VOL. 25. NO. 193 NOV. 1939.

THE BEHAVIOUR OF VARIOUS ENGINE AND GEAR LUBRICANTS IN SEIZURE TESTS.* †

BY D. CLAYTON, B.Sc.‡

SYNOPSIS.

The results described in this paper are part of an investigation of the effect of various lubricants on the seizure characteristics of hard steel in the four-ball apparatus. It is found that ordinary lubricants, as well as extreme-pressure lubricants, give significant results. Commercial engine oils cover a range of quality from similarity with B.P. paraffin almost to fatty oils, overlapping with the mineral gear oils. Two kinds of extreme-pressure lubricants have been tested, early ones of the sulphurized-fatty oil type and more recent ones of the lead soap–sulphur type. The former behave in a similar manner to the mineral and fatty oils, but with appropriately superior qualities. The latter are different, giving appreciable wear at the low loads, and slight rises of friction at moderate loads instead of a sudden rise to a high value at high loads; moreover, they take an enormously high load without welding occurring. Tests have been made of the effect on a mineral oil of the proportion of an extreme-pressure dope of the sulphurized-fatty oil kind, and it has been found that a range of qualities could be obtained.

Kerosine and petrol, although causing appreciable wear even at low loads, behave surprisingly moderately throughout, the damage when "scuffing" occurs being less than with most mineral oils. Finally there is some discussion of the applicability of the results to gear lubrication.

INTRODUCTION.

THE four-ball apparatus, which has been used in these tests, was originally obtained for tests on extreme-pressure lubricants. On testing ordinary lubricants, however, the results were found to be equally interesting, and the range of substances has therefore been considerably increased. The primary aim in this extension of the work has been to provide information on the nature of wear and seizure. The apparatus has advantages for this work, in that it uses test-pieces (steel balls) which are highly consistent in material and finish, and that it provides well-defined contacts. Moreover, there is apparently freedom from fluid pressure film, which is a considerable advantage, as there is usually difficulty in eliminating the influence of fluid films in test machines.

A secondary aim has been to make a fairly complete investigation with this apparatus, so that comparisons will be possible with the behaviour of the same or similar lubricants in other testing machines, such comparison being a matter of some urgency at the present time.

Earlier work was reported in two papers to the 1937 General Discussion on Lubrication and Lubricants held by the Institution of Mechanical Engineers.[1] [2] Where relevant, brief summaries of some of these results are included in the present paper, to make the account of the behaviour of engine and gear lubricants more complete.

---

* Work carried out for the Lubrication Research Committee of the Department of Scientific and Industrial Research.

† Paper presented for discussion at the Morning Session (B) on 24th May, at the Summer Meeting of the Institute of Petroleum, held in Birmingham, 22nd–24th May, 1939.

The Discussion of all papers read at this Session will be published in the December *Journal*, together with the remaining papers.

‡ National Physical Laboratory.

Apparatus and Method of Test.

In this apparatus, supplied by the N. V. de Bataafsche Petroleum Maatschappij, and first described by Boerlage,[3] a ½-inch-diameter hard-steel ball is rotated under load in the cavity formed between three other similar balls clamped together in a cup containing the lubricant to be tested. Means are provided for recording the frictional torque on the balls in the cup, a friction–time chart being produced. Having applied the particular load, the short-circuit driving motor for the top ball is switched on, reaching its running speed of 1500 r.p.m. very quickly. There is a small peak on the friction chart due to the initial movement of the cup and the plate on which it stands. The friction then remains constant until, if the load is high enough, seizure occurs with a rise of the friction to a high value (generally 0·3–0·55); normally there is recovery from the seizure, the friction falling to a steady value. The motor is switched off after 1 minute.

Impressions closely circular in shape are worn on the three clamped balls. If seizure does not occur, the diameters of these impressions are closely equal to those calculated by Hertz's formula for elastic deformation under static loading. The mean diameters are plotted against the loads on logarithmic paper, and the Hertzian values plot as a straight line (cf. Fig. 2). When seizure occurs, the impressions are much larger, and the points fall generally on a straight line above the Hertz line. The load at and above which seizure occurs in the course of the one-minute run is referred to as the breakdown load; it is thus given by the line joining the two portions of the wear-load curve. If the load is made high enough, the seizure ultimately becomes so severe that the balls weld together. The time to seizure decreases with increase of the load, at a decreasing rate (cf. Fig. 2). There is normally some " scatter " of the plotted observations, as is to be expected from the consideration that, when failure is imminent, the roughness of even bearing-ball surfaces must be large compared with the thickness of the boundary oil film; the failure will thus depend on the particular configuration of the contact surfaces, which is certain to vary somewhat from test to test with different balls.

As regards the initial specific pressures, it may be noted that when the load (on the single ball) is 20 kg., the maximum pressure at the centre of each contact area, calculated according to the Hertz theory, is 27,600 kg./cm.^{2} (175 tons/in.^{2}); when the load is 100 kg., the maximum pressure is 47,100 kg./cm.^{2} (300 tons/in.^{2}). The mean pressure over the contact area is two-thirds of the maximum. The linear speed of translation is 58 cm./sec. (113 ft./min.).

The balls were all of one make, and no difference has been found between different consignments that was greater than the variation in the results with any one consignment. The results were not dependent on the particular method of initial cleaning with solvents.

Early Extreme-Pressure Lubricants.

The extreme-pressure lubricants previously tested [1] were current types in November 1935, and consisted of sulphurized fatty oil in mineral oil, except in one case, where a chlorinated compound was used. The mean

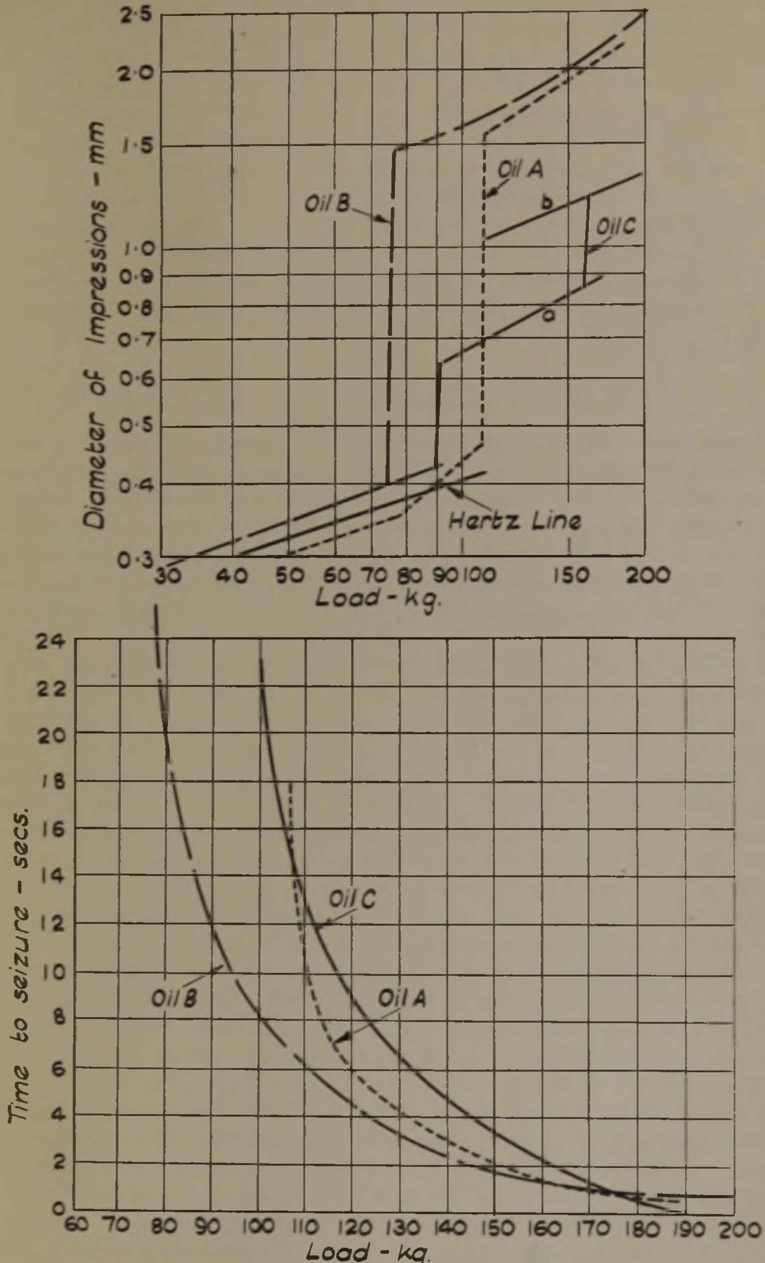


FIG. 1.

EARLY-TYPE EXTREME-PRESSURE LUBRICANTS.

wear and seizing-time curves are shown in Fig. 1. Oil A represented three oils very similar to each other (including the one containing the chlorinated compound), and oil B was generally similar, but had a rather lower breakdown load. Oil C was different in giving two types of seizure, and wear impressions in two corresponding groups. In the one case with this oil only a slight rise of friction occurred, the friction falling again slowly; the wear was moderate (region *a* of Fig. 1). In the other case there was a sharp peak in the friction–time chart and a quick recovery; the wear was then higher (region *b* of Fig. 1). The maximum coefficient of friction at seizure was 0·4–0·5 for oil B and those represented by oil A, but was 0·2–0·35 for oil C when a peak was obtained and 0·15 otherwise. The time to recovery was generally 1–1½ seconds, but rather more than 2 seconds for oil B.

THE EFFECT OF THE PROPORTION OF A DOPE.

After completing the work just described, a small quantity of extreme-pressure dope (marketed in January 1937) became available, and in view of the interest at the time in adding small quantities of dope to oils to improve their oiliness, some tests were made on the effect of adding different proportions to a mineral oil. The makers gave the information that the dope was prepared by adding 10 per cent. of sulphur chloride to a mixture of equal parts of mineral and fatty oil, and then expelling hydrochloric acid and chlorine.

The mineral base oil chosen was a current, winter-grade, motor-car engine oil. The seizing-time and wear-load diagrams for this base oil, H1, and for the mixtures containing 1·27 per cent. and 0·15 per cent. of dope, are shown in Fig. 2. (In the seizing-time diagram the arrows at the top indicate that in these tests there was no seizure within the 60 seconds of the test; where a number is added, this shows the number of seconds to seizure, the point falling above the limit of the diagram.) It was interesting to find that the 1·27 per cent. mixture showed peculiar characteristics similar to those of the oil C referred to above. As with this oil, two types of friction–time charts were obtained, as shown at (*a*) and (*b*) in Fig. 3. In chart (*a*) the friction rose relatively slowly to the maximum, and then only slowly decreased in value during the remainder of the one-minute run, there being no recovery of the usual kind. In chart (*b*) there was a sharp rise to maximum friction and a quick recovery; this was the type of chart obtained uniformly with all the normal extreme-pressure lubricants previously tested. Further, for the same load, the first type of seizure occurred only after a relatively long time, and both the maximum coefficient of friction at seizure and the wear were less than when the second type of seizure occurred. In the seizing-time-load diagram in Fig. 2 the long times are uniformly those of the first type of seizure; the corresponding wear values are plotted in region *a* of the wear-load diagram. The values of the maximum coefficient of friction at seizure were all about 0·3, whilst those with the second type of seizure ranged from 0·45 to over 0·6 with increasing load. The wear values corresponding to the latter are plotted in region *b* of the wear-load diagram; this wear was closely equal to that of the normal extreme-pressure lubricants at the corresponding loads.

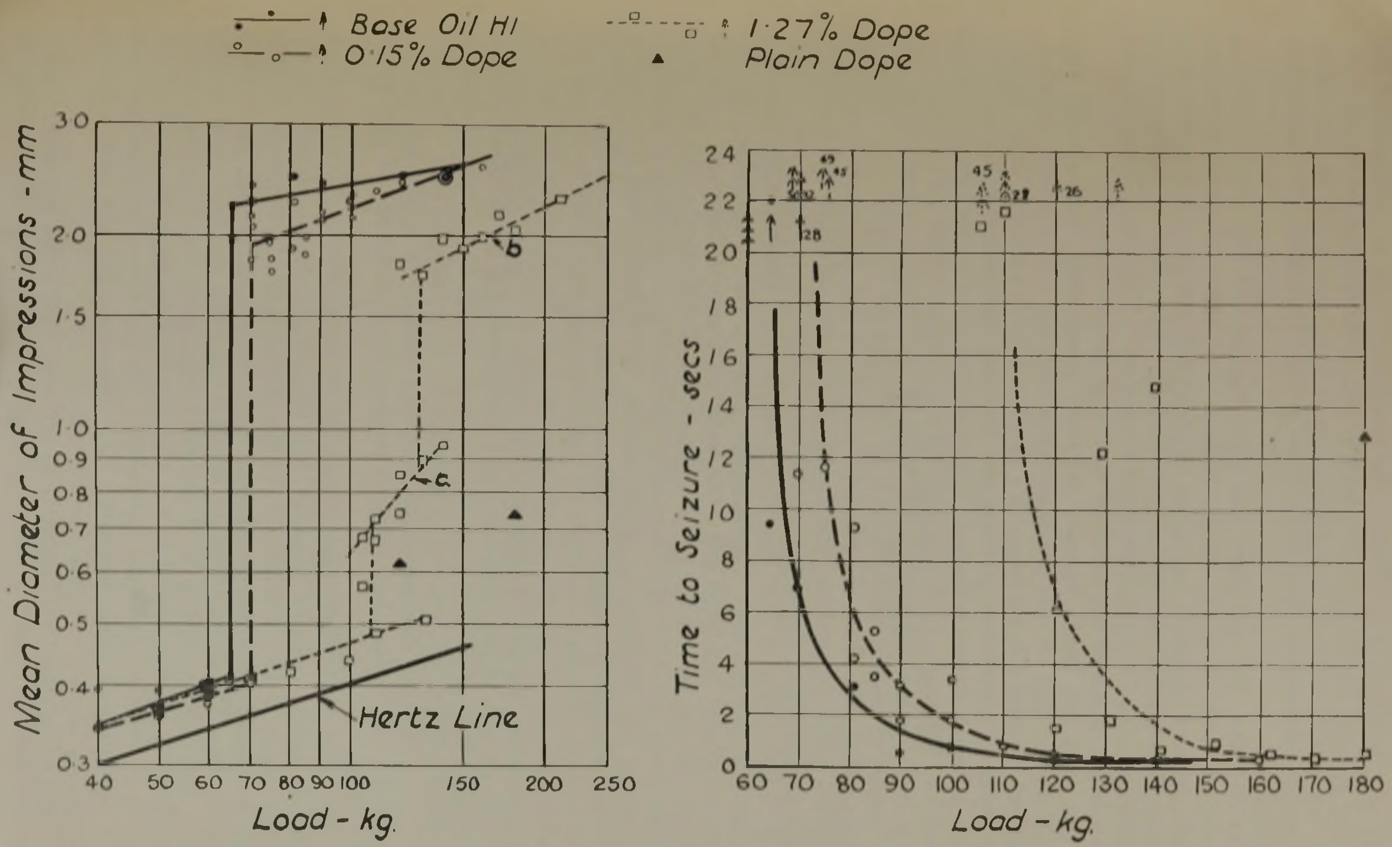


FIG. 2.
DOPED MINERAL OIL.

It may be noted that whereas the breakdown load to mild seizure was about 110 kg. (as high as the best of the extreme-pressure lubricants), the fact that the times to seizure were so long would add to the safety in many mechanisms, the extra time giving opportunity for conditions to change.

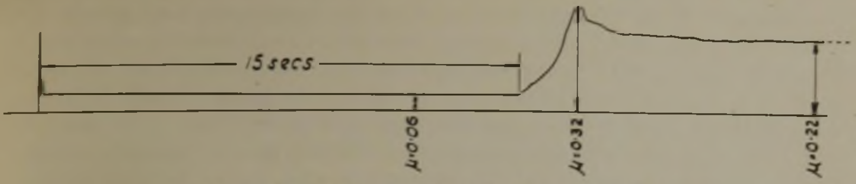
At 170 and 210 kg. there was quite exceptional behaviour with this mixture: after recovery in the normal way the coefficient of friction gradually and smoothly rose again to about 0·3, and remained at this or a slightly lower value until the end of the test. The effect on the size of the wear impressions was apparently not very great. This behaviour had never been found in any of the previous very large number of tests.

The 0·15 per cent. mixture behaved consistently throughout. The effect on the base oil was much less than with the 1·27 per cent. addition, but was beneficial in all respects. The breakdown load was 5 kg. higher, the times to seizure were greater, and the wear was rather less at the lower loads at which seizure occurred. The time to recovery from seizure ranged from 3 to 7 seconds, averaging 4½ seconds, compared with 7 to 12 seconds, with an average of 9½ seconds, for the base oil. The maximum coefficient of friction at seizure ranged from 0·45 to nearly 0·6 in each case. Typical friction–time charts are shown at (*c*) and (*d*) in Fig. 3. There were black deposits in the impressions with the doped oil; this points to decomposition having occurred at the high temperatures reached at the contacts.

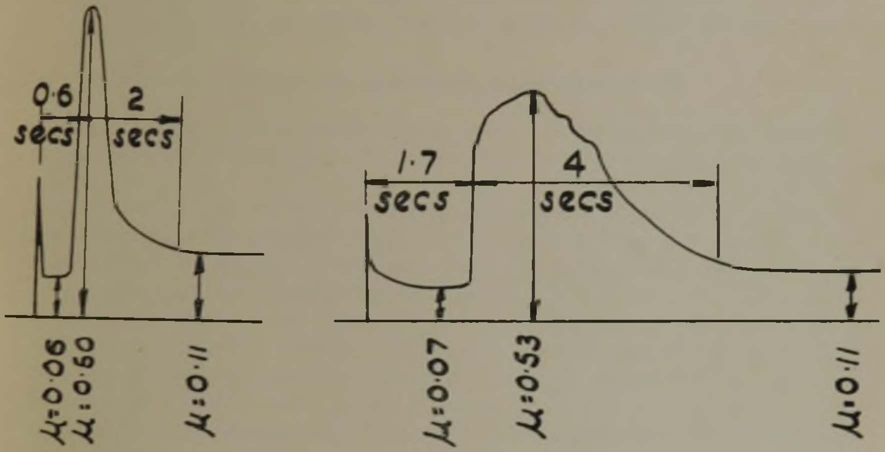
It is interesting to note how this 0·15 per cent. mixture compares with castor oil[2] (see p. 720). The breakdown load is only 5 kg. lower, and the time to seizure is a little less; the wear with seizure, however, is on the average the same over the range of loads, but is different in that the slope of the mean curve for this portion of the wear-load diagram is less than for castor oil. Further, a welding seizure was obtained with castor oil at 150 kg., whereas the behaviour with the doped oil was normal at 160 kg. The time to recovery averaged 4½ seconds, compared with 3 seconds for castor oil. Generally the results are very similar to those for rape oil as previously reported,[2] although here again a welding seizure occurred at 150 kg. It seems, therefore, that properties similar to those of fatty oils might be conferred on a mineral oil by the addition of a small proportion of dope such as the one being tested, and if welding seizure with fatty oil is due to major decomposition, as is not unlikely, it is possible that the stability of the mineral-oil mixture might extend the range of application of such oils.

Tests were made of the plain dope itself at 120 and 180 kg. At the lower load no definite seizure occurred, but there was some irregularity of the friction–time chart; the position of the plotted point in Fig. 2 shows that this irregularity was associated with some wear. At 180 kg. there was a seizure after 13 seconds, but the friction rose from the basic 0·05 to only 0·10, recovery occurring in 6 seconds; the wear was relatively small. The dope itself was therefore not characterized by high breakdown load, but by features related with the friction; the low wear was associated with low friction and quick recovery. The dope attacked the balls and cup, blackening them in the period of the test.

Tests of mixtures containing 0·02 per cent. and 0·005 per cent. of dope were of interest in seeing how small a proportion of dope would affect the

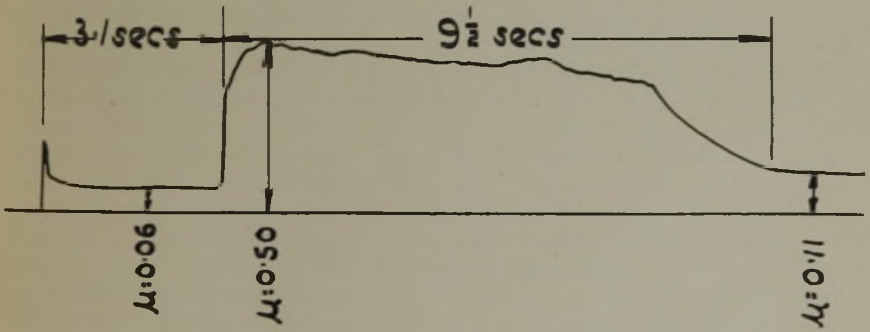


(*a*) Mineral Oil H1 + 1·27% E.P. Dope. 140 kg.



(*b*) Mineral Oil H1 + 1·27% E.P. Dope. 140 kg.

(*c*) Mineral Oil H1 + 0·15% E.P. Dope. 100 kg.



(*d*) Mineral Oil H1. 81 kg.

FIG. 3.

FRICTION–TIME CHARTS.

behaviour of the base oil, in view of the possible use for "oiliness" improvement. With 0·02 per cent. of dope the breakdown load was 70 kg., as with 0·15 per cent., and a certain number of long times to seizure were obtained, raising the mean seizing-time-load curve to almost the same position as that of the 0·15 per cent. mixture. In other respects, however, the difference from the base oil was only just perceptible; thus the wear with seizure at the lower loads was rather less in a number of cases, and the time to recovery ranged from 5 to 11 seconds, with an average of 8 seconds, just a little less than for the base oil. With another mineral oil of much inferior quality, 0·02 per cent. of this dope increased the breakdown load by nearly 10 kg., but otherwise was without effect. With 0·005 per cent. of dope the results were identical with those of the base oil.

Recent Extreme-Pressure Lubricants.

Results are now given for more recent commercial types of extreme-pressure lubricants (purchased early 1938), which showed marked differences from the earlier ones.

The first of these, E, was a medium-viscosity hypoid gear oil of the lead soap–sulphur type (10 per cent. lead naphthenates, and $2\frac{1}{4}$ per cent. sulphur). The seizing-time and wear diagrams are plotted in Figs. 4*a* and 4*b*, and the mean curves of a typical extreme-pressure lubricant D of the earlier type are superimposed on the diagrams to show the differences. Instead of the breakdown at a certain load and a sudden increase of diameter of impression, the later lubricant E gave a gradual increase of diameter throughout the whole range of loads. From 20 to 50 kg., region *a* of Fig. 4*b*, the impressions were similar to the non-seizure type of previous tests—viz. flat, very lightly scored impressions—but the diameters were rather greater, as can be seen from the positions relative to the Hertz line. A photograph of a typical impression of this type is shown at (*a*) in Fig. 5. From 50 to 70 kg., region *b* of Fig. 4*b*, the impressions became slightly cupped instead of flat, although still remaining round, as shown at (*b*) in Fig. 5; however, this further removal of material in developing the cupped form was not accompanied by any variation of friction sufficient to show on the charts. The size of the impressions was higher still than for the earlier type of lubricant D. From 80 to 150 kg., region *c* of Fig. 4*b*, an action more like tearing of the metal occurred, the impressions being rough and the edges irregular. The impressions were no longer round, and examination of a number of balls suggested that relatively large particles were torn out of the contact region, and, being carried round by the top ball, caused scoring of the ball surfaces outside the initial contact area by being trapped in the space between them; the impressions were thus elongated at right angles to the direction of motion, as shown at (*c*) in Fig. 5, in which the original circular impression can be seen faintly. This tearing of the metal was accompanied, from 90 to 150 kg., by very slight changes of friction, the maximum coefficient being only 0·11 in all cases. The "times to seizure" in Fig. 4*a* are the times to this rise of friction, as representing the first stage of failure, but it is important to contrast this mild behaviour with that of the earlier type of lubricant, with which the coefficient of friction rose at failure for a short time to a peak value of over 0·4 at corresponding loads. Fig. 4*a* shows that the times to the change of friction are shorter, indicating inferiority; on the other hand, the wear does not rise at corresponding failure loads to the high values of the earlier type of lubricant. Similarly the load at which this curve becomes vertical is not a breakdown load in the usual sense.

There is thus a need for an explanation of the mechanism of the action of the lubricant, by which with the one type there is a gradual transition with increase of load from a fine wear (with removal of particles ranging possibly from the crystal size of hard steel to even molecular size) to a tearing wear (in which particles consisting of groups of crystals are removed), and with the other a finer wear persists to a relatively high load, but then there is a sudden removal of large particles, to a greater extent than occurs in the former case. The coefficients of friction before seizure occurred were not dissimilar in the two cases, so that explanation on the basis of the heat developed is not feasible.

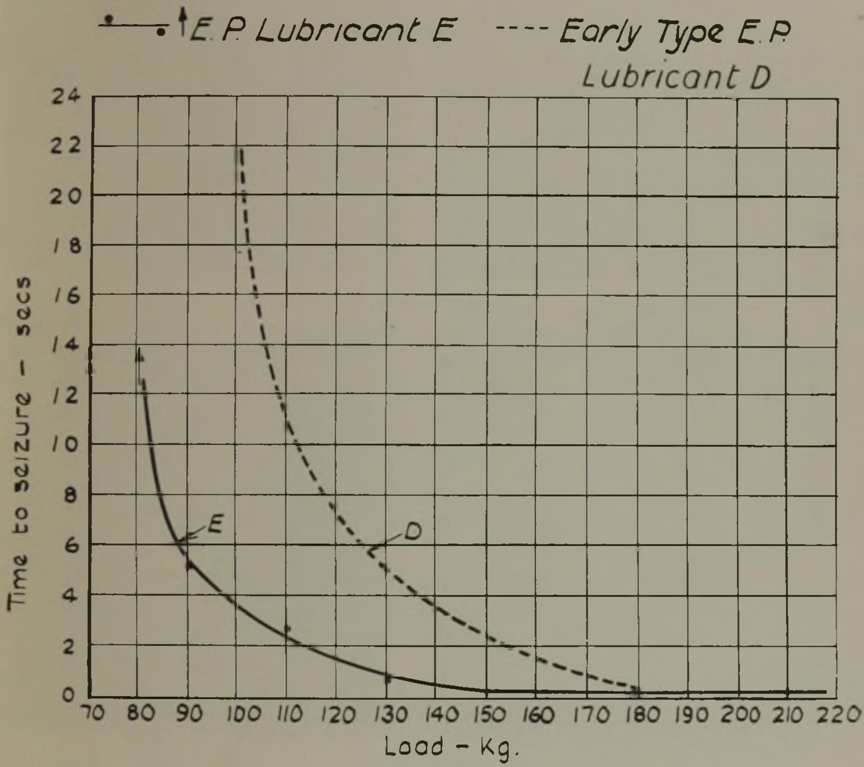


FIG. 4*a*.

TWO EXTREME-PRESSURE LUBRICANTS.

Although the time to " seizure " had become so short at 150 kg., the wear was so moderate that tests were made at higher loads to see what would happen. It was found that the load could be taken to the limit of the machine (730 kg.) without very great alteration in the character of

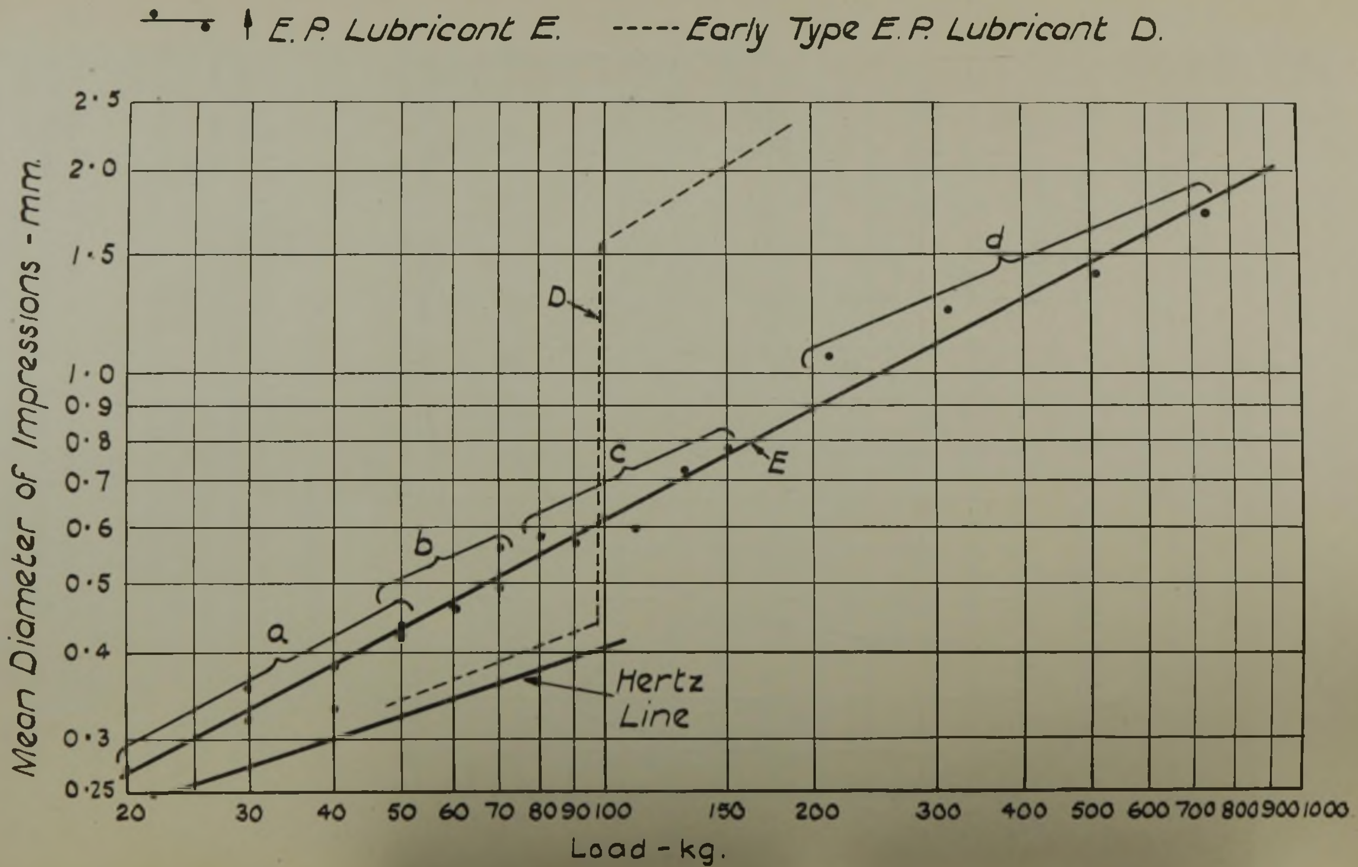
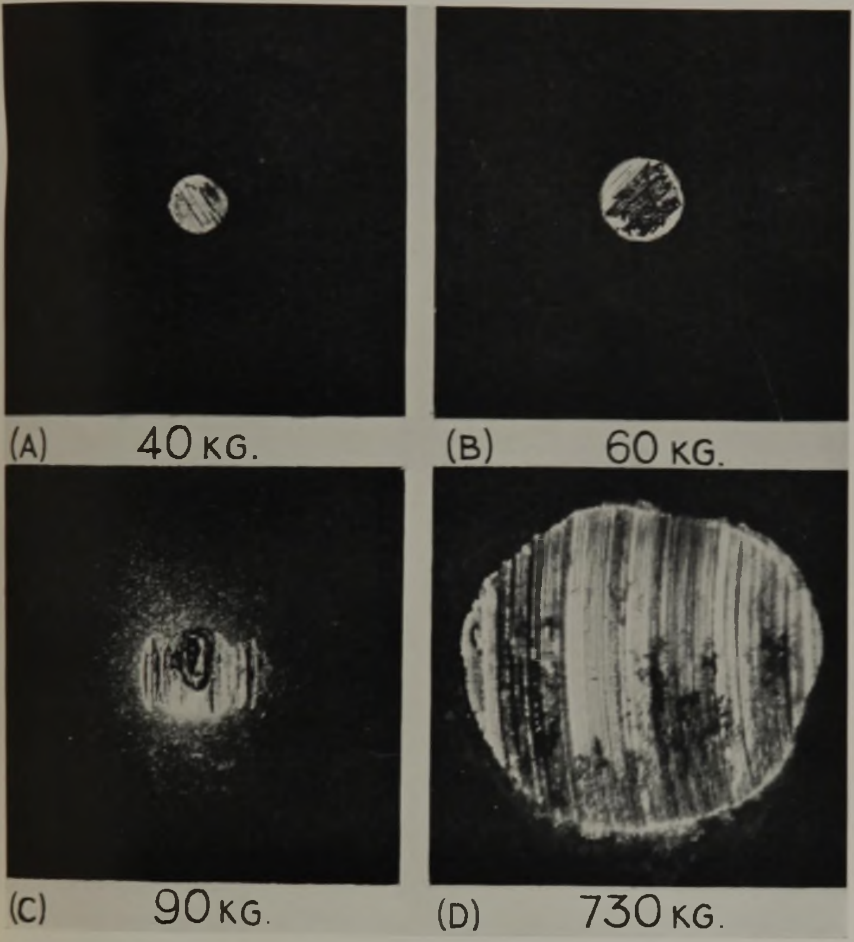

E.P. Lubricant E.
----- Early Type E.P. Lubricant D.
Mean Diameter of Impressions - mm.
2·5
2·0
1·5
1·0
0·9
0·8
0·7
0·6
0·5
0·4
0·3
0·25
20
30
40
50
60
70
80
90
100
150
200
300
400
500
600
700
800
900
1000
Load - kg.
a
b
c
d
D
E
Hertz Line

FIG. 4b.



