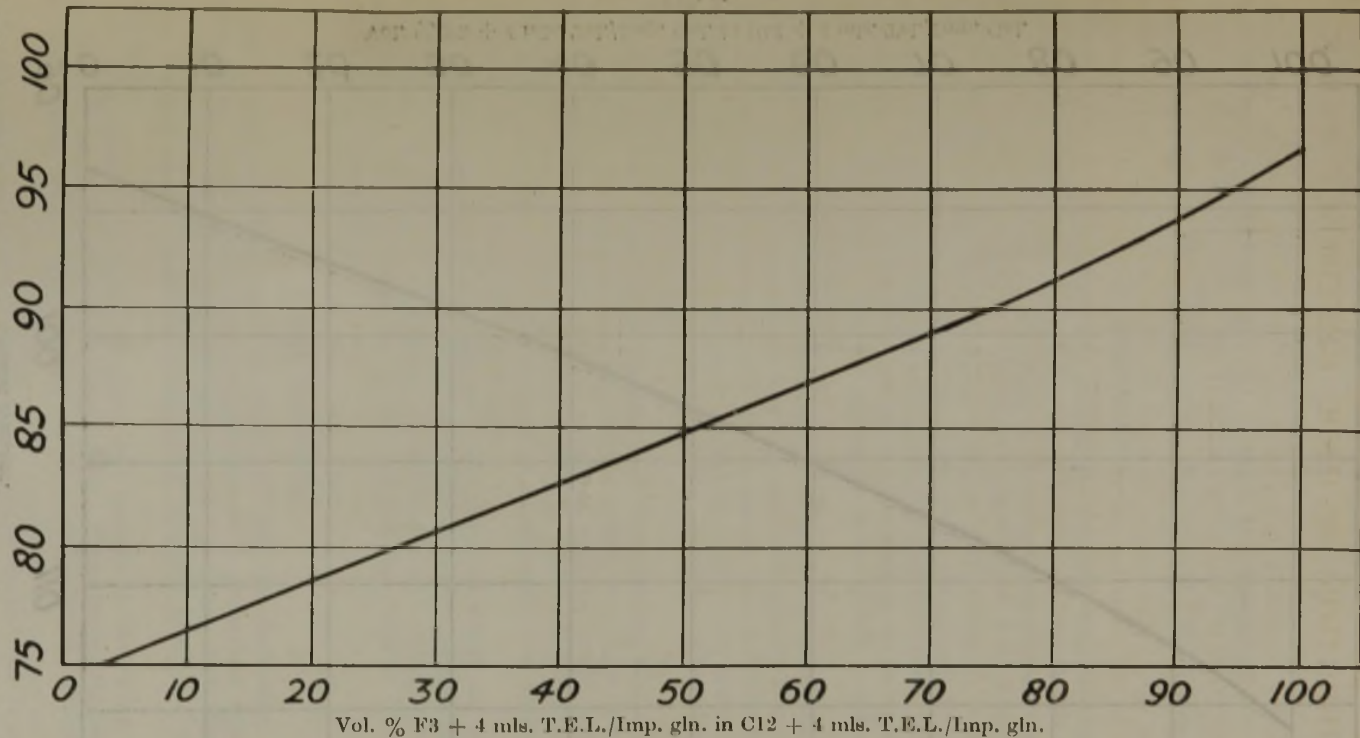
FIG. 2.

CALIBRATION (BY 17° MOTOR METHOD) OF LEADED ISO-OCTANE AND N-HEPTANE AGAINST LEADED F3/C12.

Octane Number.

Vol. % F3 + 4 mls. Tel./Imp. Gal. in C12 + 4 mls. Tel./Imp. Gal.
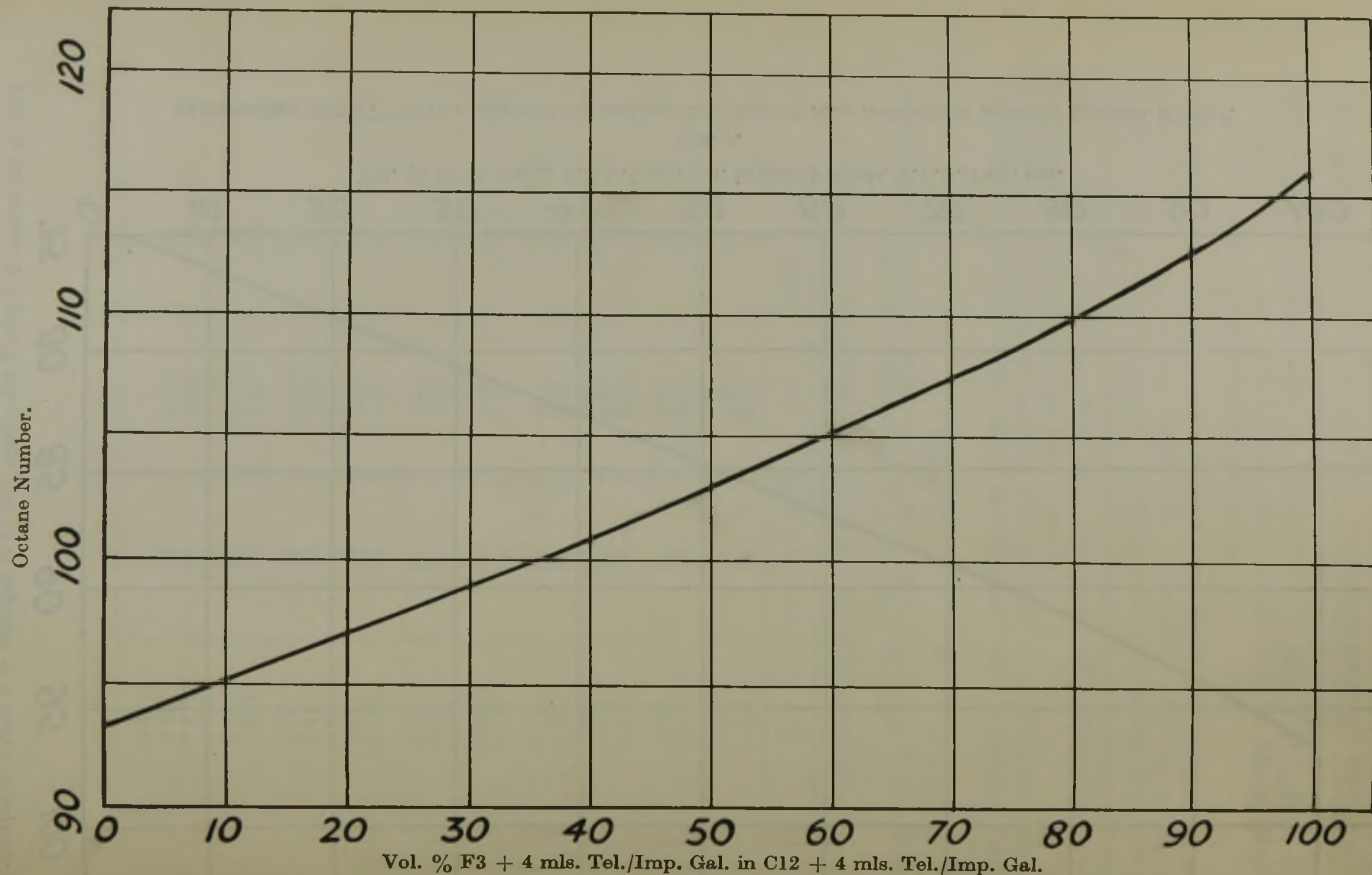
FIG. 3.

CALIBRATION CURVE. "C.F.R. MOTOR METHOD" UP TO 100 O.N. AND THENCE BY 17° MOTOR METHOD. (I.P.T. G. 39 (T).)

Approved by the Institute of Petroleum, London, March, 1941.

Blends of Standard Reference Fuels : F3 + 4 mls. Tetra-ethyl Lead per Imp. gln. and C12 + 4 mls. Tetra-ethyl Lead per Imp. gln.

ABSTRACTS.

AUTHOR INDEX.

The numbers refer to the Abstract Number.

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

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Geology and Development.

443.* Hawkins is New Woodbine Field in East Texas Area. H. L. Flood. *Petrol. Engr*, Feb. 1941, **12** (5), 25.—The Hawkins discovery well was completed in November 1940, and the southern limit of the field now seems to have been partly defined. The structure is stated to be a dome, elongated in a north–south direction. Crude is obtained from the Woodbine at depths of 3924–4490 ft. below sea-level. The oil differs considerably from the Woodbine oil found elsewhere. One well blew out with high-pressure gas from the Sub-Clarksville, which overlies the Woodbine, at a depth of 4360 ft.

A table gives the depths of various horizons in the nine wells drilled to date.

G. D. H.

444.* Dyersdale may Broaden Frio Trend Play in Coastal Texas. F. L. Singleton. *Oil Gas J.*, 20.2.41, **39** (41), 22.—The Dyersdale field lies 13 ml. north-east of Houston, and is one of the few shallow discoveries to be made on the upper Texas Gulf Coast in several years. It is the most northerly field to produce from the Marginula–Frio sand. The area was worked over by reflection seismograph and soil surveying, and in September 1940 the discovery well was brought in at 4068–4073 ft. Thirteen producing wells have now been completed. Some believe that it is a salt structure.

After several unsuccessful wells, oil was found in the Mount Houston area quite near to Dyersdale. Much gas and a little distillate are obtained from the Miocene at a depth of 3465–3486 ft. Mount Houston is believed to be separated from Dyersdale by a major fault. There is promise of production from the Jackson in this area.

Other similar structures probably exist along this trend, and several wildcats have been located. Interest is being revived in old prospects as a result of this shallow development.

G. D. H.

445.* New Venezuelan Field Indicated by Sinclair Well in Monagas. J. P. O'Donnell, *Oil Gas J.*, 20.2.41, **39** (41), 24.—1 Santa Barbara in the State of Monagas has found production, estimated at 4000 brl./day according to a drill-stem test. It lies about 10 ml. west of the Jusepin field, and on the south flank of a dome revealed by the torsion balance, and indicated to be oil-bearing by soil surveying. The well is 4321 ft. deep and the sand section 99 ft. thick.

A little earlier 1 Santa Rosa was successfully completed in Anzoategui, 10 ml. north of the San Joaquin field.

A map shows the oil-fields, exploratory wells, refineries, and pipe-lines.

G. D. H.

446.* Well Logs and Field Data of Active Oil Areas—South Central Illinois. Anon. *Oil Gas J.*, 20.2.41, **39** (41), 58.—This area came to the fore with the discovery of the Centralia, Salem, and Louden fields. Oil is obtained chiefly from Pennsylvanian sands, the Palestine sand, Waltersburg sand, Tar Springs, Hardinsburg sand, Cypress sand, Paint Creek stray sand, Bethel sand (Benoist), Aux Vases sand, Rosiclare sand, Fredonia lime (McClosky), St. Louis lime, and Devonian lime. Where productive, these horizons are practically all above 3000 ft.

Up to the end of Lower Mississippian times more or less blanket deposits were formed, first of sand and then of lime, over much of southern Illinois. From time to time they were eroded, and they are productive locally at well-defined unconformities. At present the Trenton is productive, with minor exceptions, only on the western rim of the basin. The Devonian has been proved north-north-west from Centralia and Salem, and the Salem and St. Louis are productive in the eastern part of this belt. The McClosky is important for production in a triangular area north-east from Centralia.

The area was submerged and the Chester series deposited, of which Benoist and Aux Vases production is most widespread. After the Chester the main structural trends were developed, and chief among these is a series of north–south belts parallel to the Du Quoin anticline, north-west–south-east trends in the west of the area and north-east–south-west trends in the east. Production is mainly from the intersections of these trends.

Pennsylvanian seas covered the Chester, and local structures were developed during

this and later periods. Some of the structures reflect Chester structures, but others do not, a consequence which has led to many disappointments.

Production per acre is relatively low from individual sands, but many fields produce from several sands, and thus 15,000–20,000 brl./acre may be obtained in the richer pools.

It is possible that many small pools remain to be discovered. The Devonian has not been adequately tested in any part of the basin south and east of Salem. The Trenton has been tested only at Centralia, and there with poor results. The St. Peter has not yet given indications of commercial production. G. D. H.

447.* Illinois Anticipates a Good Year Despite Production Decline. H. F. Simons. *Oil Gas J.*, 27.2.41, **39** (42), 36.—The Illinois daily production in Jan. 1941 was nearly 50,000 brl. or 13·8% below that for Jan. 1940. However, more wells were completed in Jan. 1941 than in the corresponding period of last year. The Trenton at Salem has just been found to be productive, but the size of the wells and the cost of development are making operators cautious. So far all the Trenton tests have been deepening jobs. Numerous small fields were discovered in 1940.

The relationship between the number of wells and production is discussed. A curve gives the production/day for 1940, and pipe-line runs are compared for 1st Jan. 1940 and 1st Jan. 1941.

50% of the development is in the south-east of the State. The Louden pool is practically completely developed. Hoodville is the most outstanding of the new fields, and gives 400-brl. wells from the Benoist and Aux Vases. Mount Carmel yields oil from several zones. At Calvin oil is being sought in Chester sands, the McClosky lime, and some Pennsylvanian sands. Several wildcats are showing promise, and some new fields have been opened this year. G. D. H.

448.* New Mexico Drilling Activity Centres on Maljamar Area. D. H. Stormont. *Oil Gas J.*, 27.2.41, **39** (42), 42.—Oil was first discovered in the Artesia–Maljamar area in 1923, but development was never strong. Since 1936, however, there has been an increase in activity, and the production has risen from 2,202,411 brl. in 1938 to 5,318,925 brl. in 1940. The oil is obtained largely from the Artesia sand-zone, the Grayburg, Jackson, and Maljamar lime-pays. Much of the present activity is development of the shallower sand-pays. The producing horizons of this general area are all believed to be found in the San Andrea lime of the Permian.

The main structural feature is a lime-high plunging from the west. Minor features on it are thought to be roughly at right angles to the main high, and to account in part for the oil and gas accumulation in the sand-fields flanking the main uplift, although cementation and lenticularity probably afford the chief control. Production has been found along the high for 20 ml., although not continuously, with an average width of $\frac{1}{2}$–1 ml. On the south flank of the high the sand pays are thought to be shoreline deposits, and on the north lagoonal.

At Maljamar early production was from a sandy lime at 4100 ft., but now the principal development is in a 3900-ft. sand. There is also oil at 2400 ft. In the Grayburg–Jackson area development of the main 3900-ft. lime- and sand-pays was likewise intensified in 1940.

In Eddy county three new oil-producing areas were added last year. Dayton gives oil from a sand at 4030 ft. At Barber, east of Getty, oil is obtained at 1600 ft. 5½ ml. north of the Jackson area, 1 Etz was brought in as a small pumper at 3200 ft. G. D. H.

449.* Peru. Anon. *Oil Gas J.*, 27.2.41, **39** (42), 55.—In 1940 Peru's production of 12,127,135 brl. was 10% below the 1939 figure. It came mainly from the established fields : Zorritos, 730,000 brl., Lobitos, 2,455,504 brl., and La Brea-Parinas, 9,626,831 brl. The Rio Brava pool was opened in the north of the La Brea-Parinas area, giving 1072 brl./day from a depth of 2375 ft. A deep test is drilling in the Cretaceous at 9200 ft.

Apparently there is little activity in the Pirin field of the Lake Titicaca area. Five wells have now been drilled at Agua Caliente, where the crude is accompanied by little gas, and is seemingly under hydrostatic pressure. Its temperature is 165° F. G. D. H.

450. The Lloydminster Gas and Oil Area, Alberta and Saskatchewan. G. S. Hume and C. O. Hage. *Canada Dept. Mines and Resources. Geological Survey Paper* 40–11, 1940.—The town of Lloydminster is situated on the fourth meridian, the dividing line between Alberta and Saskatchewan, and about 24 miles south of North Saskatchewan River. The area first came into prominence in 1934, when Lloydminster No. 1 well was completed and a measured flow of 16,750 M. cub. ft. of gas was obtained at a pressure of 565 lb.

This report gives details of wells drilled and indicates the possible relation of structure to production. In addition, analyses of gas and petroleum are quoted and logs of the various wells reproduced in tabular form. Summarily, it would appear that, with the exception of Lloydminster No. 1 well, most of the gas and oil occurs in sands at or just below the top of the Lower Cretaceous sediments. Most of the wells give an initial pressure slightly greater than 400 lb. from a depth of approximately 1700 ft.

Hitherto no continuous production tests have been made of any of the wells, and it is not therefore known whether oil can be produced without accompanying water. There is relatively small difference in specific gravity between the heavy oil and water, and consequently separation between oil and water in the sands may not be very clearly defined.

Nevertheless the fact remains that gas and oil occur in the Lloydminster area in what appears to be a structure of low relief. The significance of this as an indication of what may eventually be expected from the large area included within central eastern Alberta and western Saskatchewan should not be under-estimated.

H. B. M.

451. Structure and Oil Prospects of the Foothills of Alberta between Highwood and Bow Rivers. G. S. Hume. *Canada Dept. Mines and Resources. Geological Survey Paper* 40–8, 1940.—In 1924 natural gas was discovered in Turner Valley at the eastern edge of the foothills, and in 1936 crude oil was found on the west flank of the same field. By 1939, as a result of these discoveries, exploration had led to the drilling of over 200 wells into the Palaeozoic limestone at depths ranging from approximately 3500 ft. to approximately 9700 ft. In addition, other foothill structures had been subjected to systematic testing.

Up to the present, however, other structures have not been productive, and failure of a well in the Jumpingpound area, 22 miles west of Calgary, to reach the Palæozoic limestone led to a study of data collected during the course of field work. This report embodies the results of this study and illustrates structure interpretations by means of six geological cross-sections.

The conclusion is reached that in relation to oil and gas prospects the foothill structures can be divided into two types : folds like that of Turner Valley, which are anticlinal at surface and involve the Palæozoic limestone at depth ; and folds like that of the Jumpingpound area, which are equally anticlinal at surface but which do not involve the limestone at depth. Folds of both types are cut off on the east flank by overthrust faults. In Turner Valley Palæozoic limestone occurs in the fold above the fault, but in the Jumpingpound area it does not.

The productive closure in the oil and gas area of Turner Valley is 4893 ft. between the highest gas-well in which the gas is at 786 ft. above sea level, and the lowest crude-oil well in which the oil comes from 4107 ft. below sea level from the same horizon as the gas. Approximately 2000 ft. of the closure holds oil, and the remainder gas. The huge productive closure and the amount of oil and gas in the Turner Valley field suggest that source materials must have been abundant and rich. The author is, therefore, of the opinion that if other structures exist with conditions as favourable as those obtaining at Turner Valley, they offer excellent prospects for oil and gas.

H. B. M.

Drilling.

452.* Detailed Drilling Studies. H. F. Simons. *Oil Gas J.*, 7.11.40. **39** (26), 50–52.— The paper deals in particular with the Cumberland field, which is deep enough to permit drilling studies to be made and at the same time not so deep that drilling is complicated by this factor. Production in the field is obtained from the Bromide sand topped at about 4800 ft., although one well has been drilled deeper and then plugged back.