(A) 40 KG.

(B) 60 KG.

(C) 90 KG.

(D) 730 KG.

Fig. 5.

WEAR IMPRESSIONS ON STEEL BALLS WITH EXTREME-PRESSURE LUBRICANT E.

(Magnification = 25 ×.)

[*To face p.* 718.

(A) KEROSINE 50 KG., x 25

(B) KEROSINE 120 KG., x 2

Fig. 8.

WEAR IMPRESSIONS.

the failure. The impressions were progressively larger and were rounder, becoming cupped as in a seizure with other lubricants, but the size at the highest load was still no larger than those of the earlier lubricant at 100–150 kg., see region *d* of Fig. 4*b*. A photograph of the impression at 730 kg. is shown at (*d*) in Fig. 5.

At 210 kg. and higher loads a thick black deposit was formed round each of the impressions, and in considerable quantity on the top ball, presumably due to decomposition of the lubricant at the high temperatures reached at and near the contacts. Smaller amounts of staining had occurred at lower loads, down to 130 kg., but the amount of deposit became much greater at 210 kg. and above.

At these higher loads failure occurred immediately the test began and the maximum value of the coefficient of friction could not be ascertained with any accuracy; the earliest value that could be measured was quite low, however, being about 0·13, and falling smoothly to about 0·07. The earlier type of extreme-pressure lubricant with which the present one is being compared was not tested beyond 180 kg., but with another of the same type there was a complete failure at 210 and 250 kg., the balls welding solidly together with the material melted or softened at the contacts (compare Fig. 8(*b*)).

Considering the wear results as a whole, all the points fall fairly closely on a straight line, the deviations of the points at each stage not justifying any departure from this form. At low loads the lubricant must be considered to be inferior to most of the lubricants of all kinds previously tested, in that greater wear occurred during the test. When the breakdown load of those lubricants is passed, however, this one is greatly superior, in that the coefficient of friction and the wear were smaller, and an enormously high load could be taken without catastrophy. In use, therefore, it would appear that a low continuous wear would have to be tolerated for the sake of immunity from severe failure when high loads were encountered.

Two other extreme-pressure lubricants, F and G, sold by one company, were tested. Oil G was specifically a hypoid gear lubricant, containing 4½ per cent. lead soap and 2½ per cent. sulphur, whilst oil F was a milder, general-purpose, extreme-pressure lubricant, containing 13½ per cent. fatty oil, 1½ per cent. sulphur and 10 per cent. chlorinated product (3 per cent. chlorine). Oil G was thus of similar type to oil E described above, but contained less lead soap; oil F apparently differed from the earlier lubricants of the sulphurized fatty oil type in containing a chlorinated product in addition.

This chlorinated product altered the whole character of the behaviour of the lubricant. Comparing the wear curve with that of oil D in Fig. 4*b*, the definite breakdown no longer appeared, and loads up to the limit of the machine could be taken without a welding seizure occurring. The wear diameter increased continuously with load, the plotted points falling on a straight line as in the case of the lead soap–sulphur lubricant E described above. Indeed, there was a very close similarity in behaviour in all respects to this lubricant, closer actually than in the case of the other lead soap–sulphur lubricant G. With the latter there was a difference of behaviour from that of oil E in the region of 150 kg. which resulted in the wear rising locally to almost double the value.

Generally, lubricant G gave more wear than that, F, containing the chlorinated product, except at the highest load, although F was said to be a milder, general-purpose lubricant. The wear results for F and the lead soap–sulphur lubricant E were on the average about the same, but the rate of variation with load was different; the smaller wear for F at the low loads must be counted an important advantage for general use. The times to rising friction showed the increasing order of quality G, E, F; the general-purpose lubricant is thus best, the curve being practically the same as that of the early extreme-pressure lubricant D. Owing to the rise of friction not being as high as with other lubricants, however, these curves cannot be given the significance previously attached to the seizing-time curves, and in particular the load at which the curve becomes vertical cannot be regarded as a breakdown load with quite the same weight as before. Staining round the impressions, presumably due to decomposition of the lubricant, occurred as with lubricant E, increasing from traces at about 100 kg. to noticeable amounts at 210 kg. and higher; that with lubricant F was lighter in colour than with lubricants E and G. Comparing the wear results with those of other substances, the mean wear curve for lubricant G crosses over that for "golden syrup"[2] between 100 and 150 kg., to show greater wear at the higher loads; it similarly passes through the results for the exceptional sulphurized-fatty oil lubricant C, Fig. 1.

OTHER GEAR LUBRICANTS.

Castor Oil.[2]

The breakdown load for castor oil was 75 kg., intermediate between the mean values for the mineral oils and the early extreme-pressure lubricants, although equalling that of the worst (B, Fig. 1) of the latter. A welding seizure was obtained at 150 kg. The maximum coefficient of friction at seizure varied from 0·45 at low loads to nearly 0·6 at the highest. The time to recovery from seizure varied from 3 to 5 seconds, again intermediate between the mineral and extreme-pressure oils.

Oils Containing Zinc Oxide.[1]

Comparing a gear-box oil X and a back-axle oil Y, both containing zinc oxide, with their mineral base oils, the most striking effect of the zinc oxide was the conversion of long, ragged seizures into much smoother, short seizures, almost as good as those of castor oil. The times to recovery were 3–4 seconds for the gear-box oil and 4–7 seconds for the back-axle oil, compared with 20 to over 60 seconds and 20–40 seconds for the base oils, respectively. The wear with seizure was correspondingly reduced, becoming very similar to that of castor oil, and the appearance of the wear impressions was improved, the impressions being smoother and not discoloured by heat. The zinc oxide has no effect on the maximum coefficient of friction at seizure. The breakdown load for the gear-box oil was raised some 10 kg. to that of castor oil, but that of the other was scarcely affected. The wear when seizure did not occur was higher than usual with the gear-box oil, as though the zinc oxide were abrasive, but there was no such effect with the back-axle oil. Testing castor oil containing zinc oxide there were only the very minor differences from plain castor oil of a few mild seizures in the neighbourhood of the breakdown load, and a slightly lower wear at the highest seizure loads.

Mineral Engine and Gear Oils.

The results for all the engine and gear oils so far tested in this apparatus are collected in Table I, those for B.P. paraffin being added as a matter of interest. Most of these results have been given in earlier papers; the exceptions are H1, described earlier in this paper (p. 712), H2, as ample of nominally the same oil obtained previously, and oil J. This last oil was known to contain an oxidation inhibitor, and this addition was said to improve the behaviour under high-pressure conditions; the results below show, however, that the oil falls rather low in the scale of the mineral oils.

Table I.

Results for Mineral Engine and Gear Oils.

Oil and Reference.	Description of Oil.	Break-down Load, kg.	Maximum Coefficient of Friction at Seizure.	Time to Recovery, secs.	Average Intensity of Pressure at Break-down Load, lb./in.^{2}.	
					No Seizure.	Seizure.
B.P. Paraffin [2]	Medicinal oil	40	0·3–0·5	20 to >60	286,000	16,600
Oil H2	Winter-grade, motor-car engine oil.	40	0·3–0·5	15 to >60	280,000	16,800
Oil J	Summer-grade, motor-car engine oil.	40	0·3–0·5	20 to >60	247,000	10,200
Dried Oil [2]	Winter-grade, motor-car engine oil.	50	0·3–0·45	15 to >60	290,000	(12,500)
Oil B [2]	Solvent-refined summer grade, motor-car engine oil.	55	0·35–0·5	15 to >60	284,000	10,000
Oil G [1]	Motor-car gear oil.	55	0·35–0·5	20 to 30	276,000	(10,500)
Oil A [2]	Conventionally-refined summer grade, motor-car engine oil.	60	0·4–0·5	5 to 15	332,000	13,000
Base Oil X [1]	Motor-car, gear-box oil.	60–65	0·4–0·55	20 to >60	277,000	9,100
Base Oil Y [1]	Motor-car, back-axle oil.	65	0·4–0·55	20 to 40	316,000	9.300
Oil H1	Winter-grade, motor-car engine oil.	65	0·45–0·55	12 to 7	286,000	9,700
Oil JXB [1]	Partly-refined gear oil.	75	0·45–0·55	3 to 4	317,000	17,300

In Table I the oils are arranged in the order of increasing breakdown load. The range is from 40 to 75 kg., thus overlapping that of the fatty oils, and it is interesting to note that the range for motor-car engine oils is from 40 to 65 kg., indicating marked differences of properties under these test conditions. Most striking is the difference between the two kinds of nominally the same oil, H1 and H2. The inferiority of the solvent-refined oil to the same brand of conventionally-refined oil, oils B and A respectively, may be noted; this is the one known case where this comparison can be made. Two of these motor-car oils have very closely the same properties as medicinal paraffin in this test. The range for the few gear oils tested lies generally a little higher than, but overlaps, that of the engine oils. The gear oil with the highest breakdown load, JXB, is exceptional in being only partly refined and probably containing an unusually large proportion of unsaturated constituents; this oil behaved like a fatty oil in time to recovery and wear, as well as in breakdown load. That the unsaturated constituents are so effective in this test is interesting. They are expected to be effective in friction tests, but whereas additions of fatty acid to an oil are effective in friction tests, they are not so influential in the high-pressure test, even as much as 10 per cent. of oleic acid in B.P. paraffin having only a very moderate beneficial effect.[2] The difference due to adding 10 per cent. oleic acid is barely as great as that between the conventionally-refined oil A and the solvent-refined oil B. The one gear oil G known to contain a proportion of solvent-refined oil is inferior to engine oil A. Three of the gear oils (all the normal ones) are inferior to the exceptionally good engine oil H1.

Table I shows that with increase of breakdown load there is some increase of the maximum coefficient of friction at seizure. With one or two exceptions, however, there is a general tendency to the same value at the same load; the same values are obtained with the fatty oils castor and rape, and it is apparent that some fundamental phenomenon is occurring. It is thought to be significant that the mean values found, 0·35 at 50 kg., 0·5 at 100 kg., are similar in order to the values found for the coefficient of friction of clean dry steel on steel. The values obtained with the extreme-pressure lubricants are lower, but there may be some chemical action in this case, making the comparison invalid.

With all the oils except H1 the time to recovery increases with load; also, generally the slope of the wear curve beyond breakdown is greater when the time to recovery increases rapidly to high values, the very flat curve for oil H1, for which the time decreased with increase of load, being noticeable. For the range of oils, there is little systematic variation of the time to recovery with breakdown load, except perhaps in the sharp decrease at the highest breakdown loads. In the cases in which there is a smaller average value, there is generally less wear, as would be expected. No definite explanation of the mechanism of the recovery has been found, but there must be a re-establishment of some kind of effective lubrication. The surfaces are sufficiently rough to make the formation of a complete fluid film seem impossible, and there must be at any rate a large proportion of boundary friction. The quality of the oil which leads to quick recovery from seizure is desirable to reduce the amount of damage should failure occur in practice. It is probably of importance in running-in, for when local cohesion occurs at the high points in contact, the removal of material is much more likely to remain local with an oil giving quick recovery. Similar behaviour may be expected with regard to particles trapped between the surfaces. As regards the possible partial influence of this feature on breakdown load, it may be noted that with the different classes of lubricants there is quicker recovery with the lubricants giving the higher breakdown load.

Generally the wear resulting from seizure at the breakdown load increases with increase of this load. Working out the intensities of pressure on the projected area of the impressions, assuming uniform distribution, the values given in the last column of Table I are obtained. In a few cases the mean wear value corresponding to the breakdown load is not well defined, and the calculated pressures are then put in brackets. Over the middle of the range of breakdown loads the pressures are scattered within ± 2000 lb./in.^{2} of 11,000 lb./in.^{2} (*i.e.*, ± 20 per cent.), showing a general tendency to proportionality of load and area. The exceptional values depart so widely from this range, however, as to reduce the significance that might be attached to this result. Moreover, at higher loads than the breakdown loads, at which similar behaviour might be expected, the intensities of pressure not only depart greatly from these values but differ enormously from each other. A fundamental feature is therefore not apparent. For the purpose of comparison with the values given above, it may be added that the intensities of pressure at breakdown load for the fatty oils tested were : castor oil 18,600 lb./in.^{2}, and rape oil (two samples) 11,700 and 14,400 lb./in.^{2}; for the worst (B) of the early extreme-pressure lubricants (Fig. 1) and the normal one (A) the values were 26,000 and 32,800 lb./in.^{2}, respectively.

The mean intensities of pressure when seizure does *not* occur at the breakdown load are given in the next to the last column of Table I. These values take into account the small differences of departure of the size of the impressions from the Hertzian size, and the effect is to destroy any systematic variation with the breakdown load. The average value is 290,000 lb./in.^{2} (130 tons/in.^{2}). If therefore seizure (" scuffing ") occurs at this load, the pressure that can be taken is reduced to 1/30 of its no-seizure value.

It is apparent from the above account that whilst the breakdown load is the most important single quantity observed, the other observations all contribute to assessing the qualities of an oil.

KEROSINE AND PETROL.

Interesting results having been obtained with a variety of lubricants, and the results apparently being independent of viscosity, it was decided to try really thin liquids.

Kerosine.

In tests of kerosine almost immediate seizure occurred at all loads except the lowest load of 20 kg. There was recovery from seizure, however, the time to recovery being very short for low loads; it increased with increase of load from less than 1 second for 30 kg. to 2½ seconds for 60 kg. The maximum coefficient of friction also increased from 0·25 to 0·3 over the same range of loads; the values were thus quite moderate for seizures. A typical friction–time chart is shown at A in Fig. 6. With seizure occurring at all these loads, there was no portion of the wear curve following the Hertz line, as in the case of the ordinary lubricating oils : there was a progressive departure as shown at *a* in Fig. 7, the appearance of the impressions gradually changing from a lightly-scored, flat impression to a scored, cupped impression, in a similar manner to the extreme-pressure lubricants E, F, and G. (pp. 719 and 720). The wear in this region was only slightly greater than with the extreme-pressure lubricant G.

Above 60 kg. the seizure hump in the friction–time chart became much more pronounced, as shown at B in Fig. 6. The time to recovery became generally longer, 4–8 seconds, and the maximum coefficient of friction higher; the latter increased from 0·4 at 65 kg. to 0·5 at 100 kg., thus equalling the average values for mineral and fatty lubricating oils. Corresponding with these increases the wear suddenly became greater, to give portion *b* of the wear curve in Fig. 7 for the range of high loads. The seizure at 120 kg. was so severe that the balls welded together; material was wiped off the top ball into the spaces between the bottom ones. It is interesting to note that the wear in this region of high loads was less than with most of the mineral oils; the appearance of the impressions was similar.

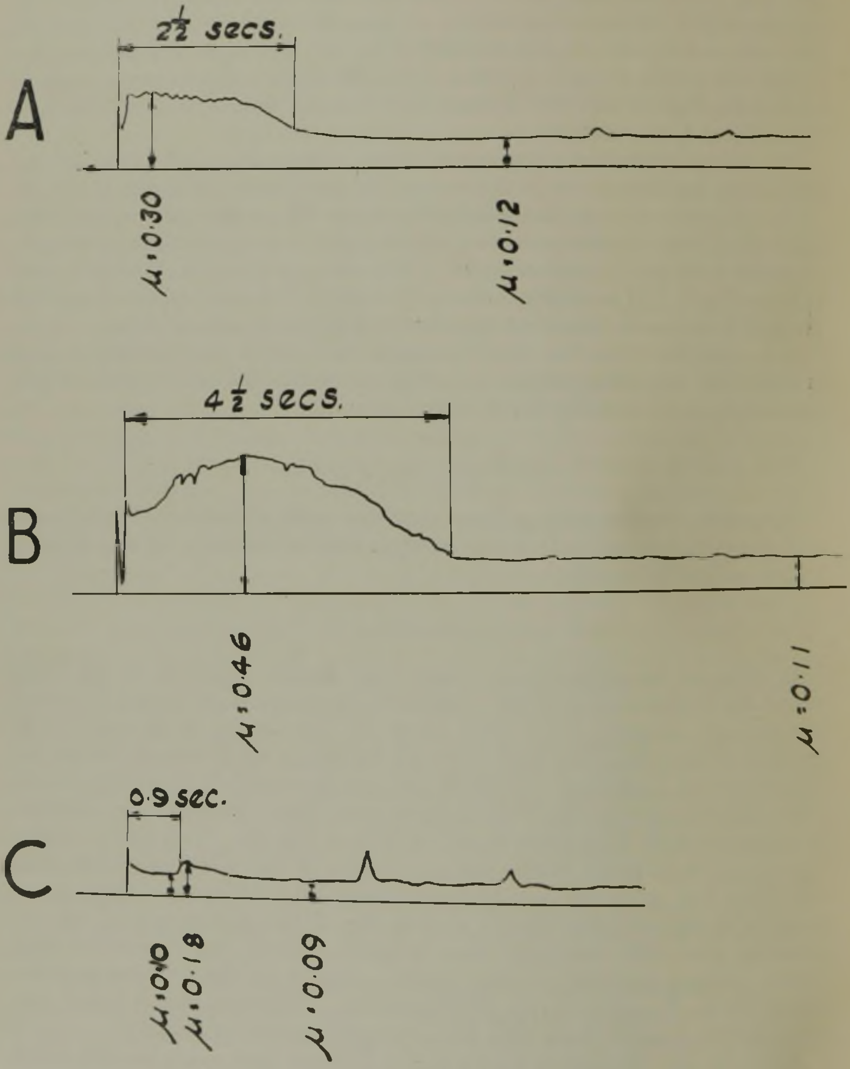


Fig. 6.

FRICTION–TIME CHARTS.

A. Kerosine. 60 kg.
B. Kerosine. 70 kg.
C. Petrol. 45 kg.

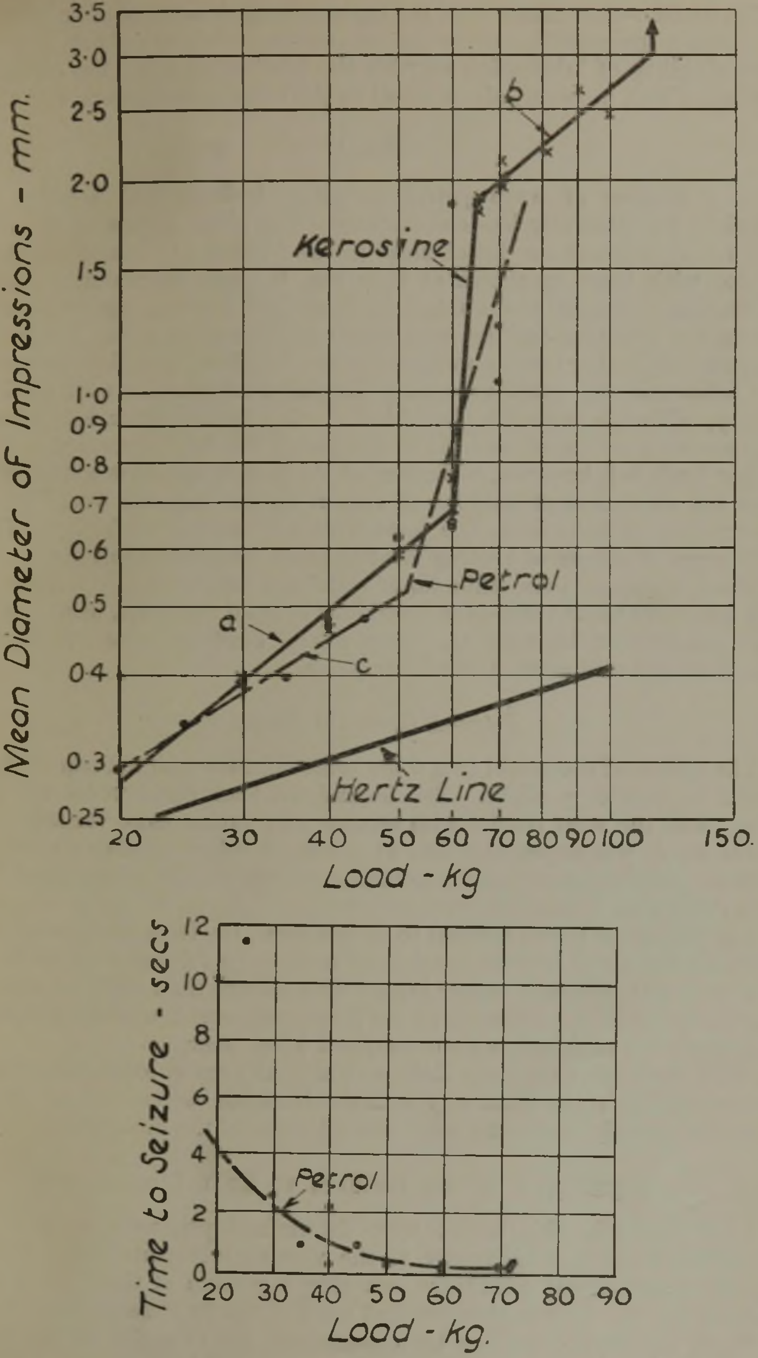


FIG. 7.

KEROSINE AND PETROL.

The friction–time charts were not quite as smooth as usual after recovery, very slight irregularities occurring at intervals, indicating not quite the same stability of lubrication as with the lubricating oils; the coefficient of friction was, however, about equal to the average for mineral oils.

Petrol.

In a number of ways petrol (aviation, hydrocarbon) behaved like kerosine, but generally less consistently. The slight seizure at low loads became with petrol a series of kicks in the friction–time chart decreasing in size with time, as shown at C in Fig. 6. The maximum coefficient of friction averaged about 0·2. At these low loads a regular series of points was obtained for the wear curve in the region *c*, Fig. 7, the wear tending to be rather less than with kerosine. At 60 kg. and higher, however, the behaviour was more uncertain, ranging from seizures with quick recovery, although rather higher friction than before, to seizure without any recovery in the 60 seconds of the test. The heat generated at these higher loads led, however, to boiling of the petrol, and as it seemed likely that the formation of bubbles of vapour at the contacts would lead to uncertainty of behaviour, the tests were not carried on further. There were signs of abnormal heating in some cases, confirming this point.

Thus, although these thin liquids are not regarded as lubricants—in fact generally the reverse—the behaviour is quite moderate, in spite of the high pressures at the contacts. Even when " scuffing " occurred, the wear was less than with most of the mineral oils.

Petrol–Mineral Oil Mixtures.

The effects of the petrol in a 6 per cent. mixture with mineral oil A (see Table I) were only slight. The breakdown load was lowered by about 5 kg., and the wear results with seizure were rather more variable. The latter result was apparently due at the lower seizure loads to a lowering in some cases of the maximum coefficient of friction, and at the higher loads to a prolonging of the time to recovery.

Increasing the petrol content to 30 per cent., the form of the wear curve was still the same, but the breakdown load was a further 5 kg. lower, and the wear was generally rather higher with seizure than with the plain oil. Again, however, the influence of the petrol was seen in a number of milder seizures being obtained, with consequent lower wear.

With both concentrations there was normal wear at loads below 50 kg., corresponding in the usual way with the Hertzian values, and not showing the continuously increasing wear characteristic of the plain petrol.

APPLICABILITY OF THE RESULTS TO GEAR LUBRICATION.

The results in this report were determined primarily as interesting observations of the behaviour of the various lubricants under the particular experimental conditions, covering a portion of the field in which seizure occurs. It was thought that some of the features revealed were of general significance, as has been suggested, for example, in the section on the mineral oils; that the differences found between the lubricants would appear in other applications; and that there would be direct applicability to some of the mechanisms in which plain sliding occurs with high pressures at the points of contact. It was not expected that the results would be directly applicable to gearing, because the motion in this apparatus is different from that between gear teeth; at the same time it was considered that the results should approach those for gear teeth at loads causing nearly instantaneous seizure, under otherwise similar conditions, as the influence of the superimposed rolling motion for the gear teeth would then become very small. It was in this respect that an oil with a flatter seizing-time-load curve was regarded as having a relative advantage; only this general inference was drawn, however, as the loads causing breakdown in specific very short times were not precisely determinable.

As far as extreme-pressure lubricants were concerned, it seemed that the speed of sliding might be too low, as several papers had brought out the importance of speed in its effect on temperature at the contacts, the good qualities of these special lubricants appearing only at relatively high temperatures. Against this the rating of the various classes of lubricants was undoubtedly in the right order, the hypoid gear lubricants showing seizure characteristics appropriately superior to the others; further, the appearance of the impressions showed that high temperatures had actually been reached at the contacts. As regards the first point, however, it was possible that the results were qualitatively in order, but not quantitatively represented, and as regards the second, that the high temperatures were the result of time and the absence of rolling motion, whereas high temperatures were required to be developed in a fraction of a second to represent hypoid gear teeth. Van Dijck and Blok[4] have suggested, however, that the high intensity of pressure at the contacts may compensate for the low speed, and give for the highest loads a rate of heat generation comparable with that of the S.A.E. machine, which gives the nearest experimental approach to the conditions of the hypoid gear. It seems, therefore, that the results may be of more direct utility than was at first apparent.

Further, and more generally, Blok has recently claimed that rating lubricants according to the breakdown load giving seizure even in as long a time as 2½ seconds represents the behaviour in gearing, including the hypoid type. The evidence for this is not yet available, but it follows from the arguments above that it is not unreasonable, and a list of the "2½-second" breakdown loads for the lubricants tested in this investigation is given in Table II. The 2½-second interval is not as short as would have been thought desirable, but it does take account of the slope of the seizing-time-load curve, and it is possible to read off the load at this interval more accurately than at shorter intervals. Nevertheless the accuracy is not great, owing to the scatter of the results, particularly in the case of the extreme-pressure lubricants; it is important to keep this in mind in comparing oils of similar breakdown loads.

Generally the engine oils, gear oils, and early extreme-pressure lubricants maintain their previous relative positions. Some of the gear oils gain considerably from flat seizing-time-load curves, but not generally so much as the early extreme-pressure lubricants. The most striking feature of the table is, however, the position of the recent extreme-pressure lubricants, which occupy a low position again, due to the relatively low load at which friction rise is first found. As remarked before, this is not quite a fair comparison, as the rise of friction is not nearly so high as when the full seizure occurs in the other cases. It follows from this that the 2½-second breakdown load is unsatisfactory for the recent extreme-pressure lubricants in that it introduces the time to "seizure," which is not a comparable feature and leaves out of account other valuable qualities of these oils.

TABLE II.

The "2½-Second" Breakdown Load.

Lubricants.	2½-Sec. Breakdown Load, kg.	Ordinary Breakdown Load, kg.
B.P. Paraffin	50	40
Mineral Engine Oils :		
Dried Oil (winter)	60	50
Oil H2 (winter)	60	40
Oil J (summer)	60	40
Oil B (summer, solvent refined) . .	65	55
Oil A (summer, conventionally refined) .	75	60
Oil H1 (winter)	80	65
Gear Oils :		
Base Oil X (mineral)	75	60–65
Oil X (ZnO addition)	85	75
Base Oil Y (mineral)	85	65
Oil Y (ZnO addition)	80	65
Oil G (mineral)	80	55
Oil JXB (partly-refined, mineral) . .	110	75
Castor Oil	110	75
Early E.P. Lubricants :		
E.P. Oil B	135	75
E.P. Oil A	145	110
E.P. Oil C	160	90
Recent E.P. Lubricants :		
E.P. Oil G (hypoid)	95	60 *
E.P. Oil E (hypoid)	110	80 *
E.P. Oil F (general purpose) . .	150	95 *

* Based on seizing time curves.

ACKNOWLEDGMENT.

The work described in this report is part of a general research programme undertaken at the National Physical Laboratory for the Lubrication Research Committee of the Department of Scientific and Industrial Research; the author expresses his thanks to this Committee for permission to publish the results. The tests were carried out by Messrs. M. J. Wilkie, B.Sc., and B. W. J. Greig, and acknowledgment is made of their efficient assistance.

References.

[1] "General Discussion on Lubrication and Lubricants," 1937, **2**, 34. Inst. Mech. Engrs.

[2] *Ibid.*, p. 274.