An opportunity to determine the relative efficiency and cost of different types of rotary rigs is presented by the Cumberland pool. At the present time electric, mechanical, and steam rigs are running in the field, and the Pure Oil Co. is compiling data to determine the relative merits of each type in a field where gas and water are available. Water, suitable for use in boilers with only light treatment, may be obtained from the Washita River, which runs through the heart of the field. Wells on production now provide sufficient gas for fuel if most of the rigs use internal-combustion engines.

One of the outstanding features of the rotary rigs at Cumberland is the completeness and thoroughness with which they are rigged up for drilling the 5000-ft. holes. This is due to the time which must be spent drilling, approximately 60 days being required to complete a well. This is based on the last five completions in the field. Modern methods and equipment are also noticeable, and particularly outstanding are the instruments for obtaining fundamental data. By visiting the rigs in the field, practically every method for determining drilling time, rotary speed, torque weight on bit, and pump pressure may be seen.

Details of the rigs, of their operations, and of difficulties and mud troubles encountered are given. A. H. N.

453.* **2600 ft. of Cemented Tubing Removed.** N. Williams. *Oil Gas J.*, 21.11.40, **39** (28), 32.—The first step in the fishing job was to pull that part of the tubing string above the top of the cement. As the height of the cement was not known, a series of inside cuts were made at approximately 1000-ft. intervals, up the hole, starting about 200 ft. from bottom, until the tubing was found free, which was at approximately 5700 ft. The free section was then pulled. This done, the job called for washing down over the outside of the tubing through the cement, and then cutting out, with inside cutting tool, as long sections as possible as the hole was washed down.

For washing down over the 2-in. tubing, 4-in. flush-joint pipe was used. This was run on 2⅛-in. drill-pipe. A rotary shoe was run on the bottom of the 4-in. pipe to cut the cement. In the first 600–700 ft., down to about 6300 ft., the cement, which there had not set up so well, was soft, and the tubing was washed over without great difficulty, and then cut and pulled. Very hard cement was then encountered, and from then on the job became slow and tedious.

In the hard cement trouble was experienced owing to the rotary shoes splitting up. Sometimes large pieces and strips would be left 6–8 ft. up in the hole. On one occasion a slab 13 in. long and 3 in. wide broke off and was lost in the hole. Frequently not more than a few feet could be made until the shoe started to split, rendering it unusable. The longest section of tubing washed over in any one trip through the hard cement was between 300 and 400 ft. long.

Best results and longest service were obtained with the use of a 3-tooth shoe, with teeth about ½-in long. After the first few trips this type of shoe was run exclusively.

Details of incidental operations, of cleaning, etc., are also given. A. H. N.

454.* **Effects of Different Properties of Rotary Drilling Fluids. Part 2.** H. F. Simons. *Oil Gas J.*, 21.11.40, **39** (28), 46. Control of the wall-building property is what is generally sought when viscosity of the mud is increased. Viscosity is often a poor index of the quality and performance of the mud, factors which cause the viscosity being more important. This is particularly true of the wall-building properties.

A flocculated mud will have an extremely high viscosity—so high, in fact, that the mud will not flow down the ditch. Yet it has very poor wall-building qualities, due to the fact that larger clots, or coagulates, cannot form an impervious sheath on the wall of the hole. The flocculated mud often builds up a very thick filter cake on the walls of the hole, and trouble may ensue.

A dispersed colloidal mixture will cause a thin impervious layer of mud to be deposited on the wall of the hole and will shut off the water from the formation. This is mainly due to the fact that water in the mud is absorbed on the outside of the clay particles and there is a firmer attachment between the water and smaller particles.

Elevated temperatures encountered in wells greatly affect the plastering properties of muds, some muds showing a minimum viscosity at one temperature and others at another temperature. Different densities of the same mud reacted differently to temperature. The filtration of mud is primarily affected by the amount and nature

of the solids present, degree of dispersion of solids, distribution of particle size, degree of hydration, and presence of dispersing or agglomerating agents. In general, preponderance of highly hydrated colloidal material and presence of a dispersing agent are conducive to the lowest rate of filtration.

On deep wells it will sometimes be impossible to break circulation following the running of casing, due to high gel strength of the mud. This is generally overcome by circulating some gelled fluid out of the hole by starting the pumps at intermediate points while running casing. Viscosity of the mud coming from the hole will be much higher following a trip than just before a trip was made, as mud in the hole has gelled, and stirring will be required to break up the gel. In many cases chemical treatment to reduce the viscosity will be necessary. Gelling of mud in the pits serves no useful purpose, and can be prevented by light agitation with the mud-guns while the trip is being made. Thixotropy is discussed in this connection.

Violent agitation by jetting or gunning the mud will increase its stability. Chemical treatment may either increase or decrease the stability, depending on the treatment. Presence of salt generally decreases stability, whereas bentonite greatly increases it, particularly if the mud is kept slightly alkaline. Salinity, alkalinity, and acidity of muds are briefly studied. A. H. N.

455.* Portable Spudders Used for Deepening Wells. H. F. Simons. *Oil Gas J.*, 2.3.41, **39** (46), 198.—The spudding machines have three advantages : small moving expense, very little rigging-up time, and low operating costs. The rotaries take from 18 to 24 hr. to rig up on a deepening job ; the cost of moving drill-pipe and machinery is an important item, and the labour and bit costs increase the total bill.

The deepening of the wells equipped with $4\frac{1}{2}$-in. casing would be extremely hazardous, as the smallest drill-pipe commonly used ($3\frac{1}{2}$-in.) does not permit sufficient clearance for efficient operation. Smaller sizes of pipe could be obtained, but their cost for a limited amount of work would be excessive. Holes equipped with larger casing present no obstacle to rotary drilling from this viewpoint.

For deepening the wells, both the horizontal-beam type and the oscillating-type spudders have been used ; several portable standard rig-fronts have also been at work in the field under study. In recent months some regular standard rigs have been brought into the pool. The time required to deepen the wells depends to a great extent on the efficiency of the spudder used. Spudders which are easily controlled, which have a good motion, and can hoist and lower the tools and bailer rapidly, have an advantage. The better spudders are also very easy on a drilling line, and can also make hole faster, as they have a better motion.

The modern spudders possess a distinct advantage when it comes to handling tubing, casing, and liners. Because they have multiple-speed drums, they resemble a rotary hoist, and in most cases can run casing in approximately the same time. A saving of 5 hr. is made with the better spudding machines over those not so well designed for the running of casing and tubular equipment.

With a good machine and a good crew, it is possible to complete a deepening job in less than 28 days. This was done on one of the early wells in the field, with 50 hr. of that time being lost due to a fishing job and a fire. The spudder used was of the oscillating type. As the drilling crews become more familiar with the formations and conditions encountered, this time will be reduced.

Details are given of the equipment used, of completion practice, of cementing jobs, and of other incidental operations. A. H. N.

456.* Heaving Shale Problems. H. H. Power and C. R. Houssiere, Jr. *Oil Wkly*, 3.3.41, **100** (13), 10–14. *Paper Presented Before American Petroleum Institute*.—Great pressures are encountered in deep wells, particularly in wells located on the steeply plunging flanks of salt-dome structures. It has been suggested that gliding or slipping of these steeply tilted beds is a major cause of the movement of shales into bore-holes. It has also been noted that shales which contain bentonite absorb water from drilling fluids, swell, and thereby develop pressure which squeezes or " heaves " the shale into a well.

Some operators have reported that certain shales contain large volumes of gas under extremely high pressure. Pressure relief provided by the bore-hole allows such gas-saturated shales to be blown into the hole with drastic consequences. Other operators

have described a so-called plastic flow at considerable depth. They have postulated one essential difference between a shale which flowed plastically and one which swelled due to hydration. As the plastic flow continued, its fluidity was thought to increase, and flow became progressively worse. Artificial causes are also discussed, such as the " swabbing action " incidental to removing drill-pipe. After giving the types of heaving shales in detail, each of the above causes of heaving is further discussed separately.

The methods used in combating heaving shales are reviewed. As a general consideration, the best proportions between hole-diameter and drill-pipe should be determined and maintained. Danger zones should be recognized in advance. For instance, in one field it was considered best practice to keep a close watch for calcite crystals, checking with palæontology, and to bottom the hole immediately upon the establishment of the presence of calcite, and/or " vicksburg."

Mechanical methods for keeping the water from muds off the shale have not been developed. It does not appear likely that any practical equipment will be developed to accomplish this purpose. On the other hand, the mechanical restraint of swelling shale seems impractical.

Mud weight appears to be an important physical property of drilling fluids up to a certain critical value, beyond which other properties may become of greater significance. Generally speaking, high-weight muds provide a high hydrostatic head, which may oppose shear of the shale. They may also assist in controlling high gas pressures. Fundamentally, the mud used to combat heaving shale should have the following properties : (1) inert in relation to its effect on the shale and consequent heaving ; (2) capacity to build thin, impervious walls rapidly, in order to seal off the formations from penetrating fluids—in other words, the filtration values of the mud sheath should be low ; in some cases special emphasis may be laid on extra mechanical strength ; (3) satisfactory viscosity, gel-strength, and gel-rate ; (4) capacity to reduce the tendency of ion exchange between the mud and the formation.

A research programme is outlined for tackling the problem.   A. H. N.

457.* Drilling with Water-Tube Boilers and Full Condensing Operation. Anon. *Petrol. World.* February 1941, **38** (2), 18–22.—The use of marine-type water-tube boilers for drilling purposes in California is described. Of particular interest is the fact that this departure from orthodox steam practice comes at a time when combustion-engine outfits are forging ahead rapidly, thanks to the development of hydraulic torque converters, hydraulic couplings, improved clutches, transmissions, etc.

Flow-sheets and photographs illustrate the plant. The power-plant, the cost of which is said to be comparable to or lower than conventional plants of modern design, centres around two Foster Wheeler boilers, each built to deliver 17,500 lb./hr. of 350-lb. steam at 550° F. (114° superheat). The A.S.M.E. nominal rating based on heating surface alone is 175 boiler horse-power, or the equivalent of 5630 lb./hr. under the pressure and temperature specified above. Thus it is seen that the guaranteed capacity is 311% of rating, and it is possible that considerable reserve is still available.

Structurally the boilers are portable, skid-mounted adaptation of the marine-type steam generators currently being installed in naval and cargo vessels built for high speed and economy.

With an over-all height of 13 ft. and width of 8 ft., the compactness of these boilers is surprising, particularly when it is considered that they contain about 40% more heating surface than conventional boilers outweighing them by approximately 25%. The extreme effectiveness of this heating surface is emphasized by the fact that full-load performance provides a heat-transfer rate of 9450 Btu./hr./sq. ft., compared with a fair average of about 5000–6000 in conventional practice. The superheater and burner designs are briefly described.

All exhaust steam is conserved (including that from the feed-pumps) and returned from the rig through 8-in. lines equipped with vapour-type oil scrubbers to the condenser. The surface-type two-pass closed condenser is mounted directly on the horizontal feedwater tank, which, with the necessary pumps and controls, comprises another single portable skid-mounted unit. Additional protection from oil contamination is furnished by a filtering grease extractor on the feed-water supply line to the boilers. Condensing and cooling systems are described in some detail and feed-water treatment methods are mentioned.

Amongst the advantages of the plant studied are dependability and safety. The chief disadvantage is the necessity of cooling water for condensing and cooling exhaust steam which would be felt in localities where water is scarce.   A. H. N.

458.* Few Injuries from Mechanical Failures (Safety in Drilling Operations). Anon. *Petrol. World.* February 1941, **38** (2), 38.—Of 250 injuries occurring to member-company employees during 1940, and which were studied and analyzed by the California Petroleum Safety Board, Inc., 234 were caused by errors by the men, and only sixteen by mechanical failures. Three things immediately became apparent : mechanical equipment and mechanical safeguarding have reached a point of near perfection, and no matter how much more effort is expended on mechanical safeguards, only a minor percentage of injuries will be affected ; also, as is the case in everything else, the human element is the thing that has to be reckoned with.

These figures—and others—which show that of all injuries in the oil industry, 85% are caused from human errors of judgment, inefficiency, or carelessness, point to the need for safety education. They show that the men, even though protected by the best mechanical safeguards and using the newest and most improved equipment, will be injured unless they themselves know how to carry out their jobs safely, alertly, and efficiently. Examples are given of the frequently occurring accidents—those of crushed feet and toes and of eye troubles—being minimized by co-operative and educational methods.

The accident record of the member-companies of the California Petroleum Safety Board as a whole for 1940 is declared to compare very favourably with the records of the major company group and the oil industry in general. One member-company, for example, drilled fifteen wells during 1940, and experienced a total of only seven days' lost time because of injuries to workers. The same company carried on all production activities involving the handling of 77 producing wells without a single lost-time accident to any of the producing department employees. Another company drilled eleven wells last year without a single lost-time injury to any of its employees, and at the same time handled 40 producing wells without a day lost because of an accident on the job.

One of the most significant results of the year for members of the California Petroleum Safety Board was that there were no cases of infection from cuts or minor wounds, which fact is significant because it shows the attitude of the men themselves. Minor cuts can be disregarded, thereby becoming focal points of infection, or they can be treated immediately, thus being rendered harmless. The man himself makes the determination, so that when there are no infections it indicates that the men have a definite interest in their own safety.

The interest instilled in the men themselves is the reason for the Safety Board record, which compares favourably with major-oil-company records, although the California Petroleum Safety Board has been in existence for but 4 years, and most of the major oil companies have carried on safety programmes for more than 20 years.
                                                                                A. H. N.

459.* New Portable Derrick. W. M. Greenfield. *Petrol. World*, February 1941, **38** (2), 42.—The derrick is designed for a gross capacity of 100,000 lb. when extended to its full height of 84 ft. It is of the telescoping open-face type, made in two sections capable of being extended and locked in an 84-ft. and in a 50-ft. position (the latter position for extremely heavy work). The front legs in both sections are constructed of 5 by 5 by 5/16 silicon steel angles, and the rear legs of 3½ by 3½ by 5/16 silicon steel angles. Interior bracing is of structural steel shapes. Levelling screws are used in the two front legs of the derrick. The back legs are supported by a mounting bracket on the truck, and the truck is supported underneath by legs with levelling screws.

The crown block, consisting of four 18-in. roller bearing sheaves, is built in an integral part of the derrick. The tubing-board is adjustable for height and has a capacity of 6500 ft. of 2½-in. upset tubing, racked in 60-ft. doubles. Space is also available for hanging rods in the derrick at the same time. The tubing-block and lines are strung up permanently and ready for use at all times. The same is true of the sand-line on the bailing drums.

After the unit is backed up to the well to be serviced, a hose is unreeled and connected to the dry gas-line for motor fuel.

The derrick is raised to a vertical position by means of twin screws operated by two ball-bearing bronze-alloy drive-nuts, which in turn are operated from a separate power take-off from the truck engine. The vertical position of the derrick is then ascertained by a plumb-bob arrangement mounted on the leg of the lower section. When the derrick is 4° off vertical, towards well centre, the four levelling screws are tightened until snug, and the second, or upper, section is then ready to raise.

The second section of the derrick is extended by means of a ¾-in. cable operated by a separate winch mounted on the side of the truck. After the section is raised it is locked by means of a pawl-and-lug mechanism operated from the ground. The operator does the complete erection of the derrick from one place by the truck.

A. H. N.

460.* Speed of Rotation in Rotary Drilling. R. W. Marshall. *Petrol. World*, February 1941, **38** (2), 56. *Paper Presented Before American Petroleum Institute.*—This short discourse outlines early tests to determine the optimum values of rotating speeds. Speeds between 300 and 600 r.p.m. are termed high speeds.

The present maximum speed that appears to be in use is 450 r.p.m. This maximum speed is applied in certain areas where the material is sandy shale and shale, and from a point below the surface casing at approximately 2000 ft. to a depth of approximately 6500 ft.

There are two reasons why this maximum speed has not been continued to great depths as regular practice. First, the drill-pipe at greater depth becomes more flexible, and therefore cannot be rotated safely at excessive speeds. Second, the formation being drilled becomes harder in character and is not so well suited to this maximum speed.

Tests made in limestone formation at various depths showed that speeds above 150 r.p.m. were destructive to drill-pipe and that faster penetration was possible at the lower rotating speeds of 80–100 r.p.m. This same condition will apply to some extent in any hard formation where bouncing is in evidence.

In some areas the use of rotary speeds of 175–300 r.p.m. is everyday routine, and in all cases they are used in conjunction with larger pumps and with bits that will readily clean. Bits have been so improved recently that bearing trouble is infrequent. This speed, together with limited, controlled weight on the bit, has rendered possible the drilling of straight holes with greater speed and economy. A. H. N.

461. Instruments for Logging and Sampling Oil and Gas Wells while Drilling. J. T. Hayward and L. M. Swift, *Instruments*, 1940, **13** (8), 155.—The " Bavoid Well Logging Service " is described. Twenty instruments are mounted in a trailer, and taken to the well, the necessary power for operating the equipment being obtained from the rig. The essential principle of the equipment is that a sample of the mud which has been flowing past the bit as it penetrated some known depth is abstracted from the mud return line and submitted to analysis for gas (by hot wire detector), oil (by fluorescence), and salt (by electrical conductivity). The equipment also provides depth and drilling-rate measurement, and the method of assuring that the sample of mud tested corresponds to the depth allocated to it is described. The principle would be vitiated if there should be an inflow into the mud from the surrounding strata, but this is stated to occur only rarely. Equipment for core analysis and mud testing is also included. P. D.

462. Patents on Drilling. A. Boynton. U.S.P. 2,232,688, 25.2.41. Appl. 28.11.38. Cement dump-bailer made of a tubular shell, a comparatively thin disc closing the lower end and an arcuate cutter which can slide within the shell.

A. J. Penick and K. T. Penick. U.S.P. 2,232,844, 25.2.41. Appl. 27.9.37. Casing and tubing-head assembly with an annular, resilient and flexible sealing means with a reserve supply to be screwed in when this seal wears out to an appreciable extent.

C. K. Stillwagon. U.S.P. 2,232,890, 25.2.41. Appl. 5.4.40. Derrick elevator in the form of a car running on a track attached to the side of the derrick.

W. S. Jones and C. E. Munn. U.S.P. 2,232,949, 25.2.41. Appl. 29.8.38. Overshot fishing tool with slips and packing means.

W. T. Caldwell. U.S.P. 2,232,995, 25.2.41. Appl. 25.2.41. Drilling apparatus of the rotary type whereby the drill-pipe is fed by a pressure actuated mechanism.

T. R. Alley. U.S.P. 2,233,041, 25.2.41. Appl. 14.9.39. Blowout preventer with a sealing means around a pipe being actuated by well-pressure.

H. J. Hawthorne. U.S.P. 2,233,260, 25.2.41. Appl. 12.4.38. Means and method of drilling wells by means of a rotary system utilizing hard abrasive particles carried in the mud flush to cut the formations, the abrasive particles being recirculated.

E. G. Leonardon. U.S.P. 2,233,410, 4.3.41. Appl. 4.6.37. Method of and apparatus for exploring drill-holes by means of determination of electrolyte-containing porous beds.

P. Liddicoat. U.S.P. 2,233,421, 4.3.41. Appl. 15.11.37. Detachable drill-bit for percussive drilling.

W. B. Sounitza. U.S.P. 2,233,648, 4.3.41. Appl. 18.12.37. Crown-block construction.

R. B. Bryant. U.S.P. 2,233,692, 4.3.41. Appl. 20.4.39. Drilling apparatus by a rotary system utilizing a flushing liquid for removing the cuttings.

R. D. Heater. U.S.P. 2,233,740, 4.3.41. Appl. 13.1.40. Combination rope-socket and jar, comprising an elongated perforated cylinder and a piston with a head engaging in the cylinder.

C. S. Howe. U.S.P. 2,233,867, 4.3.41. Appl. 18.6.38. Suspension of solids and method of making it for use as an aqueous drilling fluid containing a treater dust.

R. R. Proctor. U.S.P. 2,233,872, 4.3.41. Appl. 27.7.36. Means and method for solidifying underground structures by using an initially fluid but finally set hydraulic cement.

T. H. Dunn. U.S.P. 2,233,973 and 2,233,974, 4.3.41. Appl. 22.6.39 for both. Slow-setting cements containing an alkali metal hexametaphosphate and an alkali-metal triphosphate, respectively.

R. D. Wyckoff. U.S.P. 2,233,992, 4.3.41. Appl. 3.1.38. Method and apparatus for surveying wells by means of measuring the speed of sound in the various formations.

M. Williams. U.S.P. 2,235,955, 25.3.41. Appl. 21.9.37. Addition agent for enhancement of the properties of drilling mud, consisting of a water-soluble glass containing a phosphare radical and a normally solid element.

R. R. Crum. U.S.P. 2,235,982, 25.3.41. Appl. 20.6.39. Core-bit with roller cutters.

G. H. Trevor. U.S.P. 2,236,022, 25.3.41. Appl. 10.7.39. Rope-socket.

A. H. N.

Production.

463.* Removal of Paraffin by Electrical Heating from the Producing Wells in the Texas Panhandle. B. Turner and C. R. Rider. *Oil Gas J.*, 6.3.41, **39** (43), 34. *Paper Presented Before American Petroleum Institute.*—Basically the method supplied heat to melt the paraffin in the tubing by passing a direct current through the tubing and rods and using them as elements of a resistance heater. The tubing is insulated from the tubing-head and casing by special insulators. At a point in the well below which paraffin is known to form, contact is made between the tubing and casing to complete the circuit to the surface. Heat is generated in the tubing and rods rather than in the casing, because the former have a smaller metal area, with a consequent higher resistance.

Current is supplied at the surface by a direct-current, shunt-wound, high-amperage, low-voltage generator. Contact is made to the well-head by means of removable cables, the tubing being used as the positive, and the casing as the negative terminal.

Special well equipment is necessary, and this, together with the details of operations involved, is described and illustrated.

The following conclusions are reached from the study up to date : (1) By electrical heating with a 70-k.w. d.c. generator, the paraffin in the average Texas Panhandle well can be returned to the fluid state in not more than 90 mins. treating time. (2) The cost of installing electrical heating equipment in a well will not, in most cases, exceed one-half that of a normal pulling and stripping job. (3) When a well has frozen tight with paraffin but no mechanical failure has occurred, approximately 80% of the cost of pulling and stripping the paraffin from the tubing and rods can be saved by melting the paraffin electrically and pumping it out of the well. (4) When a well has suffered mechanical failure and substantial amounts of paraffin are between the rods and tubing, approximately 50% of the pulling cost can be saved by melting the paraffin by electrical heating before pulling the well. (5) There are no occupational or well hazards of an unusual nature connected with the application of this process. (6) Fusing of the tubing to the casing or of the contactor to the casing is not possible under the methods of treatment now being used. (7) Fusing of the tubing couplings is not to be feared, because the couplings constitute points of low resistance. (8) In general, in the Texas Panhandle it is not necessary to heat the paraffin in the tubing to a temperature in excess of 100° F. to be able to pump it from the well. (9) The tubing insulators and the contactor offer no obstruction to obtaining the fluid level of the well by the sonic-reflection method. A. H. N.

464.* Practical Economics of Cycling. B. B. Boatright and P. C. Dixon. *Oil Gas J.*, 6.3.41. **39** (43), 41. *Paper Presented before American Petroleum Institute.*—A preliminary investigation is always advisable before seriously considering any cycling project, as this casual survey will frequently reveal conditions that preclude a reasonable chance of success. This survey need not be exhaustive, but should include a brief investigation of available data to determine : (a) that the distillate content of the gas is sufficient to justify treatment ; (b) that there is a possibility of unitizing sufficient acreage to assure an adequate gas reserve ; (c) that contractual requirements are not prohibitive or, in the event of them being prohibitive, that they can be modified ; (d) that well potentials are sufficiently high to obviate the necessity for an excessive number of wells ; and (e) that subsurface conditions are favourable for cycling. In the event of a cycling project appearing desirable after preliminary examination, a thorough evaluation is in order.

Sampling of the well products must be conducted with a maximum degree of accuracy, for all economic considerations will be based on the computed recovery shown from this test. The probable degree of accuracy may bear a relationship to the time of test, or to the degree of refinement of gas and liquid measurement, but in any event the limits of accuracy are known by the person conducting such a test, and these limits should be carried through to the final balance sheet of proposed operations.

Total reserves in place in the reservoir must be calculated, and this is done in the conventional manner. Deviation due to supercompressibility and surface shrinkage due to condensation of liquids should be determined, and the proper correction factors applied if these factors are in excess of the limits of accuracy of the metering or the analyses from which the factors must be calculated. Average sand thickness is derived from the customary sources, but at this point a new element may enter some calculations. If the reserve calculations were being made to determine total gas reserves in place and available for pipe-line sale, the entire sand section containing gas is usually weighed for average porosity and connate water to determine the void space containing gas.

Other factors are similarly studied to decide the drainage and development patterns, plant type and size, the possibility of unitization, etc.

The purpose of this paper is to present in practical form a discussion of factors which, in the ultimate analysis, determine the probable degree of success and profit to be derived from a cycling enterprise. In order to co-ordinate the presentation of many divergent subjects, it is written as though directed to persons who seek a pattern about which they may intelligently attack the problems of inspecting and possibly developing a cycling project. A. H. N.

465.* Energy Requirements for Pumping Oil Wells. S. B. Sargent, Jr. *Oil Gas J.*, 6.3.41, **39** (43), 51. *Paper Presented before American Petroleum Institute.*—The

approach to the problem was started by plotting data from a group of wells in the form of a curve showing production as a function of depth. The wells selected were scattered throughout various areas in the United States.

Some theoretical basis for the performances involved was then sought. It was felt that the solution might lie in the horse-power which any given string of sucker-rods might transmit.

The first step in the study was to develop a method of evaluating the hydraulic horse-power required. The hydraulic horse-power required to produce a well is given by the expression : $\text{Hp.} = (\text{Brl./day}) \dfrac{(\text{Operating depth})}{1,000} (0\cdot0074)$. From this, of course, it is necessary to subtract the work done by expanding gas. An approximate expression for the horse-power available by expanding any given volume of gas is : $\text{Hp.} = \left(\text{P.V.} \log_e \dfrac{\text{P}_2}{\text{P}_1}\right) (4\cdot75 \times 10^7)^{-1}$.

The utilization of this energy is determined by the efficiency of the system. A graph gives a probability curve for gas-lift efficiency as determined from about 450 installations. The most probable efficiency according to this curve is 10%. This value seems reasonable, and in keeping with the general opinion expressed by various operators.

The determination of the horse-power transmitted by a string of sucker rods is based on the conception of the work involved in deforming them and the number of times/sec. that this is done at a frequency equal to the natural period of the rods. The natural frequency was chosen, as it is a frequency with which the rods vibrate on the imposition of any given force on them.

Equations are developed on these assumptions. This study suggests that sucker-rod pumping has an exceedingly wide application, both as to depth and quantities of fluid which can be produced by the method. It carries the additional suggestion that large quantities of fluid, such as 15,000 bbl./day, are within the realm of sucker-rod pumping. The paper further suggests the possibility of successful pumping of depths of 12,000–15,000 ft.

Perhaps the most pertinent suggestion is that sucker-rod pumping installations are the heavy-duty lifting installations commonly used for pumping oil, and that they are capable of even further development in this field of application. The corollary of this statement is that perhaps in many light installations, heavier pumping installations than necessary are used, which has often resulted in the use of other means of producing oil, whereas the pumping installation might well have served the purpose to better advantage.   A. H. N.

466.* **Experimental Investigation of Gas-Well Gauging.** D. J. Grady, Jr., and A. L. Vitter, Jr. *Oil Gas J.*, 27.3.41, **39** (46), 200.—A preliminary discussion of the accuracy of Oliphant and Reid's formulæ for pitot-tube measurements of gas-flow shows the superiority of the latter formula for open-hole gauging of gas-wells. Pitot-tube measurements can be misleading if stabilization of the well is not certain before the impact-pressure observation is made. Therefore, the time necessary for stabilization must be ascertained to assure reliable open-flow-capacity determinations. Preliminary tests seemed to indicate that in the case of the larger wells, the well is almost stabilized within 15 mins., although a small decline thereafter is realized. On the other hand, actual tests show small wells not having reached stability after $1\frac{1}{2}$ hrs.' blowing.

An attempt was made to establish from fundamental theory what might be the time expected as the time of stabilization. Starting from the equation of state of a gas, Darcy's law of viscous flow of fluids through porous media, and the equation of continuity, the deductions show the time required for stabilization and the predicted open flow at the time under certain assumed conditions. There are, in the theoretical formula, four factors which are unknown, viz., (1) H, effective thickness of producing section ; (2) k, permeability of producing section ; (3) R_w, well-bore radius ; (4) R_e, effective drainage radius.

The assumption of any one of the first three necessarily determines the remaining two, and the fourth is assumed independently. Therefore, only two independent assumptions are made, and both can be estimated within reasonable limits. It is not the intention to accord too much weight to the numerical theoretical deductions, but they do give indications of unreasonably long time-periods for stabilization. Observations support these conclusions,

Back-pressure methods were then tried. The wells were " rocked-up " for 24 hrs. prior to the test, and this practice introduces an abnormal condition around the well. Another difficulty encountered in interpreting the tests was in ascertaining whether the correct shut-in pressure had been obtained. In a majority of the wells the pressure will continue to rise for several days after closing the well in, and the amount that it will rise per day will be irregular and affected by offset operations. Thus it has been established that in the Monroe field the actual blowing of wells to the atmosphere clearly gives unreliable results and involves a pointless waste of gas. The regular back-pressure test is impractical because of the time involved, and shortening of the tests leads to unreliable results. The authors then develop a test which they call " productivity test," and give a chart to simplify its plotting.

The data necessary are the working pressures and respective rates of flow at two different producing rates. The points should be taken such that the working pressures are reduced approximately 10 and 50% from the closed-in pressure. The closed-in pressure may be used as a point in place of the 10% pull-down point, if it is felt that the closed-in pressure is reliable. However, the suggestion is offered that the independence of this test from the closed-in pressure is an advantage, since, as already mentioned, closed-in pressures are more susceptible to error due to offset operations. The simplicity of the productivity well-test form facilitates its use directly in the field or office without the need of calculations, excepting the rate of flow of gas from the orifice-meter readings.

In conclusion, the productivity test is shown to give a reliable gauge in a minimum of time. It is practical for one man to obtain productivity tests concurrently on fifteen to twenty wells over a period of 2–3 days. Thus, it requires about the same amount of time to gauge all the 1300 wells in the Monroe field as is required by pitot-tube open flow—that is, on the assumption that in front of and behind the man making the pitot-tube measurements there are crews breaking down the connections on the wells and making them up again. A. H. N.

467.* **Field Tests of Gas show Prospects for Cycling.** E. O. Buck. *Oil Wkly*, 3.3.41, **100** (13), 15–17. *Paper Presented before American Petroleum Institute.*—The testing of wet gas and its associated free liquid for liquid content is not a simple process like testing dry gas.

First, the product from the well is two-phase—that is, a mixture of gas and liquid instead of true gas. Second, the amount of liquid or the gas–liquid ratio varies throughout the flow system, depending on pressure and temperature.

A study of the gas–liquid ratio reveals that in most instances all the product is in a gaseous or single-phase state under reservoir pressure and temperature, and that condensation occurs in varying amounts as pressure is released and temperature reduced. Liquid condensation increases until the optimum conditions are reached ; the process then reverses and the vaporization of liquid starts. Thus, for any wet gas there is a definite pressure at a fixed temperature where a maximum condensation occurs. This point can only be determined by actual testing.

Field testing has now advanced to a point where, in working in conjunction with the laboratory, all the economics of a recycling plant can be determined. These tests can be taken somewhat as follows : (1) The productivity index of the well or wells should be determined. This test will determine the number of wells necessary to supply a sufficient volume of gas for recycling operations. (2) The total liquid content of the gas must be known. This fact enables the operator to decide if the liquid yield is sufficient, for the volume of gas processed, to offset the expense of constructing and operating a plant. (3) The chemical composition of the flow-stream must be accurately-determined for a basis for plant design. (4) Complete liquid, pressure, and temperature curves must be plotted on the mixture. These data balance the economy of plant-operating pressure with compression costs to give the greatest liquid yield at the lowest possible operating expense.

The potential test can be taken by the usual " back-pressure methods," by producing the well through various size orifices and measuring the gas and corresponding pressure drops. Texas conservation regulations permit a daily production of 25% of the open-flow potential of the well.

The usual physical gas-analysis tests are now conducted by the continuous-sampling method. This method of testing offers many advantages over other methods formerly in use. Some details are included regarding the tests and methods of interpreting the data. A. H N.

468.* **New Uses Found for Acid in Production Work.** B. Mills. *Oil Wkly*, 10.3.41, **101** (1), 14–17.—Acidization, until quite recently a practice confined to increasing oil and gas production from limestone formations, is now being employed extensively for many other purposes, including dissolving or removing drilling mud left in or on the producing formation; cleaning screens and perforations; releasing stuck drill-pipe; cleaning and completing salt-water-disposal wells; completing gas-injection wells, and increasing oil and gas production from sand formations.

Development of an acid or chemical solution capable of dissolving the mud cake often left in producing wells prompted use of acid for treating the sand formation itself. The acid acts as a solvent for bentonitic materials and carbonates, and apparently increases the porosity and permeability of the oil-sand near the hole.

One acid developed for dissolving clays used in drilling mud consists of such agents as inhibited hydrochloric acid, to which have been added several chemicals that sharply change the action of the solution. The additions include several wetting agents and surface-tension reducing agents. The acid used for treating the oil-sand to increase porosity and permeability is the same as or similar to that used for dissolving mud and for cleaning screens and perforations. Laboratory tests have proved that the solubility of clays is increased greatly in hydrochloric acid by the addition of certain agents. Chemical companies making this acid have, however, withheld its exact nature.

Inhibition of the chemical solution is a prime consideration, since high bottom-hole temperatures tend to accelerate the corrosive action of certain acids. Screen design also is such that only inhibited acid may be used with safety.

Various acidizing jobs varying widely in character and objective to be attained are given in some detail.

Several unusual results have been observed after acid treatment in sand wells. In one well making 15 brls. of water and 20 brls. of oil daily before treatment, water production after treatment was reduced to zero and oil production increased to 37 brls. In another well that made no water along with 41 brls. of oil daily before treatment, water production after treatment was 77 brls. and oil production 25 brls. daily.

Acid has been used to free stuck drill-pipe, but results have not been altogether favourable. Where it has been possible to concentrate the acid on the affected area, the drill-pipe has been freed in a few wells. It is often difficult to determine the exact point of trouble in the hole, and the failure of many attempts to free drill-pipe has not been the fault of the acid.   A. H. N.

469. Patents on Production. J. B. Stone and P. G. Shelley. U.S.P. 2,232,931, 25.2.41. Appl. 23.3.38. Method of treating wells with hydrochloric acid in which a small proportion of certain classes of organic aromatic nitrogen compounds is added.

L. C. Chamberlain. U.S.P. 2,232,938, 25.2.41. Appl. 1.2.39. Treatment of wells with hydrochloric acid solution containing between 5% and 20% of a water-soluble calcium salt.

D. G. Hefley. U.S.P. 2,232,946, 25.2.41. Appl. 2.3.38. Method of cleaning wells by means of alkaline starch solution to remove detritus by means of gas pressure, and later decomposing the solution deposits on the tubing by means of hydrochloric acid.

G. A. Humason and W. J. Clay. U.S.P. 2,233,013, 25.2.41. Appl. 25.1.38. Combination packer and swab device.

K. T. Penick. U.S.P. 2,233,029, 25.2.41. Appl. 14.6.38. Counterbalance device for use with the walking-beam of a well-pumping unit, consisting of a pneumatic cushioning device.

K. T. Penick. U.S.P. 2,233,030, 25.2.41. Appl. 15.7.38. Pump-plunger.

C. P. Gillespie and E. L. Barber. U.S.P. 2,233,077, 25.2.41. Appl. 10.10.38. Well-controlling apparatus, to be used with flowing wells, in which a valve located in one of the branches of the Christmas tree closes when rate of flow exceeds a certain predetermined value.

H. W. Ramey. U.S.P. 2,233,225, 2,233,226, and 2,233,227, 25.2.41. Appl. 14.9.37, 8.8.38, and 27.12.38, respectively. Hydropneumatic counterbalance for parts having uniform relative movement, utilizing gases and liquid in compression chambers.

R. G. De La Mater. U.S.P. 2,233,245, 25.2.41. Appl. 3.8.37. Hydropneumatic counterbalance for a member having uniform relative movement, utilizing gases, and liquids in compression chamber.

J. G. Staudt. U.S.P. 2,233,271, 25.2.41. Appl. 17.2.38. Treatment of wells by means of alternate introduction into the formation of acid alone and of acid and a non-penetrating liquid mixture to seal the pores of the formations.

M. De Groote and B. Keiser. U.S.P. 2,233,381 and 2,233,382, 25.2.41. Appl. 6.3.40 for both. Flooding processes for recovering oil from subterranean oil-bearing strata in which an aqueous solution of a water-soluble, surface-active, alkaline earth-resistant polyglycol ether of certain reactions is used.

F. M. Mason. U.S.P. 2,233,672, 4.3.41. Appl. 6.12.37. Submersible electrical motor having a neutral liquid in the casing of the motor, and a gas-forming apparatus for lowering the liquid in the casing and creating a gaseous atmosphere.

V. A. Hoover. U.S.P. 2,233,890, 4.3.41. Appl. 8.12.37. Eccentric suspension and cable connection for submersible motor-pumps.

F. A. Witt. U.S.P. 2,233,930, 4.3.41. Appl. 4.8.38. Oil-well cleaner for perforated casing by means of blasting portions of a sleeve, which is supported against the casing, through the perforations.