[3] *Engineering*, 1933, **136**, 46.

[4] *Proc. 2nd World Petroleum Congress, Paris*, 1937, **3**, 445.

PRACTICAL METHODS OF TESTING LUBRICANTS.*

By J. H. Evans.†

The efficient lubrication of anti-friction bearings may be effected by any of the following types of lubricant :—

1. Lime-soap grease.
2. Soda-soap grease.
3. Mixed-base grease.
4. Aluminium stearate.
5. Mineral oils of varying degrees of refinement from light to heavy cylinder stock.
6. Lead soap and extreme pressure-type oils and greases.

Of these, lime- and soda-soap greases are the most widely used, and between them probably account for over 95 per cent. of the grease-lubricated applications.

Much has been written of the advantages and disadvantages of these two greases, and considerable experimentation has taken place to improve the characteristics of each. This has resulted in greatly improved products.

In the early days most greases were prone to exude mineral oil on standing and under service conditions, whilst they also thinned down excessively or completely separated into their component parts when slightly heated.

In addition, enclosures were often inefficient, and the separated oil ran out, with disastrous effects in automobile-wheel applications.

It was mainly on account of the instability of lime-soap greases that soda-soap greases became so widely used. Another factor in favour of soda-soap greases was their long, stringy, fibrous texture, as this formed an additional seal and prevented the separated oil from leaving the enclosures.

Soda-base greases, however, are easily washed out of the enclosures by excess of water, leaving the highly ground bearing-elements unprotected and free to corrode. In addition, many of these fibrous greases channelled badly in cold weather; consequently the bearings, operating without adequate lubrication, soon overheated, and in many cases seizure of the component parts resulted.

These conditions did not exist where a good-quality lime-soap grease had been used, and the co-operation of the grease-makers was sought to improve, and eventually standardize on greases of this type.

In accordance with this procedure, it soon became apparent that specifications and standardized testing methods were both desirable and necessary if the maximum benefits were to be obtained.

Lime-soap greases showed considerable variation in consistency, and it was felt that this characteristic should be the first to receive attention. Unfortunately there was no universal standard method for checking this property, and after careful consideration it was decided to adopt the same

---

* Paper presented for discussion at the Morning Session (B) on the 24th May, at the Summer Meeting of the Institute of Petroleum, held in Birmingham, 22nd–24th May, 1939.

† British Timken, Ltd.

method as that employed by our associated American company—namely, the Karns Maag consistometer.

A photograph of this apparatus is shown in Fig. 1. The consistometer is made up of an alloy base 6 ins. × 9 ins., with a centring device for the grease-cup, and an upright 16½ ins. high, to which is attached a projection for a release device. A metal ball is held in place by this arrangement 12 ins. above the surface of the grease, and can be released by pressing a trigger.

The cup is filled with grease levelled and heated to 75° F. for 1 hour, centred, and the ball is then allowed to fall freely into it. The depth of penetration is measured in millimetres direct from the rule attached to the saddle-gauge, as shown in the photograph. The other parts of the apparatus are used for testing the consistency of hard block greases and the like.

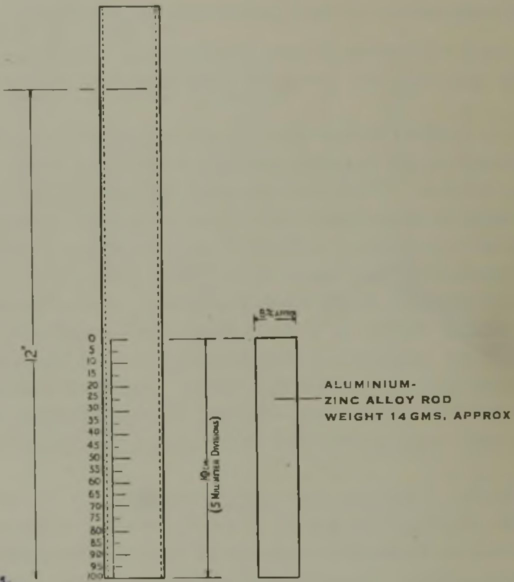


FIG. 2.

A much simpler device giving concordant results with the Karns Maag was later suggested by E. A. Evans of Messrs. Wakefields. An illustration of this is shown in Fig. 2. It consists of a piece of ordinary burette tubing with a mark scribed 12 in. from the bottom. A millimetre paper scale 100 mm. long is attached to the bottom of the tube as shown.

The plunger is an aluminium alloy rod 100 mm. long, and it is allowed to fall freely down the tube from the scribed mark into the levelled sample of grease.

The depth of penetration is read off direct in millimetres from the top edge of the plunger to the millimetre scale.

The results are identical with those obtained on the Karns Maag.

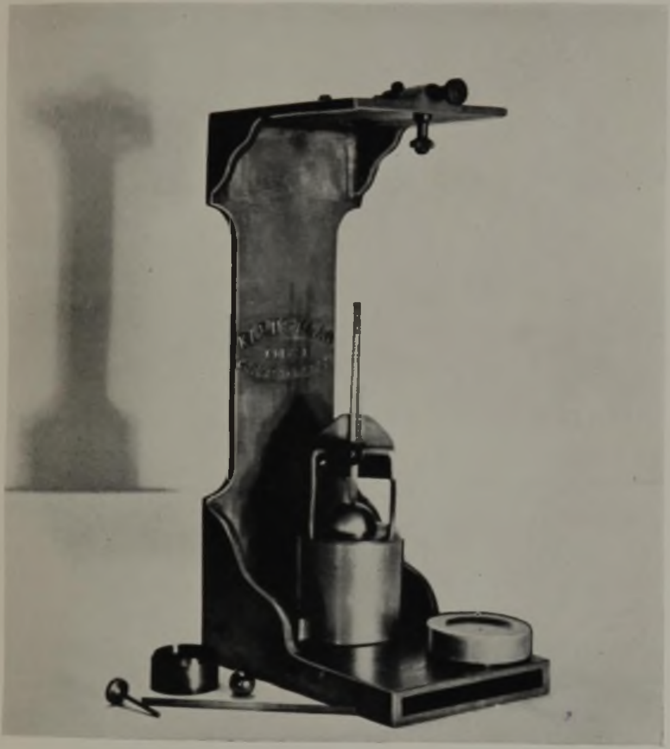


FIG. 1.

KARNS MAAG CONSISTOMETER.

[*To face p.* 730.

Consistency tests are taken on the grease as received and also after working (60 double strokes) in the standard grease-worker.

The I.P.T. and A.S.T.M. Grease Penetrometer is also used, and readings between 225 and 270 agree fairly closely with the specified 15–23 Karns Maag.

The effect of heat on the consistency on lime, soda, and various other types of grease is given in Table 1.

Table 1.

Consistency.

(Plunger readings in mm. = Karns Maag at ° F.).

Grease.											Mixed Soda and Lime.	Lime Latex.	Aluminium Stearate.
Lime Soap.						Soda Soap.							
° F	A.	B.	C.	D.	E.	F.	G.	HA.	HB.	J.			
70°	15	27	15	20	17	11	14	15	30	16	21	21	42·5
80°	19	30	16	23	17	12	17	20	35	20	25	25	47
90°	22	34	18	25	21	15	21	23	37	22	29	27	65
100°	26	36	22	27	22	17	24	27	49	25	31	30	—
110°	30	41	25	31	25	22	29	35	55	26	34	35	—
120°	32	45	26	35	27	26	35	41	67	29	37	37	—
130°	35	49	29	40	30	29	40	55	—	30	40	42	—
140°	38	50	35	42	37	32	44	70	—	31	30	45	—
150°	39	55	42	46	42	41	48	—	—	31	30	50	—
60°	42	56	62	50	45	50	60	—	—	32	30	53	—
70°	45	60	—	50	47	54	—	—	—	37	27	60	—
80°	52	—	—	50	50	57	—	—	—	42	22	—	—
90°	65	—	—	50	52	62	—	—	—	—	17	—	—
00°	—	—	—	62	57	—	—	—	—	—	15	—	—

Remarks.

HA. Reading taken immediately on falling.
HB. Reading taken after 1 min. interval.
J. Very fibrous grease.
Mixed soda and lime. Grease stiffens at 140° F.
Lime latex. Stringy texture.
Aluminium stearate. Semi-fluid.

Standardization of the method for determining moisture next received ttention. Originally it was contended that at least 2 per cent. water was ecessary to ensure complete hydration of the lime, but, as assumption ielded to experiment, it was soon found that by using correctly hydrated me it was possible to manufacture grease in bulk with a water content less than 1 per cent. This figure was therefore fixed as a maximum. he method fixed for determining the moisture was the Dean and Stark istillation Method using gasoline as solvent.

Ash content was fixed at 2 per cent. maximum calculated as oxide.

The question of separation of mineral oil on standing and heating had ill to be considered, as although great improvement in the quality of the ease had resulted from controlling the properties already mentioned, paration of oil from the soaps sometimes occurred.

Eventually the following method for estimating the separated oil was evolved :—

25 gms. of grease are placed in the standard Pensky–Martin flash-point cup and heated at the rate of 10° F. per minute to 250° F. The grease is maintained at this temperature for ½ hour. During heating and maintaining the grease is stirred at the rate of 2 revolutions per second for alternate minutes. It is then poured into a silica tube approximately 3 ins. long by 1 in. inside diameter, one end of which is sealed with a cork. After ½ hour atmospheric cooling the cork is removed and the grease, supported by two pieces of flattened wire $\frac{1}{16}$ in. wide, wound vertically round the tube, is suspended over a conical measure graduated in c.c.s. No separation of mineral oil is allowed after 48 hours cooling.

Melting-point determinations are made by the Ubbelohde method, in which the drop point is recorded. A minimum temperature of 210° F. was fixed.

Acidity or Alkalinity.—It has been established that free fatty acid—calculated as oleic—up to 0·5 per cent. has no injurious effect on anti-friction bearings. Most lime-soap greases are, however, slightly alkaline, and alkalinity up to 0·14 per cent. CaO is approved.

Corrosion tests in which copper and steel plates are submerged in the grease for 48 hours at atmospheric temperature should show no pitting or corroding.

Useful information can often be obtained by studying the behaviour of the grease when submitted to a heat-stability test. A recommended test is similar to the separation test already described, except that half of the grease is poured on to a cold watch-glass direct from 250° F. The other half is heated up to the fire-point of the base oil, and then also poured on to a cold watch-glass. If the greases show any oil separation, appreciable hardening or softening from 250° F., they are rejected, whilst it is found that most greases submitted to the fire-point test show no oil separation, but appreciable hardening. Little work is necessary to bring these back to perfectly good lubricants.

Lime-greases are also checked for emulsion-forming properties by shaking up with hot and cold water. Greases showing any emulsification are rejected.

The mineral oil is extracted and its physical characteristics are determined. The most satisfactory type of base is a well-refined mineral oil having a minimum viscosity of 420 seconds Redwood at 100° F. Open-flash, min. 340° F. Fire point, min. 380. Cold pour, max. 40° F.

With the advent of these new non-separating lime-base greases, it was found that for practically all automotive, locomotive, and many industrial applications, only one grade of grease was required. This is a smooth, well-milled product composed of high-grade soap and a refined filtered mineral oil of the viscosity mentioned above. The grease must be free from fillers of all kinds. Other physical properties as mentioned under their respective headings.

SODA-BASE GREASES.

Greases compounded from mineral oil and soda soaps are recommended for applications where the operating temperatures are high and enclosures mperfect.

When high temperatures are encountered, it is advisable to ensure that they are not an effect of over-tightening of the bearings, incorrect clearances in associated component parts, or too much lubricant in the housing.

Fibrous, string-texture soda-soap greases are prone to track in cold weather, leaving the bearings dry and liable to burn up. They also retard the action of the revolving elements in the bearings, thus generating a greater amount of heat, as well as absorbing more motive power.

The type of soda-soap grease found most suitable has the following characteristics :—

Consistency	15–25 Karns Maag.
Moisture	max. 0·3%
Melting Point	min. 300° F.
Soda soap	15–18%
Base oil	
Viscosity at 100° F. . . .	approx. 420 secs. Redwood.

Other properties, with the exception of emulsification, are similar to lime-soap greases. The grease must be a smooth, cold-milled product of short-fibre texture and free from all fillers.

MIXED-BASE GREASES.

Frequently 3–5 per cent. of lime soap is added to soda-soap greases to improve the appearance of the grease and give it a smooth, buttery, non-grainy texture similar to that of lime-base grease.

These products are stable, and have melting points intermediate between lime- and soda-soap greases. They are best compounded from Pennsylvania pale oil of approximately 300 secs. Redwood viscosity at 100° F. Melting points are generally in the region of 150° C.

Sometimes small percentages of aluminium stearate are added to lime-soap greases to improve heat stability.

ALUMINIUM STEARATE GREASES.

These greases are generally used for aircraft rocker-arm bearings and variable-pitch propellers. Samples recently examined had the following physical properties :—

Moisture	0·1–0·3
Ash	0·8–1·0
Aluminium soap	15–18%
Melting point	212° F.
Separation.	Nil
Emulsification	Nil
Alkalinity	Neutral
Open flash.	515° F.
Fire	575° F.
Consistency	35 mm. Karns Maag—others too thin.
Mineral-oil base	Viscosity at 210° F. 150 Redwood secs.

In estimating the aluminium it is generally sufficiently accurate to dissolve the ash in boiling water, filter, burn, and weigh as Al_2O_3, ignoring any trace of iron which may be present.

The advantages claimed for aluminium-stearate greases over other types may not be justified, although they are generally accepted. Among them are the following: Melting point intermediate between lime- and soda-soap greases; water repellant—similar to lime-soap grease: become more adhesive and cohesive on heating to near the melting point, whereas lime- and soda-soap greases tend to thin down considerably on heating: heat stable—they can be heated above the melting point, and return to their original consistency on cooling—in this respect they resemble modern lime-soap greases.

Many of these properties can be checked, but it is also advisable to test the corrosive effect of aluminium-stearate greases on copper and steel test-pieces. This has been found necessary as some aluminium stearates contain appreciable quantities of stearic acid. A method used to accelerate the corrosive action of these or any lubricant is to submerge the test-plates in the lubricant and heat to a temperature of 210° F. for several hours. This method often shows corrosion when it is not obvious on samples tested at ordinary atmospheric temperature.

There appears to be some difficulty in controlling the consistency of aluminium-stearate greases, and as this is partly a function of the speed of cooling during manufacture, careful control in production is necessary.

There is sometimes a tendency for these greases to thin down in storage, but on heating to their melting point they return to their original consistency.

Fillers.

The use of fillers such as talc, graphite, waxes, rosin, clay, or mica, is not recommended in any greases intended for use with anti-friction bearings, as they not only lap the components in, but continue wearing them away, causing frequent replacements.

The tests on the consistency of the various greases at increasing temperatures (Table 1) are most illuminating, as so much has been written on the advantages of soda-soap greases when running temperatures are high.

The soda-soap greases examined were grades universally recommended for the lubrication of anti-friction bearings, and the experiments show them to thin down more quickly on heating than lime-soap greases. The general softening range appears to lie between 140° and 160° F. and even though the melting points—as determined on new grease by the Ubbelohde method—are so much higher than the lime-soap greases, they thin down between these temperatures to such an extent that only very efficient enclosures could retain them.

The lime-soap greases soften gradually, and are more viscous at the higher temperatures.

As a point of interest the melting points of these greases were :—

Grease.		Drop point Ubbelohde, °C.
Lime-soap	A.	98
,,	B.	107
,,	C.	99
,,	D.	109
,,	E.	107
Soda-soap	F.	142
,,	H.	172
,,	G.	149
,,	J.	155
Mixed Lime-soda		166
Lime latex		104
Aluminium stearate		100

RUNNING TESTS.

In these tests a bearing was run under 90·5 per cent. overloading conditions at 550 r.p.m., using each of the greases mentioned above as lubricants. The bearing and housing were filled with grease, and a top plate, carrying a thermometer, fixed in position to make an efficient seal. The thermometer contacted directly with the top face of the inner component of the bearing, and the temperature rise was read off every minute for the first twenty minutes or so, and then at frequent intervals until the rise became steady. The results are plotted in Figs. 3A and 3B as temperature rise above starting temperature against time in minutes.

The results confirm the consistency tests—*i.e.*, in practically every case the grease thins down between the rolling elements at a temperature of 140–180° F., irrespective of the type of grease used.

Lime-soap greases softened gradually without tracking, and eventually flowed through the bearings in a similar manner to oil giving equivalent lubrication

The soda-base grease (J.) tracked badly, whilst greases H. and F. absorbed considerable energy in the early stages on account of their fibrous texture (compare 3A and 3B between 20 and 40 min. under load), then thinned down at 140–160° F., to behave generally like lime-soap greases. They churned and rotated, showing a similar centrifugal tendency to lime-soap greases, with no further evidence of tracking.

The soda base G. was a cold-milled product resembling lime-soap in appearance and texture. This had the highest softening point, 170–190° F., and did not melt, although it thinned down considerably, and pieces of normal grease could be seen floating about in the semi-fluid mass round the bearings.

The mixed-base grease softened between 150 and 170° F., and showed a tendency to track during the early stages. It did not churn, consequently the temperature was lower, but the grease in contact with the rolling elements thinned down to the consistency of cream, with a gradual transition to the stiffer grease in the sheltered parts of the housing.

The lime-latex commenced to soften and churn between 160° and 180° F., and the grease in contact with the bearing thinned down, but, on cooling, regained the stringy texture. The temperature rise with this grease was the highest of those examined.

The aluminium-stearate grease is not a recognized or recommended anti-friction bearing-grease, and has been included in all the tests solely as a matter of interest.

Before leaving the question of greases for ordinary applications, it is interesting to note that experiments are being made in America with barium-soap greases. These greases are water-repellant, have a melting point of over 300° F., and are similar in consistency and texture to lime-soap greases. It is expected that these greases, when fully developed, will prove an ideal lubricant for anti-friction bearings, as they possess the best properties without the respective disadvantages of soda- and lime-soap greases.

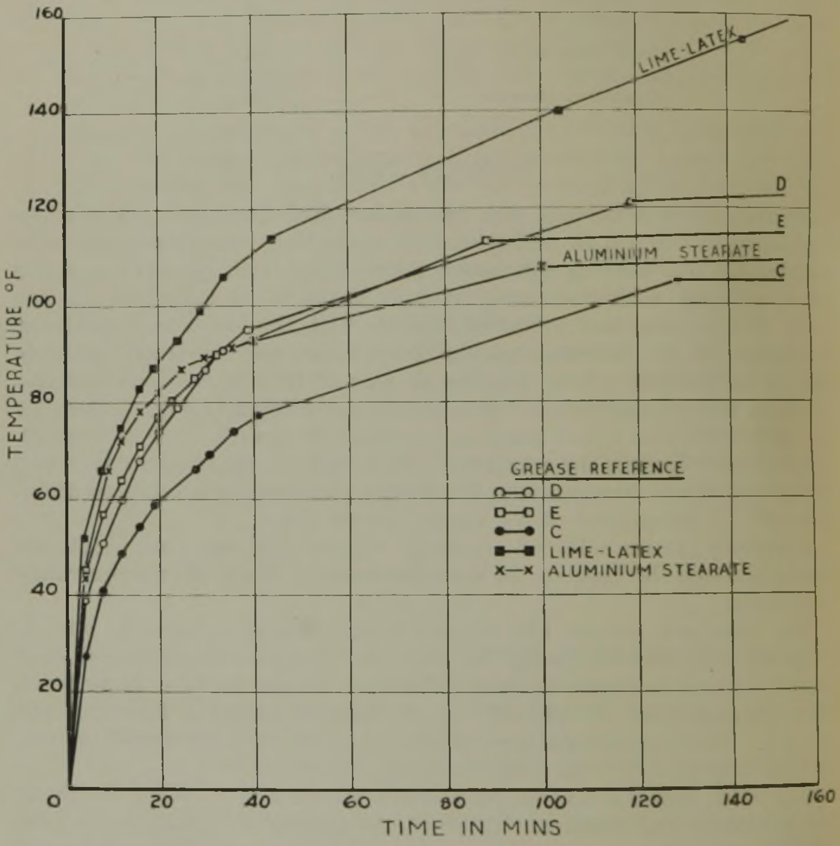


Fig. 3A.

LOAD TEST.

Lime Soap Greases. 90·5% overload.
Lime Latex. Speed 550 R.P.M.
Aluminium Stearate.

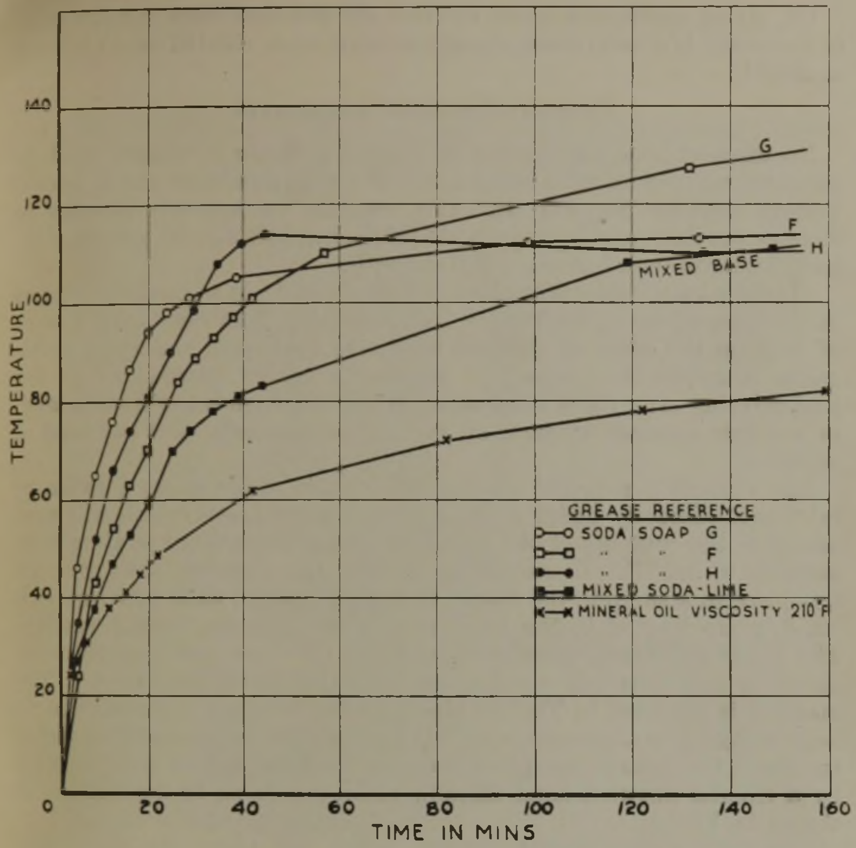


Fig. 3b.

LOAD TESTS.

Soda-Soap Greases.
Mixed Soda-Lime Greases.
Mineral Oil

90·5% overload.
Speed 550 R.P.M.

Mineral Oil.

No special tests are necessary when checking mineral or compounded oils. Experience proves that the lubricants used, under normal loading conditions, are entirely satisfactory for the lubrication of anti-friction bearings. The viscosity range of oils found satisfactory in service varies between 60 and 170 secs. Redwood at 210° F., depending on the size, load, and speed of the application.

Railway Bearings.

Oil is recommended for the lubrication of axle-box bearings, but in certain applications, where it has been found impracticable to make boxes oil-tight, standard lime-soap greases compounded from a base oil of 420 secs. Redwood at 100° F. have been found perfectly satisfactory.

Oil, giving satisfaction under different climatic conditions in many parts of the world, is a well-refined straight-mineral oil of 125–150 secs. Redwood at 210° F.

EXTREME-PRESSURE LUBRICANTS.

No discussion on the testing of extreme-pressure lubricants could be complete without mention being made of the Timken Wear and Lubricant Testing Machine (see Fig. 4). This machine was specially designed to measure the load-carrying capacity of lubricants, both oils and greases, when loaded near to their boundary film strength.

The Lubricant Tester illustrated in Figs. 4 and 5 was originally developed in the laboratories of the Timken Roller Bearing Company during a series of tests on the effect of different lubricants on hypoid and spiral bevel-gears in automotive axles. It provides accurate information on the load-carrying capacity of lubricants, on the measurement of friction, and, in a simple accurate manner, on the wear characteristics of any kind of material

The container, mounted on top of the base, holds about $\frac{1}{2}$ gallon of lubricant. Directly under it is an electric plate-heater which will raise and hold the contents of the container at any desired temperature from ambient to 250° F. In operation, oil from the container flows over the test-piece to a sump in the base. It is then pumped back by means of a small pump located in the base, and driven from the testing mandrel. The latter extends longitudinally through the base, and may be either direct- or belt-driven by a 2-h.p. synchronous-speed electric motor. The mandrel is mounted in Timken tapered roller bearings so arranged as to hold it rigidly in alignment, and is tapered at the end opposite the pulley to receive the tapered test-piece or cup. The latter is held firmly in place by a circular nut (left-hand thread), which screws on to the mandrel as shown in Fig. 4.

The lever system consists of two levers, one above the other. The upper is known as the load lever, and the lower as the friction lever. The upper, which carries the test-block holder, is pivoted on a knife-edge mounted in the lower lever. The latter is also pivoted on a universal knife-edge and provided with a stop at the unloaded end. The friction lever is provided with a vernier scale and a sliding weight for obtaining accurate measurements, and both levers are supplied with weight-pans. By virtue of this arrangement the test-block is always in the same relative position to the revolving cup, and the unit loading over the length of the two test-pieces is always constant. The test-block is inserted in a notch in the holder and held firmly in place by a wedge. For testing lubricants the test-pieces consist of a cup of a size that fits accurately on the mandrel, and the block, which is a $\frac{1}{2}$ in. square by $\frac{3}{4}$ in. long. Both test-pieces are made of steel, hardened to 60° C. Rockwell and ground. Four tests can be run with one test-block, but each new face tested requires a new cup on the mandrel. The cups can be reground. Newly ground faces on both pieces are necessary to ensure uniform results, and in no instance must the finish of the test components be altered.

The operation of the lubricant tester is substantially as follows:—

Assuming both test-pieces in place, the lubricant heated to the desired

FIG. 4.

TIMKEN WEAR AND LUBRICANT TESTING MACHINE.

[*To face p.* 738

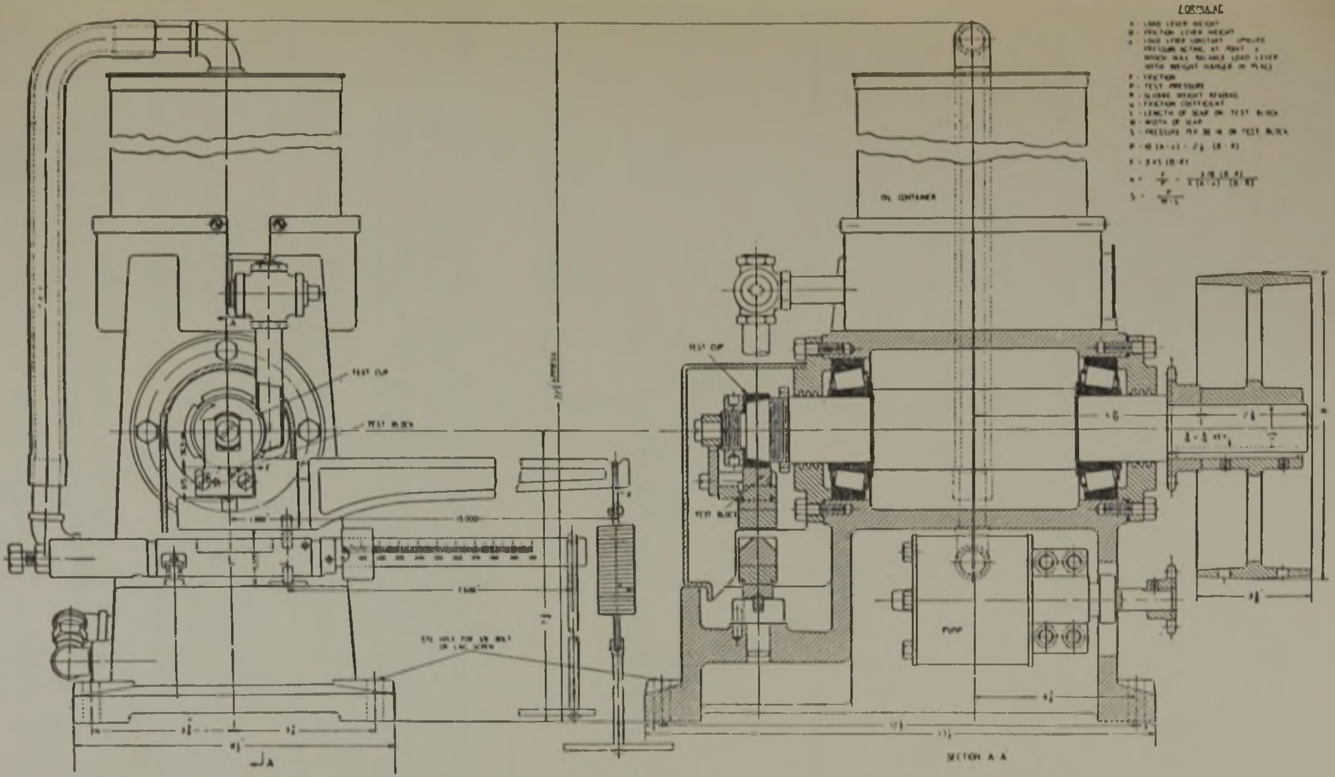

FORMULAE
A = LOAD LEVER WEIGHT
B = FRICTION LEVER WEIGHT
F = FRICTION
P = TEST PRESSURE
μ = FRICTION COEFFICIENT
L = LENGTH OF SCAR ON TEST BLOCK
W = WIDTH OF SCAR
TEST CUP
TEST BLOCK
OIL CONTAINER
PUMP
SECTION A-A
A

FIG. 5.

temperature, and allowed to flow over the test-block, the driving motor is brought up to the required speed. The loading lever is then loaded by means of weights until the desired unit pressure at the predetermined rubbing speed is obtained. It is important that the total testing load should be applied at once, rather than by gradually adding weights to the load lever, since it is the first few seconds of operation which determine the possibility of sustaining loads when near the scoring point.

A load test is usually run for a period of ten minutes. The surface of the block after test is examined, and if it is badly abrased or scored, the applied load has been too high for the lubricant under test.

The usual speed for testing lubricants is 400 f.p.m. (800 r.p.m. of the spindle).