W. F. Grisham. U.S.P. 2,236,137, 25.3.41. Appl. 25.2.38. Flow-valve for use in well-tubing.

G. D. Johnson. U.S.P. 2,236,177, 25.3.41. Appl. 21.12.36. Control-valve for well-casings.

G. N. Foggan. U.S.P. 2,236,210, 25.3.41. Appl. 2.11.39. Oil-well pump and sand-trap.

C. A. Combs. U.S.P. 2,236,332, 25.3.41. Appl. 7.7.39. Well-control equipment consisting of a separator for water and oil-fluids. A. H. N.

Natural Gas.

470.* Liquefying Natural Gas for Peak Load Supply. R. W. Miller and J. A. Clark. *Chem. Met. Eng.*, January 1941, **48** (1), 74–76. *Paper Presented before American Gas Association.*—Generally speaking, the pipe-line has been the gas-holder of the natural gas utility. Natural gas has been stored in the pipe-line by the simple expedient of raising pressures therein during the night to the limits allowable. The gas thus stored is available during the following day.

It has become increasingly evident, however, that such a method is not entirely successful under all conditions, and must be supplemented or augmented by storage at or near the point of use. Various methods were tried between August 1937 and 1939.

By September 1939 research work had progressed sufficiently far in the laboratory to warrant the erection of a pilot plant, wherein relatively large quantities of natural gas could be liquefied, stored, and regasified, making use in a practical way of the methods developed on a small scale, and whereby certain preconceived ideas could be tried out for the first time.

It was realized that early in cooling the gas for liquefaction, water, and carbon dioxide would solidify and completely plug the tubes, so that these materials had to be removed at the very start of the process. For this, a scrubbing plant using mono-ethanolamine and diethylene glycol was first introduced, followed by two tanks filled with granulated aluminium oxide to remove the last trace of water vapour.

For storages a horizontal symmetrical tank was used, 10 ft. in diameter by 18 ft. long, holding 14,500 gal., equivalent to about 1,000,000 cu. ft. of gas. This was made of alloy-steel plates, and was covered with 2 ft. of formed cork, cemented on and water-proofed with bituminous tar.

The working of this pilot plant and the conclusions reached are reported in detail. Based on these conclusions a large-scale plant is being built using spherical tanks with 3 ft. of cork insulation for storing the liquid. A. H. N.

471. Natural Gas in Brantford Area, Ontario. J. F. Caley. *Canada Department of Mines and Resources.* *Geol. Surv. Paper* 40–22. Ottawa, 1940.—The author of this report, which is the forerunner of a more detailed and comprehensive paper on the same subject, suggests that, in view of the present more or less acute natural gas position, possibilities of increased production both from tested and untested parts of Brantford Area, Ontario, might usefully be investigated.

The area includes approximately 4800 sq. miles, and extends in an east–west direction from Dundas to Aylmer and in a north–south direction from Mount Forest to the north shore of Lake Erie. At the present time production is confined to that part of the area which lies south of the latitude of Paris. All the natural gas is drawn from rocks of Silurian age—namely, Clinton, Guelph, Grimsby, and Whirlpool formations.

Contours drawn on top of the Clinton formation show that the general structure on this horizon has a southerly dip averaging about 24 ft. per mile over the entire producing area. There are local variations and reversals in dip, but few definite folds with strutural closure. There is no apparent relation between structure and the presence or absence of producing gas. Accumulations of gas are for the most part due to the porous character of certain beds and the existence of gentle anticlinal rolls or decreases in regional dip.

Inasmuch as presence or absence of features favouring accumulation of natural gas cannot be foretold and there is no evidence of their being confined to the southern productive area, it is conceivable that they may equally occur in other parts of the area. In fact, if, as the author believes, porosity, differential cementation, and stratigraphic form, combined with gentle anticlinal rolls and local flattenings of the regional structure, account for the gas-fields so far discovered in Brantford Area, then much of the untested country in the southern part intervening between producing areas should prove worth testing.

Natural gas has so far not been found in commercial quantity in that part of the area north of the latitude of Paris and, of the producing horizons in the south, only the Guelph presents any prospects of production in the northern region. Nevertheless only a relatively small amount of drilling has been done, and the fact that shows of gas have been obtained might justify further exploration. H. B. M.

472.* Dehydrogenation of Propane Gas Produced from Kinsui. K. Shiomi and H. Nishimata. *J. Soc. Chem. Ind. Japan*, December 1940, **43** (12), 451 B.—An investigation has been made of the hydrogenation of propane gas from Kinsui at the reaction temperature from 500° to 700° C. with Al_2O_3–Cr_2O_3 as catalyst. The yield of total olefines in the presence of catalyst was much larger than that obtained in its absence at the same reaction temperature. The units are shown in the following table :

Reaction temperature (° C.).	Flow rate (l./hr.).	Degree of expansion *	Concentration of olefines in exit gas, % by vol.				Conversion to olefines, % by vol.			
			C_4H_8.	C_3H_6.	C_2H_4.	Total.	C_4H_8.	C_3H_6.	C_2H_4.	Total.
518	4·8	1·30	4·30	9·20	3·07	16·57	5·82	12·5	4·15	22·47
606	,,	1·80	5·62	11·4	5·08	22·10	10·20	20·4	9·15	39·75
650	,,	1·82	3·95	14·1	10·1	28·15	7·20	25·7	18·4	51·30
703	,,	2·02	2·90	10·8	17·9	31·60	5·83	21·8	36·2	63·83

B. M. H. T.

473.* Composition of Natural Gas Produced from Kinsui, Taiwan. A. Matui and M. Yasuda. *J. Soc. Chem. Ind., Japan.* December 1940, **43** (12), 454B.—The composition of the natural gas was determined using Podbielniak's low-temperature fractionating apparatus.

The result of the analysis is as follows :

0·74% CO_2 ;   94·75% CH_4 ;   2·30% C_2H_6 ;
0·86% C_3H_8 ;   0·27% O_2 ; and 1·08% N_2.

B. H. M. T.

* The ratio of the volumes found after and before the reaction.

Cracking.

474.* Hydro-Cracking of Gas Oil, Part I. H. Otuka and Y. Miyahara. *J. Soc. Chem. Ind.*, Japan, November 1940, **43** (11), 363B.—The effect of reaction temperature has been observed on the hydro-cracking of a Siragiku gas-oil, ammonium thiomolybdate being used as catalyst. The yield of liquid products was highest at 400° C. and lowest at 550° C., the maximum yield being at 450° C. The hydro-cracked gasoline consisted mainly of naphthene, paraffin, and aromatic hydrocarbons.

At temperatures between 400° C. and 500° C. the hydrogen consumption was almost constant (3–4% by weight of the sample).

At 550° C. the apparent consumption of hydrogen was very small owing to hydrogen evolution, due to dehydrogenation reactions which occurred at this temperature.

B. M. H. T.

475.* Hydrocracking of Gas Oil, Part II. H. Otuka and Y. Miyahara. *J. Soc. Chem. Ind.*, *Japan*, December 1940, **43** (12), 454B.—This investigation deals with the hydro-cracking of a Siragiku gas-oil in the presence of nickel catalyst. The maximum yield of hydro-cracked gasoline was (as in the case when molybdenum catalyst was employed —see Abstract No. 474) obtained at the reaction temperature of 450° C. The amount of gaseous products including heavy hydrocarbon gases adsorbed by active charcoal increased rapidly with the rise of reaction temperature. Comparing the results with those obtained with the molybdenum catalyst, it is seen that the amount of gaseous products was generally larger with the nickel catalyst, except at 400° C.

The nickel catalyst was more destructive in action and more sensitive to temperature than the molybdenum catalyst. B. H. M. T.

476. System of Interlocking Air-Operated Controllers Applied to Oil Cracking. S. H. Isaacs. *Instruments*, 1940, **13** (8), 216.—A system of controllers is described which enables the top temperature of a distillation tower and the temperature and oil level in an accumulator drum to be automatically maintained by a single stream of oil.

P. D.

Hydrogenation.

477. Patents on Hydrogenation. A. V. Grosse. U.S.P. 2,231,446, 11.2.41. Appl. 14.4.37. Catalytic hydrogenation of hydrocarbons by subjecting them at a tempera-ture between 400° and 700° C. to contact with dehydrogenating catalysts. The re-action is carried out in containers the inner surfaces of which, exposed to the hydro-carbons and catalyst, are composed of an alloy consisting essentially of aluminium and copper, and are substantially free from iron and tin.

H. Dreyfus. U.S.P. 2,231,990, 18.2.41. Appl. 20.7.38. Production of hydro-carbons by the reaction of carbon monoxide and hydrogen in the presence of a hydro-genating catalyst. The absolute pressure in the reaction zone is normally above 0·5 atmosphere, but is periodically reduced to below 0·5 atmosphere without inter-ruption of the flow of the reactant gases whenever the activity of the catalyst falls considerably. H. B. M.

Polymerization.

478.* Catalytic Polymerization of Ethylene under Ordinary Pressure. Y. Konaka. *J. Soc. Chem. Ind.*, *Japan*, November 1940, **43** (11), 363B.—Continuing the researches on the polymerization of CH_4, the author has studied the effect of H_2 and N_2 as media on the formation of polymer oil. When CH_4 and H_2 mixture was used, lower yields of polymer oil were obtained than with CH_4 alone, the proportion distinctly decreasing with increasing amount of H_2. Nitrogen had no effect on the polymerization of CH_4 apart from acting as a diluent. The rôle of CH_2 in the course of oil formation was also investigated. Using CH_2 alone, the oil yield was very poor and catalytic activity was quickly destroyed. CH_2–H_2 mixture in proportion 1 : 1 gave the maximum yield of polymer oil and the longest catalytic life. The polymer oil obtained from the latter was mainly composed of aromatic and olefinic hydrocarbons, and the greater part of the product distilled above 100° C. These results were quite different from

P

those obtained with the oil from CH_4 only, which was composed of paraffinic hydrocarbons and distilled below 100° C. The chemical composition of the oil obtained from CH_2, CH_4, and H_2 mixture also distinctly differed from that of the oil from CH_4 only, the former being mostly composed of aromatic and olefinic hydrocarbons.

B. M. H. T.

479. Patents on Polymerization and Alkylation. Standard Oil Development Co. E.P. 534,151, 28.2.41. Appl. 22.8.39. The invention refers to the conversion of normal or straight-chain hydrocarbons into more valuable isomers having branched-chain structure, and particularly to the conversion of straight-chain paraffinic hydrocarbons into branched-chain olefins. The original hydrocarbons are subjected at a temperature between 600° and 1100° F. at atmospheric pressure for a period of 5–200 sec. to the actions of isomerization catalysts. Examples of such catalysts are aluminium oxide and aluminium silicate in porous form such as bauxite, clay, kaolin, alone or on a carrier such as silica gel. They may be further activated by treatment with a mineral acid or a Friedel–Crafts catalyst such as aluminium chloride or iron chloride.

V. Komarewsky. U.S.P. 2,230,461, 4.2.41. Appl. 25.2.38. Production of aromatic hydrocarbons by contacting normally gaseous olefins at polymerizing temperature with a granular catalyst comprising a phosphoric acid and a metal of the eighth group of the periodic table.

A. Schwarcman. U.S.P. 2,230,470, 4.2.41. Appl. 8.2.39. Polymerization or bodying of fatty oils by heating to a temperature between 500° and 600° F. in the presence of a small amount of a polycyclic aromatic compound carrying at least two phenol groups and a carboxyl group, and adapted to catalyze polymerization of the oil.

E. T. Layng. U.S.P. 2,230,648, 4.2.41. Appl. 1.6.39. Method of converting olefinic hydrocarbons into hydrocarbons of higher-boiling points by contacting the former at an elevated temperature with catalytic material comprising as an essential ingredient mercury pyrophosphate.

E. T. Layng. U.S.P. 2,230,978, 4.2.41. Appl. 1.6.39. Treatment of an olefin-rich hydrocarbon mixture by contacting it at an elevated temperature with catalytic material containing as an essential ingredient a metal pyrophosphate capable of reduction to an active modification which is a polymerization catalyst. The catalytic material is maintained in a reducing atmosphere other than the said olefin-rich hydrocarbon mixture at an elevated temperature, and for sufficient time to effect reduction of a portion of the metal pyrophosphate to the active modification thereof. Thereafter passage of the olefin-rich hydrocarbon over the catalyst is initiated at a temperature not much greater than 600° F.

J. C. Morrell. U.S.P. 2,231,452, 11.2.41. Appl. 16.10.39. Production of higher-molecular-weight hydrocarbons from paraffin and olefin hydrocarbons by simultaneously contacting an alkylatable paraffin and an olefin with a phosphoric acid catalyst at a controlled reaction temperature.

M. Levine. U.S.P. 2,233,951, 4.3.41. Appl. 8.4.37. Method of polymerizing gaseous olefinic hydrocarbons to produce low-boiling liquid hydrocarbons. The hydrocarbons are heated in their reaction zone in contact with nitrosyl chloride and at a temperature sufficiently high to effect polymerization of the hydrocarbons. Afterwards they are condensed and the liquid hydrocarbons so formed collected.

H. B. M.

Refining and Refinery Plant.

480.* Testing of Furnace Oils Presents Difficult Problem. A. W. Trusty. *Refiner*, March 1941, **20** (3), 71–73.—Generally clean, distilled oils are necessary for satisfactory operation of pressure burners. A viscosity of 45 sec. is considered the maximum for good operation on pressure-type burners operating at low feed-rates.

Pot-type and vaporizing burners have no fans or blowers, and generally burn a No. 1 grade of oil. Domestic atomizing-type burners of the gun-and-vertical-rotary type generally burn a No. 3 oil. The significance of flash point, pour point, water and

sediment, carbon residue, ash, distillation, sulphur, colour, thermal value, and of stability tests is briefly described in short paragraphs for each test. Three tests for stability are given : the ferric sulphate test, the heater test, and the oven test.

The deposition of sludge during the heating test is apparently caused by condensation of some of the more unstable unsaturated hydrocarbons. However, it should be noted that the unsaturates are not the sole cause of the sludge. In some cases it is reported that straight-run oils have caused complaints of sludge deposition. Part of the deposit in this case was no doubt caused by the formation of soaps by reaction of the copper or iron equipment with organic acids in the oil. Resinous condensation products may also be formed.

The source of most furnace oils is usually : (1) straight-run oil from the topping operation ; (2) gas oil from the cracking operation. In the past most of the furnace oils were straight-run products. Cracked furnace oils could be produced which would meet all the specifications for a No. 1, 2, or 3 oil, but complaints of poor colour stability and sludge formation were received in some cases.

Colour stability is a requisite for a satisfactory oil, not from a performance viewpoint, but from the customer sales viewpoint.

Another more serious complaint was the deposition of a sludge, or resin, which clogged filters, lines, and burner tips. The factors which accelerated this condition were : (1) Brass or copper lines and screens. The copper metal acted as a catalyst to accelerate the deposition. (2) Heat. Some types of burners were equipped with pumps which by-passed the excess oil back into the storage tanks. This excess oil received a certain amount of preheating, which gradually raises the temperature of the main body of oil in the storage tank. (3) The type of oil. In general, the more highly cracked oils, containing high percentage of unsaturated compounds, have more trouble with sludge deposition.

A strong caustic wash has been found effective in treating cracked furnace oils. Usually a caustic wash is not sufficient treatment to produce a satisfactory oil as tested by any of the three suggested methods, but in most cases the caustic wash will reduce the sludge-depositing tendency to half its original value.

Treatment with sulphuric acid and subsequent neutralization with an alkali is probably the surest and most effective method of producing a satisfactory oil. The quantity of acid will vary with the nature of the oil, but 3–10 lb. of acid/brl. will be sufficient for most types of cracked gas-oil. A. H. N.

481.* Centrifugal Separation of Doctor-Black-Strap Emulsions. H. Bottomley. *Refiner*, March 1941, **20** (3), 74–76.—In all doctor-treating systems black-strap emulsions— *i.e.*, PbS–spent Plumbite–oil—are present to some extent, depending on the type of material being treated and the local conditions affecting such treatment. It is the general condition that more black-strap emulsion is formed in doctor-treating sour gasolines than those of lesser mercaptan content. Also the type of treating equipment, batch or continuous, affects the emulsion formation in addition to other factors, such as the turbulence obtaining in the mixture of the reagents with the oil, the hardness of the water used in making up the doctor solution, and soaps present in the oil being treated.

The continual formation of these emulsions, which are difficult to break economically by former means, substantiates many of the arguments against doctor treatment. The loss of the oil contained in the emulsion, the chemical inactivity of the lead sulphide that is coated with the oil, and the utilities required properly to regenerate the recovered black-strap are items that loom large in the treating schedule. If the oil phase is not completely removed from the treating solution, heavy ends remain, that on subsequent revivification of the lead sulphide are oxidized, thus causing deterioration and increase in the gum content of stocks treated with this solution. In addition to the monetary loss involved in evaporating the gasoline from the black-strap, the vapours evolved constitute a distinct fire-hazard.

Gravity settling of these emulsions is not successful, as judged after many years of experience. The purpose of the centrifuge described is to accelerate the settling rate and make the separation sharper than is normally obtainable by multiplying the force of gravity by a large number. Until recently no centrifuge was available that could discharge solid material continuously ; the machine described successfully accomplishes this separation. The centrifuge is described in detail, but to understand its operation

reference should be made to the original paper for the illustrations. It is a modified bowl-type; the solid material is discharged continuously from the bowl without the use of any moving mechanical contrivance.   A. H. N.

482.* Perco Copper Sweetening. M. W. Conn. *Refiner*, March 1941, **20** (3), 77–85.— Discussing the chemistry of copper-sweetening, it is noted that the reaction is essentially an oxidation–reduction one, involving the mercaptan constituents of the sour oil and cupric copper solutions. This fact imposes on the design and operation of a copper-sweetening unit two fundamental conditions, viz. (*a*) that the sour oil be intimately contacted with the copper solution, and (*b*) that the cuprous chloride and hydrochloric acid formed in the reaction be retained in the solution and intimately contacted with molecular oxygen as the revivifying agent. As a result of these two requirements, two separate and distinct modes of application of copper-sweetening have been developed which are generally known as the " solid process " and the " liquid and solution process," both of which are based on identical chemical principles.

It is essential in either process to have the sour oil free of hydrogen sulphide and elementary sulphur prior to contact with the copper reagent. Unless these substances are removed by stabilization and refractionation, caustic washing is usually employed in the conventional manner for the removal of hydrogen sulphide, or a caustic solution of polysulphide ions may be employed for the removal of both elementary or corrosive sulphur and hydrogen sulphide. Some gasolines have an inherent tendency to retain caustic solution in suspension for periods longer than it is economical to allow for proper settling. In these cases it is expedient to add some sort of filter between the caustic settler and the copper treater—usually sand and rock, to knock out the final traces of suspended caustic.

A detailed account is given in the succeeding paragraphs of both the solid and the solution processes.

The materials of construction for the pre-caustic wash and the sodium sulphide systems are ordinary steel, as required in any conventional caustic washing system. It is customary to apply one or two coats of an acid-resisting varnish to the interior walls of the steel reagent towers used in solid units. The application of this varnish prevents any corrosion of the interior of the tower by the solid-copper reagent.