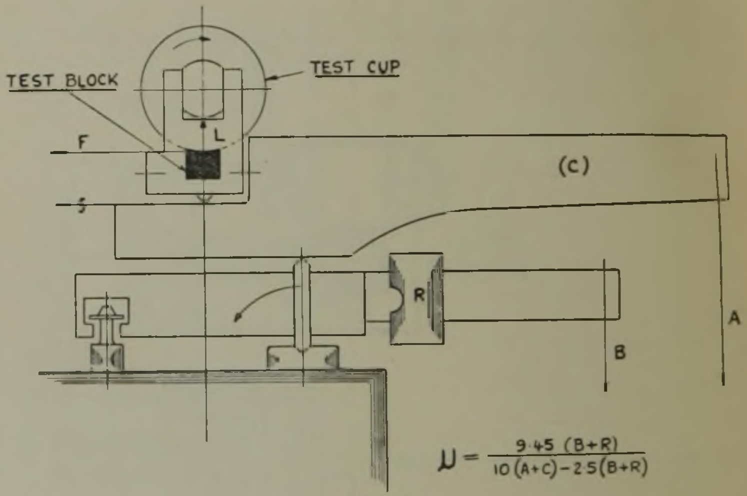


Fig. 6.

Greases can be tested by using the oil splash-guard surrounding the test-pieces and filling it with grease before commencing the test. The guard is then kept filled by continually adding grease by means of a grease-gun. To make grease tests comparative, care has to be taken to feed the grease at a constant rate.

Friction depends on loads, temperatures, rubbing speeds, and lubricant. Changing any one of these may affect the friction. To find the friction, weights are added to the (friction lever) weight-pan, or, if the friction is very small, the sliding weight is moved along the lever until the lever just leaves the stop-pin. Knowing the weight on the load lever and the friction lever, the normal load and the friction at the test-surfaces can be determined. After having found these forces, the coefficient of friction can be obtained.

To ensure that the test-pieces contact over the full width of surface, an adjustable universal knife-edge carries the lever system at the base of the machine.

The normal load on the test-pieces produced by the weight A (Fig. 6) on the end of the load lever creates a friction force at right angles to the normal load depending on the rubbing speed, pressure, and lubricant used. This load, in turn, creates a force on the knife-edge resting on the top of the load lever, which is transferred to the knife-edge at the top of the friction lever. This tends to rotate the friction lever in a counter-clockwise direction, which is resisted by a stop-pin fixed to the base of the machine. To measure the friction, weights B are added to the bottom lever until it is just balanced (until the lever just leaves the stop-pin). The coefficient of friction can then be calculated from the formula:

$$M = \frac{9{\cdot}45 \times (B + R)}{10 \times (A + C) - 2{\cdot}5(B + R)}$$

where A = load on end of top lever,
B = load on end of friction lever,
C = load lever constant, and
R = friction lever sliding weight.

TABLE 2.

Load on Beam Arm in lbs.	12	18	25	33	43	51	59	68	77	86	96	105
Scar Width	Pressure in lbs. per sq. in.											
·021 in.	11,500	17,250	23,750	31,500	41,000	48,500	56,250	64,750	73,500	82,000	91,500	100,000
0·6 mm.												
·025 in.	10,500	15,750	21,750	28,750	37,500	44,500	51,250	59,250	67,000	74,750	83,500	91,500
·025 in.	9,750	14,500	20,000	26,500	34,500	40,750	47,250	54,500	61,750	68,750	76,750	84,000
0·7 mm												
·027 in.	9,000	13,250	18,500	24,250	32,000	37,750	43,750	50,500	57,000	63,750	71,250	77,750
·029 in.	8,250	12,500	17,250	22,750	29,750	35,000	40,750	46,750	53,000	59,250	66,250	72,500
0·8 mm.												
·031 in.	7,750	11,500	16,250	21,250	27,750	32,750	38,000	43,750	49,750	55,500	62,000	67,750
·033 in.	7,250	11,000	15,250	20,000	26,000	31,000	35,750	41,250	46,750	52,000	58,250	63,750
0·9 mm.												
·035 in.	6,750	10,250	14,250	18,750	24,500	29,250	33.750	39,000	44,000	49,250	55,000	60,000
·037 in.	6,500	9,750	13,500	17,750	23,250	27,500	32,000	36,750	41,750	46,500	52,000	56,750
1·0 mm.												
·039 in.	6,150	9,250	12.750	17,000	22,000	26,000	30,250	35,000	39,500	44,250	49,250	54,000
·041 in.	5,850	8,750	12,250	16,000	21,000	24,750	28,750	33,250	37,500	42,000	46,750	51,250
1·1 mm.												
·043 in.	5,500	8,250	11,500	15,250	20,000	23.750	27,500	31,750	35,750	40,000	44,750	48,750
·045 in.	5,350	8,000	11,250	14,750	19,250	22,750	26,250	30,250	34,250	38,250	42,750	46,750
1·2 mm.												
·047 in.	5,250	7,750	10,500	14,000	18,250	21,750	25,000	29,000	32,750	36,500	40,750	44,750
·049 in.	5,000	7,250	10,250	13,500	17,500	20,750	24,000	24,000	27,750	31,500	35,250	43,000
1·3 mm.												
·051 in.	4,750	7,000	9,750	13,000	17,000	20,000	23,000	26,750	30,250	33,750	37,750	41,250
·053 in.	4,500	6,750	9,500	12,500	16,250	19,250	22,250	25,750	29,000	32,500	36,250	39,750
1·4 mm.												
·055 in.	4,350	6,500	9,000	12,000	15,500	18,500	21,500	24,750	28,000	31,250	35,000	38,250
·057 in.	4,250	6,350	8,750	11,500	15,000	17,750	20,250	24,250	27,000	30,250	33,750	37,000
1·5 mm.												
·059 in.	4,000	6,000	8,500	11,250	14,500	17,250	20,000	23,000	26,000	29,250	32,500	35,600
·061 in.	3,950	5,900	8,200	10,750	14,000	16,750	19,500	22,250	25,250	28,250	31,500	34,500
1·6 mm.												
·063 in.	3,800	5,750	8,000	10,500	13,500	16,250	18,750	21,500	24,500	27,250	30,500	33,250
·065 in.	3,700	5,500	7,700	10,250	13,250	15,750	18,250	21,000	23,750	26,500	29,500	32,250
1·7 mm.												
·067 in.	3,600	5,500	7,500	10,000	12,750	15,250	17,500	20,250	23.000	25,750	28,750	31,250
·069 in.	3,500	5,350	7,250	9,500	12,500	14,750	17,000	19,750	22,250	25,000	27,750	30,500
1·8 mm.												
·071 in.	3,400	5,000	7,000	9,250	12,000	14,250	16,500	19,000	21,750	24,250	27,000	29,500
·073 in.	3,300	4,900	6,850	9,000	11,750	14,000	16,250	18,500	21,000	23.500	26,250	28,750
1·9 mm.												
·075 in.	3,200	4,750	6.750	8,750	11,500	13.500	15,750	18,000	20,500	23.000	25.750	28,000
·077 in.	3,100	4,675	6,500	8,550	11,250	13,250	15,200	17,650	20,000	23,350	25,000	27,250
2·0 mm.												
·079 in.	3,000	4,550	6,250	8,250	11,000	13,000	15,000	17,250	19,500	21,750	24,250	26,500

1 mm. = ·0394 inches.

When conducting wear tests, the weights of the cup and block are taken before and after the test run, to determine the amount of metal removed.

Formulæ are provided by which the results obtained on the machine can be readily converted into lb. per sq. in. and the coefficient of friction determined.

The chart drawn up in Table 2 shows the load in lb. per sq. in. from lever load and scar width.

MINERAL OILS.

It has been demonstrated by Maag[1] that the film strength of a straight uncompounded mineral oil is directly related to the viscosity as is shown in Table 3.

TABLE 3.

Viscosity. Saybolt at 210° F.	Load on Lever Arm.	
	O.K. Load.	Score.
40	1	2
48	5	6
65	7	8
73	9	10
99	11	13
124	13	15
153	15	17
180	18	20

The effect of additions of various metallic soaps and esters on the film strength of a mineral oil of 125 secs. Redwood at 140° F. were investigated by E. A. Evans ;[2] using the Almen Machine.

Experiments on the Timken Machine to check these results using the same viscosity mineral oil with similar additions gave the following results :—

TABLE 4.

	Almen M/c.	Timken.		
		O.K.	Score.	Approx. lb. per sq. in.
Film strength of mineral oil	—	6	7	4300
Metallic Soaps :				
5% lead oleate	3,000	7	8	4800
5% sodium oleate	4,000	6	7	4300
5% tin oleate	5,000	8	9	5600
5% aluminium oleate	8,000	8	10	5600
5% chromium oleate	13,000	8	9	5600
Esters :				
3% ethyl phthalate	9,000	9	10	6100
3% butyl phthalate	5,000	9	10	6100
3% methyl salicylate	10,000	8	9	5600
5% ethyl phthalate	9,000	10	12	6700
5% methyl salicylate	12,000	9	10	6100
5% butyl phthalate	—	11	13	7200

These results confirm those obtained by Evans, in so much as they prove the esters have more effect on the film strength than the metallic soaps. But even the esters do not increase the film strength sufficiently for them to be considered extreme-pressure lubricants.

It has been shown that film strength is a function of the viscosity of straight mineral oil; when an E.-P. base is added to the oil, however, viscosity is of secondary importance.

EXTREME-PRESSURE OILS.

Extreme-pressure oils were primarily developed for the lubrication of hypoid gears, and although the use of such gears is not general in this country, there are indications that in the near future they will be more or less universally adopted.

Bearing this in mind, a few comments on the position of hypoid-gear lubrication as it is at present in America are given, in the hope that advantage may be taken of American experience.

For the past three years opinion has been divided between the advocates of an active sulphur hypoid oil and those preferring a mild-type E.-P. oil. Active sulphur hypoid oils are those which quickly tarnish a bright copper plate, whereas the mild-type E.-P. oils are more stable and less corrosive.

The mild types include sulphur-saponifiable combinations—*i.e.*, mineral oils containing approximately 20 per cent. of a sulphurized or chlorinated fatty oil base. Included in this group are also certain phosphorus compounds.

There has been, and still is, considerable diversity of opinion as to the respective merits of each type, but there are now definite indications that the active sulphur hypoid oils will be eventually superseded by the mild-type E.-P. oils. These oils are proving perfectly satisfactory in service, and as they are more stable and less corrosive than the hypoid oils, they have the advantage of being used in transmissions as well as rear axles.

At present about 9 gallons of mild E.-P. oil is sold to 1 gallon active sulphur type.

TABLE 5.

Lubricant.	Specimen.	O.K. Load, lb.	Wear, 6 hrs. with 33 lb. on Load Lever, gms.
Chlorinated oils	1	100 plus	0·0035
	2	95	0·0030
	3	100	0·0045
	4	95	0·0020
	5	59	0·0050
Sulphurized fatty oils	1	43	0·0070
	2	43	0·0150
	3	33	0·0050
	4	33	0·0055
	5	43	0·0080
	6	43	0·0075

O. L. Maag[3] published in 1934 the results of some of his experiments on chlorinated and sulphurized fatty oil bases in mineral oil. These (Table 5) showed that as the percentage of chlorinated base is reduced, the load-carrying capacity is also reduced, but the abrasiveness increases. The sulphurized oils are definitely more abrasive than the chlorinated, and also have a lower film strength.

Experiments have been conducted on a mineral oil of 65 secs. viscosity at 210° F. and varying percentages of hexachlorethane or certain proprietary E.-P. bases (A and B), of which there are now several on the market. The result of these experiments are given in Table 6.

TABLE 6.

Lubricant.	E.-P. Base, %	O.K. Load, lb.	Loss in weight at O.K. Load, gms.
Mineral oil	—	10	0·001
Hexachlorethane	2½	60	0·006
	5	80	0·030
	7½	100 plus	0·009
Dope A.	2½	40	0·003
	5	90	0·021
	7½	90	0·074
Dope B.	7½	60	0·010
	10	60	0·015

GREASES.

Load tests on the greases used for checking consistency at elevated temperatures (see Table 1) gave the following O.K. values for the different types.

	Grease.	O.K. Load, lb.	Breakdown, lb.
Lime base	B.	11	12
	E.	12	14
	C.	12	14
	A.	15	17
	D.	12	14
Soda base	J.	7	8
	G.	6	7
	F.	12	14
	H.	14	16
Mixed base	—	7	8
Lime latex	—	13	15
Aluminium stearate	—	15	17

While it is not claimed that the number of greases reported on above is exhaustive, it is representative—in the case of soda- and lime-soap products—of a large number of each type examined.

It has been repeatedly observed that the soda- and mixed-base grease show considerably more variation in film strength, and are generally appreciably lower, than lime-base grease. The two soda-soap greases H. and F., however, show that it is possible to compound this type so that they have equivalent load-carrying capacity to the lime-soap grease.

Extreme-Pressure Greases.

In the field of E.-P. grease lubrication successful results have been obtained with compounded lime and/or lead soaps plus mineral oil and sulphurized or chlorinated base products, used either singly or in combination, together with certain phosphorus compounds.

On account of the wide variety of chemical substances being used at the present time, it is inadvisable to mix different E.-P. greases in service.

When should an E.-P. grease be used?

In all lubricating problems the most adverse conditions should control the type of lubricant used, and E.-P. greases are recommended when abnormal loading conditions are expected in service. An example of this is furnished by the application of roller-bearings to rolling-mills. In some cases the separation force between the rolls is estimated to be in the region of 3,000,000 to 5,000,000 lb. and the use of E.-P. greases for the roll-neck bearings, and also gear drives and their bearings, is recommended.

The checking of these greases offers little difficulty; sulphur, chlorine, and lead soaps are estimated in addition to the usual chemical and physical tests. Satisfactory estimations of sulphur and chlorine have been found possible by using the Parrs Bomb if the usual precautions are taken.

Corrosion tests are more important than with ordinary greases, on account of the nature of the additives. A suitable test is to submerge the copper and steel test-plates in the grease and hold for 1200 hours at atmospheric temperature, or for a much shorter time at an elevated temperature, as previously mentioned.

Resistance to water. It is advisable to check this property very carefully, as some E.-P. greases take up large quantities of water—in fact, very few are truly water-repellant. It has been found that the characteristics of these greases in the presence of excess water vary considerably. Some thin down to such an extent that they would be quickly washed out of the bearings, whilst others absorb large quantities in forming emulsions of different degrees of stability.

To test this property, a quantity of grease is churned up with water, added a little at a time, and stirred until it is absorbed or the grease thins down. If an emulsion is formed which does not thin down, the addition of water is continued until free globules exist. The percentage water content is then checked by the Dean and Stark distillation method.

Some lead-lime-soap greases take up as much as 60 per cent. water and still retain their original consistency; others take up the same quantity before becoming saturated, but then exude water on standing until approximately 25 per cent. remains as a fairly stable emulsion.

Greases thinning down under this test are rejected.

The usual 1200-hours corrosion check is conducted on the emulsions, and those showing staining or corrosion are rejected.

In addition to these tests, those described under lime-soap greases are also made.

Load Test.

All E.-P. greases must carry a load of 43 lb. on the load-lever arm of the Timken machine in order to be approved. The ultimate breakdown load is also determined and recorded.

If the grease successfully passes this test, an abrasion test at 33 lb. for 2 hours is run. The test components are weighed before and after, to determine the loss in weight.

Finally a stability test is made on the grease used during the abrasion test. In this the ultimate load is checked. It is often found that the maximum load is much less than originally, and chemical analysis generally shows this to be caused by a reduction in the sulphur or chlorine content.

As appreciable heat is developed during the load tests, some of the unstable compounds break up, and cause serious staining or corrosion of the test parts. This condition is carefully noted, and also the load at which it commences.

Greases are not approved if they show staining at the specified load of 43 lb. on the lever arm.

Two lead-lime-soap sulphurized base greases recently examined, which formed emulsions, had the following characteristics :—

(Speed 800 r.p.m.; Time 10 minutes.)

Grease.	Load on Lever, lb.	Friction Load on Lever, lb.	Scar Width, mm.	Loss in Weight, grams.
A . . .	43	2·99	2·1	0·005
	45	4·22	Scoring badly.	—
2 hrs. test . .	33	1·4	2·45	0·011
Stability test .	43	Broke down.	—	—
	33	2·23	1·8	0·002
B . . .	43	2·80	2·2	0·012
	50	3·40	2·9	0·014
	70	4·30	4·2	0·037
2 hrs. test . .	33	1·45	3·0	0·010
Stability test .	43	3·00	2·6	0·015

LOAD TEST ON EMULSIONS.

Samples emulsified until saturated (both took 60 per cent. of water to saturate), and left to stand for 3 days before test.

Grease.	Load on Lever, lb.	Friction Load on Lever, lb.	Scar Width, mm.	Loss in Weight, grams.
A . . .	43	Broke down	—	—
	33	„ „	—	—
	25	1·5	1·5	0·005
	28	Broke down	—	—
B* . . .	43	1·15	2·0	0·010
	55	2·60	2·2	0·013
	60	3·00	2·8	0·017
	70	3·25	3·2	0·025
	80	Broke down	—	—

* Slight staining at 55, 60, and 70 lb.

MOISTURE ON SAMPLES TESTED.

Grease—A—exuded water on standing until 25 per cent. remained in solution. Grease—B—retained 60 per cent. in solution.

Corrosion after 1,200 hours—Greases A and B, nil.

It will be observed that the grease forming a stable emulsion (*B*) had the same load-carrying capacity as new grease, but the unstable emulsion (*A*) had a much lower film strength than originally.

When using greases of either type, saturation point is soon reached on rolling-mills where the rolls are flooded with coolant, particularly as it is difficult, if not impossible, to maintain perfect seals. The free water, existing as globules, is liable to cause corrosion of the highly ground bearing surfaces, and until a truly water-repellant E.-P. grease is available or, alternatively, designers of enclosures can produce a perfect seal which will prevent the ingress of water into the bearings, it is advisable to replenish the greases at comparatively frequent intervals.

As most modern mills are equipped with pressure-feed installation, this is not a difficult procedure.

EFFECT OF FINISH ON FILM STRENGTH.

The test components used on the Wear and Lubricant Tester are deliberately made to a good-commercial-quality grinding finish, as this represents general industrial production.

It is fully appreciated that the load an oil film will carry is to a large extent dependent on the finish of the wearing surfaces. Different degrees of finish can be very easily obtained by the investigator as a means of checking the effect of similar finishes on components.

What is the effect of better finish to gears, crown wheels, pinions, cams, etc., on the film strength of a lubricant? The following experiments (Table 7) show to what a remarkable extent load-carrying capacity can be increased, friction reduced, and abrasion practically eliminated by merely improving the surface finish of the test components.

The cups used in these tests were polished on the spindle of the machine and the blocks hand polished.

TABLE 7.

Lubricant :—Motor Oil 66 secs. viscosity at 210° F.

Finish.	Temp. of Oil, ° F.	Load on Lever, lb.	Load on Friction Lever, lb.	Scar Width, mm.; Length, ins.	Temp. of Oil at End of 10 mins. ° F.	Load, lb. per sq. in.	Coefficient of Friction.
Rough grind .	100	5	0·44	1·0 mm. × ½ in.	109	3,500	0·062
Standard grind .	102	10	0·89	1·05 mm. × ½ in.	115	5,530	0·072
Standard I.F. Emery paper .	106	40	0·94	1·1 mm. × 7/16 in.	121	21,600	0·0210
Standard I.F. plus 00 emery paper	102	50	1·08	1·2 mm. × ½ in.	114	22,420	0·0197
Standard I.F. plus 00 and rouge .	101	55	1·07	0·9 mm. × ½ in.	110	31,420	0·0185

These results are shown graphically in Figs. 7, 8, and 9. Fig. 7 shows coefficient of friction plotted against pounds on lever; Fig. 8 lb. per sq. in.

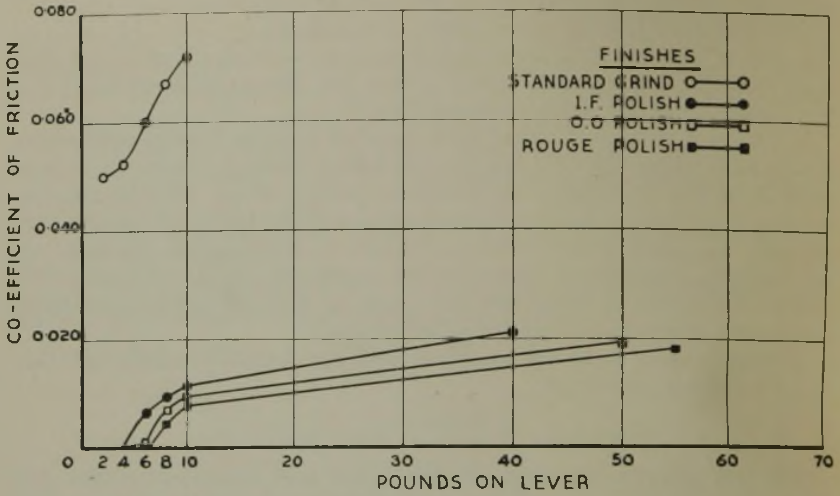


FIG. 7.

MOTOR OIL 66 SECS. VISCOSITY AT 210° F.

Effect of Polishing Cups.
Coefficient of Friction.

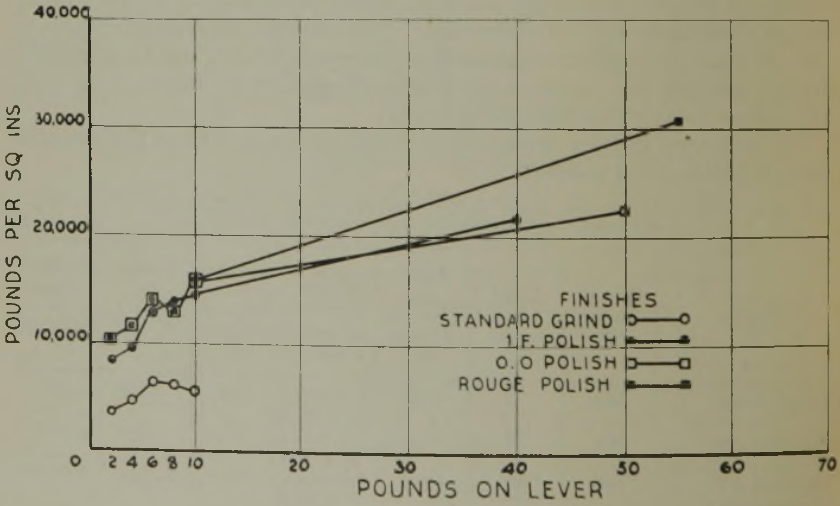


FIG. 8.

MOTOR OIL 66 SECS. VISCOSITY AT 210° F.

Effect of Polishing Cups.
Pressure lbs. per sq. ins. on actual scar area.

against lb. on lever; and Fig. 9 * increase in temperature of block against lb. on lever and increase in temperature of oil against lb. on lever.

The results of these experiments clearly show that the benefits derived from an improvement in surface finish would outweigh any extra cost entailed, by reducing the number of costly failures caused by abrasion or seizure. It would also, in a number of cases, negative the need for extreme pressure lubricants.

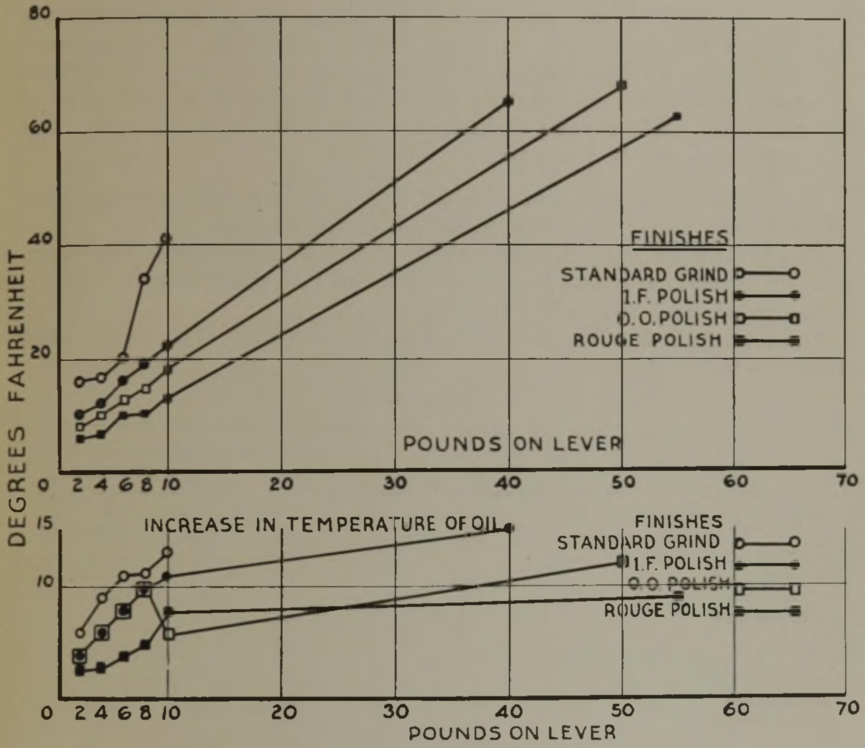


FIG. 9.

MOTOR OIL 66 SECS. VISCOSITY AT 210° F.

Effect of Polishing Cups.
Temperature rise of Block.

In numerous instances E.-P. lubricants are being used to procure this desired effect by their lapping action, and when the parts are properly "run in," the E.-P. doped oils are washed out and replaced by normal lubricants.

This does not mean that E.-P. lubricants are not necessary and here to stay, but it is intended to convey that they should only be used when experience proves their necessity, after a proper finish has been found insufficient to meet the loading requirements. Such cases may be hypoid

---

* The temperature of the block was taken with a thermometer at the end of the test run before dismantling the machine.

gears or special applications continually subjected to extremely heavy running and shock loads—*i.e.*, rolling-mill applications.

In concluding this extremely important part of the paper, the following comments, made by Dr. Vogel,[4] have been chosen out of the many references which have been made to surface finish during recent years.

Discussing results obtained on a special wear tester he had constructed, Dr. Vogel said :—

> "No wear of the unhardened test-pieces could be observed at a load of 300 kg. per sq. cm. after 12,000 revolutions, if the surface of the Böhler steel was polished like a mirror, which was in accordance with the observation that at an infinite number of revolutions—*i.e.*, when the surface was polished, the wear tended towards zero. The only lubricant used was air."

In conclusion, the effects of metallized surfaces on the film strength of an oil of 50 secs. Redwood at 210° F. have been investigated.

The test-pieces were standard cups, plated by electrolytic deposition, and the normal hard-steel test-blocks, finished I.F. emery paper.

The speed in all tests was 800 r.p.m.

The bright chrome was nickelled first, but the hard chrome deposited direct on to the steel.

TABLE 8.

Surface.	O.K. Load, lb.	Breakdown, lb.	Coefficient of Friction.
Standard steel cup and block	8	9	0·091
Tin	25	30	0·052
Copper	43	45	0·027
Cadmium	43	45	0·064
Hard chrome . . .	30	33	0·080
Bright chrome . . .	Peeled at 9 lb.	—	—
Nickel	Peeled at 7 lb.	—	—
Tests on bonderized and Parkerised cups :—			
Bonderized . . .	50	55	0·075
Parkerized . . .	60	65	0·071

The author wishes to place on record his thanks to the Directors of British Timken, Ltd., for permission to publish this paper; to Messrs. Wolseley Motors, Ltd., for the different plating finishes; to Messrs. Wakefield for the metallic soaps and esters; to Mr. O. L. Maag of the Timken Roller Bearing Company, Canton, for his continued advice on all problems relating to lubrication, and finally to Messrs. C. Thomas and A. Mould, members of the Laboratory Staff at British Timken, Ltd., for their valued assistance.

REFERENCES.

[1] Maag. O. L., "The Development of Specifications for Lubricants," I. & S.E.E., 1935.

[2] Evans, E. A., "Extreme Pressure Lubricants," I.Mech.E. General Discussions on Lubricants, Group III, 1937.

[3] Maag, O. L., "Industrial Lubrication and Lubricants." National Association of Lubricating Grease Manufacturers, Chicago, 1934.

[4] Vogel, Dr., Discussions on papers in Group IV. I.Mech.E., 1937, Vol. 2, pp. 488.

A TENTATIVE LABORATORY TEST FOR THE RING-STICKING PROPERTIES OF LUBRICANTS *

By J. C. McNicol,† C. G. Williams, M.Sc.,† and P. V. Lamarque, B.Sc.†

Synopsis.

A description is given of a simple laboratory test for assessing the oxidation and ring-gumming propensities of engine lubricants. The test, which consists principally in measuring the strength of a thin oxidised film of the lubricant, has been used for a preliminary study of the oxidation process over a range of temperatures and exposure times in the case of one lubricant, and at a fixed temperature in the case of a number of petrol- and diesel-engine lubricants of known service performance.

Although the information obtained so far is not extensive, it is shown that, in lubricants which are prone to cause ring-sticking in diesel engines, the strength of the oxidized film is much higher than in the case of lubricants giving comparative freedom from ring-sticking. In addition, it is shown that high film strength is associated with high viscosity index of the lubricant. In the limited number of petrol-engine lubricants examined, volatility appeared to be a better criterion than the strength of the oxidised film.

Introduction.

Piston-ring sticking is associated with the formation of oxidation products by the lubricant, and is influenced by mechanical and thermal conditions in the engine. The only completely satisfactory method of testing the stability and ring-gumming properties of engine lubricants is, therefore, on engines under appropriate operating conditions, but this method is experimentally difficult and expensive since it involves a prolonged study of the effects of operating conditions, detail mechanical design, and lubricating conditions. With these difficulties in mind, oxidation tests on engine lubricants were undertaken with a view to developing a simple laboratory test which, in the light of service experience, could be used for the rating of engine oils as regards their ring-gumming and oxidation propensities. The test adopted for this investigation was the simplest it was possible to devise—viz., a mechanical adhesion test subsequent to the oxidation of a small sample of oil, of the order of 0·25 gm., in an electric oven over the temperature range 180–240° C.

At the outset, attention should be directed to certain limitations of the test. In view of the comparatively high temperatures used, the test does not take into account the effect of prolonged low-temperature crank-case oxidation. Furthermore, some distinction should be drawn between lubricants for petrol engines and for compression-ignition engines. In the light of the known effects of combustion conditions and fuel characteristics on ring gumming and oxidation in compression-ignition engines, the simple test discussed must inevitably be inadequate, since it does not take into account the solvent or detergent properties of the lubricant. In so far as ring-sticking in compression-ignition engines is due to gum formation by the lubricant, the test may, however, be of some value.

---

* Paper presented for discussion at the Morning Session (B) on the 24th May, at the Summer Meeting of the Institute of Petroleum, held in Birmingham, 22nd–24th May, 1939.

† Research Department, Institution of Automobile Engineers.

Although a service test is necessary before conclusive indication of the behaviour of a lubricant under particular conditions can be obtained, it should be possible, on the other hand, to use a simple test, such as that described in the present report, for the broad classification of lubricants for high-temperature conditions.

DESCRIPTION OF APPARATUS.

In the electric oven used for the tests (see Fig. 1) the heating elements were placed over two sides and on the floor, and separated from the free air space by perforated sheet metal. The oven had a total internal volume of 0·84 cu. ft., and a free air space of 0·58 cu. ft. The temperature was thermostatically controlled to within ± 2° C., and was read off a mercury thermometer projecting through the top of the oven into the free air space.

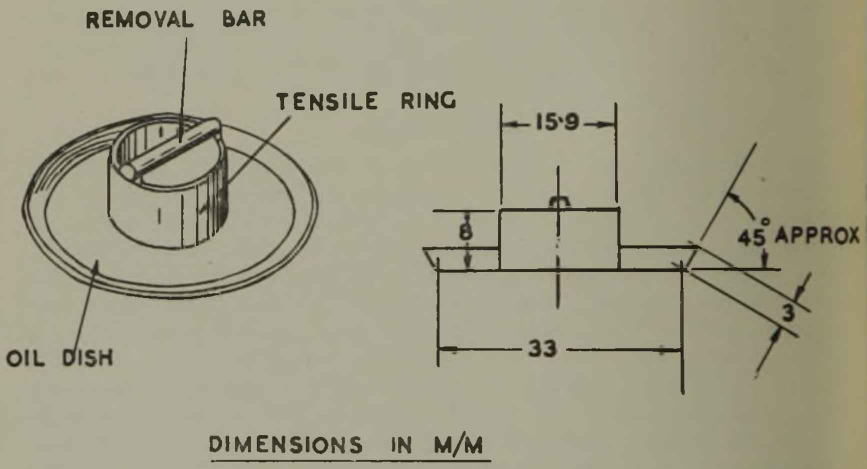


FIG. 2.

For simplicity, air circulation in the oven was uncontrolled, and was provided by two 1-in. holes in the floor and a 1-in. hole in each of the sides. A perforated copper shelf was also provided and, for the tests, was placed at about the middle of the oven.

An exploration of the temperature distribution in the oven revealed that, after soaking, the actual temperature of objects placed on the copper shelf was 11° C. above that shown on the mercury thermometer. This difference, which, with the exception of a narrow area in close proximity to the door, was uniform over the shelf, can probably be accounted for by conduction through the shelf. Over the whole shelf the maximum variation of temperature was 4° C.

To approximate to conditions on pistons and cylinders in actual engines, the tests were mostly carried out on comparatively thin films of oil. These conditions were obtained by introducing a small sample of the oil under test into a shallow steel dish which gave a ratio of exposed surface area to volume

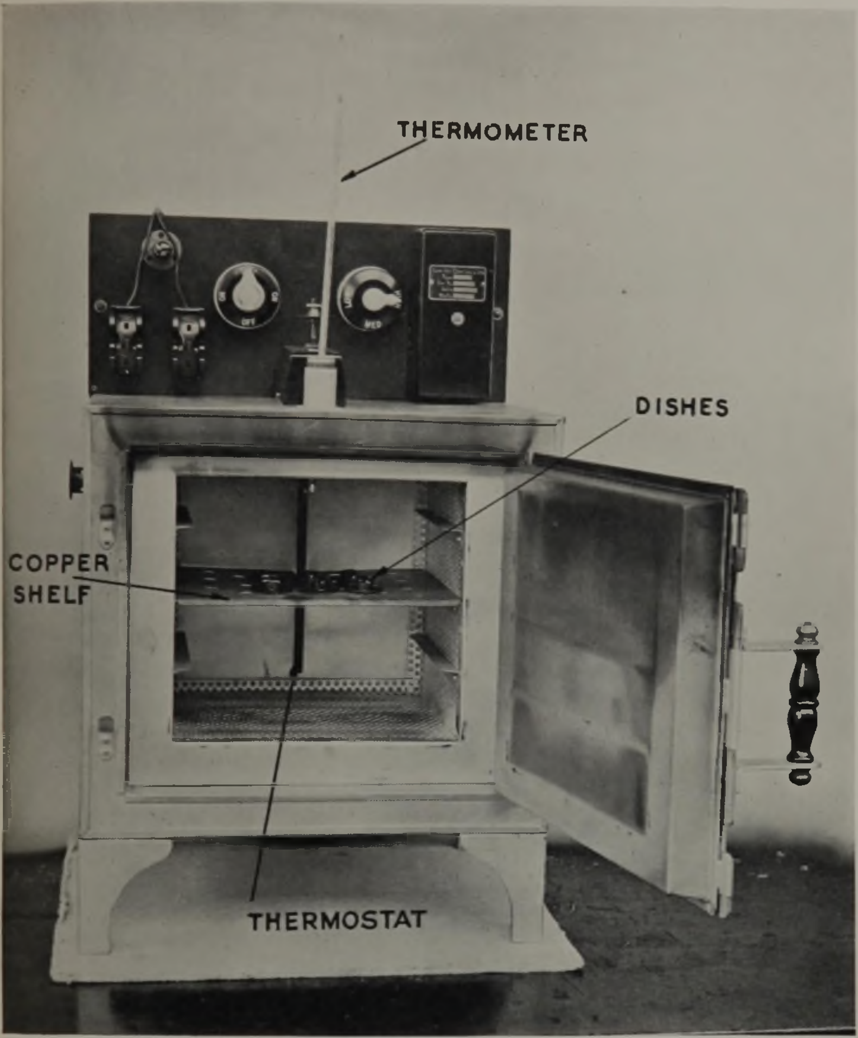


Fig. 1.

ELECTRIC OVEN USED IN TESTS.

[*To face p.* 752.

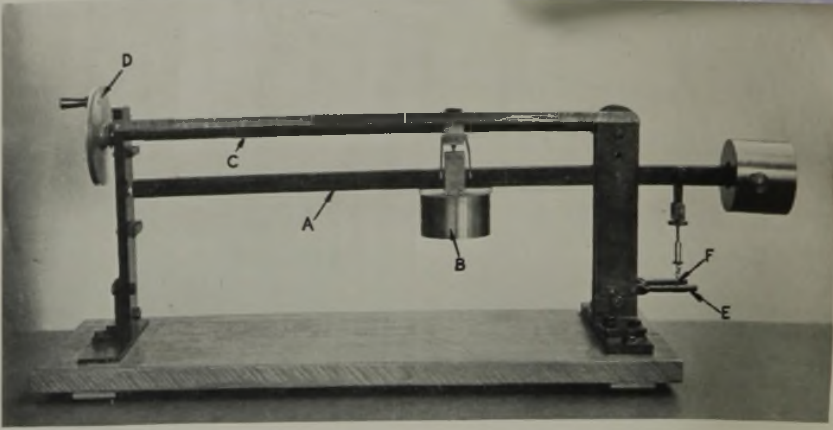


FIG. 3.

TENSILE MACHINE.

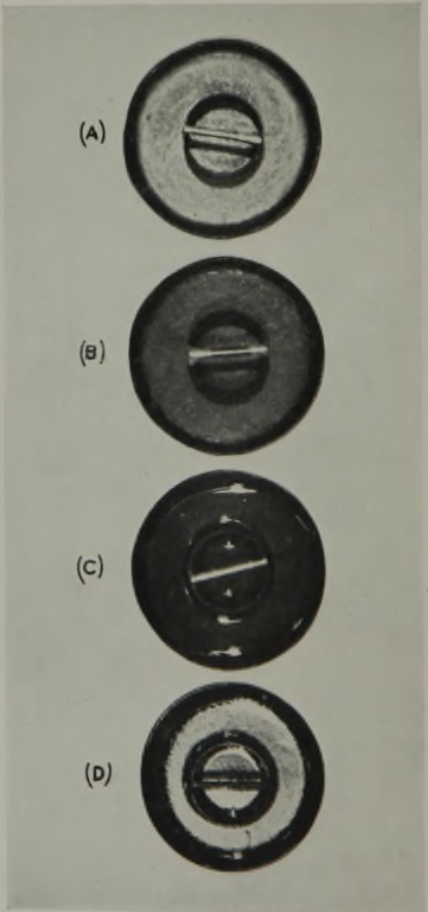


FIG. 4.

A. Dish and ring after cleaning.
B. Dish and ring after prelim
C. Dish containing oil sampl

of oil sample of about 30 sq. cm. per 1 c.c. of oil. A thin steel ring, bridged at one end by a bar, was also placed in the dish at the beginning of the test, the dimensions of the dish and ring being shown in Fig. 2. During the subsequent heating of the oil sample in the electric oven, the lighter fractions evaporated, leaving residues adhering to the ring and dish. Under engine conditions, the gum formed in the piston-ring grooves tends to harden on cooling of the engine, ring sticking becoming evident in subsequent operation. To simulate these conditions in the test, the dish and ring were allowed to cool before any attempt was made to disturb the residue formed. When the dish and ring were thoroughly cold, the force required to separate them was measured on the small tensile machine shown in Fig. 3. This machine consisted of the weighing lever *A*, mounted on a knife edge, and a jockey weight *B* which could be moved, either mechanically or by hand, by the control screw *C*. During the first few tests it was found that hand operation did not give a sufficiently uniform rate of load application, and the results were erratic. In all subsequent tests the screw was belt driven from an electric motor, through pulley *D*. The dish was placed under the fork *E*, and a hook *F*, connected to the weighing lever, engaged the bar bridging the open end of the ring.

As the investigation progressed, the effect of film thickness on the oxidation of the oil was also studied, together with the effect of prolonged heating. It should be noted that mild-steel dishes and rings were used throughout the tests, no study being made of the catalytic effect of other metals on the oxidation of the oil.

TEST PROCEDURE.

To ensure uniform surface conditions on the dishes and rings at the beginning of each test throughout the series, the following procedure was adopted. After pickling in dilute hydrochloric acid and rinsing in hot water, the dishes and rings were dried by hand and placed in the oven, which had already been stabilized at the temperature of the subsequent test, and heated for about half-an-hour until the surface had assumed a uniform colour. The dishes were then removed and allowed to cool, after which they were weighed with the rings in place. A $\frac{1}{4}$-gram sample of oil was transferred to the dish from a calibrated dropping pipette, the actual weight being determined by weighing the assembly before and after introducing the oil. The oven was always stabilized at the test temperature before placing the dishes inside, and these were allowed to heat up for 5 min. before the test was considered to have begun. In the early tests six oil samples were tested at a time, but later the number was increased to nine, the first six samples being removed at hourly intervals and the others after about 20–30 hr. The various stages of the test are indicated in Fig. 4, in which (*A*) shows the dish and ring after cleaning; (*B*) the same components after the preliminary heating in the oven; (*C*) the dish containing the oil sample and ring ready for heating; and (*D*) the appearance after oxidation.

After cooling, the combined dish and ring were, in each case, weighed to determine the evaporation loss, and the force required to separate them measured on the tensile machine, the load being applied at the rate of $\frac{1}{3}$ lb. per sec. A chemical examination was also made of the oxidation products remaining in the dishes. In each case the residue was examined for solubility in petroleum ether and benzene. After treatment with these two solvents, there always remained a precipitate which represented the insoluble matter present in the residue. The procedure for the chemical examination was to transfer the sample obtained, after scraping each dish and its corresponding ring with a steel spatula, into a weighed boiling tube, which was then re-weighed to obtain the sample weight. Normally the sample consisted of about 70 per cent. of the residue present on the dish and ring. The contents of the boiling tube were then allowed to drain down to the bottom and the sides of the tube washed down with 10 c.c. of 60/80 aromatic free petroleum ether, refluxed for 30 min., and allowed to settle. The liquid was next decanted through a weighed Gooch filter, retaining as much of the solid matter as possible in the tube, and this solid matter washed with petroleum ether and again decanted. The total filtrate was then evaporated on a water-bath, dried at 120° C., and weighed. The residue in the boiling tube was refluxed with 10 c.c. benzene, filtered through the same Gooch filter, and washed with benzene until the runnings were colourless, after which the benzene extract was dried and weighed. Finally, the Gooch filter was also dried and weighed.

TEST RESULTS.

Effect of Temperature.—The first variable studied was that of temperature, the tests being carried out on a medium viscosity, solvent-treated mineral oil. This lubricant had a viscosity of 16·1 centistokes at 100° C., and a viscosity index of 95, indicating high paraffinicity. The effect of temperature on the loss due to evaporation after a uniform exposure time of 6 hr. is indicated in Fig. 5, in which the evaporation loss, expressed as a percentage of the original sample, is plotted against exposure temperature. The loss due to evaporation increased with temperature, but at a decreasing rate within the range studied.

Temperature had a marked effect on the formation of petroleum ether insolubles, or hard asphalt constituent, in the oil. It may be mentioned that, for the particular oil under review, no petroleum ether insolubles were formed at temperatures up to about 180° C. within the 6-hour test period, indicating only partial oxidation of the oil at these temperatures. At higher temperatures, however, petroleum ether insolubles were formed after exposure periods which varied with the test temperature. As a basis for comparison, the time to form 5 per cent. petroleum ether insolubles in the oil was determined over the temperature range 180–240° C. The results are shown in Fig. 6, in which the time to develop 5 per cent. petroleum ether insolubles is plotted against exposure temperature. The amount of the residue also varied with exposure time, as shown in Fig. 7, in which the percentage petroleum ether insolubles is plotted against exposure time for a number of temperatures. At the lower temperatures studied, the residue formed during the early period of exposure was completely soluble in benzene after treatment with petroleum ether, but with continued exposure the residue became only partly soluble in benzene, an increasing percentage remaining insoluble. With increasing temperature, the formation of insoluble residue occurred after shorter exposures. At the highest temperature tried, an insoluble residue was formed almost from the commencement of the test.

The influence of exposure time and temperature on the strength of the oxidized film, as given by the force required to separate the dish and ring,

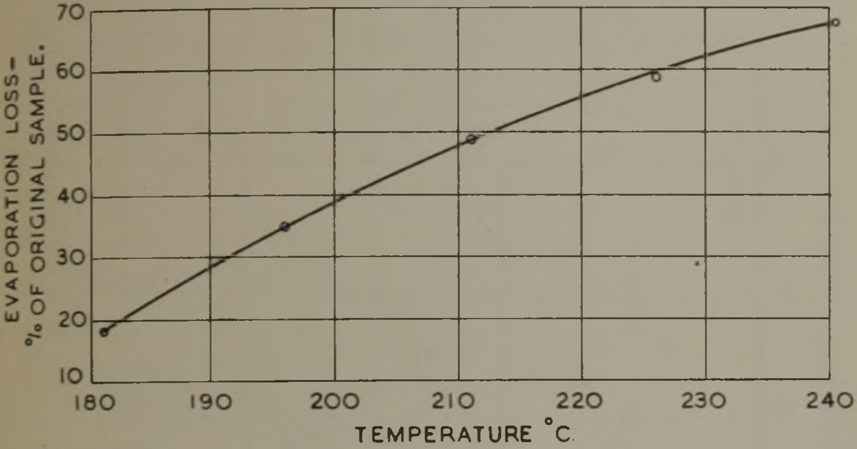


Fig. 5.

EFFECT OF TEMPERATURE ON EVAPORATION LOSS AFTER 6 HRS.' EXPOSURE.

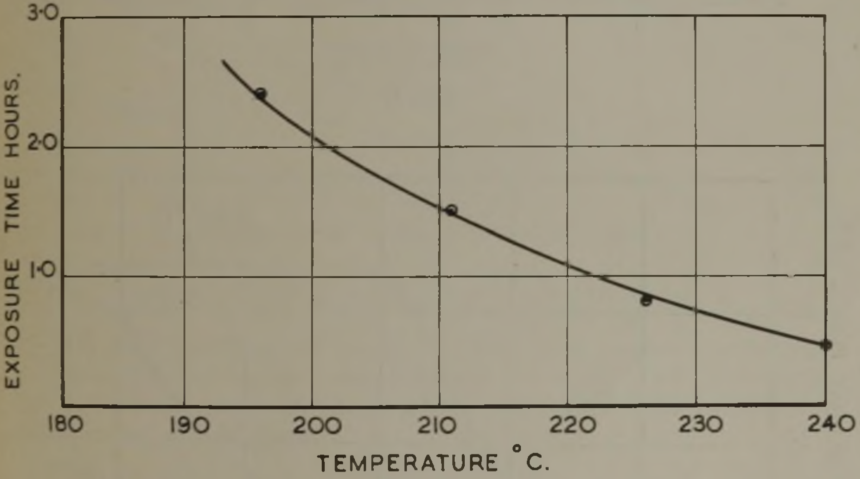


Fig. 6.

TIME TAKEN TO DEVELOP 5% PETROLEUM ETHER INSOLUBLES.

is shown in Fig. 8, in which the breakaway force is plotted against exposure time for a number of temperatures. In view of the small quantity of oil involved, the magnitude of the force required to separate the dish and ring appears unexpectedly high, but in subsequent tests on other oils a breakaway force as high as 65 lb. was recorded.

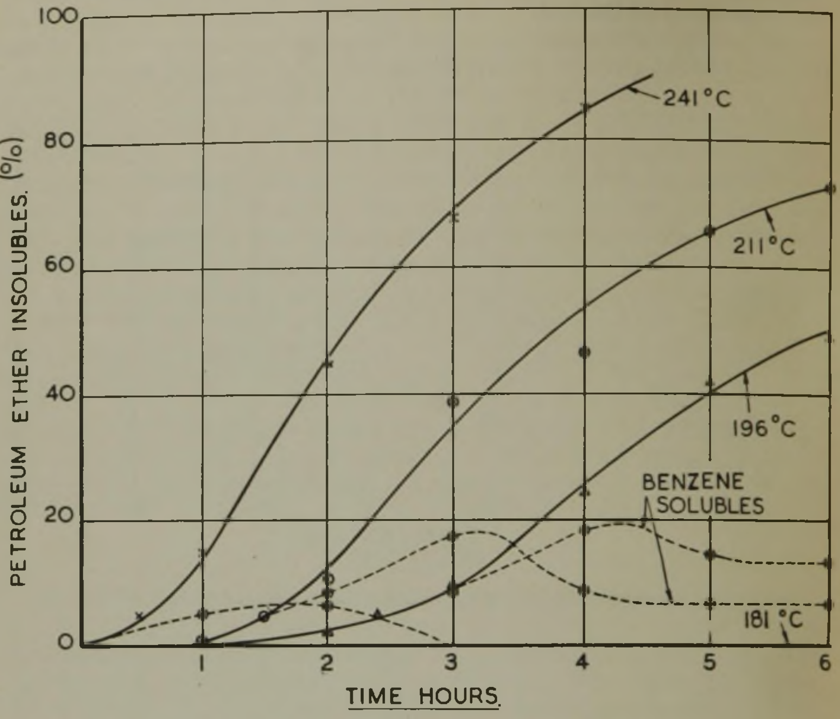

PETROLEUM ETHER INSOLUBLES (%)
100
80
60
40
20
0
241 °C
211 °C
196 °C
BENZENE SOLUBLES
181 °C
1
2
3
4
5
6
TIME HOURS

Fig. 7.

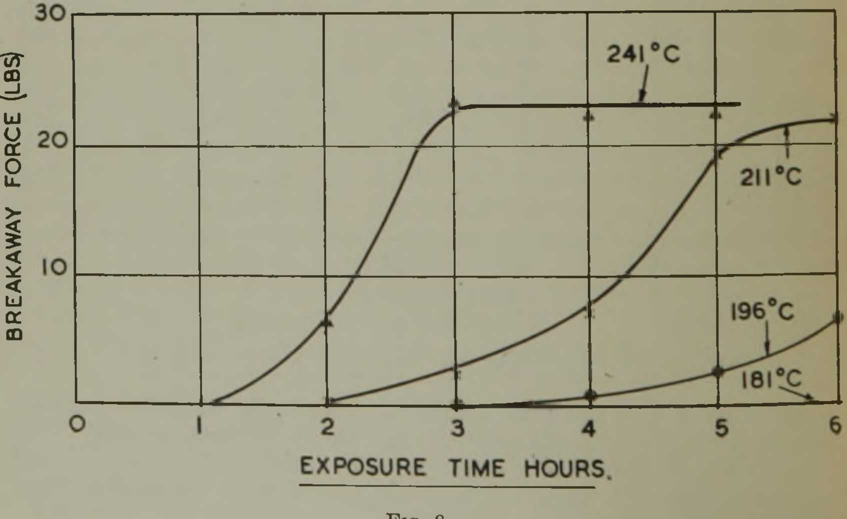

BREAKAWAY FORCE (LBS)
30
20
10
0
241 °C
211 °C
196 °C
181 °C
1
2
3
4
5
6
EXPOSURE TIME HOURS.

Fig. 8.

Some long period tests at 226° C. on four similar oils of different volatilities showed that the maximum breakaway force occurred with the oil giving the lowest evaporation loss.

Effect of Weight of Oil Sample.—The same size of dish and ring as in previous tests was used, but the weight of the oil sample was varied from 0·05 to 0·5 gm. The opportunity was also taken of investigating the effect of the initial oil viscosity. Samples of low-, medium-, and high-viscosity paraffinic engine-oils were tested at a temperature of 211° C., the exposure time being 4 hr. Data on these lubricants are given in Table I. In the present instance the low-viscosity oil was No. 18, the medium-viscosity oil No. 9, and the high-viscosity oil No. 1. The breakaway force is plotted in Fig. 9 against the initial oil sample weight. The greater gum-forming propensity of the lightest oil is clearly shown. In addition, within the range studied, the breakaway force increases with decreased sample weight—*i.e.*, with decreased film thickness.

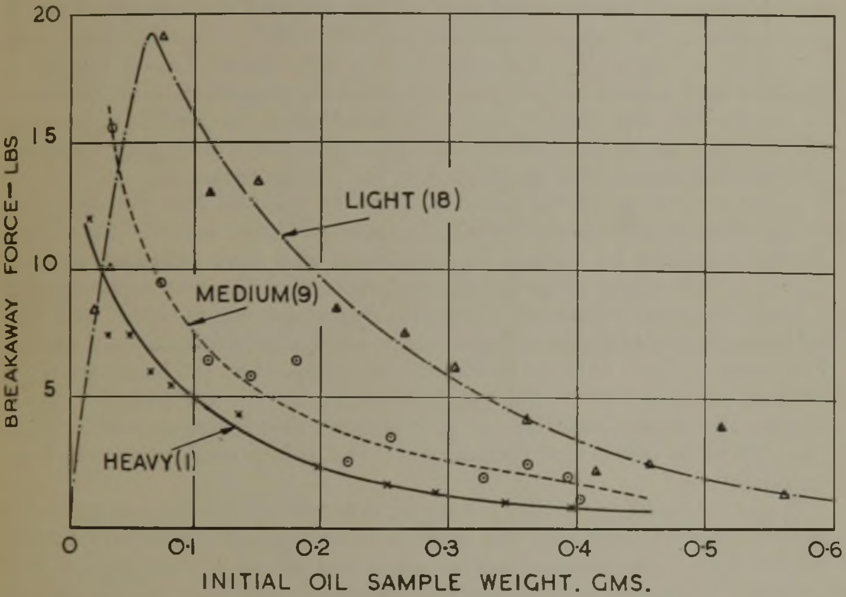


Fig. 9.

EFFECT OF OIL SAMPLE WEIGHT ON BREAKAWAY FORCE.

TABLE I.

Oil No.	Type.	Viscosity.	
		Index.	At 100° C. Centistokes.
1	Aero Oil, a blend of synthetic oil and Penna Bright Stock.	111	21·0
9	Solvent-treated mineral oil.	95	16·1
18	Solvent-treated mineral oil.	99	8·3

Effect of Extended Periods of Exposure.—These tests were carried out on oil No. 9. Seventeen dishes were prepared containing the standard 0·25-gm. sample of oil and heated to 226° C. for periods up to about 90 hr. To cover the possibility of experimental variations in the results, several samples were examined at each interval of the test. The strength of the oxidized film was measured in each case. The results were erratic, and it is probable that, once having reached its maximum strength, the oxidized film becomes brittle or friable with continued exposure.

CORRELATION WITH SERVICE PERFORMANCE.

It will be appreciated that the foregoing describes an experimental technique giving results which may or may not bear any relation to service performance. In order to establish any correlation, it would obviously be necessary to undertake extensive engine tests under known conditions, together with a series of oxidation and gumming tests on the same lubricants at comparable test temperatures. It would then be possible to ascertain whether any correlation existed under appropriate test conditions, but such a correlation has not been undertaken in the present instance.

Some indication of the possible value of the test has, however, been obtained by the laboratory testing of a variety of lubricants which have been kindly submitted by certain oil companies, who have indicated, in many instances, the engine ring-sticking performance of the lubricants supplied.

One company submitted six petrol-engine lubricants which had been rated in air-cooled single-cylinder engines and also in full-size aero engines. The order of merit of these lubricants, as indicated by the breakaway force after exposure at 211° C., did not, however, agree very well with the order of merit under service conditions. It is possible that better correlation might exist at some other test temperature, and this possibility is now being examined.

It is of interest to note that the engine order of merit of these six lubricants agreed precisely with both the order of volatility and of chemical stability of the lubricants, determined as described above. Thus, engine ring-sticking increased with increasing volatility, the best oil showing an evaporation loss after 4 hr. of 24 per cent. and the worst oil a loss of 47 per cent., the others having intermediate values. The chemical stability was taken as the time to develop 5 per cent. petroleum ether insolubles, and in this respect, the lubricant most resistant to ring-sticking was rated at 3·8 hr., whilst the worst was rated at 1·4 hr., the others again having intermediate values.

In regard to lubricants for compression-ignition engines, a large number were submitted which had been tested under a variety of service conditions, but adequate particulars of these conditions were not supplied. It is therefore not possible to attempt, at this stage, any extensive correlation between engine and laboratory figures of merit, but the results indicate, in general, that lubricants which had been found to give low ring-sticking in service showed a maximum breakaway force ranging from 0·2 to 6 lb., the usual value being in the region of 4 lb. Such oils had relatively low viscosity indices, ranging from 28 to 60, and were asphaltic, Russian, or Gulf-type oils.

Oils which gave high ring-sticking on compression-ignition engines showed, on the other hand, a maximum breakaway force ranging from 3·6 lb. to 65 lb., most values exceeding 20 lb. Such oils were mostly of high viscosity index—*i.e.*, in the region of 80 to 110—and were essentially paraffinic.

CONCLUSION.

It will be appreciated that the simple test methods described in this report for evaluating the stability and ring-sticking propensities of lubricants are tentative in nature, and that a good deal of further experimental work will be necessary to indicate their precise value. It is considered, however, that the work so far accomplished may be of some interest to both petroleum technologist and automobile engineer.

OBITUARY

RICHARD VERNON WHEELER.

Dr. R. V. Wheeler, Professor of Fuel Technology in the University of Sheffield, died on 29th October, at the comparatively early age of 56.

He had been the occupant of the Chair of Fuel Technology at the above University for nearly twenty years, and simultaneously held the important post of Director of the research stations of the Safety in Mines Department.

Dr. Wheeler was educated at Owen's College, Manchester University, where he worked on the phenomena of combustion with the late Professor Bone. Later his researches on flame propagation were to win him an international reputation.

After some useful experience in industry, he took up his life work on combustion phenomena. He was intimately concerned with the stone dusting of pits and with colliery explosions. As a member of Government and trade Committees and as an advisor to Government Departments and industrial organizations, he made many contributions to safety in mines and to the application of scientific knowledge to industry. He was the first chemist appointed to the Explosion in Mines Committee of the Home Office, and was responsible for starting the work at the Home Office Experimental Station at Eskmeals, afterwards transferred to Buxton. In the domain of petroleum chemistry he did outstanding and pioneering work on the pyrolysis of hydrocarbons.

Prof. Wheeler was the author of many papers given before learned societies, and many members of the Institute of Petroleum will remember his paper on " Flame Characteristics of Pinking and Non-Pinking Fuels," read before the Institute in 1928. He was the editor of the well-known journal *Fuel in Science and Practice*, and wrote several monographs on his own subject. Of special interest is his work with Dr. Marie Stopes on the constitution of coal and its segregation into four chief classes.

Last year he was awarded the Melchett medal of the Institute of Fuel, and two years ago the gold medal of the Institute of Mining Engineers. He had been a member of the Institute of Petroleum since 1925.

His untimely death is a most serious loss to applied science and infinitely regrettable to his many friends.

A. E. Dunstan.

ABSTRACTS.

AUTHOR INDEX.

The numbers refer to the Abstract Number.

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

Geology.

1118.* Geology of Texas Panhandle Oil- and Gas-field. H. Rogatz. *Bull. Amer. Ass. Petrol. Geol.*, 1939, **23**, 983–1053.—A description is given of the stratigraphy and structural geology of this field, and a discussion on the lithologic changes in the rocks and oil-producing formations; the oil pools are described with special reference to lithology.

The subsurface geology is treated by counties and is taken in two parts: (1) prominent tectonic features and their effect on production, (2) stratigraphy of each formation, special attention being given to changes occurring throughout the county.

Production in the Panhandle is governed by the situation of the oil-water and oil-gas contacts, which, by regional tilting of the surrounding area, have been shifted from their original horizontal positions. Any porous formation which intersects the zone between the oil–water and gas–water contact surfaces will be productive.

The probability of finding many new shallow oil pools in the Panhandle is thought to be remote, but the likelihood of ultimate discovery of deep oil is such as to warrant considerable exploratory drilling and geophysical work. Areas believed to be worthy of such exploration are outlined.

Many geological maps and sections accompany the paper. G. S. S.

1119.* Geology of Hugoton Gas-field of South-western Kansas. C. C. Hemsell. *Bull. Amer. Ass. Petrol. Geol.*, 1939, **23**, 1054–1067.—This field includes parts of Kearny, Finney, Haskell, Grant, Stanton, Seward, Stevens, and Morton counties (Kansas), and Texas County (Oklahoma).

The area is mostly covered with sands and caliche of the Ogallala series (Tertiary). Subsurface rocks—as shown in a type section—include the Dakota Sand (Cretaceous) up to about 450 ft. in thickness, and a thick series of Permian deposits. Important formations of the Permian, met above 2000 ft. from the surface, are the Blaine Gypsum (at about 1000 ft.) and the Stone Corral (Cimarron anhydrite) at approximately 1750 ft. Below these rocks occur shale and anhydrite of the Wellington formation, Upper Summer (225–370 ft.), followed by the gas-bearing dolomites and limestones of the Summer and Chase groups, 200–250 ft. thick. These, the producing horizons, are encountered at depths ranging from 2460 to 2750 ft. and dip approximately 12 to 14 ft. per mile across the Hugoton Field.

The author states that at the time of writing 307 gas wells have been completed in the field, with a daily open flow of 2,277,071,000 cu. ft., averaging approximately 7·4 million cu. ft. per well. G. S. S.

1120.* Summary of Rocky Mountain Geology. J. G. Bartram. *Bull. Amer. Ass. Petrol. Geol.*, 1939, **23**, 1131–1152.—This is a brief account of the stratigraphy and tectonics of the Rocky Mountains from the Pre-Cambrian to Recent. All geological formations are represented in the Rocky Mountain area of the western United States, and excellent outcrops enable detailed examination to be made. The author presents his account by the aid of a series of paleogeographic maps and cross-sections.