In a solution-process unit that portion of the equipment which is in contact with copper solution, including the copper contactor, separating tank, regeneration tanks, and the intermediate piping, valves, and fittings, must be made of a corrosion-resistant material capable of withstanding the copper solution. Due to a series of important improvements that have been made in the last few years in suitable corrosion-resistant materials, the design of the recently constructed solution-process units differ to a very large extent from that of the first commercial unit put into operation several years ago. These differences are detailed.

Curves for construction costs are given for both processes. After discussing operation advantages, several typical plants are discussed to illustrate certain of these advantages. In conclusion it is stated that the copper-sweetening processes described unquestionably prevail in economy and quality of product and simplicity of operation over doctor-treating. As motor-fuel specifications improve, and particularly as anti-knock requirements increase, monetary savings from these processes will be correspondingly increased. Copper-sweetening is more versatile in its application to various types of gasoline stocks, and therefore does not require the technical control and readjustment necessary in doctor-sweetening units. Copper-treating units, with respect to cost and return on investment, compare favourably with other types of refinery equipment, being substantially equal in quality and serviceability.

                                    A. H. N.

483.* Solutizer Sweetening and Gasoline Stability. D. L. Yabroff, E. L. Walters, A. C. Nixon, and H. B. Minor. *Refiner*, March 1941, **20** (3), 87–89.—The treating agent employed in the solutizer process is a strong caustic solution to which has been added a suitable organic material, termed a " solutizer," and this results in a caustic solution of " high solvency power " for mercaptans. Previous publications have discussed the underlying theory of the process, the extraction and regeneration steps, the attractive improvement in octane number and lead susceptibility as compared to the untreated sour gasoline, pilot-plant studies, and finally the operation of a 15,000-brl./day commercial plant at the Wood River refinery of Shell Oil Co., Incorporated.

The present article, on the solutizer process, discusses the general aspects of gasoline stability, and the effect of solutizer sweetening in particular. In evaluating the influence of any treating process on stability, it is important to separate the effect of the particular process itself and the effect of natural inhibitors that may be present. A method for doing this is presented, based on the " basic inhibitor susceptibility " of the gasoline.

Solutizer-sweetening preserves the inhibitor susceptibility, whereas many other sweetening methods cause a degradation in this property due to the introduction of deleterious by-products.

Gasoline sweetened with a " mixed "-type solutizer solution (contains both *iso*-butyrate and alkyl phenolate salts) will have a definite alkyl phenol content, because of the equilibrium established with the alkyl phenol salts in the solutizer solution itself. In many cases this equilibrium alkyl phenol concentration in treated gasoline is more than sufficient to assure adequate stability.

Two new commercial solutizer plants, just beginning operation in California, will utilize a " mixed "-type solutizer solution to sweeten full-range cracked gasoline.

A. H. N.

484.* The Study of Water Problems in Atmospheric Cooling Systems. D. W. Haering, D. M. Considine. *Refiner*, March 1941, **20** (3), 91–96.—Problems occurring in these systems are influenced by atmospheric contamination from gases, such as oxygen, carbon dioxide, and hydrogen sulphide, bacteria, algae, and dust, which frequently introduces appreciable amounts of silica into the equipment. Velocity, temperature, and incomplete wetting of metal surfaces are design features, and a variety of metals and alloys present in systems encourage and introduce water problems inherent to the systems, unless corrective treatments are employed.

Corrosion occurs commonly in atmospheric cooling systems because of the repeated aeration of the water. The problem is not solved conveniently by oxygen removal, because of this fact. The high velocities obtaining in condensers and in connecting rods of internal-combustion engines accelerate the corrosion rate. The rate of corrosion is still further increased by the multiplicity of voltaic couples normally present in large cooling systems.

Living organisms are a serious problem in cooling systems, and algae, bacteria, or both may be factors responsible for scale, corrosion, or simply slime found on heat-transfer surfaces. Apart from repeated contamination due to atmospheric contact, the property of many of these organisms of developing resistance to unfavourable environments, including chemcials intended to destroy them, is a difficult and disconcerting factor in their control.

The present paper is a preliminary to a series of pure research studies which will isolate the individual ions and elements and determine the critical limits responsible for scale and corrosion troubles in this type of system. In addition, the relative effectiveness of various chemicals in the control of these factors, plus the control of bacterial and algal factors, will be studied.

From experimental facts presented in the paper in detail the following conclusions are reached : (1) It is possible to duplicate plant-operating conditions in the laboratory and obtain identical scale and corrosion results obtained in practice. (2) Dissolved solids concentrations are an important factor in scale control, and determine to a large extent the effectiveness of chemicals employed for treatment. (3) Sulphate and silica deposits are factors in cooling-system operation. (4) Phosphate chemicals hydrolyze, reducing, if not eliminating, the effectiveness of so-called threshold treatment. (5) This type of research is important in isolating factors and concentrations effecting scale and corrosion control in this type of system. A. H. N.

485.* Total Removal of Sulphur Compounds is Goal of Sweetening Technique. P. M. Robinson. *Nat. Petrol. News*, 21.8.40. **32** (34), R. 298.—Used originally only for the purpose of improving the odour of gasoline, sweetening processes assumed a greater significance when anti-knock properties became important. All existing processes based on the conversion of sulphur compounds possess some disadvantage of greater or less importance. The development of the " solutizer " processes which remove all sulphur bodies from the gasoline are a big step forward. It is suggested that the only really satisfactory solution is the removal of sulphur bodies from the crude. H. G.

486.* **High-Temperature Creep Strength Checked for Low-Alloy Steels.** R. F. Miller, W. G. Benz, and W. E. Unverzagt. *Nat. Petrol. News*, 21.8.40, **32** (34), R. 306.—The creep strengths of seventeen low-alloy steels of different compositions and after different heat treatments were determined at 1000° F. The C.S. of C/Mo steels increases with increasing Mo content, both in the normalized and normalized and tempered conditions. In the latter condition the C.S. is lower than in the former. In the normalized (only) condition the steel is less stable than after tempering. An increase in the Mn and C content of normalized and tempered C/0·5% Mo steel produces a slight increase in the C.S. An addition of Cr, Si, or Al to these steels tends to impair C.S., and Ti and Cb to improve it. Conservative estimates of C.S. should be based only on materials possessing a stable structure.   H. G.

487.* **Thermal Insulation for Industry.** S. V. Saginor. *Chem. Met. Eng.*, January 1941, **48** (1), 82–86.—The historical development of insulating material from the first commercial clay and asbestos-fibre type from a century ago up to the present time is given.

A good insulant is generally constructed on the basic principle of numerous air-cells which prevent the flow of heat. Highly polished light-coloured metals, however, such as aluminium foil, although inherently not insulants, serve to retard the flow of heat by functioning as reflectors. Since the original efficiency of commercial insulants depends primarily on the voids they contain, these voids should preferably be microscopically small, so that circulation within them and radiation across them will be reduced to a minimum.

Further, the material must be adaptable to the condition for which it is being considered—that is, the insulant must be of such form as to be easily applied. It must have high original resistance to heat-flow and the ability to retain this resistance; it must have sufficient strength for proper handling and application. Ability to withstand wear and tear encountered in service is also important. In some cases it should be vermin-proof, not susceptible to bacterial growth and, in itself, odourless. It must have the ability to withstand the temperatures to which it will be subject without appreciable deterioration. To be effective at low (refrigeration) temperatures, the insulant should be, in itself, highly resistant to moisture-vapour penetration, or be properly protected by an asphalt coating, asphalt-impregnated membrane, or other suitable vapour barrier.

A detailed list of basic data, a knowledge of which the author finds essential in making an analysis of the proper type and thickness of insulation for industrial requirement, is given. The properties of insulants are discussed.   A. H. N.

488.* **Slurry-Type Copper Treater Stops Octane Number Losses.** R. G. Atkinson. *Nat. Petrol. News*, 11.12.40, **32** (50), R. 450.—In the plant described yellow pressure distillate is scrubbed with caustic soda to remove H_2S, saturated with water and passed with controlled quantities of oxygen through a slurry of clay and cupric chloride. After settling, the distillate is washed with water and sodium sulphide to remove copper salts. The process is claimed to eliminate vapour and emulsion losses and to cause no significant drop in the octane number. In cost the process is claimed to be comparable with the usual " doctor " treatment.   H. G.

489.* **Alkylation Plant in California.** C. K. Viland and J. Seth. *Oil Gas J.*, 12.9.40, **39** (18), 32.—A sulphuric-acid alkylation plant was completed in June 1940 at a refinery in Avon, California, producing from *iso*butane and butylenes a light 92–93 O.N. blending stock and a heavy alkylate of slightly lower O.N. The *iso*butane-bearing charging stock is derived from cracking-plant operations, straight-run gasoline stabilization, and from natural gasoline plants. The butylene charge-stock is derived from two debutanizer units handling depropanized pressure distillate. The average charge consists of 73% cracked butanes and 27% straight-run butanes, one-quarter of the former being charged to the reactor unit and three-quarters to the alkylation de*iso*butanizer column (to recover maximum *iso*butane and dispose of surplus butylenes). *iso*Butane–butylene ratio is kept at between 5 : 1 and 8 : 1, acid being continuously added to keep the strength of the acid in the system at over 90%. Propane refrigeration removed the heat of reaction, keeping the temperature to 40–50° F. The mixed reaction products are neutralized and debutanized, the *iso*butane being returned to the de*iso*butanizer column. Fractionation of the stabilized product yields three

alkylate grades, a light grade of O.N. 92·5 and boiling range 135–310° F., an intermediate grade of O.N. 83·0 and boiling range 314–390° F., and a residue of O.N. 80·0 and boiling range 396–644° F. The first product is suitable for blending into high-octane aviation spirit. Operation of the plant has been smooth and efficient since its installation, only two men per shift being required for control. C. L. G.

490.* Application of Catalytic Desulphurization Process. M. W. Conn. *Oil Gas J.*, 24.10.40, **39** (24), 40–47.—The lead susceptibility of gasolines is directly influenced by sulphur content, and hence increased attention has been given recently to removal of this sulphur. It is now realized that the conception that gasoline is sufficiently refined if doctor sweet and non-corrosive does not go far enough, and further processes, such as cold acid treatment and the use of mercaptan-solvent-inducing agents in the caustic washing systems, have been introduced. In the opinion of the author, these processes are inefficient and uneconomic, and he would replace them by catalytic decomposition of the organic sulphides to H_2S—the Perco catalytic desulphurization process.

In this process the raw gasoline is passed over the catalyst at 750° F. and $1\frac{1}{2}$–2 atmospheres, cooled, and the H_2S removed by a caustic wash. Mercaptans, alkyl and aromatic sulphides, and disulphides are readily converted into H_2S and the corresponding hydrocarbons, thiophanes and carbon disulphide with more difficulty, and thiophenes least readily of all. Fortunately these last have the least unfavourable results on lead susceptibility. Reduction of sulphur content is therefore dependent on the original thiophene content, and is generally upward of 85% for uncracked and about 50% for cracked and polymer gasolines.

Tables of the properties of eight different gasolines before and after pilot-plant desulphurization are given, together with those of three gasolines treated on a commercial plant. Straight-run gasolines show, on desulphurization, an increase in octane number of about 2 units for the base spirit itself, whilst with base spirit + 2 c.c. TEL/gal. the corresponding increase is about 8 units. Cracked and polymer spirits show an increase of about 2–3 units for the base spirit, and about 4 units for base spirit + 2 c.c. TEL/gal.

In the case of one of the commercial plants in operation processing 1000 barrels per day, the total operating cost per day is $56·04, exclusive of indirect charges. Since the tetraethyl lead saving is approximately 18 cents per barrel, the economic advantages of the process are apparent. T. T. D.

491.* The Combustion Gas Turbine. J. T. Rettaliata. *Engineer*, 1940, **170** (4411 and 4412), 63–65 and 78–79.—A gas turbine unit is described, which consists of a five-stage reaction turbine direct coupled to a fifteen-stage axial compressor. Part of the air discharged from the compressor is used for combustion of oil and the remainder mixes with the products of combustion, cooling them to a satisfactory temperature for expansion in the turbine. A description of the mechanical construction of the unit is given.

The turbine operates on the Brayton cycle which is composed of two isentropic and two constant pressure lines. This cycle is examined in terms of temperature–entropy and temperature–enthalpy diagrams.

Axial compressors have the advantage of a higher efficiency than the centrifugal type, but suffer from the disadvantage of a limited range of stable operation. Although a reaction turbine bears a physical resemblance to an axial compressor, the design problems associated with each are quite different. For instance, in the turbine re-heating caused by friction leads to an overall efficiency better than the stage efficiency, but in the compressor the reverse is the case.

The effects of turbine inlet temperature, compressor pressure ratio, and turbine and compressor efficiencies on overall thermal efficiency are given ; and, in this connection, it is mentioned that the highest operating temperature of turbine units built to date is 1000° F. Factors leading to the selection of the axial type of compressor for use in conjunction with the turbine are discussed.

Altitude and temperature have a large effect on the available power output and diagrams are given showing the extent of the variations. The author points out that loss of power may be made up by water injection, although this is uneconomical.

Various applications are mentioned, such as : the use in oil refineries, where the compressed air can be used in a process and the necessary heat obtained from the

process itself; for supercharging Velox boilers where the exhaust gas from the boiler drives the turbine; and the possibility of adaptation to railway locomotives. A 2200-h.p. gas turbine locomotive now being built is described.   J. G. W.

492.* Creep under Combined Tension and Torsion. Part I.—The Behaviour of a 0·17% Carbon Steel at 445° C. H. J. Tapsell and A. E. Johnson. *Engineering*, 1940, **150** (3887, 3889, 2891, 3892, and 3894), 24–25, 61–63, 104–105, 134, and 164–166.—The apparatus used by the authors in their experimental work is described. The test specimens were tubular in form, the material for which had been heat-treated before machining; finishing was by lapping and polishing. The measurement of axial and circumferential creep simultaneously and independently was obtained by means of optical systems enabling small changes to be observed.

Tests were of about 150 hours duration, readings being taken at frequent intervals during the first day and thereafter at daily intervals. Experiments were made with pure tension, pure torsion, and several ratios of torsion to tension stress.

Curves of axial and circumferential creep stress were found in all cases to have the same geometrical form, and each individual curve was therefore derived from the common curve. No axial creep took place in the pure torsion tests, which, in the authors' opinion offers strong evidence that the creep in a plane is unaffected by the stress acting normally to it. Except in the case of pure torsion, creep occurred in the direction of the tube-wall thickness, indicating that shear stresses on planes in addition to those of maximum shear take part in producing creep.

Various theories are examined in relation to the results obtained, from which the authors concluded that the plain difference of maximum shear stresses was not a satisfactory stress function, and they give suggested expressions for the principal creep rates in which the principal stresses were proportional to the difference of the nth power of the maximum shear stresses. There was no evidence that a strain–energy function was essential to the theory.

Appendices are given, showing the method of computing from the measured creep rates the corresponding rates in the three directions of principal stress for the thin-walled tubular specimen subjected to combined stress; and a theoretical analysis of the various theories that have been suggested.   J. G. W.

493.* Catalytic Cracker Specializes in 100 Octane Fuel Base. M. G. Van Voorhis. *Nat. Petrol. News*, 30.10.40, **32** (44), R. 386.—High octane number catalytic-cracked gasoline has hitherto been excluded from military aviation by virtue of its high acid test, a measure of the unsaturateds content. Although this is not considered to be a valid reason for the exclusion owing to the nature of the unsaturateds in this type of gasoline, the replacement of the existing catalyst by a new synthetic one shortly to be available is stated to obviate this disadvantage. A 10,000 bbl. unit is described in some detail.   H. G.

494.* Make High-Grade Neutrals by Cracking Bright Stock. C. R. Wagner. *Nat. Petrol. News*, 25.12.40. **32** (52), R. 460.—The tendency towards the increasing use of lower viscosity lubricants for automobile engines is increasing the demand for " neutral" oil at the expense of bright stock. In the process described bright stock is blended with 10% of kerosine and heated in shell stills, in the presence of steam. The distillate to 525–550° F. is naphtha and gas oil. The rates of heating and steam supply are then controlled to maintain the viscosity of the overhead stream at 90–120 S.U.S. at 100° F. The final still temperature is 700–720° F. The yield is claimed to be 98% and the cost 3·25 cents per gallon.   H. G.

495.* Sharpness of Separation in Batch Fractionation. A. Rose, L. M. Welshans, and H. H. Long. *Industr. Engng Chem.*, 1940, **32** (5), 668, 673, and 675.—In the first of these papers a method is developed for calculating the sharpness of separation when hold-up is negligible, the size of the intermediate fraction (defined as having composition between 10 and 90% of the more volatile component) being used as criterion. Only reflux ratios approaching infinity are considered.

In the second paper the method is extended to include cases where hold-up is appreciable, the reflux ratio being infinite.

Finally, in the third paper, a general equation is derived which allows the calculation

to be made for all reflux ratios and values of hold-up. The equation is solved graphically.   P. D.

496. An Unusual Temperature Controller Job. V. H. Heirmeier. *Instruments*, 1940, **13** (8), 217.—A distillation unit comprising a prefractionator and main column is described which, due to the pressure and level interconnections between the prefractionator and main receiving tanks suffers from surging. This can be suppressed by suitable temperature control applied to the top of the main fractionator.

P. D.

497. Patents on Refining and Refinery Plant. Edeleanu Gesellschaft m.b.H. E.P. 533,348, 11.2.41. Appl. 31.10.39. Process for cooling oils preparatory to extraction by the Edeleanu process, on the countercurrent principle. The fresh oil is admixed with extract solution, if desired after precooling the oil in a heat exchanger, and sulphur dioxide caused to evaporate from the mixture by suction. Thus the heat required for evaporating the sulphur dioxide is derived directly from the mixture.

Standard Oil Development Co. E.P. 534,111, 27.2.41. Appl. 27.12.39. Improved process for the recovery of phenols from petroleum oils. A phenol-containing petroleum oil is contacted with an alkali, the oil separated from the resultant sludge containing alkali phenolates and the said alkali sludge extracted with a solvent for the oil. Thereafter the solvent extracted sludge is blown with steam or an inert gas and the phenols regenerated by acidification. As a rule solvents employed are from the class of lower boiling petroleum hydrocarbons, *e.g.* solvent naphtha and gasoline.

A. W. Nash. E.P. 534,212, 3.3.41. Appl. 22.7.39. Method of reducing the wax content of a wax-containing oil by extraction with a solvent only partially miscible with the wax-free oil present in the wax-oil mixture treated. The solvent is further only partially miscible or immiscible with the wax present in the wax-oil mixture at an operating temperature equal to or above the melting point of the wax, but below the critical solution temperature of the wax with the solvent. The solvent may be either an aliphatic saturated ketone, an aliphatic monohydric alcohol, a fatty acid, a monohydric phenol, a phenylamine, a nitro-derivative of benzene, or an alkyl-benzene, a halogen ester of the glycols, furfural, or furfuryl alcohol.