Four main structural epochs are cited: (1) the formation, in Algonkian time, of the Cordilleran geosyncline, which extended from Utah to British Columbia and remained until the close of the Upper Cretaceous; (2) the extension in the Pennsylvanian and Permian of the Arbuckle–Wichita–Amarillo mountain ranges into New Mexico and elsewhere, followed by erosion and burial under Trias and Jurassic sediments; (3) the uplift of the Cordilleran land mass on the west and south-west, in the Middle Triassic, and (4) the eastward extension of the uplifted folded and faulted Cordilleran highland at the close of the Upper Cretaceous, thus giving rise to the present Rocky Mountains. G. S. S.

1121.* Contribution to Jurassic Stratigraphy of Rocky Mountain Region. R. L. Heaton. *Bull. Amer. Ass. Petrol. Geol.*, 1939, **23**, 1153–1177.—A large number of sections of Jurassic sediments have been measured in the Rocky Mountain region. These, together with similar detailed results obtained by other workers, are used in vertical sections for correlation purposes.

Thus, the basal sandstone of the " Jurassic " of northern Colorado is shown to be probably partly Entrada and partly Upper Triassic. Further, it is shown that the latter grades into red sediments southwards, and the former continues into New Mexico, where it is identical with the so-called Wingate. The true Wingate of the Zuni Mountains merges laterally into red beds, and may be Upper Triassic in age.

Lithologically, the Entrada is unlike the Wingate both in colour and method of weathering. The Entrada weathers to rounded forms, is almost jointless, and is banded in grey and pinkish colours. The Wingate is distinctly columnar-jointed, forms vertical blocky cliffs, and is deep red in colour.

Maps, sections, and photographs illustrate the paper. G. S. S.

1122.* Environments of Origin of Black Shales. W. H. Twenhofel. *Bull. Amer. Ass. Petrol. Geol.*, 1939, **23**, 1178–1198.—Many theories exist regarding the origin and environment of black shales, and certain of these are reviewed and discussed.

Black shales were obviously black muds before lithification, or compaction, and this colour is largely caused by the presence of organic matter: black monosulphide of iron and the black oxides of manganese are also contributors in this connection. Muds that are black at the time of compaction because of organic matter or manganese, remain so after compaction. Black ferrous sulphide in muds, however, renders them light-coloured on compaction, as this sulphide alters to either marcasite or pyrite.

Organic matter may be composed of plant fibres, or it may be present in a very finely divided state, and at the time of deposition was evidently of colloidal dimensions. Some organic matter originally of this nature occurs in all black shales. Again, other black shales contain spores and pollen grains, and some are filled with remains of fatty algæ—these materials originally carried a high percentage of fats, waxes, etc.

Sediments associated with humic black shales are mainly continental in origin, consisting of sandstones, coals, and limestones; some beds may be of marine origin. Environment appears to be similar to that in the accumulation of vegetable matter resulting in coal.

The conclusion is that black shales originate under a number of environmental conditions: for example, in land waters (lakes and ponds), in deep sea-water extensions of the ocean (Black Sea), shallow marine waters (lagoons, bays), and over mud flats of lagoons, estuaries, and deltas. G. S. S.

1123.* Mississippi Well is Flowing Oil. N. Williams. *Oil Gas J.*, 7.9.39, **38** (17), 25.—It seems almost certain that commercial oil production has been found in Mississippi about 10 ml. south-west of Yazoo City. The oil sand is 10 ft. thick and 4540 ft. deep. It has a porosity of 25% and is in the uppermost part of the Cretaceous. The oil is of asphaltic base and 34·2° A.P.I. gravity. The area was selected on the basis of reflection seismograph work and also on surface structural evidence.

There have been few favourable showings of oil in all the wildcatting in Mississippi. Three outlying wells of the Jackson gas-field have given small amounts of very heavy oil intermittently with salt water, from the Selma Chalk. Evidences of oil have been found at Collins, Covington County, in the Wilcox; Hiram, Wilkinson County, in the Cockfield; Quitman, Clarke County, in the Eutaw; and in the Amory area of north-eastern Mississippi. Two salt domes were discovered in South Mississippi in 1937.

G. D. H.

1124.* New Pays Prolific as Revival Continues in Creek County. D. Dalrymple. *Oil Gas J.*, 7.9.39, **38** (17), 25.—Active development in the county began in 1906 following the discovery of the Glenn pool in 1905. In 1912 the Cushing pool was opened, followed by the Bristow–Slick area. In addition to these major fields, many smaller pools were discovered. Activity waned with the decline of the principal fields, but in the last two years there has been a revival of drilling. Several small pools have been opened, some of the older areas have been extended, and some success has been obtained with reworking, plugging back or deepening old wells in the Drumright–Shamrock and other areas.

The Zoller or Central Commercial pool, opened in 1938, found gas in the Bartlesville at 2521 ft. and oil at 2532–2552 ft. The oil flowed at 12 brl./day and gas at 3,500,000 cu. ft./day. Seven wells have been completed in the Bartlesville sand. The Dutcher and other horizons have yet to be tested.

1½ ml. south-west of the Zoller area is the Strozier pool. This, too, produces from the Bartlesville and may cover more than 100 acres.

In Township 17–9e production has been found in the Oswego lime and the Dutcher sand. The Dunn pool found oil in the Misener and the Wilcox. The Leverett pool yields oil from the Bartlesville, and Wilcox production has been found in a new area in the South Manford district. Furthermore, there have been discoveries in Sections 24 and 25–18–9 (Wilcox), Section 13–17–10 (Red Fork and Taneha), Sections 4–17–10 and 33–18–10 (Dutcher) and Section 30–14–7 (Prue sand). G. D. H.

1125.* Wasson–Denver–Bennett is Now One Big Field. R. M. Sanford. *Oil Gas J.*, 14.9.39, **38** (18), 26, 34.—The Wasson–Denver–Bennett field, started in several widely separated spots, has, after two years' drilling, an estimated proven area of 43,000 acres and an estimated oil reserve of about 344,000,000 brl. It is not yet fully defined. The productive Permian lime is about 5000 ft. deep.

The discovery wells of the three original fields were not less than 6 ml. apart. At the beginning of September 1939, there were 398 wells in the field. G. D. H.

1126.* Sandoval Devonian Structure. K. A. Spitznagle and H. Moore. *Oil Gas J.*, 14.9.39, **38** (18), 23.—The structure of the Devonian lime at Sandoval is now thought to have a north–south axis. This runs parallel with the main grain of the west side of the Illinois basin. The pay horizon, which is highly porous, lies 36–51 ft. below the Devonian erosional surface, and consists of a very soft, brown dolomite. There is at least 80 ft. of proven productive closure above the water-table. G. D. H.

1127.* University Lease is Louisiana's Second Most Active Area. N. Williams. *Oil Gas J.*, 21.9.39, **38** (19), 62.—This field is in East Baton Rouge Parish. The productive area, in which about thirty-five wells have been drilled, is about 1 ml. from north to south and 1½ ml. from east to west. Dry holes have been drilled on the extreme north-east, the west and south-west, the south and south-east sides. The outlying dry holes are structurally higher than any of the wells in the producing area, pointing to the field being on the downthrown side of the bordering faults. The first well found the producing sand at 6450 ft., and other oil and gas shows. A spacing programme of one well to 10 acres has been adopted.

The oil zone is 10 to 12 ft. thick and fairly uniform throughout the field. It is of Miocene age, as is also a gas sand found at about 4340 ft. The wells have potentials of 300–500 brl./day on ⅛ to $\frac{5}{16}$ in. chokes, with pressures ranging from 1000 to 2250 lb./in.^{2} G. D. H.

1128.* Pratt County, Kansas, Scene of Revived Exploration. D. Dalrymple. *Oil Gas J.*, 28.9.39, **38** (20), 20–21.—In the eastern part of Pratt County recent developments indicate the joining of the Cunningham and Cairo pools into one major gas- and oil-field. The No. 1 Royse well lies 1½ ml. east of the nearest Cairo production and 2¾ ml. south-west of the nearest Cunningham production and gives 1,110,000 cu. ft. of gas daily from 4268 ft. This and other gas wells produce from the Viola lime, whilst a well with a potential of 772 brl. of oil/day has been completed in the Lansing lime at 3402–3458 ft.

The Cunningham field was opened in 1931 with Lansing lime oil production at 3385–3441 ft. In 1932 Arbuckle lime production, mainly gas with a little oil, was found at 4093–4175 ft. Later a well plugged back to 3922 ft. gave 52,000,000 cu. ft. of gas daily from the Viola lime. Due to careful reservoir control, nearly all the wells flow. Gas from the Admire shale is used for repressuring. A number of other horizons show gas.

The Cairo sector was opened in 1937, when a well gave 10,000,000 cu. ft. of gas daily from the Viola lime at 4278 ft. The two fields cover about 10,000 acres.

The Luka pool has Simpson dolomite oil production. G. D. H.

1129.* Loco Hills Field is Most Active in New Mexico. D. H. Stormont. *Oil Gas J.*, 5.10.39, **38** (21), 23.—This field, discovered in January, now has producers scattered over a semi-proven area of 4500 acres. Oil is relatively shallow (2600–2800 ft.). The productive limits are apparently defined on the south-west and west sides, and on the north and north-west sides several dry holes have been drilled.

Production is obtained from the " Artesia " sand pay (Permian), with accumulation apparently due to lensing out of the sand to the north and west on lime highs, forming an embayment. The regional dip is to the south and east at 60–70 ft./ml. The oil sand thickness ranges from 30 ft. well within the field to 12 ft. in the north and west.

A well which missed the Loco Hills pay entirely is being completed as a producer in a lime section at 3252 ft.

At present the producers have an allowance of 65 brl./day. G. D. H.

1130.* New Discovery in Burkburnett Starts Redrilling Activity. R. M. Sanford. *Oil Gas J.*, 5.10.39, **38** (21), 33.—4½ ml. south-west of the town of Burkburnett a new oil-field of some twenty-five wells has started a redrilling and re-exploration campaign in the Burkburnett, Clara, and other old shallow fields in the northern part of Wichita County. It is thought that twenty years ago in the rush to tap the prolific Burkburnett sand shallower sands may have been ignored.

The new Warren and Reilly area has given a 150-brl. well from 20 ft. of sand at 1362 ft., and a 29-brl. well at 800 ft. The deeper production is better, and the field is of typical lenticular type. At present it covers little more than 80 acres.

A number of comparatively deep wells were drilled in this area during the past ten years, but all were dry. G. D. H.

1131.* Drilling Activity Assuming Boom Proportions in Golden Meadows. N. Williams. *Oil Gas J.*, 14.9.39, **38** (18), 24.—Golden Meadows is the most active spot in Louisiana despite disappointing results in the development of production. There appears to be a badly faulted and irregular sand condition, and although there are at least nine sands at depths of 2600 ft. to over 10,000 ft., and 12–30 ft. thick, they are extremely segmentary, with very spotted productivity. All the sands are not present in all the wells and only four have given commercial production. The side of a fault on which a sand is found seems to have nothing to do with its productivity. The zone of oil saturation in the sands generally does not exceed 5 ft., and it is difficult to exclude water completely. The spotted accumulation has been attributed to the sands being fed from a common source via the faults.

To date ten producing wells have been completed, although eight other tests have been drilled below present producing horizons.

The history of the development of the field is described. G. D. H.

1132.* Mesozoic and Cenozoic Most Important Texas Producing Zones. M. C. Dalton. *Oil Wkly*, 2.10.39, **95** (4), 24.—All oil-fields located in the south, east, and Gulf Coast areas of Texas are producing from Mesozoic and Cenozoic formations. The Balcones fault zone roughly separates Mesozoic and Cenozoic oil-producing fields in Texas from those producing from the Palæozoic. In Texas seventy-three fields produce from the Mesozoic and 214 from the Cenozoic. On the Gulf Coast all the fields produce from the Cenozoic, whilst in East Texas production is predominantly from the Mesozoic. In East Texas the main producing horizon is the Woodbine sand.

The history of oil development in Texas is briefly outlined and a graph shows the number of fields discovered each year. The peak year was 1937, with forty-nine new fields. A table summarizes the modes of discovery of the fields in the various regions of Texas.

There is a definite trend towards deeper drilling in all the areas under consideration. In East Texas Lower Cretaceous beds of Glen Rose age are being penetrated. In South Texas exploratory drilling has gone below 10,000 ft. Generally production on the Gulf Coast is deeper than in the other two areas, although there are some very shallow fields. This latter area offers good opportunities for successful deep drilling. There the Frio formation is of major interest, and the underlying Cockfield, Upper Saline Bayou, and Lower Saline Bayou are possible favourable deep producing sands. A table summarizes the number of fields producing from various depths, whilst a further table classifies the fields according to the type of structure. Domal structures are commonest on the Gulf Coast, whereas sand lensing predominates in South Texas. Monoclinal producing structures are rare, but faults are very important. Terracing is of minor importance. In South Texas eight fields are associated with igneous intrusions.

The fields have been classified according to the type of producing formation. The dominant lithological type is sand. A generalized columnar section of the Mesozoic and Cenozoic of Texas has been constructed, and on it the stratigraphic positions of the producing fields are shown. G. D. H.

1133.* Simple Device for the Construction of the Trace of the Axial " Plane " of a Competent Fold. G. D. Hobson. *Geol. Mag.*, Sept., 1939, LXXVI, 427–432.—If the form of a fold is known, but not the centres of curvature of the components of the curve, it is not a very simple matter to locate those centres in order to determine the trace of the axial " plane " according to Busk's method. The instrument described consists of a plane, vertical, metal mirror, to the bottom edge of which is attached a graduated strip which is extended horizontally along the line of the mirror edge. The zero mark of the scale, etched on the mirror, is set on the curve, and the mirror is rotated about this as vertical axis until the curve and its image appear to run smoothly into each other. The edge of the scale is then along the normal to the curve at that point. In this way, by alternate application to the two limbs of the fold, generally at pairs of points on each limb, it is easy to locate a series of points which are equidistant from the two limbs, and they lie on the trace of the axial " plane." G. D. H.

1134.* Alberta Oil Progress in the Half-Year. J. L. Irwin. *Petrol Times*, 12.8.39, XLII, 201.—The production in the first half of 1939 was 3,254,000 brl., an increase of 424,000 brl. over the corresponding period of 1938. The production history since the beginning of 1936 is briefly described.

A new refinery was opened in East Calgary in May.

Drilling at Steveville, 150 ml. east of Turner Valley, has given a gas flow of 12,000,000 cu. ft./day with 0·15 gal. of gasoline/1000 cu. ft., which is almost commercial production. At Pouce Coupe, which lies within 430 ml. of the Pacific, an extensive drilling programme has been arranged. 150 ml. east of Edmonton, wells at Lloydminster have shown encouraging recoveries of oil and gas at depths of 1925 and 1751 ft. Wells are being drilled at Vermillion, 25 ml. west of Lloydminster. On the Kootenay dome a well has penetrated 800 ft. of Devonian limestone and encountered promising gas strikes. The Ram River and Clearwater wells, also Devonian tests, have found gas. Information is given regarding wells in other areas.

The bulk of Turner Valley's production now comes from the south from an area 5 ml. long and 1 ml. broad. The productive zone seems to extend from the gas area in the east to the sudden dip in the structure. Turner Valley's prospects seem very bright. G. D. H.

Geophysics.

1135.* Advancements in the Use of the Gravimeter in Oil Exploration. L. M. and F. W. Mott-Smith. *Petrol. Engr*, Midyear 1939, **10** (10), 85.—To be of value for oil exploration the instruments must be capable of measuring about 1 ten millionth of the total acceleration of gravity. They consist of a mass supported by an elastic member, and a means of measuring differences in the position of the mass caused by variations of the gravitational attraction. The constructional and operational problems are described.

For reconnaissance work one station per square mile may suffice, but for detail ten may be required. Bases and subsidiary bases are used for checking the behaviour of the instruments after every five to ten observations. The instrument readings are converted to milligals by means of a calibration curve, and a drift curve is plotted showing the gravity values against time of reading, the repeat values at the various bases and subsidiary bases showing the drift and serving as a check on instrument operation. In this way the gravity differences for the various stations can be obtained. Before plotting on a map, elevation and latitude corrections must be applied. Gravity contours are then drawn. An example is described and discussed.

The value of a gravity map depends on its accuracy. There are three principal causes of error : (1) Erratic fluctuations in instrument reading from such causes as temperature variation, elastic after-effect, jarring, etc. The probable value of this error can be determined by tests. (2) Inaccuracy of calibration curve. This may be tested against pendulum observations. (3) Errors in making latitude and elevation corrections caused either by inaccurate surveying or by the use of an incorrect elevation correction constant.

The accuracy of gravity maps obtained with a torsion balance depends more on the character of the terrain than does that of those obtained with a gravimeter. The torsion balance being more strongly affected by nearby terrain irregularities, the gravimeter is more effective in irregular territory. The torsion balance is probably more suitable for detecting small-scale shallow structures, whilst the gravimeter is probably at an advantage with larger anomalies. A gravimeter is probably about ten times more rapid in operation than a torsion balance, and hence the cost per square mile is considerably lower. G. D. H.

1136.* Probable Discovery Rates in the Gulf Coast Area. V. G. Gabriel. *Oil Wkly*, 11.9.39, **95** (1), 46.—Tables are given showing the results achieved by seismic and torsion balance exploration in the Gulf Coast area prior to the middle of 1938. The information includes the location of the oil-field, the date and means of its discovery, the amount of oil produced, the ultimate oil recovery, and the amount of oil which can be credited to seismic or torsion balance methods. The probability table gives some data pertaining to discovering oil- and gas-fields and wells under various conditions, chiefly in the Gulf Coast area. There is a marked improvement from year to year in the chance of discovering oil, and the high value of combined geological and geophysical information in "wildcat" drilling is demonstrated.

It is estimated in the periods 1925–1938 and 1935–1937, that 65% and 76%, respectively, of the oil discovered can be attributed to geophysics. The balances fall to geological discoveries. The average cost of a geophysical discovery is computed to be \$0·023/brl. of oil. G. D. H.

Drilling.

1137.* Augering and Core-Drilling in Trinidad. E. C. Scott. *J. Inst. Petrol.*, 1939, **25**, 501–508.—A paper presented at the Trinidad branch which describes the use of four main types of rotary machines used in this type of drilling and the scope of the work. G. R. N.

1138.* Method for Handling Drill-Cutting Samples at Well. D. H. Stormont. *Oil Gas J.*, 6.4.39, **37** (47), 45.—An efficient method of handling rotary drill cuttings is described. The equipment for sampling, washing, and drying the cuttings is of an improvised nature, but takes representative samples of the returns with uninterrupted service. The sample is collected in a pan, washed, and finally dried in a steam-jacketed 3-in. pipe, utilizing cheap material and exhaust steam throughout. The installation is both economical and simple. A. H. N.

1139.* Combination Drilling Method Used at Van Horn, Michigan. H. F. Simons. *Oil Gas J.*, 13.4.39, **37** (48), 34.—A saving in time and in cost of drilling wells in the Van Horn field is effected by drilling a little more than one-third of the well by the rotary rig, whilst drilling the remaining depth of the well and completing it by the cable-tool method. A detailed description of the formations encountered, the drilling programme, and difficulties is given. A. H. N.

1140.* Review of Illinois Basin Operating Problems. R. E. Damp. *Oil Gas J.*, 13.4.39, **37** (48), 44.—The rotary method was the principal one used for exploration and exploitation of oil and gas in the Illinois Basin. Some 2046 wells were drilled, of which 1910 were productive in 1938. It is estimated by the A.P.I. that 208 million brl. reserve have been discovered in the same year.

The new rotary rig is of a light type, which has a limit of 3000 ft. using 4½-in. drill pipes. Most contractors use the following sizes of machines and other items: rigs powered with two gasoline, semi-diesel, or diesel engines, from 80 to 175 h.p.;

pumps, from 5 × 10 to 7¼ × 14 ins.; drill pipe, 4½-in.—3½-in. may be used in certain cases, whilst some wells were drilled using D.P. 2⅞-in. and setting 4½-in. O.D. casing. Cost per ft. has been lowered, and averaged $1·75 for 6¼-in. to $3·50 for 8¾-in. hole up to 3000 ft., excluding casing and cement. Drilling time has also been reduced. Casing strings have been lighter and smaller than previously. Fast-setting cements have been in general use, with a minimum setting time of 48 hr. To obviate excessive pressures being encountered when using light-weight pipe and circulating cement, Aquagel has been added, with good results. A 3%-by-weight Aquagel-cement lightens a 15-lb. slurry to about 13·5 lb., and has about the same viscosity.

Cores have been taken in the first wells, whilst in the later wells electrical logging has been used, resulting in appreciable saving.

Whether well completion by rotary or cable-tool methods is preferable is still a debatable question. While shooting has been practised, acidizing has been improved and used. In one method a flexible tube has been run on the end of a "macaroni" string, through which acid is pumped to impact at the formation at high velocities, destroying the lime and allowing the flexible tubing to project out into the formation. In a test it was possible to reach 42 ft. laterally. Packers and retainers have proved valuable assets in acidizing tight formations. The size of treatment ranges from 500 to 10,000 gal.

Removable lines have been used to produce two or more formations in the same well. They are run in the string of casing, and are removed by a special pilot bit or with a well scraper, and, in the case of a recent metal alloy, by acid. It was found that these liners should be placed with shoes on top and bottom of the liner, the shoe on the bottom being inverted.

It is believed that in pumping wells electricity will undoubtedly be the source of power. Individual pumping units range from 3·5 to 7·5 h.p.

Pressure maintenance is being practised in two basin pools. Original reservoir pressure in the Louden pool was about 650 lb. and is at present about 580 lb. Gas returns to the sands at 650–750 lb. and in sufficient quantities to maintain a low rate of decline in reservoir pressure. Gas injection will be slow, in order to avoid creating gas caps. Input wells are located in the centre of eight producing wells in each quarter section and the adjoining quarter section. A. H. N.

1141.* No Limit Yet to Deeper Drilling in the Gulf Coast. N. Williams. *Oil Gas J.*, 20.4.39, **37** (49), 105.—A record is given of the deepest wells drilled in the Gulf Coast. Data are supplied in the text and in tables regarding the records broken in recent years by producing and non-producing deep wells. A. H. N.

1142.* Many Unusual Features in Rig Design Reported on Louisiana Discovery. N. Williams. *Oil Gas J.*, 20.4.39, **37** (49), 114.—The rig was assembled with a view to expediting the carrying out of a comprehensive development programme in coastal Louisiana. As an exploratory test, the Kenilworth well has been drilled to a total depth of 11,469 ft. Oil and gas sands have been encountered below 10,500 ft.—chiefly between 10,532 and 10,960 ft., and several below 11,190 ft. Seven-inch casing was cemented on bottom and perforated. The well was completed by perforating an 18-ft. section at 10,608–26 ft.

From 8401 ft. to bottom six Schlumberger surveys were run, and every formation was tested as thoroughly as possible.

The world's second longest string of 9⅝-in. casing was run and cemented in 15 hr. 36 min. The string was 10,807·94 ft. long and 483,673 lb. (241·8 tons) in weight. Going from bottom upwards the string consisted of one Baker high cement upwhirler float shoe; two joints of 47·60-lb. NGCR-2 flush-joint casing; one Baker Baklu cement float collar; ninety-six joints of 47·60-lb. NGCR-2 flush-joint casing; one combination joint; 183 joints of 43·50-lb. NGCR-3 speedite casing.

Drilling mud was reconditioned before running in casing.

Record time was also made in running and cementing the 7-in. flow string. Details are given of operational times in both cases. No difficulty was experienced in cementing.

In setting the surface 13⅜-in. casing two clamps instead of the usual one were employed below the collar. A heavy preventer and drilling control were necessarily used. The assembly was placed in the 9 × 9 × 9-ft. cellar under the derrick floor.

The steel substructure is the first of its kind, and provides ample working clearance. The rotary table sills are supported in it by longitudinal beams, on which the entire length of the rotary skids rests. The beams rest on columns 12 ft. apart. They are only 16 in. high instead of 24 in., and consequently give an additional 8-in. clearance.

The rotary table support is, unusually, independent vertically of the remainder of the structure. Also steel floor sills are used instead of the wooden ones in common practice. The substructure includes a wood-covered steel ramp with a capacity to take the draw-works (60,000 lb.) with a drum full of line. The engine substructure is also of steel.

Derrick is of 136 ft. by 30 ft. base size, with a 15-ft. gin-pole and a platform extending the entire length of the gin-pole cross-beam.

The weight indicator is placed on a 3-in. pipe which extends through a hole in the platform to the concrete substructure. None of the vibrations in the derrick can be transmitted to the weight indicator.

The deadline tie-down is made through a 2½-in. U-shaped pipe grouted in the concrete; thus only little wear is possible on the wire, and the strain is taken off the derrick leg.

Sizes and weights of equipments were designed so that no single unit would have a greater size, weight, or capacity than could be effectively utilized in co-ordination with the operation of other units. A. H. N.

1143.* Illinois Drilling Rigs. H. F. Simons. *Oil Gas J.*, 27.4.39, **37** (50), 38.—The shallow wells of the Illinois Basin require a technique of drilling different from that used in deep-well drilling in Texas, Oklahoma, and Kansas. Due to the formation, particularly the Pleistocene, being loose and unconsolidated, much cement is lost, and this necessitates smaller holes and clearances between casing and wall. Hence much pipe-sticking occurs. In many cases it is cheaper to abandon the well, skid the rig, and redrill than to follow a fishing programme, as drilling the hole takes 100 hr. or less. Smaller pipes are now used to reduce sticking, the resultant loss of weight on the bit being made up by lengthening the collar. Damage to drill pipe still constitutes one of the principal costs of drilling in Illinois. Speeds are consequently reduced from 120 r.p.m. to 75–90 r.p.m.

In completing the wells many operators are using removable alloy pipes opposite the Weiler zone. Shooting continues to be the customary treatment for sand wells.

A. H. N.

1144.* Applying High Explosives in Completing Oil Wells. B. Altman. *Oil Wkly*, 15.5.39, **93** (10), 28.—The object of shooting wells is to increase the permeability, to enlarge the hole, to clean the face of old pumping wells, and to straighten crooked holes—in short, to increase production. Shooting is also applied as a last resort before abandoning a well.

Three types of explosives are used: blasting gelatin, liquid nitroglycerin, and gelatin dynamite. Straight dynamite is not suitable, as water affects its properties.

After briefly describing different methods, it is pointed out that in shooting limestone to open new channels, it has been found from experience that the highest concentration gives the best results.

Many factors must be studied before deciding upon using solid or liquid stemmings. Solid stemming confines the reservoir energy to a greater extent than liquid stemming, increases the size of the shot hole, and reduces the number of casing failures. In liquid stemming oil is preferable to water, as oil absorbs the shock more effectively. Diagrams are given of probable shapes of shot-holes with different stemmings and points of detonation.

Solid stemming should always be placed on a bridge, usually of broken bricks. It can take the shocks from the hailer without danger of premature explosion, and will confine the shot energy downwards.

In preparing to shoot a well, the hole should be cleaned, the fluid level or oil/water contact level determined, and the temperature of the well taken. Temperatures in the neighbourhood of 140° F. have produced pre-detonations. All the stemming material and bridging should be ready. If liquid explosives are to be used the container should be tested for leaks. Detailed considerations should be taken of the weight, size, and kind of casing, total depth of hole, and size of shot before deciding on the kind and extent of stemming.

Much scientific research is required before this art of oil-well shooting can be thoroughly understood. A. H. N.

1145.* Study of Physical Properties of Rotary Drilling Muds. F. G. Tickell and M. H. Stekoll. *Oil Gas J.*, 11.5.39, **37** (52), 56.—The purpose of this paper is to describe those physical and mechanical properties of drilling muds which should be correlated with the kinds and amounts of chemicals added. The effects of treating three varieties of natural muds with sodium tannate are given and correlations of properties discussed. The properties are : (1) Apparent viscosity as shown by a Stormer viscometer. (2) Gel strength at 0, 10, 20, and 90 min. as shown by weight required to start motion in a Stormer viscometer. (3) Yield point as shown by a special simple apparatus. (4) Thickness of filtrate cake and volume of filtrate expressed as shown by a small hydraulic press and piston-and-cylinder type of pressure filter (1000 lb./sq. in.). (5) Percentage of water separating from mud in 24 hr. as shown in a graduated cylinder. (6) p_H value as shown by a Leeds–Northrup glass electrode and potentiometer. All tests were made at room temperature. Graphs are given correlating the amount of chemical used, time elapsed, and effects observed on each of the various items mentioned. By studying all the graphs together the different items are correlated. A. H. N.

1146.* Fishing Job on Kansas Well Cleaned Up by Cutting Pipe. H. F. Simons. *Oil Gas J.*, 18.5.39, **38** (1), 58.—A detailed description of fishing a stuck pipe is given. A. H. N.

1147.* Satisfactory Service of Rotary Drill Pipe is Dependent upon Care in Operation. H. F. Simons. *Oil Gas J.*, 25.5.39, **38** (2), 48.—Care and thorough understanding of drill pipe are much more essential nowadays than formerly, as speeds and weights are used far in excess of old practices. Speeds up to 400 r.p.m. have produced difficulties and dangers which have to be taken fully into account in designing the drill pipe. Longer collars are more widely used than previously. The author discusses these and other problems, such as weight on bit, derrick alignment, tool-joint threads, corrosion, etc., which have to be considered if a long and useful life is to be expected of a drill pipe. A. H. N.

1148.* Design of Casing Programmes. J. O. Hills. *Oil Gas J.*, 25.5.39, **38** (2), 60.—The importance and cost of casing programmes justify careful engineering design based on the best available information on strength and loading conditions. A method of design is outlined which considers actual conditions, and which results in a consistent compromise between economy and safety. Factors influencing choice of sizes, weights, grades, etc., are discussed ; method of tabulation is shown ; and an example of the design is included. Collapse and tension data in Table I are given primarily to illustrate the method, but are believed to be the most reliable available at the moment. A. H. N.

1149.* Preliminary Evaluation of Factors Controlling Rate of Penetration in Rotary Drilling. J. E. Brantly and E. H. Clayton. *Oil Wkly*, 22.5.39, **93** (11), 15.—An exhaustive study of questionnaires, tour reports, bit records, and formation records has been made on more than 500 wells in typical fields of Texas, Oklahoma, Louisiana, California, New Mexico, Wyoming, and Kansas in order to ascertain the relative influence of four factors on the rate of rotary-tool penetration during the past eight years. The four factors are : personnel and equipment, rotary speed, volume of drilling fluid, and weight on bit. Detailed analyses of these factors are given in both tabulated and graphical forms, the analyses being for both single and composite effects. It was found that improvement in personnel and equipment had a relative effect of 55·5%, as compared with rotary speed effect of 39·6% and drilling fluid volume of 28·6%. The weight on the bit was included in the three preceding factors, as it was quite impossible to separate it from " personnel." Rotating speeds and fluid volumes have apparently reached their maximum limits, as has weight on the bit in many cases.

It was also concluded that an increase in value of each of the four factors will result in increased rates of penetration when drilling soft material with rock-bit or softer still with drag-bit. A limit undoubtedly exists for all these factors except personnel.

In plastic formations, brittle shales, etc., it appears that the upper limit for the weight on the bit has been reached. Increased rates of penetration may be attained by improving the other factors and by using higher pressure jetting from the fluid nozzles of the bit.

In plastic, clayey, silty, and shaley formations, rate of penetration increases depends largely on increased fluid volumes, jetting action, and character of fluid. Use of proper short drag-bits is assumed. A. H. N.

1150.* Selective Exclusion of Fluids from Wells. P. D. Torrey. *Oil Wkly.* Appearing in seven successive parts. Pt. I, 22.5.39, **93** (11), 26; Pt. II, 29.5.39, **93** (12), 36; Pt. III, 5.6.39, **93** (13), 40; Pt. IV, 12.6.39, **94** (1), 17; Pt. V, 19.6.39, **94** (2), 24; Pt. VI, 26.6.39, **94** (3), 6; Pt. VII, 3.7.39, **94** (4), 30.—The paper is devoted primarily to modern methods which are employed in the completion of oil wells, and in re-working jobs when these may be necessary.

Squeeze cementing, which is used widely as a completion and remedial measure, is a process whereby cement slurry is forced, or " squeezed," under pressure into or against a permeable formation, either in open hole or through gun perforations in the casing. Breaking down the formation by water under high pressure before the cement is introduced seems to be a prerequisite to the success of squeeze cementing. It is believed that openings in the formation are formed by the water under pressure, which provides spaces—sometimes of considerable size—in which the cement may lodge. Evidence is presented that would indicate that cement will set preferentially in a gas pay or a water sand rather than in an oil sand, and that in ordinary circumstances the cement has no detrimental effect on the oil sand.

Methods employed in squeeze cementing with and without a cement retainer are described. An interesting method for the testing of a deep wildcat well, without the running of a long string of casing, by cementing a short string opposite to the horizon to be tested, is described. A description is also given of a method that has been developed for the completion of a well producing from a series of oil sands through one string of casing.

Case histories in various fields of Texas, Louisiana, Arkansas, and Illinois, where squeeze cementing has been employed for the reduction of high gas–oil ratios and for the exclusion of water, are presented. Maximum squeeze pressures in excess of 3000 lb. per sq. in. appear to give the best results for the reduction of high gas–oil ratios, and maximum squeeze pressures of approximately 4000 lb. per sq. in. appear to give the best results for the exclusion of water. Squeezing in close proximity to the gas–oil or the water–oil contact is essential. Squeezing is generally much more effective through gun perforations in the casing than in open hole. Of the various records studied, 44% were entirely successful in the reduction of high gas–oil ratios, and 61% were entirely successful in the exclusion of water. The employment of higher maximum squeeze pressures, gel types of cement, and multiple-batch jobs is increasing the percentage of success that is being obtained from squeeze cementing. The results from squeeze cementing may not be permanent when readjustments are made in the gas–oil and water–oil contacts in the reservoir.

Various plug-back methods for the exclusion of water are described, and particular reference is made to results that have been obtained in various West Texas fields, in the Rodessa field, and in the East Texas field. No squeeze-cement job for the exclusion of water has been entirely successful in the Permian lime-fields of West Texas. In the Rodessa field very good results have been obtained by cementing a short string in the bottom of the hole and then gun-perforating for production. Many plug-back methods have been used in the East Texas field, but no one method appears to be universally applicable. Past experience has shown that about 50% of the attempts made have resulted in failures. New technique in placing the cement so that the casing may be protected from excessive pressure, and the use of gel types of cement, have indicated more promising results.

Owing to low allowables and the use of small-size chokes, there does not seem to be any great difference in the productivity of wells completed by gun perforation and of those completed by the setting of conventional liner and screen. Gun-perforated well completions permit a close control of oil production, and provide an easy means for remedial work at some future time. Completions by setting screen and liner may result in larger ultimate oil recovery, and are used widely in thick-sand sections where there is no question as to the water–oil or gas–oil contact.

New chemical methods for the exclusion of water are assuming considerable importance. Two different processes are described, and some of the results that have been obtained are listed. The gel-plugging agent has been applied very successfully in hardrock fields for the exclusion of water. A. H. N.

1151.* Economic Study of Slim-hole Drilling in the Gulf Coast. I. W. Alcorn. *Petrol. Engr*, May, 1939, **10** (8), 25–30.—The paper gives a breakdown and analysis of costs derived from factual data which indicate the feasibility of exploratory slim-hole drilling for testing deep Gulf Coast structures. Data on the drilling of extra large (18⅝-in. surface casing), normal holes (10¾-in. surface casing) and slim-holes (7⅝-in. or 8⅝-in. surface casing) are analysed. The result is to show that drilling of exploratory small holes has been sound practice, and that its economy is a big factor in its favour.

In general, the chief difference between the operations of drilling a large hole and a small one is that for the same depth a larger number of cubic feet of earth must be removed from the former than from the latter. From this analysis it is seen that, for similar drilling conditions, the rate of drilling or time required to drill to a given depth varies as the square of the diameter of the hole after the surface casing has been set. Hence the slim hole is distinctly a saver of time and, therefore, of money. The author finds reason for believing that slim holes can be drilled to a depth of 9000 ft. at an average cost of between one-third and one-fourth that of the average conventional exploratory well, assuming average drilling conditions and the use of a diesel mechanical rig.

This low cost makes it possible to drill several holes on a prospect to determine the general geological conditions, so that a conventional deep test may be located more rationally. A. H. N.

1152.* Drilling Patents. L. A. Gauthey and W. C. Kaykendall. U.S.P. 2,152,628, 4.4.39. Appl. 23.7.37. Rotary well drilling bit.

G. A. Smith. U.S.P. 2,152,671, 4.4.39. Appl. 26.10.35. Well-surveying instrument.

R. C. Baker. U.S.P. 2,153,034, 4.4.39. Appl. 10.10.36. Cementing casing shoe with radial passage-ways extending from the central passage-way to the outside.

C. E. Burt. U.S.P. 2,153,035, 4.4.39. Appl. 21.1.37. A method for casting slips for oil-well tools.

M. G. Featherston. U.S.P. 2,153,079, 4.4.39. Appl. 27.10.37. A wire splicer which twists the end of a wire upon itself.

J. H. Schumacher and W. C. George. U.S.P. 2,153,680, 11.4.39. Appl. 30.1.36. Direction control mechanism for rotary well-drilling tools. When the pipe deviates from the vertical, a force is exerted on it in the opposite direction.

J. J. Jakosky. U.S.P. 2,153,802, 11.4.39. Appl. 23.11.36. Method and apparatus for continuous exploration of bore holes, consisting of taking electrical measurements using the drill pipe and bit as one electrode in conjunction with another electrode connected to earth in a remote position of well.

L. L. Snyder. U.S.P. 2,153,815, 11.4.39. Appl. 27.7.37. Fluid-operated latching means for inner drill assemblies for use in drilling wells where a circulating fluid is used.

H. C. Block. U.S.P. 2,153,822, 11.4.39. Appl. 19.8.35. Wash-line drive connection for a well-bottom washing.

W. C. Irwin. U.S.P. 2,153,882, 11.4.39. Appl. 14.1.35. Rotary jar.

W. L. Foster. U.S.P. 2,153,883, 11.4.39. Appl. 6.7.36. Oil-well jar.

W. H. McKissick. U.S.P. 2,153,934, 11.4.39. Appl. 15.6.35. Tubing catcher.

A. C. Catland. U.S.P. 2,154,032, 11.4.39. Appl. 10.7.37. Rotary-well bit.

J. C. Hewitt, Jr., and V. E. Kuster. U.S.P. 2,154,162, 11.4.39. Appl. 15.4.35. Means to orient tools in a well.

I. R. Henderson. U.S.P. 2,154,308, 11.4.39. Appl. 16.4.38. A cement sprayer.

A. J. Penick and K. T. Penick. U.S.P. 2,154,408, 11.4.39. Appl. 4.6.35. Combination tubing head and blow-out preventer.

E. G. Gartin. U.S.P. 2,154,445, 18.4.39. Appl. 1.11.34. Rock drill.

L. A. Layne. U.S.P. 2,154,461, 18.4.39. Appl. 21.6.37. Well-gravelling and developing assembly and method.

J. A. Zublin. U.S.P. 2,154,553–2,154,554, 18.4.39. Appl. 29.8.38. Bits for rotary drilling.

C. R. Jenkins. U.S.P. 2,154,621, 18.4.39. Appl. 6.12.35. A device for measuring the length of flexible elements such as ropes, cables, and the like.

A. L. Armentrout. U.S.P. 2,154,654. 18.4.39. Appl. 2.2.38. A fishing tool utilizing a fusible electrode which is to be fused to the lost article in well by an electric current.

R. W. Mueller and G. F. Carle. U.S.P. 2,154,855, 18.4.39. Appl. 2.2.37. Well-casing control head.

R. R. Sanderson. U.S.P. 2,154,960, 18.4.39. Appl. 9.1.36. Percussion bit.

E. B. Hall and A. L. Armentrout. U.S.P. 2,155,129, 18.4.39. Appl. 18.1.38. Drillable well liner made of aluminium, and free of such ingredients as copper, which easily deteriorate in presence of the saline oil-well waters usually encountered.

J. J. Jakosky. U.S.P. 2,155,133, 18.4.39. Appl. 28.10.36. Method and apparatus for electrical logging of wells by measuring the electrical conductivity of formations.

E. B. Hall and A. L. Armentrout. U.S.P. 2,155,369, 18.4.39. Appl. 27.7.36. Well liner built in sections, connected by weak joints; thus sections may be broken and removed.

R. N. Bean. U.S.P. 2,155,380, 25.4.39. Appl. 13.3.37. A packer.

R. N. Bean, H. C. Block, and L. A. Layne. U.S.P. 2,155,381, 25.4.39. Appl. 25.9.37. A bottom assembly for setting strings.

R. N. Bean. U.S.P. 2,155,382, 25.4.39. Appl. 27.9.37. Hydraulic release for well bottoms

H. H. Jones. U.S.P. 2,155,552, 25.4.39. Appl. 5.6.29. Well-hole inclinometer.

G. D. Johnson. U.S.P. 2,155,601, 25.4.39. Appl. 22.8.36. Bailer.

W. R. McClendon and W. D. Owsley. U.S.P. 2,155,609, 25.4.39. Appl. 23.1.37. Multiple stage cementing.

D. Scaramucci. U.S.P. 2,155,620, 25.4.39. Appl. 21.3.38. Measuring line equipment.

C. R. Dale. U.S.P. 2,155,785, 25.4.39. Appl. 25.10.37. Cement dump bailer.

A. J. Penick and K. T. Penick. U.S.P. 2,155,837, 25.4.39. Appl. 2.8.35. Blow-out preventer with bypass for pressure relief.

C. W. Cooper. U.S.P. 2,156,052, 25.4.39. Appl. 19.4.37. A well-logging apparatus using sound waves.

J. E. Terrill. U.S.P. 2,156,207, 25.4.39. Appl. 4.2.38. An apparatus for washing and cementing wells.

T. H. Dunn. U.S.P. 2,156,219, 25.4.39. Appl. 5.6.37. A method of plugging brine-bearing strata chemically by injecting lead nitrate under pressure. Lead chloride is precipitated thus plugging the formation.

T. H. Dunn. U.S.P. 2,156,220, 25.4.39. Appl. 30.6.37. A method of plugging water-bearing formations by introducing under high pressure a solution of magnesium salt followed by a solution of an hydroxide. Magnesium hydroxide is formed in a copious, voluminous, gelatinous precipitate which plugs the formation. A. H. N.

Production.

1153.* Bemis Potential Obtained by Productivity Index. H. F. Simons. *Oil Gas J.*, 2.3.39, **37** (42), 49.—Three instruments may be used in a new method for obtaining productivity index by determining the fluid level in the well. The author describes the principle of the instrument and mode of operation in finding the productivity index. A typical wave-reflection chart from one of the test runs is shown.

If this new method proves successful, it is believed that open-flow physical potentials may be entirely abandoned in the State of Kansas. Productions during the pre-test and test period averaged less than 500 brl./well, whilst a similar potential formerly would have required the production of at least 1116 brl./well. A. H. N.

1154.* Recycling of Gas Following Completion Aids Recovery from Shoe-String Sand Field. H. F. Simons. *Oil Gas J.*, 9.3.39, **37** (43), 44.—An old property was employed as a large-scale laboratory for determining the type of formations and methods most suitable for repressuring, whilst at the same time the increase obtained in production made the project profitable. A detailed description of the equipment and well spacing and all relevant data regarding pressure and time are given. A. H. N.

1155.* Pressure Maintenance Project of Corpus Christi Corporation. N. Williams. *Oil Gas J.*, 16.3.39, **37** (44), 50.—Efficient fluid recovery is facilitated from high-pressure gas-producing horizons by recycling operations carried out by Corpus Christi Corporation in the Stratton field. Conservation of gas is effected by returning stripped gas to the producing formation, thus maintaining reservoir pressure. The extraction of fluid from the gas is done entirely by pressure reduction, cooling, and expansion of the gas. The stripped gas is picked up by compressors which boost the pressure and return the gas to the field. 55,000,000 cu. ft. of gas are handled daily. Details of the cooling, pressure-reducing, and boosting operations are given, together with the properties of the extracted fluid and figures relating to the actual values of pressures and temperatures at various points.

The plant is designed with efficiency as a guiding principle. Energy is conserved by heat exchangers and the correct application of thermodynamical principles.

In the installations are special safety features, which are described; these should prove of interest to readers. A. H. N.

1156.* Condensate Wells—Completion and Recycling Operations. E. V. Foran and P. C. Dixon. *Oil Gas J.*, 23.3.39, **37** (45), 82.—It is pointed out that at high pressures liquids have higher vapour pressures than is ordinarily the case, and that at 3000–4000 lb., and below about 185° temperature, the upper zone (Big Lake field), with its water-white oil, is existent in the formation in the gas phase entirely. Wells which produce these high-pressure gases from which a " water-white oil " is condensed are called " water white," " distillate," or " condensate wells." The last term is the most fitting name.

Retrograde pressure condensation is defined as a process wherein a condensation is produced by pressure reduction at constant temperature, and retrograde pressure vaporization is the reverse of this process. Similarly, retrograde temperature condensation is a process wherein a condensate is produced by temperature increase at constant pressure, and retrograde temperature vaporization is the reverse of this process. The principle and operation of condensation processes are given.

In the well completion it was found that gun perforation did not give good results, due probably to the hardening of the formation and consequent reduction of its permeability just around the shot hole. One type of efficient completion in an unconsolidated formation was to set the casing on top of the producing horizon, drill into and underream the pay, and set a screen with gravel pack.

The mechanics of recycling operation is considered, and some mistakes in pattern development are pointed out. The paper ends with 5 references to recent papers.
A. H. N.

1157.* Oil Development and Production Practices in South-west Texas. C. H. Row and R. H. McLemore. *Oil Gas J.*, 23.3.39, **37** (45), 89.—In the latter part of this extensive paper a summary of drilling completion and producing practices in three zones is given. Steam-driven rotary rigs are generally employed. The usual rig is capable of drilling upwards from 9000 ft. Details of the rigs, water, mud, and operational programmes are given for each zone.

While wire-wrapped screen is still employed in the completion of many wells, the general practice is setting casing on bottom, perforating and producing without any screen or liner. The wells are flowing under a 24-hr.-per-day programme under the smallest choke which will permit the allowable to be obtained over the 24-hr. period. Details of artificial lifting operations are also given.

An interesting item included in the paper is the cost of typical wells. A. H. N.

1158.* Well-Completion Data Obtained in Oil-Field Development. S. F. Bowlby. *Oil Gas J.*, 23.3.39, **37** (45), 98.—A better understanding of the reservoir and its contents, obtained through early detailed observations and proper interpretations, has made it possible to take immediate action in determining the best completion procedure. As a consequence, it is now expected that the improved methods of completion and production will recover a far greater percentage of the oil underground than was formerly estimated, whilst in the exploitation of high-pressure gas distillate zones it is possible to recover and save approximately 100% of all hydrocarbons present.

The data and records necessary for the efficient completion of wells and development of a field are studied by the author under three headings: (*a*) basic completion data, (*b*) actual completion data, and (*c*) performance data. Each of the three items is discussed in detail, and the use of electrical logging is defined both with regard to the advantages accruing from using it and to its limitations, such as its inability to differentiate between gas and oil. Typical well-completion records are given, and it is concluded that usability should be the keynote in assembling data and keeping records. Only data which have a correlative value should be included in the graphic record, whilst the written record should be unstinting with regard to all factual details. Three good reasons are given for the proper recording of completion data: (1) technical—the graphic record is a tool of the engineer and geologist, and should be understandable by all; (2) scientific—the proper recording of actual facts gives the research worker a practical background which will eliminate lost motion in this direction, and (3) legal—the graphic record with the subsurface deductions to be made therefrom is admitted as evidence in conclusion. A. H. N.

1159.* Ryan Salt-Water Disposal in Bemis Pool. P. Reed. *Oil Gas J.*, 30.3.39, **37** (46), 174.—The disposal of some 1877 brl. of saline water which is unsuited for either human or animal consumption is being carried out by pumping it back through a disposal well by a closed system. The dimensions and operation of the system are given, as well as the chemical analysis of the saline water. The well takes the water at a pressure of 235 lb., whilst the pressure between each of the pumping period falls to 20 lb.

The cost of the system is tabulated, an abridged table being given below:

Drilling and equipping of disposal well and pumping station	$5,242·63
Lead lines (2 items)	820·80
Total	$6,063·43

Since the system was put into operation a total of 55,650 brl. has been injected (up to March 1st). A. H. N.

1160.* Study Pressure Maintenance at Cotton Valley. G. Weber. *Oil Gas J.*, 6.4.39, **37** (47), 49.—An experimental plant for gasoline extraction and recycling has been recently put into operation, handling 12,000,000 cu. ft. daily at present operating pressures, for the purpose of providing data for a general pressure maintenance plan now under consideration for the field as a whole. The plant is located in the centre of the field structure. The importance of the plan is due to the size and importance of the field. The Bodcaw sand of the lower Marine formation is now proved to be productive of gas and distillate over an estimated area in excess of 10,500 acres, with estimates of recoverable distillate reserves reaching nearly 50,000,000 brl. under present production practices.

A structure contour map of the field, with contours drawn on top of Bodcaw sand, is given, together with present production practice. The development is on an 80-acre spacing pattern. The field structure is anticlinal and is of unusual regularity, and the sand is uniform and continuous. A. H. N.

1161.* Vacuum Applied to Oil Production. H. F. Simons. *Oil Gas J.*, 6.4.39, **37** (47), 59.—The use of vacuum to reduce the pressure on a producing formation has been revived in California. In small producing areas the practice was originally to pull a vacuum on an entire area with a central plant used to obtain a reduction in pressure. Arguments both for and against the advisability of pulling an extremely heavy vacuum on wells are put forward by production men. The chief argument against it is the danger of producing channelling, thereby affecting the gravity of the oil, whilst the main argument in its favour is that production by vacuum is akin to repressuring.

Most of the wells in the Centralia area are pumped by individual units driven either by internal-combustion engines from 5 to 15 h.p. or by small electrical motors ranging from 3 to 5 h.p. Two general plans have been followed : one calls for a separate installation for vacuum ; the other utilizes the same engine or motor for pumping wells and producing vacuum. The former method uses a 1-h.p. motor-driving vacuum pump connected to the well-head. In the latter the pumping beam is made to drive a piston that develops a vacuum with each stroke of the pump. Several arrangements of doing this exist, but all are relatively simple.

In California the gas discharged from the vacuum pump is bubbled through the oil tank, and this is sufficient to raise the gravity of the oil and put it into a higher price class. A. H. N.

1162.* Efficiency of Water-Flooding in Bradford, Important Production Problems. H. M. Ryder. *Oil Gas J.*, 13.4.39, **37** (48), 54.—Efficiency is considered here as the production of the maximum quantity of crude per acre at a minimum cost per barrel. The ultimate cost of a flooding operation may be devided into interest, development, and operation, and this total divided by the number of barrels produced over the life of the flood provides the figure per barrel. The ultimate amount of interest paid is controlled by the rate of development, the volume of production, and the time in which it is obtained. The development cost involves the drilling and equipping of wells and construction of a pressure plant and powers. The direct operating cost includes labour, supplies, and fuel.

To produce with maximum efficiency the following must be considered : (1) drilling pattern, (2) well spacing, (3) water pressure, and quality, (4) completion of wells, (5) conservation of gas supplies, (6) selection of machinery, (7) effective control of operations.

The first four items are considered, as they have in common a dependence on sand conditions. All, however, are important.

The five-spot appears to be the most widely used drilling pattern, although Muskat has shown the four-spot or seven-spot to be somewhat more efficient. The author confirms Muskat's findings.

There is a waiting period between water first being pumped in and the desired increase in oil production. The shorter this waiting period the better, and three ways may be used to effect this shortening : (1) heavier shooting, (2) higher pressures, (3) increasing the number of intake wells in a given area. This again, on analysis, shows the seven-spot pattern to be the most efficient.

The inefficiency of too many wells per acre is shown by equating cost of well and number of barrels of oil producible per acre; yet many operators still use the closer spacing. The time required to deplete an area, using any particular pattern, will vary roughly with the square of the spacing. By changing the pattern and adjusting the pressure this can be compensated for. Hence there is no best spacing for all sands.

The higher the pressure the higher are the capital investment and operational expense, but the smaller the number of wells required; also the higher pressures remove a larger percentage of oil from the sand. The highest pressure, at the surface, that may be used is equal in lb./sq. in. to the number of feet to the top of the sand. Each property must be worked out on its merits, taking permeability of sand into account.

The water quality should be such as not to clog the sand nor corrode the pipe. The area should be flooded regularly and no area " watered out " before the others for maximum efficiency.

The problem of the ever-varying permeability of the sand tending to make the last requirement almost impossible should be studied in detail, and the corrections introduced by appropriate shots using shells of varying diameters and placing spacers in accordance with the exact nature of the sand as found by test in each well.

Typical cases are illustrated in detail in the paper. A. H. N.

1163.* Economics of Gravel-Packing in Completing Oil Wells. W. A. Clark. *Oil Gas J.*, 27.4.39, **37** (50), 46.—The paper is in the nature of a progress report covering the performance of gravel-packed wells in certain areas having the oldest histories of gravel-packing. During 1938 operating costs on individual wells showed a substantial advantage in favour of those wells which were gravel-packed, as compared with conventional wells of similar structural and zonal position. Costs are shown in detail in tabular form.

The average monthly production per well favoured those which were gravel-packed by 41%. The following may account for the greater production :—

(1) The gravel-packed wells may pump for long periods before pulling.

(2) Better pump efficiencies are possible, as the pumps may be inserted deep within the liner in the gravel-packed wells without fear of sanding up, as in the case in conventional wells.

(3) Possibly improved production efficiency from the zone, due to the large-diameter hole in the gravel-packed wells.

(4) In the San Joaquin Valley an additional reason may be that gravel prevents heaving and appears to act in part as a " gas separator." A. H. N.

1164.* Gas Lift in Many West Texas Fields. D. H. Stormont. *Oil Gas J.*, 4.5.39, **37** (51), 56.—Various reasons are leading West Texas operators to adopt gas-lift methods for the recovery of oil. High-pressure gas is led directly from gas producers to inlet wells. The gas-lift problems in West Texas have been resolved by adapting the equipment at hand to conditions existing in each individual case. A review is given of different cases and the action of intermitters is described. A. H. N.

1165.* Multiple Sand Completion Uses Removable Casing. H. F. Simons. *Oil Gas J.*, 11.5.39, **37** (52), 49.—To produce efficiently from two horizons simultaneously through one well, a removable section of casing is employed. This removable section is either dissolved by acid or removed mechanically. In the Louden field it is imperative for effective production to have open holes opposite both producing horizons, whilst the intermediate formations should be properly cased. The lower producing formation is left as an open hole. The upper producer is located accurately and a removable liner is interposed in the steel casing pipe so that it comes exactly against the sand. The whole string is cemented in the usual manner. After 72 hr. the removable section is drilled out in one case; a scraper is then used to form a cement-free sand face ready for shooting. In the second case, from 1000 to 1500 gal. of 15% hydrochloric acid are pumped through tubing. When hydrogen no longer comes out of the well the metal pipe is considered dissolved. Excess acid is used, and this is pumped out. After shooting and testing the upper sand, the cement is drilled out of the lower depths and the lower sand is shot and cleaned for production. In another method the lower sand is completed first and the upper sand put on production last.
A. H. N.

1166.* Pumping Problems in the Sand Areas of Winkler, Ward Counties, Texas. J. T. Reeves. *Oil Gas J.*, 18.5.39, **38** (1), 76.—The specific problems of this field are discussed with reference to an average well. The chief troubles of general interest are due to floating sands and to the large volumes of gas accompanying the oil, producing general gas-lock troubles.

Gas anchors are discussed. The most usual form is a closed-end type, with or without a dumping valve; but this, in the opinion of the author, is not as effective as the open-end type, which he describes in detail.

To avoid sand troubles in the pumps, it is recommended that the fluid be as little agitated as possible, and that a metal-to-metal arrangement of piston and liner be arranged with a clearance of only one-thousandth of an inch. A. H. N.

1167.* Time Switches Factor in Reducing Lifting Costs. W. C. Lane. *Oil Wkly*, 15.5.39, **93** (10), 35.—The advantages of incorporating a time-switch in order to operate automatically and intermittently electrically controlled pumping wells are discussed. A diagram of connection is given. A. H. N.

1168.* Problems of Pumping in Repressured Areas. J. W. Cushing. *Oil Wkly*, 29.5.39, **93** (12), 18.—Repressuring introduces problems in oil pumping which are both new and difficult, varying with such factors as the producing formation, type of oil produced, repressuring medium, pumping equipment, pumpers and combinations of two or more of these. For instance, a great deal depends on the pumpers in watching and reporting wells which are unduly influenced by injected gas or air, or if the gas/oil ratio appears to increase excessively as compared with other wells.

Vapour lock may introduce difficulties in pumping. When gas is injected into the sand, the gas which is not absorbed by the oil moves along with the oil to a producing well and causes a vapour lock in the working barrel.

The use of air creates more difficulties than gas, as it has a corrosive action on subsurface pumping equipment. Reducing the air flow from the well to a minimum should help to combat corrosion.

Amongst the problems and difficulties discussed is the warning regarding the use of the gas from the sand as a fuel when air is injected. An explosive mixture may be obtained, with disastrous results. A fuel supply obtained from a different source than the oil sand should be sought. A. H. N.

1169.* Production Methods in the Rodessa Field. T. H. Gibbs. *Petrol. Engr*, May, 1939, **10** (8), 37.—The paper deals with problems encountered in successive stages of production from natural flow onward. In the natural-flow period proration, gas/oil ratios and water form the chief factors to be studied. In the last stages of natural flow the wells are " rocked " or " kicked-off " where a supply of high-pressure gas is available. Where permeability is low, " stopcocking " is found effective.

Artificial production of oil is generally occomplished by gas-lift. Starting valves are installed so that starting pressures need not be greater than operating pressures. Valves for inducing intermittent flow work on the same principles and are widely used. Under optimum operation, flow-valve operation will result in greatly reduced input gas/oil ratio. Leakage through valves would cause large gas losses, intervalve interference, and paraffin deposition.

Intermittent flow chambers, which are described, are used in the east side of the field. It is best to submerge the unit just below the fluid level in the well. Similarly plunger-lift which is also practised depends on submergence. Therefore, the productivity and operating-pressure decline of any one size of plunger will parallel the decline in reservoir pressure. A. H. N.

1170.* Comparison of Rotary, Beam, and Pneumatic Counterbalances. Pt. I. K. N. Mills. *Petrol. Engr*, May, 1939, **10** (8), 42.—The fundamental purpose of any counterbalance is to decrease the peak load imposed on the driving mechanism, and hence its effectiveness in accomplishing this purpose is the first measure of its efficiency; but it must achieve this aim with equal effectiveness at all practical operating speeds.

Detailed graphic study of the balancing effects of the three types are made, and typical polished-rod dynamometer card and torque curves for counter-clockwise rotations are given. In the case of rotary and pneumatic counterbalancing, the speed of the crank has no effect on the efficiency of the counterbalancing. In the case of beam balancing, however, the effective weight of a beam counterbalance is a function of the vertical acceleration, and consequently of the speed of the crank. Hence an efficient counterbalance at one speed may induce stresses at another speed sufficient to break the beam. By a study of the bending moment diagrams of beams at both low and high speeds with beam counterbalancing, it is shown that such effects may be obviated by so placing the weights as to have their centre of gravity coincident with the centre of the pitman bearing. A. H. N.

1171.* Comparison of Rotary, Beam, and Pneumatic Counterbalances. Pt. II. K. N. Mills. *Petrol. Engr*, June 1939, **10** (9), 144.—When the rotary counterbalance is used, the full load of the well is taken by the pitman, whilst in the other two cases the counterbalance forces oppose the well load and relieve the pitman—these forces becoming larger with increasing speed. This property cannot, however, be utilized, as it may cause bearing troubles. The chief disadvantage of the rotary counterbalance is that it imposes greater loads on the crankshaft, this increase in loading depending on the pumping speed and the general design of crank. As forces are transmitted to the reducer foundation it creates problems in designing the foundations which have to be realized and solved. It has also been shown that, with rotary counterbalance, the natural period of torsional vibration of a pumping reducer may occur in the operating speed range of the prime movers in general use. Prolonged operation at the critical speed may cause failure.

A disadvantage of beam and pneumatic counterbalancing is realized practically, although it cannot be seen from an analytical study of the problem, and that is that at two points of zero torque the gears are unloaded and have a tendency to clatter on engine-driven wells, and when the load is put on again, considerable impact is developed. Sufficient rotating inertia on the crankshaft eliminates this trouble.

The chief objection to a properly designed beam balance is that it is difficult to adjust the amount of counterbalance effect created by it. When a combination of beam and a small adjustable rotary counterbalance system is used, the maximum counterbalance efficiency may be obtained at the lowest initial investment. A. H. N.

1172.* Production Measurement and Regulation of High-pressure Gas Wells. J. J. Carter and C. E. Webber. *Refiner*, 1939, **18** (5), 206.—High-pressure dry gas can be measured with sufficient accuracy by means of the usual orifice meter, provided the Z factor for pressure correction is known. The Bean method or the authors' modification of the same is preferred for the evaluation of this factor. Graphs of this deviation factor for methane and a natural gas are given. It is claimed that reasonable accuracy is obtained in measuring dry gas by putting a stroke recorder on the compressor to count the strokes on the cylinders. This method is particularly useful in cases of pulsating flow.