F. J. Soday. U.S.P. 2,230,274, 4.2.41. Appl. 26.5.38. Method of purification of the resin-forming unsaturated hydrocarbon content of a light oil fraction. The fraction is contacted in the liquid phase with a reagent comprising sulphuric acid, 50% in concentration, but free from appreciable amounts of sulphur dioxide and sulphur trioxide, and containing a compound capable of furnishing an ion containing manganese in quantity equivalent to at least 0.1% by weight of potassium permanganate.

C. J. Wilson. U.S.P. 2,231,147, 11.2.41. Appl. 30.7.38. Separation of a mineral oil boiling in the range 100–700° F. into relatively more paraffinic fractions and relatively more aromatic fractions. The oil is contacted with a solvent selected from the class consisting of methyl acetoacetate and its halogen substitution products under conditions to form a solvent extract phase and a paraffinic phase. Thereafter the respective phases are separated and the solvent is removed.

R. E. Burk. U.S.P. 2,232,435, 18.2.41. Appl. 31.8.38. Production of lubricating and solvent oils from cracked residual petroleum by the distillation from the petroleum of fractions corresponding generally to gas oil range and to lubricating range. A desired fraction thereof is then subjected to the action of a small amount of maleic anhydride at a temperature of 200°–225° F. for a few hours. The resultant material is washed with a caustic alkali solution, then with water, and blown with air. The resultant material is finally subjected to the action of a small amount of boronfluoride at 60°–250° F. for several hours, washed with water and blown with air at 200°–250° F.

R. E. Burk and E. C. Hughes. U.S.P. 2,232,436, 18.2.41. Appl. 31.8.38. Method of purifying light petroleum distillates by removing hydrogen sulphide in such a way that substantial amounts of oxygen-containing acid reacting carbon ring compounds and mercaptans are not also withdrawn. Thereafter the oxygen-containing acid-reacting carbon ring compounds in the distillate are selectively converted to metal-

containing compounds and removed by subjection to the action of a dilute caustic soda solution of 0·5–8° Baumé. Finally the mercaptans are acted on by a more concentrated caustic soda solution.

G. L. Parkhurst. U.S.P. 2,232,722, 25.2.41. Appl. 25.2.32. Method of dewaxing and fractionation of a wax-bearing oil into fractions relatively paraffinic and naphthenic with respect to the original oil. The oil is mixed with a selective solvent adapted to assist the precipitation of wax at low temperatures; the mixture chilled to cause precipitation of substantial wax; the wax removed; and the remainder of the mixture chilled to a lower temperature to cause the mixture to separate into two liquid phases. Finally the liquid phases are separated and the solvent recovered.

E. H. Records and J. E. Louttit. U.S.P. 2,232,971, 25.2.41. Appl. 6.6.39. Method of desulphurizing hydrocarbon oil by mixing with a quantity of oil a treating mixture comprising ferric chloride, alum, alcohol and benzol, and then heating the mixed oil and treating mixture under pressure.   H. B. M.

Synthetic Products.

498. Patent on Synthetic Products. Standard Oil Development Co. E.P. 533,327, 11.2.41. Appl. 27.10.39. The invention relates to improved detergents and wetting agents, the latter implying substances which improve spreading of surface coatings and increase spreading and penetration powers of liquids such as aqueous solutions of oils. The process comprises condensing with phosphoric acid or a pentavalent phosphoric acid derivative which hydrolyzes to phosphoric acid, phenolic compounds substituted in the aromatic nucleus with saturated alkyl or *cyclo*-alkyl groups and neutralizing the resulting acid ester with an alkali metal base to produce an ester salt.
                                    H. B. M.

Fire Prevention.

499.* Properties of Flammable Liquids and Gases. The Associated Factory Mutual Fire Insurance Companies. *Industr. Engng Chem.*, 1940, **32**, 880.—The flash point, explosive limits, auto-ignition temperature and susceptibility to spontaneous heating are given for several hundred organic compounds and natural products. Suitable extinguishing agents for dealing with fires arising from the combustion of these substances are recommended.   J. W. H.

Chemistry and Physics.

500.* Elements of Vaporization and Condensation. Part XII. R. L. Huntington. *Refiner*, March 1941, **20** (3), 97–102.—The paper deals mainly with the application of the Kremser Method to the design of oil absorbers. The two principal factors to be considered in the design of the bubble plate tower are : (1) provision of ample flow capacity for the oil and gas streams so as to prevent liquid hold up and entrainment; (2) a fairly close approach toward equilibrium between the gas and oil on each bubble plate.

To take care of factor No. 1 calls for : (a) adequate down-spouts wherein the entrained vapour can free itself from the oil froth which is formed as the oil flows across the bubble caps ; (b) liquid seals at the base of the down-spout to prevent the flow of gas upward through the down-spout ; (c) a tray spacing of 20 ins. or more, generally 24 ins., between successive plates, in order to reduce entrainment or the mechanical carrying of liquid droplets upward from plate to plate.

Factor No. 2 requires the following considerations : (a) placement of bubble caps in staggered rows so as to reduce the tendency for the oil to channel across the plate ; (b) proper height for the overflow weir in order to give the rising gas stream a sufficiently deep body of oil to penetrate on each plate ; (c) ample velocity through the slots to provide intimate contact between the gas and oil ; however, the velocity must not be so high as to cause the friction loss in feet of fluid to approach the equivalent head of oil and froth in the down-spout.

Typical worked-out examples on an oil absorber and stripper design illustrate the use of the Kremser chart as modified by Souders and Brown. This chart is based on an algebraic derivation in which a material balance is made around n equilibrium plates. A number of simplifying assumptions are made among which are : (1) the volume of residue gas is substantially the same as the raw gas value ; (2) the ratio of L/V or mols. of lean to mols. of lean gas is a constant for the absorber as well as the ratio of V/L mols. of steam to mols. of lean oil for the stripper ; (3) the liquid volumes are additive.

After studying the effects of varying the pressure and other factors, the choice of an absorption oil is studied. The oil should have an initial boiling point well above the end point of the raw natural gasoline, so that the oil will not distil over with the gasoline. The oil should be free of heavy ends which may cause too high a pour test, thereby resulting in solidification of the oil in the cooling coils. Waxy hydrocarbons should be absent (or present in very small amounts). Heavy asphaltic fractions may promote the formation of emulsions which are highly undesirable. The number of mols./unit of liquid volume should be a maximum. This result can be usually accomplished by selecting a low molecular weight oil. The absorption oil should be one from which the gasoline constituents can be readily denuded or stripped out in the still. In high pressure absorbers operating at 600 lbs. or more, higher molecular weight oils are recommended since there is a tendency for vaporization to take place in the retrograde region, especially for the lighter oils.   A. H. N.

501. Computation of some Physical Properties of Oils at High Pressures. I. Density. R. B. Dow and C. E. Fink. *J. App. Phys.*, 1940, **11**, 5, 353.—The density of a fluid lubricant at pressure p lb. per sq. in. gauge is given by an equation of the form

$$\rho = \rho_0(1 + ap - bp^2)_t$$

ρ is the density at pressure p and temperature t, ρ_0 the corresponding density at atmospheric pressure. The constants a and b are evaluated over a temperature range 20 to 220° F., and the equation holds up to pressures of 50,000 lb./sq. in.

The equation was derived for mineral oils, but holds also for fish, animal, and vegetable oils.   P. D.

502.* Viscosity of Gases and Vapours at High Pressures. E. W. Comings and R. S. Egly. *Industr. Engng Chem.*, 1940, **32**, 714.—It is shown that from a knowledge of the viscosity at atmospheric pressure, the critical pressure, and the critical temperature it is possible to calculate the viscosity of gases and vapours at high pressures to an accuracy of 20%, this error being comparable with the difference between the values found for the same pure vapour by different investigators. The relationship between the variables is expressed in the form of a graph relating the reduced pressure and reduced temperature to the ratio of the viscosity at atmospheric pressure to the viscosity at the desired pressure. The graph is constructed from the experimental determinations of the viscosities of gases and vapours at high pressures made by a large number of different observers. The basis of the method is the concept of corresponding states which follows logically from the kinetic theory of gases, from which the compressibility factor has been shown to be approximately equal for a wide variety of compounds at equal reduced temperatures and pressures. The compressibility factor is derived from the ratio of the kinetic pressure to the ideal pressure. This ratio may be replaced by the ratio of the viscosity at the desired pressure to the viscosity at a pressure sufficiently low to be independent of pressure (*i.e.* atmospheric pressure). From theoretical considerations it is also shown that the thermal conductivity and diffusivity at high pressures may be calculated by replacing the viscosity ratio by conductivity or diffusivity ratios. No data are, however, available for checking the validity of this application of the corresponding state concept.   J. W. H.

503.* Phase Equilibria in Hydrocarbon Systems. B. H. Sage, H. M. Lavender, and W. N. Lacey. *Industr. Engng Chem.*, 1940, 32, 743.—The volumetric behaviour of mixtures of methane and decane over the temperature range 70° to 250° F. and at pressures up to 4500 lb./sq in. has been determined. This range of temperature and pressure covers measurements in the condensed liquid and two phase regions. From this data the partial specific volumes of methane in decane and decane in methane have been calculated.   J. W. H.

504.* **Destructive Hydrogenation of High Molecular Weight Polymers.** V. N. Ipatieff and R. E. Schaad. *Industr. Engng Chem.*, 1940, **32**, 762.—Destructive hydrogenation of *iso*butene polymers, butadiene polymer and rubber has been carried out in the presence of black nickel oxide. The apparatus employed consisted of an electrically heated rotating autoclave, made of stainless steel, the reaction temperature was 250° C. and the initial hydrogen pressure was 100 kg. per sq. cm. at 25° C.

The *iso*butene polymer was obtained by polymerising *iso*butene in liquid propane solution in the presence of aluminium chloride and hydrogen chloride, and was a white rubber-like compound. On destructive hydrogenation under the above operating conditions, and removal of the solvent, fractions were obtained consisting of octanes, dodecanes, hexadecanes and hydrocarbons of the formula $C_{44}H_{90}$. The products from the destructive hydrogenation of *iso*butene polymer are thus essentially paraffinic.

Butadiene polymer was produced by heating this hydrocarbon at 150° C. under 40 atmospheres pressure. Destructive hydrogenation of this polymer produced only naphthenic hydrocarbons.

Similarly naphthenic hydrocarbons were formed when a natural rubber was subjected to destructive hydrogenation.

Hydrogenation of *iso*prene yielded *iso*pentane in addition to cyclic hydropolymers.
H. E. T.

505.* **Thermodynamic Properties of Paraffins and Olefins.** R. H. Ewell. *Industr. Engng Chem.*, 1940, **32**, 778.—This paper presents a critical correlative study of the data available on the entropy and heat of formation, particularly at 25° C. of the paraffin and olefin hydrocarbons. Extrapolation of the experimental data on the lower members of these two series of hydrocarbons yielded a set of rules for estimating the entropies and heats of formation of any paraffin or olefin at 25° C. These properties are tabulated for all paraffins through the octanes and for all olefins through the hexenes.

The data obtained can be used to calculate the approximate state of equilibrium in any hydrocarbon reaction. For example, the equilibrium proportions of 2 : 3-dimethyl-1-butene, 3 : 3-dimethyl-1-butene, and 2 : 3-dimethyl-2-butene at 300° C. are calculated to be 25·4 : 2·2 : 72·4 in comparison with Whitmore's experimental values of 31 : 3 : 61. Equilibrium calculations for the paraffins show that in the temperature range 150° to 175° C. all the isomeric hydrocarbons in any group of isomers have approximately the same free energy. The more highly branched isomers are more stable below this temperature range and the straight-chain ones more stable above it.   H. E. T.

506.* **Retrograde Condensation.** D. L. Katz and F. Kurata. *Industr. Engng Chem.*, 1940, **32**, 817.—A general description of the phenomenon of retrograde condensation ; including a discussion of the physical state of the material in this region.
P. D.

507.* **Correlating Vapor Pressure and Latent Heat Data.** D. F. Othmer. *Industr. Engng Chem.*, 1940, **32**, 841.—Vapour pressures of liquids, solids, solutions having a non-volatile component, solutions having two or more volatile constituents, hydrates losing water by efflorescence, and of other materials undergoing decomposition, give straight-line relations when plotted on logarithmic paper against values of the vapour pressures at corresponding temperatures of a reference substance. The gradient of the line is equal to the ratio of the latent heat or other local heat quantity involved in the evolution of the vapour to the latent heat of the reference material. These results indicate the validity of the equation

$$\log P = L/L' \log P' + C$$

where P, P' are pressures, L, L' molal latent heats of the two compounds at the same temperature, and C is a constant.

Graphs have been constructed to illustrate the utility of this relation with various materials in checking and correlating vapour pressure data.

Latent heats have been evaluated and checked ; and heats of fusion, of hydration, of dissociation, of dilution or solution, and of chemical reactions are shown to be related to the graphical method and may be calculated.

Freezing points, enthalpy charts, steam distillation relations, and many related phenomena may also be conveniently studied by this method.

A comprehensive relation is developed which includes all of the other general methods used for graphic vapour pressure representation. In addition other useful forms of equation for similar calculations are suggested.   H. E. T.

508. Sensitive Method of Flow Control. M. G. Martin. *Instruments*, 1940, **13**, 8, 214.—The head on the upstream side of a V notch weir (chosen in preference to an orifice for ease of cleaning) is used to control the rate of flow of a liquid by means of an automatic valve. In order to obtain the necessary control accuracy the valve actuating mechanism must respond to changes in head of 0·025 inches. This is too small a change for a float, and the difficulty is overcome by using a submerged pipe upstream from the weir, with a small discharge of air into the liquid, the pressure in the pipe actuating the controller.   P. D.

509. Flow of a Gas through Porous Media. J. L. Fowler and K. L. Hertel. *J. App. Phys.*, 1940, **11**, 7, 496.—Kozeny's approximate solution to the problem of fluid flow through porous media is developed, and the resulting formula checked by experiments on air flow through plugs of cotton, wool, rayon, and glass wool.   P. D.

510.* Mechanism of Catalytic Hydrogenation of Phenol Under High Pressure. S. Ando. *J. Soc. Chem. Ind., Japan*, November, 1940, **43** (11), 355 B.—*cyclo*Hexanol and *cyclo*hexane, assumed to be the intermediate products to form methyl*cyclo*pentane from phenol, were hydrogenated in a continuous apparatus, molybdenum sulphide being employed as catalyst.

The sample and hydrogen were continuously charged at a constant speed into the reaction chamber, which was maintained as high as the required reaction temperature and pressure. The products were discharged continuously from the chamber, the pressure being kept constant. The hydrogen was fed at such a rate that the residual gas was drawn off at the required rate.

In one experiment 144 c.c./hr., of *cyclo*hexanol were charged into the reaction chamber, 155 lit./hr. residual gas were drawn off. The reaction temperature was 380° C. and reaction pressure 200 atm. In the other experiment, 145 c.c./hr. of *cyclo*hexane were charged, 149 lit./hr. residual gas drawn off, the reaction temperature being 379° C. The composition of the products obtained was compared. The following observations were made : (1) a greater part of *cyclo*hexanol was converted into hydrocarbons boiling at about 70–80° C. (2) In each experiment, the main fraction of the oil obtained may be taken as being composed principally of *cyclo*hexane and methyl*cyclo*pentane. (3) The proportion of methyl*cyclo*pentane contained in the main fraction of the saturated hydrocarbons obtained is remarkably larger in the case of *cyclo*hexanol than with *cyclo*hexane. The reaction to produce methyl*cyclo*pentane from *cyclo*hexanol is thus not simply :

<p style="text-align:center;">*cyclo*hexanol → *cyclo*hexane → methyl*cyclo*pentane</p>
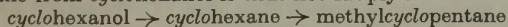
but proceeds through another intermediate. In the present experiment, *cyclo*hexane and methyl*cyclo*pentane were actually produced from *cyclo*hexanol, and the content of the latter hydrocarbon was remarkably larger than the amount which is expected to be formed by the isomerisation of *cyclo*hexane.

Strong support is thus offered to the assumption that *cyclo*hexanol is the intermediate product.   B. M. H. T.

Analysis and Testing.

511.* Investigation of High-Boiling Petroleum Oils by Adsorption Analysis. B. C. Allibone. *J. Inst. Petrol.*, March 1941, **27** (209), 94–108.—This paper describes the application of " chromatographic adsorption " to the analytical separation of the high-boiling components of petroleum.   B. H. M. T.

512.* Ollett Tube Cleaner. E. A. Evans. *J. Inst. Petrol.*, March 1941, **27** (209), 118.—An apparatus for burning off the carbon residue from Ramsbottom coke bulbs is described and illustrated.   B. M. H. T.

Motor Fuels.

513. Recent Developments in Motor Spirit Production. M. E. Kelly. *Fuel*, 1940, **19** (5), 107.—This article contains a short review of recent trends in the production of motor fuels.   H. E. T.

514. Notes on Recent Developments in Fuel Technology. J. Hiles and J. K. Thompson. *Fuel*, 1940, **19** (5), 105.—A short review of recent developments in fuel technology covering such topics as electrical thawing of frozen water pipes, octane ratings, the private motorist and alternative motor fuels, the separation of gaseous and liquid mixtures.   H. E. T.

515. Patents on Motor Fuels. D. B. Macdonald. E.P. 533,978, 25.2.41. Appl. 30.10.39. The object of the invention is to provide a material which when added to liquid fuels for use in internal combustion engines reduces pinking and knocking tendencies. The improvement involves the addition to such a fuel of a composition consisting of naphthalene and one or more nitriles either with or without one or more other improvers for liquid fuels such as wool wax, chlorophyll, and distilled bone.

E. I. Du Pont de Nemours. E.P. 534,147, 28.2.41. Appl. 18.8.39. Process for the production of improved motor fuels which will have a reduced tendency to form adherent deposits of gums or carbonaceous materials on the various parts of the engine with which they come in contact and which will soften, loosen, or remove any such deposits. These objects are achieved by incorporating in the fuel a minor proportion of an N-substituted organic sulphonamide having a melting point below 75° C. and a boiling point of at least 300° C. It should also have a high solvent power for kauri gum. The amount of sulphonamide to be incorporated varies over a wide range, but is ordinarily between 0·01 and 5%.

P. Miller and A. Y. Mottlau. U.S.P. 2,230,844, 4.2.41. Appl. 25.11.38. Preparation of an improved high octane number motor fuel consisting of a gasoline base fuel having a clear octane number above 75, 0·5 to 10 c.c. of tetra ethyl lead per gallon of fuel and from 1–5% of a compound of the formula
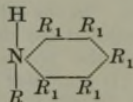
in which R represents a hydrocarbon radicle selected from the class consisting of *iso*-alkyl and alkyl-phenyl radicles, and R_1 represents hydrogen and alkyl substituents in the benzene nucleus attached to N.

A. Breitling. U.S.P. 2,231,525, 11.2.41. Appl. 8.7.38. Preparation of hydrocarbon fuels of a boiling point higher than that of commercial gasoline for use in atomized condition. The fuel is supplied to a line leading to the atomizer, heated in direct contact with copper and the temperature maintained at a point which renders the fuel appreciably hot but not above the boiling point of water.

F. E. Frey, P. V. McKinney, and W. H. Wood. U.S.P. 2,233,363, 25.2.41. Appl. 27.6.36. Continuous process for reacting paraffins of low molecular weight with normally gaseous olefins to produce predominantly paraffinic oils in the motor fuel range and of higher molecular weight.   H. B. M.

Gas, Diesel and Fuel Oils.

516. Patents on Gas, Diesel, and Fuel Oil. Standard Oil Development Co. E.P. 533,427, 13.2.41. Appl. 4.7.39. Process for the production of mixtures of hydrocarbons composed substantially of saturated normally liquid hydrocarbons boiling within the gasoline range. A mixture containing at least one *iso*paraffin boiling below the desired gasoline range and with at least one *mono*-olefin having not more than five carbon atoms or a low molecular weight polymer or copolymer, is reacted at a temperature above 10° F. in the presence of at least one metal halide and at least one alkyl halide.

Standard Oil Development Co. E.P. 533,645, 18.2.41. Appl. 17.8.39. On the basis that certain esters of thiophosphoric acid when added to a Diesel fuel improve not only lubricating properties but equally ignition properties, a new fuel has been devised. This comprises a hydrocarbon fuel and a small amount of a compound having the general formula RS_3PX where R is an alkyl, *cyclo*alkyl, aralkyl or alkaryl group, and X represents oxygen or sulphur.

J. G. Fife. E.P. 534,236, 3.3.41. Appl. 7.9.39. Process for the catalytic cyclization of paraffinic or olefinic hydrocarbons with more than 5 and at most 12 carbon atoms in the molecule. For example the invention is applicable to the manufacture of toluene from n-heptane or n-heptene, the treatment of paraffinic or olefinic gasolines with a view to obtaining gasolines with higher octane numbers, etc. The hydrocarbons are contacted at a temperature between 400° and 600° C. with a catalyst containing aluminium oxide and chromium oxide in the molecular ratios (10–40): (90–60) and also alkali compounds in such a quantity that at most 15–20 of alkali metal atoms are present per 100 molecules of aluminium oxide–chromium oxide mixture.

H. G. M. Fisher and S. H. Hulse. U.S.P. 2,230,642, 4.2.41. Appl. 13.8.38. Preparation of a liquid fuel oil composition having improved combustion characteristics. The mixture consists of a heavy fuel oil substantially free of suspended solid particles, having a gravity in the range 1° to 15° A.P.I. and containing 0·1–3% of an addition agent selected from the class of oil-soluble naphthenates of the group consisting of iron, cobalt, and manganese naphthenates.

B. H. Shoemaker. U.S.P. 2,230,817, 4.2.41. Appl. 21.12.36. Method of improving ignition properties of a Diesel fuel by treating a Diesel fuel distillate with a mixture of sodium plumbite solution and sulphur in the presence of an added mercaptan. The sulphur is used in quantities ranging from 50–350% in excess of the theoretical amount required to sweeten the distillate.

C. M. Loane and B. H. Shoemaker. U.S.P. 2,234,005, 4.3.41. Appl. 11.10.37. Production of a non-ring-sticking Diesel engine lubricating oil consisting of a mineral lubricating oil and 0·5–5% of an organic aluminium sulphonate derived from the petroleum sulphonic acid resulting from the treatment of mineral oils with concentrated sulphuric acid. H. B. M.

Lubricants and Lubrication.

517.* The Wear–Load Characteristic of the Four-Ball Test with Various Lubricants. R. Schnurmann. *Engineering*, 1940, **149**, 567.—The conditions for wear to take place during sliding are surface oxidation, thinning out of the boundary film to make it assume adhesive properties or the existence of an electric field. There is no evidence that welding of the rubbing surfaces takes place at the moment of seizure. The joint action of the above factors cannot result in anything but very irregular time–friction charts. The lower the dielectric breakdown strength the better the quality of a gear lubricant with respect to wear. The wear–load characteristic can be regarded as a guide for the selection of suitable lubricants for various mating materials and conditions of load and speed. J. W. H.

518. Studies in Lubrication. Part VIII.—Lubrication of Plane Sliders. F. Morgan, M. Muskat, and D. W. Reed. *J. appl. Phys.*, 1940, **11** (8), 541.—Experimental determinations were made of lubrication in the thick-film region for both fixed angle and pivoted slides. Viscosity, relative speed of sliding, and load were varied. Three stationary surfaces, steel, brass, and bronze, were used. The moving surface was of steel. Deviations between experiment and theory for the fixed sliders were explained on the basis of inaccuracies in the sliders. The pivoted slides gave excellent agreement with theory. P. D.

519. Patents on Lubricants and Lubrication. L. A. Mikeska and J. F. Nelson. U.S.P. 2,230,543, 4.2.41. Appl. 30.12.38. Preparation of a lubricant having a high tempera-

ture stability. The lubricant consists of a hydrocarbon of low volatility and from 0.1% to 2% by weight of a phosphite ester.

A. W. Lewis. U.S.P. 2,230,691, 4.2.41. Appl. 11.3.37. Lubrication of bearing surfaces having substantially the corrosion susceptibility characteristics of cadmium–silver, cadmium–nickel and copper–lead alloys. A lubricant comprising mineral hydrocarbon oil of a character normally tending to corrode such alloys, but having incorporated therein inhibiting proportions of an oil soluble compound of the general formula

$$R-\overset{\overset{\text{S}}{\|}}{C}-\overset{\overset{\text{H}}{|}}{N}-R'$$
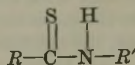
is applied to the bearing surfaces. R may be an alkyl, aryl, or aralkyl residue and R' may be hydrogen or an alkyl, aryl, or aralkyl residue.

J. H. Bartlett. U.S.P. 2,231,148, 11.2.41. Appl. 14.10.38. Preparation of a composition of matter consisting of a mineral lubricating oil and a condensation product obtained by condensing at least 5 parts by weight of an aliphatic acid halide and 1 part by weight of a petroleum lubricating oil in the presence of an active halide condensing catalyst, hydrolyzing and removing residual catalyst. The reaction products are afterwards distilled to remove low boiling constituents and to obtain the desired distillation residue.

A. R. Workman. U.S.P. 2,232,421, 18.2.41. Appl. 21.9.39. Manufacture of a lubricant consisting of a hydrocarbon oil and a relatively small amount of a plastic material including a homogeneous body composed of plasticizing proportions of an organic phosphine and an organic elastic compound selected from the group consisting of rubber, halogenated rubber, synthesized rubber compounds, etc.

L. Auer. U.S.P. 2,232,649, 18.2.41. Appl. 21.4.30. Preparation of a lubricant consisting of a major proportion of a mineral oil and a small amount of an aryl sulphonyl chloride.

J. G. McNab. U.S.P. 2,233,426, 4.3.41. Appl. 14.10.38. Production of an improved crankcase lubricant consisting of a mineral lubricating oil and small amounts of polyvalent metal soaps selected from at least two of the groups of aluminium, nickel, and the alkaline earth soaps. The total amount of soaps present is from $\frac{1}{9}-3\%$ of the oil, and the amount of soap from any one of the three groups is at least 10% of the total amount of soap present.

W. L. Steiner. U.S.P. 2,233,436, 4.3.41. Appl. 22.1.40. Preparation of a composition comprising in combination a major proportion of a lubricant and a minor proportion of a physical solution of elemental sulphur in uncombined form dissolved in a minor proportion of a solvent, comprising a halogen-bearing alkylated aromatic compound.

W. A. Smith. U.S.P. 2,233,683, 4.3.41. Appl. 9.8.35. Method of insuring uniform and maximum effectiveness of lubricant in the manufacture of lubricants in which a halogenated hydrocarbon film strength increasing agent and an oxygen-bearing friction reducing agent are added. The lubricant and at least one of the agents are heated under conditions of temperature and pressure and for a period of time which will eliminate free moisture, and the mixture homogenized while hot.

J. W. Teter and F. M. Watkins. U.S.P. 2,234,096, 4.3.41. Appl. 28.1.39. Preparation of an improved lubricating oil containing $2-6\%$ of a diphylamine having at least 10 carbon atoms in at least one of the alphyl group.   H. B. M.

Asphalt and Bitumen.

520. Patent on Asphalt and Bitumen. Standard Oil Development Co. E.P. 533,927, 24.2.41. Appl. 31.8.39. The adhesivity of asphalts to mineral aggregates in paving compositions is improved by incorporating in the asphalt a small proportion of a salt

of a polyvalent metal containing in the molecule at least one organic radicle derived from an organic acid having a molecular weight of not more than 120, and at least one organic acid radicle derived from an organic acid having a molecular weight greater than 120. The low molecular weight acid may be, for example, acetic acid, propionic acid or butyric acid. The salt may be derived from a high molecular weight fatty acid, naphthenic acid, acid obtained from the oxidation of paraffin wax, or sulphonic acid from the refining treatment of petroleum oil with strong sulphuric acid.

H. B. M.

Special Products.

521.* **Economic Aspects of Synthetic Glycerine Production.** E. C. Williams and Associates. *Chem. Met. Eng.*, January 1941, **48** (1), 87–89. *Paper Presented before American Institute of Chemical Engineers.*—The economics of glycerine is discussed for the period 1920–1940. The average selling price for C.P. glycerine over the years 1920–1940 as quoted in the trade press is about 16c./lb. During this period there have been three peaks; at 28c. in 1920, at 32c. during 1926 and 1927, and at 29c. during 1937. The lowest trough was reached, following a gradual decline through the post 1929 depression years, at a price of 10c. during 1933. Studies are made also of production and consumption records.

A short report is given of glycerine intermediates. Epichlorohydrin is undoubtedly the most interesting of the intermediates so far as the synthesis of glycerine derivatives is concerned. Fortunately this chlorine-containing epoxide is readily isolated and actually more easily obtained than glycerine itself. The reactivity of epichlorohydrin lies in its epoxide ring, and generally speaking any compound with an active hydrogen atom can be made to open the ring in the following manner :

$$RH + H_2C(O)CH - CH_2Cl \longrightarrow RH_2C - CH(OH) - CH_2Cl.$$
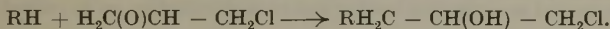
The resulting chlorohydrin can then be reacted further, so that an unlimited number of glycerine derivatives becomes readily available. A. H. N.

522.* **Rubberlike Properties of Polybutene.** W. J. Sparks, J. E Lightbrown, L. B. Turner, P. R. Frolich, and C. A. Klebsattel. *Industr. Engng Chem.*, 1940, **32**, 731.—Butene polymers produced at low temperatures possess physical properties similar to rubber. They differ from rubber chemically in that they are essentially saturated.

The commercially available polybutenes (Vistanex) have not been vulcanized by conventional methods involving the addition of sulphur and accelerators. Rubber cracks very rapidly in the presence of ozone at low concentrations, but polybutenes are inert ; rubber mixtures containing in excess of 50% polybutene are also inert to ozone. Polybutenes are inert to acids and their inertness is also exhibited by mixtures of more than 50% polybutene with rubber. Spheres of polybutene do not bounce at room temperature, but at 212° F. the rebound is similar to that of rubber.

The electrical properties of polybutene closely resemble rubber. Since rubber and polybutene are physically similar, but are essentially chemically different in regard to saturation, it is possible to draw the conclusion that the vulcanization, ozonization, and oxidation of rubber are due to unsaturation, and that the general physical similarity is independent of orientation due to carbon–double bond–carbon configuration.

J. W. H.

523.* **Carbon Black in Rubber Compounding.** D. Parkinson. *Trans. I.R.I.*, August 1940, **16** (2), 87. *Discussion*, February 1941, **16** (5), 283.—The particle size of carbon blacks can be approximately determined by a centrifugal method.

Blacks well dispersed in rubber solutions behave similarly in centrifugal fields to blacks dispersed in water and the particle size is the same in both media.

Intensity of blackness is closely related to particle size in the case of all blacks produced from natural gas, the darker the black the smaller its particles. Thus, the nigrometer, which measures blackness, provides a rapid method of comparing particle sizes. B. M. H. T.

524.* **Mineral Oils as Mosquito Larvicides.** H. D. Lord. *J. Inst. Petrol.*, March 1941, **27** (209), 73–93.—Murray's recent investigations have shown the importance of the

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spreading pressure of an oil in malarial control. Toxicity is not so crucial as has been previously accepted.

The spreading power of an oil can be characterized by the determination of its surface pressure in the Langmuir–Adam apparatus, a description of which is given. The effects on Malariol of storage, exposure to diffused and bright sunlight, and addition of resin are described. The essential requisites of a superior anti-malarial oil are discussed, and it is shown that a residue from pressure distillate fulfils these requirements.

B. H. M. T.

525. Patents on Special Products. The Enfield Cable Works, Ltd. E.P. 533,444, 13.2.41. Appl. 11.8.39. Alteration in composition of the viscous liquid normally used for impregnating the laminated di-electric material of electric cables. The impregnating compound according to this invention consists of a solution or suspension of normally solid polymers of ethylene in a mineral oil.

J. G. Fife. E.P. 533,933, 24.2.41. Appl. 13.10.39. It is claimed that the interior of engine cylinders remains clean, that the deposition of carbonaceous products on pistons and in piston ring grooves can be opposed, and that piston rings can be prevented from sticking, if soaps of Tallöl and polyvalent metals are added to the lubricants normally used. An example of such a composition is as follows. 1% by weight of the zinc salt of Tallöl is added to a Venezuelan oil distillate (aviation grade lubricating oil) refined with furfural, while heating to about 100° C.

A. E. Robertson. U.S.P. 2,232,868, 25.2.41. Appl. 4.5.38. Process for the production of a lubricating oil dye by heating a substantially adiphatic low boiling normally liquid saturated hydrocarbon at a temperature between 700° and 800° F. for a prolonged period in the presence of phosphorus pentoxide. Thereafter the catalyst is removed and the low boiling products distilled so as to collect the residue as a dye.

M. T. Flaxman. U.S.P. 2,233,203, 25.2.41. Appl. 3.5.38. Production of a lubricating oil for severe service internal combustion engines. The oil consists of a naphthenic base mineral lubricating oil containing 1–2% of an oil-soluble soap of rosin acids exclusive of those having " high grease setting properties." The soap has the property of controlling ring sticking in heavy duty internal combustion engines and does not impart substantial viscosity increase to the base oil in the stated amounts.

H. B. M.

Detonation and Engines.

526.* An Analysis of Certain Characteristics of a Kadenacy Engine. Prof. S. J. Davies. *Engineering*, 1940, **149** (3880, 3882, and 3885), 515–517, 557–559, and 617–620.—A study is made of the general movement of gases through an opposed-piston two-stroke engine to which the Kadenacy principle had been applied. By means of a Sunbury cathode-ray indicator it was possible to obtain the pressure variations in the inlet system, working cylinder, and exhaust passage. Temperature and density measurements were not possible, and, in order to obtain complete mass-flow data, some assumptions were necessary.

Theoretical considerations lead to a basis for the calculation of the mass, velocity, and momentum at any moment of the gases flowing through the exhaust ports.

On the evidence deduced from the present tests the discharge process is elucidated. When the exhaust port opens, the time–area rate is sufficient to allow the exhaust gases to pass out with the high velocities measured and to impart their momentum to the external gases. There appeared to be no discontinuity between the retreating exhaust gases and the new charge entering the cylinder, and, during the greater part of the charging period, the pressure in the cylinder showed a depression of 0·5–1·0 pounds per sq. in.

The author concludes from his analysis that the so-called " ballistic " exit of the gases is the dominating factor in establishing the conditions leading to the direct charging of the cylinder, in this case from the atmosphere, through the admission port.

J. G. W.

527. Patent on Detonation and Engines. W. G. Stephenson and G. G. D. de Coligny. U.S.P. 2,231,605, 11.2.41. Appl. 15.7.38. Method of improving the oxidation of a hydrocarbon distillate preparatory to its immediate introduction into the cylinder of an internal combustion engine. The liquid fuel is brought into contact in the presence of heat with a metallic catalyst ; air is then added and the air–fuel mixture caused to flow in contact with another and different metallic catalyst in the presence of heat. Thereafter the air–fuel mixture is introduced into the engine cylinder.

H. B. M.

Coal and Shale.

528. Patent on Coal and Shale. A. L. Stillman. U.S.P. 2,231,513, 11.2.41. Appl. 5.11.38. Production of a stable liquid fuel having coal particles equally distributed throughout. The fuel is composed of a mixture of 40–70% by weight of a fuel oil and 60–30% by weight of coal of the bituminous type which has been subjected to a grinding action in the presence of the oil so that it passes 100% through a 325 mesh sieve.

E. S. Mead. U.S.P. 2,233,894, 4.3.41. Appl. 2.3.38. Preparation of a composite physically intermixed loose granular fuel mass of anthracite fines, comminuted bituminous coal and an oil binder. The oil binder constitutes from 3% to 5% of the total weight, the bituminous coal from 15% to 20%, and the balance is anthracite fines. The oil binder prevents segregation of the bituminous and anthracite particles, and acts as a combustible constituent of the mixture. H. B. M.

Economics and Statistics.

529. Survey of Fuel Consumption at Refineries in 1939. G. R. Hopkins. *U.S. Bur. Mines. Report of Investigations No.* 3554, February, 1941.—It is pointed out in this report that during 1939 a new record in fuel efficiency at petroleum refineries in the U.S.A. was established. During that year the average fuel requirement per barrel of crude oil refined was 557,000 B.t.u. as compared with 567,000 B.t.u. in 1938 and 562,000 B.t.u. in 1937. The gain in fuel economy was achieved by operating at a higher percentage of capacity and by utilizing improved methods and equipment, and was sustained in spite of increased percentage yields of cracked and polymerized gasoline. During the year under review there were no outstanding improvements in the technique of heat production at refineries, but numerous small economies were made. Fuel was saved by maintaining clean heating surfaces, by reducing excess air, by improving combustion, installing preheaters, etc.

Analysis of types of fuel consumed during 1939 in refineries reveals an increase in fuel oil from 28,855,000 barrels in 1938 to 32,098,000 barrels in 1939, the whole of the gain being in California. The quantity of acid sludge utilized showed an unexpected gain of 542,000 barrels. There was a slight increase in coal consumption, but the ratio to total heat units declined from 2·84% in 1938 to 2·80% in 1939. Natural gas consumption again showed a decline, 97,685,000,000 cubic feet being used in 1939 as compared with 109,741,000,000 in 1938. Production of still gas increased in 1939, probably owing to increased cracking activities. Even though the amount of petroleum coke used as refinery fuel increased substantially in 1939 it represented only 7% of total output. Steam represented 1·3% of the total and purchased electricity, which has increased every year since data were first compiled, reached a total of 1,565,254,000 kilowatt hours, *i.e.* 12% more than in 1938. H. B. M.

BOOK REVIEWS.

Geophysical Prospecting for Oil. By L. L. Nettleton. Pp. xi + 444. McGraw-Hill Book Company, Inc., New York and London, 1940. Price 35s.

Of all branches of petroleum technology it is safe to say that none is more highly specialized and less generally understood than geophysics. In the first place this intimate blending of mathematics, physics, and geology calls for a particularly flexible type of mind, one as much at home with the inexact as with the exact sciences, a faculty possessed by few and hard to acquire.

The really expert geophysicist must have a flair for figures, be an expert manipulator of delicate apparatus, have clear vision in three dimensions, controlled imagination and, above all, a knowledge of the rocks. This is probably why geophysical prospecting for oil other than in outline is to all intents and purposes a closed book to many. Let it be said at once then that the author has succeeded in opening it, if not perhaps as wide as some geologists might wish, at least sufficient to rouse intelligent interest in a complex subject.

There is no question that the task of presenting geophysical methods to an audience of students or lay readers (for whom this book is primarily written) rather than to expert geophysicists, is no light one. It is made even more hazardous when designed as intended for those with geological rather than physical leanings. The author, however, is fortunate in combining a long practical experience of this form of prospecting with academic activities, and, in point of fact, his present work arises from courses of lectures given in the past to students of oil geology and engineering at Pittsburgh University. This, then, is the background of the book.

In our schooldays we were taught Newton's laws and something about the gravitational constant γ. We learnt of the work of Cavendish on measurements of Δ, the density of the earth, also about his torsion balance. We recall, too, in this connexion the advances made by Boys in determining γ. So, in the early stages of geophysical prospecting, an application of the torsion balance for gravitational surveys was at least intelligible on first principles, even if the methods of interpreting results were not. When the Eötvös Torsion Balance was introduced into the scheme of oil finding, we had to rub up our physics to understand just how this instrument could be used to locate subsurface structures, but it proved to be a complicated business.

Then came appeal to magnetic methods and, knowing something of the behaviour even of an ordinary compass in igneous as opposed to sedimentary fields, it was possible to appreciate the function of a delicate magnetometer in differentiating between rocks of varying sensitivity.

When electrical methods were introduced into oil exploration, notwithstanding their success with shallow mineral ore bodies, we were concerned to see how far they could be employed to determine electrical properties of rocks buried at really great depths below surface. Even now both theoretical and practical difficulties combine to limit the use of these methods to comparatively small depths, and it is clear from the text that much work remains to be done to improve their possibilities for locating really deep structures.

By far the most interesting weapon in the geophysical armoury is the " artificial earthquake " as it has been colloquially called. Just as a natural earth tremor is recorded on a seismograph, so measurements can be made of times of travel of earth waves set up by explosives at or near surface. These waves go out in all directions ; some are refracted or reflected back to surface and are picked up by extremely sensitive detectors. The methods lend themselves in favourable circumstances to extremely accurate geological interpretation.

It is, then, with these four principal methods, gravitational, magnetic, electrical, and seismic, that this book is mainly concerned. Each subject is treated fully and separately. From enunciation of first principles the reader learns about the instruments employed, the measurements made, the calculations necessary and

the interpretations to be placed upon the results obtained. It is all done very well indeed and even the mathematics are not too formidable to the uninitiated when clarified by the author.

The final chapter on geophysical interpretation and the importance of the geophysical map is one which might well be read first. It is short but much to the point. It could have been expanded with advantage both to physicist and geologist. Here the author does not mince his words on the interpreter's " ifs," " ands," " buts," and " maybe's," but goes straight to the root of criticism of geophysical prospecting in emphasizing that complete co-ordination between geologist and geophysicist is not always reached, but is absolutely essential if the results are to be of practical value. After all, it is the geophysicist who makes the map, and the geologist who uses it or should do. No matter how brilliant the execution of the survey, it is little more than useless unless there can be drawn from it a reasonable picture of what is for ever hidden from view.

It is no good the geophysicist blaming the geologist or *vice versa* for sins of com- mission and omission when things go wrong and oil is not found. The author sums up the whole matter by a fervent hope expressed " for the day when a really competent combination of geologist and physicist will emerge in the same man who will be truly a ' geo-physicist ' in all that the combined title implies." This end will in our view be furthered if oil geologists will give time to the teachings of this book and if physicists will detach themselves from figures and formulæ for a spell to read and learn from any standard geological text something about those " very dull-looking and superficially nondescript chunks of rock " (*sic*).

The author is to be congratulated on an excellent piece of work, on the concise manner in which he has put the subject matter together, and, not less, on a sense of humour disclosed in his last chapter, as refreshing as unexpected in a volume of this description. H. B. MILNER.

A Handbook of Malaria Control. By R. Svensson. Pp. 73. Published by the Shell Group of Oil Companies. Unpriced.

Handbooks too often have little to commend them but their usefulness, but this small and compact book is pleasant to the eye and interesting to read. Compiled by the Ross Institute with the financial aid of the Shell Group, it is intended for the use of planters, engineers, and other laymen, who have to under- take anti-malarial work in the tropics. It is written clearly and concisely, and its material is so well arranged under sub-headings and in short chapters that reference is easy. At the same time the lively style makes the book excellent reading. Thus we are introduced to insecticides by the following delightful para- graph—" The swatter acts as a useful safety valve for tempers frayed to breaking point by the maddening persistance of insect pests, but it cannot be regarded as a weapon of major importance. Man's maturer response to the enemy within his gates is the insecticidal spray."

Malaria is a fascinating subject, and many of its aspects are touched upon. The enormous medical and economic importance of the disease, and the benefits that come from its control are stressed. The essential part which mosquitoes play in the dissemination of malara is well-known, but it is not generally realized that of the 1700 kinds of mosquito which exist only 17 species are dangerous carriers. Of these, some breed in fresh water and some in salt, some in swift streams and some in stagnant marshes, some in shade and some in sunlight. Adequate methods of control can be introduced only after a study of the habits of the local carrier has been made.

The various methods of control are surveyed. Breeding places may be treated to make them unsuitable for the local mosquito carrier. Attacks are made on the larvæ by Paris Green or by oil, and on the adult insects by sprays. Of particular interest to readers of this *Journal* is, of course, the section on Malariol. In the Introduction Sir Malcom Watson writes : " Oiling is *par excellence* our great standby in emergencies, even against larvæ living in running water, as I demonstrated in Malaya in 1914, and in many places is the method to be preferred for permanent use. The discovery of a perfect anti-malarial mixture proved of incalculable value to Malaya. I am thinking in terms of the saving of tens of thousands of lives and hundreds of thousands of pounds sterling."

We hesitate to offer any criticism at all of this fine production, but as we hope this will not be its last edition, we venture to record our regret that the date of publication is not given. Here and there the text is perhaps a little too condensed. For instance, it might be made clearer just what a " culicine " is and why it is necessary to distinguish it from an " anopheline " (chapter 3). The date of the introduction of Gambusia into New Ireland might be given (page 20), and the death rate rather than the number of deaths in Klang and Port Swettenham (page 1). These amplifications would make the data more instructive.

The author and the Ross Institute, the printers and publishers are to be congratulated on the production of this excellent book. It is to be hoped that the skill of the author and the generosity of the Shell Group will be rewarded by a wide and appreciative public.   M. L. JOHNSON.

Applied Mathematics in Chemical Engineering. By T. K. Sherwood and C. E. Reed. Pp. xi + 403. McGraw-Hill Book Company, New York and London. 1939. Price 28s.

There are books which cannot, or should not, be reviewed after a lapse of time since their publication. This is particularly the case with technological books dealing with industries, like the Chemical Industry, where research and development are proceeding at a very rapid pace. However, " Applied Mathematics in Chemical Engineering " belongs to the type which is stamped with a certain degree of permanence and which is expected to be re-issued in several editions as time passes. With the view of bringing this book to the notice of petroleum technologists who have not already made good friends with it and of bringing, on the other hand, to the notice of the authors certain suggestions should they be contemplating issuing a second edition, this review is presented.

The book as a whole reveals the authors' mastery not only of the subject matter, but also of the more difficult problem of presenting complex mathematical treatments and concepts to the chemical engineer, whose only standard of evaluating mathematical methods is their utility. They have hit on the happy plan in their treatment of complex functions of evolving the problem from the particular to the general first and then descending to the particular again, thus continuously being in touch with the practical applications of these mathematical methods. Thus after the first chapter, which is a review of differentiation and integration methods, the use of differential equations is gently brought to the full understanding of the reader. A problem is set as a first step, and it is solved in steps advancing from small finite increments to a simple differential equation. When the problem and the concepts it entails are thoroughly understood, the authors move to the general concept of mathematical origin of differential equations and then revert to the concrete by giving the physical origin of such formulæ.

If there is a criticism to be made in this connection, it is that there is a tendency to make the problems met " too easy " and in certain respects mechanical in character. Thus, in chapter 2, the general rule is laid for material balance, and the reader is urged to ignore the signs of input, output, and accumulation, provided he follows the formula. Of course, the solution to the problem is right ; however, the encouragement of such rules robs mathematics of one of its chief characteristics—mental discipline.

Chapter 2 may be cited for another important generality which the authors reveal. It is the lucid manner in which they show the basic principles of mathematics which may be at the root of solving problems apparently entirely dissimilar and yet they are only variants of the functions of rates plus material and energy balance.

Chapter 3 deals with the solution of differential equations most likely to be met by chemical engineers. It is in reality a well-classified and progressive list of recommended procedures without undue explanations or proofs. Graphical and special methods are included. Although the chapter is in the abstract to a greater degree than the first two in the book, judiciously placed examples help to bring engineering realities to what would have been a purely mathematical summary.

Chapter 4 deals with the application of partial differentiation, and is by necessity a chapter on thermodynamics in so far as practical examples are given. It is to be hoped that in future editions, if extension of the book is at all contemplated,

these two chapters (3 and 4) shall be more in conformity with the others in that they will deal with a greater number of illustrative problems of practical import-ance. The powerful method of partial derivatives in Jacobian notation as used by Shaw in compiling his tabulated relationships of thermodynamical functions is an example of the artistry of the authors in presenting a really difficult and com-plex subject in lucid terms. Only once they used the term " it is clear "—and that when it was clear in reality.

Infinite series have a frightening effect on most " practical " technologists. Happily, the authors deal with these in the fifth chapter in their characteristic manner of setting a problem which leads in a natural way to the series. Thus, before the reader has time to be frightened he is in the thick of it, as it were, and has no time to worry ! Bessel functions are introduced by following the solution, step by step, of a problem dealing with the temperature characteristics of a fin losing heat to the atmosphere by convection. The solution is given first by throw-ing the Bessel equation into a power series and evaluating the terms numerically and later by the use of the Bessel function directly.

Partial differential equations are discussed in the sixth chapter ; but aside from the mathematical aspect, this chapter can be recommended as an excellent text on the elements and principles of heat conduction and of diffusion of gases. While the full treatment of the solutions to the general equation of heat conduction,

$$\frac{\partial t}{\partial \theta} = \frac{k}{c\rho} \left[\frac{\partial^2 t}{\partial x^2} + \frac{\partial^2 t}{\partial y^2} + \frac{\partial^2 t}{\partial z^2} \right],$$

is left to be pursued in texts especially devoted to the subject, sufficient is elucidated to be of value both to beginners and more enlightened students of this problem to justify thorough reading of this chapter. Schmidt's graphical method of solving problems in unsteady-state diffusion and heat conduction is specially mentioned by the authors in the preface, and the clarity of both the treatment of the general construction of the graphs and the illustrative examples is, therefore, as expected. However, a moot point exists in the problem dealing with the interdiffusion of equal quantities of helium and methane, each at 5 atmospheres, when a partition which confined them in the two halves of a long cylinder is removed instantly. It is assumed in the solution that the concentration of both gases at the central plane will instantly become 0·5 and remain so indefinitely. This will be true if Dalton's law is obtaining. Gilliland and others have shown, however, that when equal volumes of ethylene and argon, hydrogen and carbon monoxide, or nitrogen and methane, at 100 atmospheres each, are mixed there is an appreciable change in the pressure of the resultant mixture. If this event takes place in the case of helium and methane then surely the plane of equal concentration will move into the region richer in methane ? Schmidt's method is still applicable, by follow-ing a moving instead of a stationary plane, if the rate of motion is known.

Chapter 7 is a summary of standard works on numerical analysis and deals with fitting equations to curves and determining the constants in such equations. One would only wish that somewhere in the book a place could be found where dimensional analysis could be treated in the terse yet explicit manner in which the method of least squares was treated in this chapter. Interpolation is adequately covered for all practical purposes : both Newton's and Lagrange's formulæ are given.

Graphical treatments are given in the eighth chapter. The discussion on mis-leading methods of correlating experimental data where certain functions are included in both co-ordinates to yield apparently regular correlations is particularly instructive. Triangular co-ordinates are studied in some detail and a section deals with alignment charts—the simpler straight line monographs.

The final chapter deals with theory of errors and precision of measurement. One felt continuously, while reading it, that the authors were pressed for space. The last portion of the chapter, however, tends to correct this impression, and the fact that 6 out of the 38 problems set in an appendix (to be solved by the student) deal with problems on errors rectifies it completely.

In conclusion, this book should be consulted by all who may have occasion to deal with design, development, costing, or similar problems in chemical engineering.

A. H. NISSAN.

Applied Chemistry for Engineers. By Eric S. Gyngell, Ph.D., B.Sc. Pp. viii + 328. Edward Arnold & Co., 1940. Price 15s.

This book might have been entitled " Answers to Questions the Non-Specialist is likely to ask about Fuels and Combustion, Corrosion, Paint, Water Treatment, Sewage Disposal, Mortar, Cement and Concrete, and Lubrication."

The first half of the book is devoted to fuels and combustion, and, as is natural in an English work, the bulk of the information presented deals with coal and its derivatives. The classification and analysis of coals are extensively dealt with, and an adequate account of carbonization practice (coke-oven, gas works and low temperature) and the properties of the solid and gaseous products of carbonization follows.

A section on producer gas and other manufactured gaseous fuels leads up to three chapters on liquid fuels, in which a large proportion of the space is devoted to petroleum and its uses.

The information presented is extensive and covers the ground adequately from the general reader's point of view, but on certain subjects is unfortunately out-of-date and not free from factual errors.

It would be an advantage if in future editions the various sections dealing with petroleum refining, including that on lubricating oil manufacture in the final chapter of the book, were collected together and systematized.

The section on fuels concludes with an excellent chapter on combustion calcula-tions. It is doubtful, though, whether there is any advantage in devoting several pages to two slightly different ways of computing weights of air required for combustion and of flue gases.

The second half of the book consists of condensed treatises on the other subjects mentioned in the reviewer's suggested alternative title. All can be thoroughly recommended.

In the chapter on " protective films " some mention of coslettizing and parkeriz-ing might with advantage have been inserted alongside sherardizing (here spelt sheradizing) and calorizing, under " Miscellaneous methods."

A few other misprints were noted. These include Ried for Reid (p. 125) and hyphoid for hypoid (p. 313).

A term not previously encountered is " electrionic radiation," apparently synonymous with ultra-violet light, on p. 247.   C. E. SPEARING.

PUBLICATION RECEIVED.

B.S.S. No. 743—1941 for Materials for Horizontal Damp-Proof Courses including Classification for Bituminous Damp-Proof Courses. (Revised March, 1941.) British Standards Institution, 28, Victoria Street, S.W.1. Price 2s. 3d.

The principal alterations included in this edition are : (1) a reduction in the minimum thickness of copper damp-proof courses, and (2) a re-arrangement of the clauses referring to the impregnating materials and the coating materials used in the manufacture of bituminous damp-proof courses with hessian base. The maximum amount of inert mineral admissible is not now stated, but the properties of the material are more exactly specified.

INSTITUTE NOTES.

ANNUAL REVIEWS OF PETROLEUM TECHNOLOGY.

The Council has decided that, in order to effect economies in printing and paper, the *Annual Reviews of Petroleum Technology* will be issued as a special number of the *Journal* to all members and subscribers entitled to receive the ordinary monthly *Journal*. According to present arrangements ten issues only will be made of the *Journal* during 1941. The *Annual Reviews* will be issued in lieu of the August and September issues, about the end of August.

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.

BEAN, Sidney Herbert, Managing Director, Messrs. Edward Wiggins & Co., Ltd. (*E. R. Redgrove ; E. A. Evans.*)

BROWN, Harry Eugene, Sales Manager, Lobitos Oilfields, Ltd. (*J. S. Parker ; J. Wood-Mallock.*)

CAMERON, William, Refinery Manager, Shell Refining & Marketing Co., Ltd. (*J. A. Oriel ; W. W. Goulston.*)

GIBSON, Arthur Reginald, Technical Representative, Petroleum Board. (*A. E. Hope ; H. E. Priston.*)

HALL, Frederick John Spencer, Chemist, Horton Manufacturing Co., Ltd. (*E. A. Evans ; W. D. Doughty.*)

IVES, Herbert Charles, Chief Chemist, Messrs. W. H. Willcox & Co., Ltd. (*E. E. Manning ; L. O. Maskell.*) (*Application for transfer from Associate Member.*)

MIDDLETON, Charles Roger, General Manager, Shell Refining & Marketing Co., Ltd. (*J. A. Oriel ; W. W. Goulston.*)

RALPH, Noël Albert, Chemist, Horton Manufacturing Co., Ltd. (*H. Heymann ; F. J. S. Hall.*)

SKILLING, Norman L., Regional Manager, Lubricating Oil Pool. (*C. Chilvers ; C. E. Burnett.*) (*Application for transfer from Associate Member.*)

STREETON, Reginald Douglas, Chemist, Petroleum Board. (*C. Chilvers ; A. Hamilton.*) (*Application for transfer from Student.*)

WALTON, Norman Lorraine, Chief Draughtsman, Messrs. Moore & Charlton. (*H. Moore ; H. E. Charlton.*)

ARTHUR W. EASTLAKE,
Honorary Secretary.

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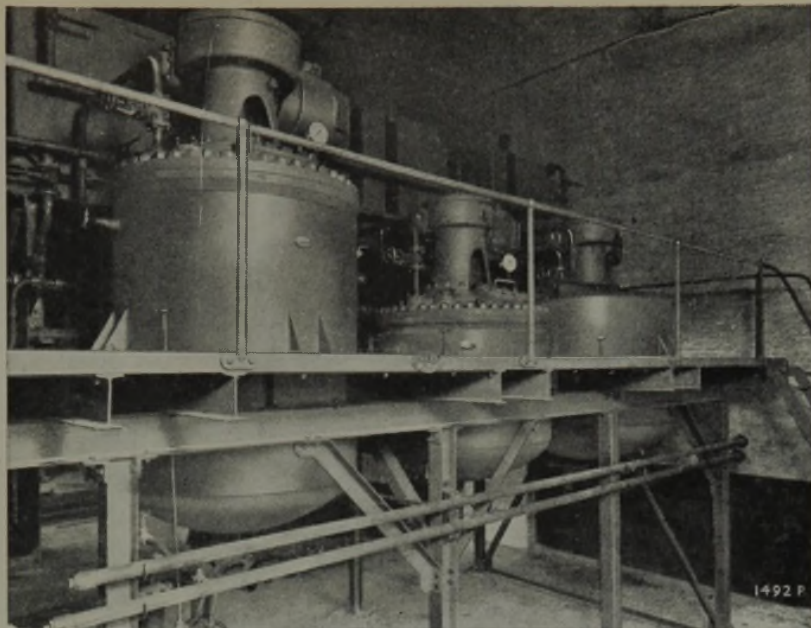
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