In the measurement of high-pressure wet gas many problems may occur—*e.g.*, retrograde condensation, hydrate formation, etc. It is considered advisable to instal chokes downstream from the orifice meters to obtain reliable measurements. Additional certitude requires a hydrocarbon analysis and a density on the gas to assess the Z and gravity correction factors. G. R. N.

1173.* Acidization of Oil Wells. A. A. Trofimuk, T. A. Shikanova, and N. M. Karpenko. *Neft. Khoz.*, April–May 1939, **20** (4–5), 33–39.—Hydrochloric acid treatment is applied when the crude is contained in limestone or dolomite. The hydrochloric acid dissolves these minerals, thereby facilitating the access of oil to the well.

Since the introduction of hydrochloric acid treatment in the Kirov field an additional yield of approximately 40,000 tons of crude oil has been obtained. Certain defects, mainly of an organizing nature, are indicated.

A general instruction for hydrochloric acid treatment of oil wells is given, including : (1) necessary acid concentration, quantity of solution, and time interval of reaction ; (2) necessary chemicals, their properties, and method of preparing solutions ; (3) safety measures in hydrochloric acid application ; (4) necessary equipment ; (5) preparation of the oil well and operations during treatment ; (6) operations after treatment ; (7) organization of work ; (8) method of estimating efficiency of treatment. L. R.

1174.* Production Patents. W. M. Mansfield. U.S.P. 2,152,701, 4.4.39. Appl. 16.11.36. Counterbalance for oil-pumping apparatus.

W. M. Mansfield. U.S.P. 2,152,702, 4.4.39. Appl. 9.8.38. A pivoted counterbalance for oil pumping.

G. T. Humphrey. U.S.P. 2,152,762, 4.4.39. Appl. 26.4.37. A straight-lift oil well pumping apparatus.

C. R. Wagner and R. H. Carr. U.S.P. 2,152,779, 4.4.39. Appl. 6.7.37. An apparatus and method of water injection for water-drive purposes without clogging the formation. The water is always maintained under an inert gas so that precipitation due to oxidation is avoided.

H. Dripps. U.S.P. 2,152,794, 4.4.39. Appl. 8.2.38. Bottom-hole sample taker.

C. H. Bills. U.S.P. 2,152,863, 4.4.38. Appl. 7.12.37. Sand, water and oil segregator tank.

W. L. Church. U.S.P. 2,152,873, 4.4.39. Appl. 10.6.37. A well pump.

A. R. Maier. U.S.P. 2,153,094, 4.4.39. Appl. 21.12.35. An oil well pumping apparatus.

M. De Groote. U.S.P. 2,153,744–46, 11.4.39. Appl. 28.2.38. Processes for resolving petroleum emulsions of the water-in-oil type.

B. H. Stevens. U.S.P. 2,153,816, 11.4.39. Appl. 30.11.37. Sucker rod jerk absorber.

B. E. Parrish. U.S.P. 2,153,843, 11.4.39. Appl. 22.7.35. Well swab.

C. D. Hathcock. U.S.P. 2,154,331, 11.4.39. Appl. 9.2.38. A well pump.

M. De Groote and C. M. Blair, Jr. U.S.P. 2,154,422–23, 18.4.39. Appl. 12.8.38. Composition of matter and process for resolving petroleum emulsions.

H. C. Otis. U.S.P. 2,154,768, 18.4.39. Appl. 14.2.35. Means for flowing oil wells with independent oil and gas valves.

I. J. McCullough. U.S.P. 2,154,859, 18.4.39. Appl. 19.5.36. Gun perforator.

I. J. McCullough. U.S.P. 2,155,322, 18.4.39. Appl. 8.3.37. Gun perforator.

E. O. Bennett. U.S.P. 2,155,635, 25.4.39. Appl. 2.5.38. Bottom-hole pressure gauge.

L. A. Layne and L. C. Mundt. U.S.P. 2,155,718, 25.4.39. Appl. 19.11.35. Washpipe anchor.

L. A. Layne. U.S.P. 2,155,635, 25.4.39. Appl. 5.5.36, and U.S.P. 2,155,636, 25.4.39. Appl. 9.5.36. Well strainer.

C. van Westrum. U.S.P. 2,155,744, 25.4.39. Appl. 23.6.36. Well strainer.

J. T. Phipps. U.S.P. 2,156,228, 25.4.39. Appl. 6.10.37. Gun perforator.

A. H. N.

Gas.

1175.* Control Practices in Processing Natural Gas. H. N. Wade. *Refiner*, 1939, **18** (6), 248.—The author gives three principles : (1) control only essential functions, (2) use the fewest devices which will secure the desired control, and (3) match the refinement of the control to the accuracy required by the process. Using these principles as a basis, the control systems are built up for a diethylene–glycol gas-dehydration unit and a distillate extraction and gas-pressure-maintenance plant.

G. R. N

1176.* Evolution of Gases in Oil Storage Tanks. A. C. Thaysen. *J. Inst. Petrol.*, 1939, **25**, 411–415.—An account of several experiments on the activity of micro-organisms, which occur in the bottom layers of oil-storage tanks. G. R. N.

1177.* Protection from Dangerous Gases in Oil Tanks. A. W. Cox. *J. Inst. Petrol.*, 1939, **25**, 416–425.—This subject is discussed under dangers of empty tanks, explosive and inflammable limits, Home Office regulations, cleaning and vapour-freeing tanks, treatment for various products, testing for inflammable vapour, taking of samples, electric-testing methods, flame-testing methods, potential sources of vapour, removal of water and residues, precautions in vapour-testing work. G. R. N.

1178.* Flue-gas Protection for Ships' Tanks. O. W. Johnson. *J. Inst. Petrol.*, 1939, **25**, 426–434.—The manner of formation of explosive mixtures in ships' tanks is reviewed, and it is shown that most of the danger from explosion can be avoided by excluding air from the tanks, supplying in its stead an oxygen lean flue gas, to take the place of the discharged oil. The equipment, making up a complete flue-gas system and its operation are briefly described. G. R. N.

1179.* Automatic Recorder for Inflammable Gases. H. Lloyd. *J. Inst. Petrol.*, 1939, **25**, 435–439.—The principles and design of instrument used by the Safety in Mines Research Board in the application of preventive measures against risks of fire and explosion in coal mines are described. G. R. N.

1180.* Portable Combustible Gas Indicators in the Oil Industry. O. W. Johnson. *J. Inst. Petrol.*, 1939, **25**, 440–448.—The development of the J.-W. combustible gas indicator is briefly described, and the use of such instruments as this to control tank cleaning is fully discussed. G. R. N.

1181.* Vapour Detectors in the Petroleum Industry. P. Docksey. *J. Inst. Petrol.*, 1939, **25**, 449–455.—Detectors for gas/air mixtures may be grouped according to basic principles—*i.e.*, chemical diffusion, volume changes on combustion, heat of combustion. The suitability of these principles are discussed, and it is shown that detectors based on the last principle meet the requirements well. G. R. N.

1182.* " Riken " Explosive Gas Indicator. J. S. Jackson. *J. Inst. Petrol.*, 1939, **25**, 456–458.—This instrument, which is based on the refractometric analyses of methane/air mixtures, incorporates the Doi refractometer. G. R. N.

1183.* Inflammation of Hydrocarbon–Air Mixtures. D. T. A. Townend and M. Maccormac. *J. Inst. Petrol.*, 1939, **25**, 459–486.—A comprehensive paper on inflammability intended to make clear its recent developments and to direct attention particularly to experimental work on " cool " flames. G. R. N.

1184.* Inflammable Vapour Explosions. J. S. G. Shotwell. *Chem. & Ind.*, 1939, **58**, 778–783.—Explosions of inflammable vapours or gases in the underground ducts and cavities of thickly populated localities form a problem that has been causing the various public authorities responsible increasing trouble. Practically all such explosions are due either to the escape of town gas into underground systems, or of inflammable liquids, usually gasoline, into sewers. Several typical examples in Great Britain, U.S.A., and Canada are instanced.

Ottawa (Canada) has investigated the problem over the last few years. In 1934, of 273 leaks of vapour into the city's underground system, 139 were due to petroleum and 134 to gas. In 1938, of 253 leaks, 89 were due to petroleum and 142 to gas.

It is interesting to note that a cupful of gasoline will give off enough inflammable vapour to create an explosive mixture through 100 yd. of the average lateral sewer in a residential district.

Experience gained by the Ottawa authorities has led them to develop a precautionary system. This is based upon a Complaints Bureau, to which the public are encouraged to report unusual odours, and upon a systematic inspection of all manholes, sewers, etc., by trained investigators using inflammable vapour detectors.

It is noted that in 1938, of 42,872 complaints, 26,180 were received through the Complaints Bureau and 16,692 through the gas company. Typical cases of explosions that have been averted by the Ottawa system are instanced. T. C. G. T.

Cracking.

1185.* Catalytic Reforming in Small Units Gives 8 to 23 Octane Number Rise. A. L. Foster. *Nat. Petrol. News*, 20.9.39, **31** (38), R.394–R.403.—The article is a critical examination from the economic standpoint of the several cracking processes, and the author concludes that the catalytic cracking process is unsuitable for operation on a small scale. On the other hand, the catalytic reforming of low-grade gasoline is feasible on a very small scale, and is capable of producing 95-octane-number aviation blending stock. The preparation of neohexane-2 : 2-dimethylbutane is also mentioned. This new product of catalysis is now available, in limited quantities, commercially. With an octane rating of 95/96 and a Reid v.p. of 9·5 lb., it possesses satisfactory volatility, and can be blended with *iso*-octane or *iso*pentane to give it a typical distillation curve. H. G.

1186.* The Houdry Process. M. G. Van Voorhis. *Nat. Petrol. News*, 23.8.39, **31** (34), R.346–R.368.—The article comprises the design and operation of a new 15,000-barrel continuous catalytic cracking plant for the production, on a once-through basis, of No. 2 fuel oil and moderate yields of high-octane gasoline. The gasoline is usually blended into premium motor fuel, but at times is used in the production of aviation fuel. Other plants of the same type produce higher gasoline yields. Operating on East Texas crude with a straight-run gasoline yield of 38%, the total gasoline yield is increased to 63% by this process. Significant features of the plant are its compactness—it occupies an area 389 × 140 ft.—the small amount of high alloy steel used, the use of molten salt instead of water for the controlling of catalyst temperatures, high proportion of liquid recovery—96%, not including excess butane, and the consequent low tar production, and low labour costs—only eight men per shift are needed. H. G.

1187.* Catalytic Refining in Vapour Phase of Liquid Phase Cracked Gasolines on a Solid Zinc Chloride Catalyst. M. M. Guerasimov, V. E. Glushnev, S. N. Solodov, A. N. Tsiba, and M. N. Sharonov. *Neft. Khoz.*, June 1939, **20** (6), 43–45.—On basis of laboratory tests it is concluded that : (1) vapour phase refining of liquid phase cracked distillates, by passing over solid zinc chloride on a coke carrier, yields a high-grade engine fuel with improved lead susceptibility ; (2) the catalytic method of refining increases the yield of commercial product and eliminates waste by-products, such as acid-sludge of sulphuric acid treatment. The polymers obtained are useful raw materials for various branches of industry. L. R.

1188.* Gunite Liners for Pressure Vessels. E. S. Dixon. *Refiner*, 1939, **18** (6), 225.—Gunite—*i.e.*, concrete applied with a cement gun—is particularly adapted for liners installed in the vapour space of soaking-chambers where temperatures of 850–900° F. and pressures of 350–400 lb. are operative, when only one year's wear is required. The wall surface of the vessel must be clean, and this is accomplished by scaling off old deposits and then sand blasting at 80–100 lb. air pressure. Reinforcement for the gunite takes the form of 3 × 3 electric welded 10-gauge mesh supported on vertical rods welded to the walls of the vessel. The gunite is applied by a machine which takes a dry mixture of 1 part Portland cement and 2½ parts of sand. On leaving the nozzle, water is added, and the wet mix is built up to a thickness of 1 to 1½ in. on the wall. Gunite liners are cured after the initial 24 hr. setting by 3 days' exposure to a water fog ; they are then air dried for the next 24 hr. Two similar periods of steam curing and air drying complete the hardening cycle. Overall costs vary from 0·86 to 1·11 dollars per sq. ft. of surface. G. R. N.

1189.* Recent Developments and Operation of Instruments for Controlling Cracking Equipment. R. L. Rude and C. Barnes. *Refiner*, 1939, **18** (7), 255.—The method for the continuous determination of density *in situ* of a flowing fluid has been applied to the construction of instruments for the control of cracking equipment. The limitations of temperature control when applied to a system in which vaporization and chemical change may be occurring are recognized. A suitable use of controls actuated by density variations not only gives a sensitive regulation of the heat supplied to a cracking furnace, but also enables the time-element in cracking to be utilized for control from yield per pass. The general arrangement of instruments and controls connected with a modern heater is described, and the advantages from the point of view of flexibility, sensitivity, and stability of operation are disclosed. In particular it has been observed that fluctuations in temperature lag from 1 to 2 min. behind the associated fluctuations in density. The ability of the control system to repress the effects of major disturbances in operating conditions is illustrated by charts obtained with the instruments. Controls responsive to density *in situ* provide additional safety factors in meeting operating emergencies. G. R. N.

Polymerization.

1190.* Synthetic Oils from Unsaturated Hydrocarbons. E. Neyman-Pilatowa. *Nat. Petrol. News*, 23.8.39, **31** (34), R.370–R.371.—Using aluminium chloride as the catalyst, olefins have been polymerized to produce bodies with lubricating properties. Three sets of experiments are described in which (*a*) pure *iso*amylene obtained by the dehydration of amyl alcohol, (*b*) technical *iso*amylene, and (*c*) cracked gasoline from a Cross cracking unit were used. The pure hydrocarbon produced the highest yield of the best-quality product. In this case a 50% yield of oil with the following properties was obtained: *d*(20/4) 0·8513, aniline point 147° C., molecular weight 620, content of cyclic bodies 6%, viscosity 251° E. at 50° C, 10·6° E. at 100° C., polarity 1·91. Although under the conditions of the British Air Ministry Oxidation Test no asphaltic bodies were produced, the oil suffered a big increase in viscosity owing to the evaporation of lower-boiling fractions. H. G.

Refining and Refinery Plant.

1191.* Lighting of Refineries and Refinery Equipment. L. E. Priester. *Refiner*, 1939, **18** (5), 204.—A general article which discusses what is considered good practice from the standpoint of efficient illumination in refineries, due precaution being taken to safeguard persons from electrical hazards and to protect buildings and equipment from possible fire or explosion hazards. G. R. N.

1192.* Petroleum Refining and Progress in Metallurgy. E. E. Thum. *Refiner*, 1939, **18** (6), 213.—A comprehensive and authoritative account of the development of alloys of steel and other metals and their application in the petroleum industry with reference to the cost of alloys, austenitic alloy, stress corrosion, and creep strength of low-alloy steels. G. R. N.

1193.* Automatic Control of Solvent Treating Plants. J. F. Thornton and T. T. Whipple. *Refiner*, 1939, **18** (6), 238.—Taking as examples a furfural unit and a M.E.K.-benzol plant the authors take each stage of these processes and describe the automatic control instruments which record as required temperature, pressure, flow, and liquid level, and which have proved the most satisfactory in service. G. R. N.

1194.* Practical Use of Engineering Factors. H. F. Moore. *Refiner*, 1939, **18** (6), 245.—The underlying principles governing automatic control of continuous processes have been developed mainly in the last ten years. Together with their evolution there has been a parallel development of control equipment, the operation and characteristics of which have been based on the successively established principles. It is probable that the next major step in control technology is in the field of proper application. Sound development along this line must depend on a departure from present crude methods of analysing control problems, which are largely empirical. Possible starting points of quantitative methods for applying automatic controls to refinery equipment are given, and two elementary examples are worked out to illustrate the author's line of thought. G R. N.

1195.* Stratcold Treating Process. Anon. *Refiner*, 1939, **18** (7), 267.—A three-stage unit of this process has been installed at the Los Angeles refinery of the Texas Co. to control the sulphur content of the cracked gasoline by economical methods. The new unit comprises the acid-contacting and separating stages only. A feature of the treating system is the weak acid pre-treating stage, in which nitrogen compounds are removed from the cracked gasoline. The refrigerating system utilizes ammonia, and three-spray type chillers cool the oil before it passes into the contactors. The plant will treat the cracked gasoline with 14 lb./brl. of 98% black sulphuric acid. The investment cost was 50 dollars per brl. of rated capacity (5000 brl./calendar day). It is stated that the refinery operation has been made much more flexible, because of the resulting ability to reduce the sulphur in the finished cracked gasoline to any required specification with a reasonably low acid dosage and a materially increased yield of marketable product of a desired specification at a very reduced and low operating cost.
G. R. N.

1196.* Application of Centrifugal Pumps to Refinery Service. K. P. Hurley. *Refiner*, 1939, **18** (7), 278.—The author briefly states the underlying fundamentals of centrifugal pump design and gives some of their most important applications. The pump designs discussed have been relatively few, and only a few specific services have been mentioned; but all the pumps have the basic features required for successful refinery pumps, and, therefore, with slight, if any, changes can be used for the wide variety of services in the modern refinery, whether it be a combination cracking plant, a polymerization unit, a solvent plant—for handling cold oil, hot oil, light refluxes such as propane, or solvents such as cresol, furfural, etc. Several characteristic graphs are given.
G. R. N.

1197.* Influence of Silicon and Aluminium on the Corrosion Resistance of Steels. C. L. Clark and C. H. McCollam. *Refiner*, 1939, **18** (7), 287.—The resistance of refinery steels to oxidation by hot combustion gases and to corrosion by hot petroleum products is called surface stability. High-temperature strength indicates what stresses a steel can safely carry; surface stability dictates how long it can carry them. Improved surface stability is obtained by suitable additions of silicon plus aluminium to chromium molybdenum steels as demonstrated by results of various tests and by refinery tube inspections under actual operating conditions. This has resulted in new steel types, which permit more economical application of intermediate alloy steels in refinery-tube service.
G. R. N.

1198.* Balloon System Prevents Vapour Losses. J. C. Albright. *Refiner*, 1939, **18** (7), 291.—Eight 80,000-brl. tanks are used to store volatile products in a tank farm adjacent to the Shell refinery at Dominguiz, California. A Wiggins balloon system is connected to these tanks to handle the variable volumes of vapours produced through product transfers and changes in atmospheric conditions.
G. R. N.

1199.* Corrosion of Plant by Gases. A. Foulon. *Oel u. Kohle*, 1939, **15**, 459–460.—In the synthetic ammonia processes corrosion is caused by high-pressure hydrogen diffusing into the steel, with the reduction of the carbon present to CH_4, etc., causing blistering. This is overcome by using low carbon steels, with 3–7% Cr and in addition Mo and W. Still greater stability is obtained by including metals with great affinity for carbon (Ti, Va, Ta, Nb). Cu is especially liable to corrosion in the presence of hydrogen as a result of its low affinity for oxygen; on the other hand, oxygen combined with Mn, Al, Mg, or Si will not react with molecular hydrogen, and these metals do not suffer attack in the presence of hydrogen.

For fuel plants a steel is required stable to H_2S and SO_2. Ordinary carbon steels are attacked by dry H_2S below 400° C.; 18/8 Cr–Ni steels at about 500–600° C. The action of SO_2 is to form protective oxidic films, so that ordinary carbon steels are not strongly attacked below 500° C., nor 18/8 Cr–Ni steels below 800° C. These figures relate to surface corrosion, and not to the inter-crystalline corrosion to which Ni steels are subject. Since, in practice, H_2, CO, CO_2, and water vapour are present normally besides the sulphur gases, the high alloy steels are preferred.

For cracking operations, 4–6% Cr–Ni steels are generally used; for apparatus especially resistant to corrosion, the steel is even more highly alloyed. For distillation and refining, medium alloy steels are satisfactory, whilst where corrosion is very liable (*e.g.*, in the water gas producer of the Fischer Tropsch synthesis, or in the reaction chamber of the formaldehyde synthesis), Cr–Ni steels are used. T. T. D.

1200.* Hydrogen Sulphide Removed by Tri-potassium Phosphate. H. N. LaCroix and L. J. Coulthurst. *Nat. Petrol. News*, 9.8.39, **31** (32), R.326–R.332.—H_2S is removed from gases or liquids by washing with a solution of K_3PO_4. $H_2S + K_3PO_4 \rightleftharpoons KHS + K_2HPO_4$. The direction of the reaction is controlled by the operating temperature. The process can be applied at temperatures up to 200° F. The velocity of the reaction depends on the ratio of KHS to K_2HPO_4. Regeneration of the spent solution is easily accomplished by boiling. Where the process is worked on a sufficiently large scale H_2S is recovered as elemental sulphur or as sulphuric acid. H. G.

1201.* Filter-Clay Treatment of Cracked Gasoline in the Vapour Phase. P. T. Sverbil and A. M. Ravikovich. *Neft. Khoz.*, 1939, **20** (3), 41–46.—The treatment of cracked gasoline in the vapour phase with filter earth included in the technological process of two-furnace cracking has a great advantage over the sulphuric-acid treatment. The inevitable losses of sulphuric-acid treatment and re-running of the cracked distillate are eliminated by refining in the vapour phase. Consequently, the yields of commercial cracked gasoline—when operating with a flash tower and returning the polymers into the cracking system—increase up to 34–35% of the charging stock.

Zikeyev filter earth gives fully satisfactory results, even in prolonged use up to 50 days. The consumption amounts to 0·3–0·4% of the finished commercial gasoline.

The gasolines treated with Zikeyev clay in the vapour phase pass the copper-strip test when washed in two stages with 2–2·5 vol. of water. They possess an improved induction period and a somewhat higher stability against gum formation during storage. Induction periods (" Ziatim " method) of gasolines treated with Zikeyev clay in the vapour phase are usually in excess of 240 min.

With the addition of 0·013% α-naphthol, or 0·065% of the wood-tar fraction distilling between 260° and 290° C., a " Ziatim " induction period of 460–565 min. is obtained—*i.e.*, 1·7–2·2 times more than without inhibitors.

In view of its advantages, the introduction of this method of treatment in all cracking plants of the U.S.S.R. is recommended. L. R.

1202.* Selection of Natural Filter Earths for Percolation Filtration. A. D. Drujinina, Babenkov, M. S. Perelmiter, and Shneyerova. *Neft. Khoz.*, March 1939, **20** (3), 46–50.—The action of (1) Volkov-Parshin, (2) Zaimkin, (3) Novo-Simbirsk, and (4) Zikeyev clays, and of (5) American floridine have been examined. At present in the U.S.S.R. for percolation treatment only (5) is used. It has, however, been proved experimentally that it is possible to use Russian clays for the final treatment of concentrate of Ssurakhany ordinary crude which has undergone only a preliminary nitrobenzene treatment and acetone–benzene dewaxing.

The relative properties of the clays have been ascertained as follows :

(1) Volkov clay gives maximum yield of finished oil—*i.e.*, 199% of the clay weight introduced. Owing to its very poor compressive strength, it is, however, unsuitable for percolation filtration. For contact filtering it is the best material available.

(2) Zaimkin earth is equally effective, but screening losses are still high.

(3) Novosimbirsk clay has a low specific weight, good bleaching capacity, small screening losses, and comparatively high compressive strength. Among the clays examined this is the most suitable for percolation treatment, and moreover large resources are available.

(4) Zikeyev clay has average qualities, high specific weight, rapid fall of bleaching capacity, but a comparatively high compressive strength. Its main advantage is the availability in unlimited quantities. L. R.

1203.* Relative Volatility of Petroleum Fractions. R. E. Johnstone. *J. Inst. Petrol.*, 1939, **25**, 558–560.—An empirical expression is derived equating the relative volatility of pure hydrocarbons or narrow cut petroleum fractions, the absolute temperature, and the atmospheric boiling points of the components. G. R. N.

1204.* Natural Gasoline and Poly Plant Chart. W. L. Nelson. *Oil Gas J.*, 22.6.39, **38** (6), 63.—The mathematical computations required in the design of natural gasoline and refinery equipment involve determinations of the compositions of the gas and liquid existing under equilibrium conditions, *e.g.*, in oil-well separators, condensation in gas compressors, temperatures in gasoline or poly stabilizer, gas separator temperatures, fractionating towers, condensers or distillate well separators. A chart has been prepared based on the usual general formulæ showing the distribution of any component between liquid and vapour when at equilibrium. The bases and method of use of the chart are explained with a typical example of the amount vaporized of a feed stock to a poly plant fractionator at 380° F. and 400 lb. per sq. in. abs. pressure.
C. L. G.

1205.* Cone in New Type De Florez Furnace Improves Heat Distribution. G. C. Leslie. *Nat. Petrol. News*, 12.7.39, **31** (28), R.294–R.296.—The furnaces described, said to be the largest of their type ever built, are of the usual vertical, cylindrical, down-draught type, the tubes being symmetrically spaced around the inner wall. A recent refinement is the incorporation of an upright brick cone in the bottom of the furnace for the improvement of heat distribution. These furnaces are stated to represent the nearest approach to the ideal yet achieved.
H. G.

1206.* Water-Tower Performance Predicted by Computation. R. Nance. *Nat. Petrol. News*, 26.7.39, **31** (30), R.316–R.318.—In discussing the economics of tower design and the relative merits of towers, spray ponds, cooling ponds, etc., the following empirical formula is used: $L = \frac{QDW}{CA}$ where L = length of the tower, Q = the quantity, in g.p.m., of water circulated, D = a design factor specific to the particular tower, W = a wind-velocity factor, C = water concentration in g.p.m./sq. ft., A = horizontally projected deck area, in sq. ft. corresponding to unit tower length. This method has been derived from the Ferrel Psychrometric equation for the determination of the total cooling head in terms of water and wet-bulb temperatures and vapour pressures at these temperatures.
H. G.

Chemistry and Physics of Petroleum.

1207. Catalytic Oxidations. II. Oxidations in the *cyclo*Paraffin Series. N. A. Milas and W. L. Walsh. *J. Amer. chem. Soc.*, 1939, **61**, 633–635.—Catalytic oxidation of *cyclo*hexane and *cyclo*pentane and some of their derivatives and adipic acid using vanadium pentoxide resulted in maleic acid as the chief solid product. Alternative views as to the course of the reaction from *cyclo*hexane to maleic acid are put forward by the authors: (1) via benzene and quinone, (2) via *cyclo*hexene, adipic acid, and *cyclo*pentanone, (3) possibly *cyclo*hexane rearranges to methyl*cyclo*pentane and the latter oxidizes to maleic acid.
R. D. S.

1208. Reactions of Paraffins with Hexahydroaromatic Hydrocarbons in the Presence of Aluminium Halides. H. Pines, A. V. Grosse, and V. N. Ipatieff. *J. Amer. chem. Soc.*, 1939, **61**, 640–643.—The authors have found that hexahydroaromatic hydrocarbons react with paraffins in the presence of aluminium bromide or chloride in a manner analogous to the destructive alkylation of aromatic hydrocarbons by paraffins in the presence of aluminium or zirconium chloride or phosphoric acid. Although 2 : 2 : 3- and 2 : 2 : 4-trimethylpentane and 3 : 4-dimethylhexane readily bring about the destructive alkylation of the naphthenes, *iso*butane being formed whatever the alkylating agent used, *n*-octane and 2 : 2 : 3-trimethylbutane do not destructively alkylate *cyclo*hexane under similar conditions. The product of alkylation of *cyclo*hexane was found to be a mixture of the different polymethyl- or methylethyl*cyclo*hexanes. Side reactions were noted to occur, such as hydrogenation and isomerization into *iso*butane of the butene formed from the scission of 2 : 2 : 3-trimethylbutane when reacting with *cyclo*hexane: the latter acts as a donor and the olefins as acceptors of hydrogen.
R. D. S.

1209. Condensation of Propene and *Iso*butene with Benzene in the Presence of Anhydrous Ferric Chloride. W. M. Potts and L. L. Carpenter. *J. Amer. chem. Soc.*, 1939, **61**, 663–664.—Condensation of propene and *iso*butene with benzene occurred at room temperature with anhydrous ferric chloride as the catalyst, but at higher temperatures the yield was not so great. Ferric chloride produced a greater yield of alkylated benzenes, but less polymerization than aluminium chloride. R. D. S.

1210. Identification of Alkylphenyl Sulphides, Sulphoxides, and Sulphones. V. N. Ipatieff and B. S. Friedman. *J. Amer. chem. Soc.*, 1939, **61**, 684–689.—Alkylphenyl sulphides and sulphones were readily identified by means of solid derivatives prepared by the following methods : (1) co-ordination of the sulphide with palladous chloride; (2) oxidation of the sulphide to the sulphone; (3) nitration of the sulphone to form *m*-nitrophenyl alkyl sulphone; (4) reduction of the latter to the aminosulphone; (5) acylation of the aminosulphone with *m*-bromobenzoyl bromide or *p*-bromobenzoyl chloride. The alkylphenyl sulphoxides were also identified by the reduction to sulphides or by oxidation to sulphones and then characterized by the above procedures. Aroylation of the aminosulphones in the presence of pyridine was found to be unreliable, but in the presence of alkali was more successful. It was found that, in the same conditions, *p*-bromobenzoyl chloride gave only the monoacyl derivative, whereas *m*-bromobenzoyl bromide gave only the diacyl derivative.

From the palladous chloride derivative it was found possible to detect and isolate small amounts of *tert.*-butyl or *tert.*-amylphenyl sulphides in mixtures of each with its isomers. *tert.*-Butyl and *tert.*-amyl sulphones differ from their isomers in that they decompose when they are nitrated at 100°. The authors describe a method by which nitration was made possible. 3-Bromo-4′-methylbenzophenone was prepared by refluxing a toluene solution of *m*-bromobenzoic acid over phosphorus pentoxide. R. D. S.

1211. Raman Spectra of the Hexanes and Heptanes. E. J. Rosenbaum, A. V. Grosse, and H. F. Jacobsen. *J. Amer. chem. Soc.*, 1939, **61**, 689–692.—In this paper are presented the Raman spectra of all the five possible hexane and the nine possible heptane isomers. R. D. S.

1212. Refraction Data on Liquid C_3-Hydrocarbons. A. V. Grosse and C. B. Linn. *J. Amer. chem. Soc.*, 1939, **61**, 751–752.—Measurements have been made of the *D*-line refractive indices at low temperatures of all known C_3-hydrocarbons with the exception of *cyclo*propene. For the molecular refraction the authors determined the hitherto unknown densities of *cyclo*propene and allene. Refractive indices and densities are recorded at temperatures between −20° and −80° and also at their respective normal boiling points. As the indices show wide differences, the authors suggest the data are of use in analysis, since binary mixtures of these hydrocarbons show a straight-line relationship. R. D. S.

1213. Kinetics of the Decomposition of *n*-Butane. II. Inhibition by Nitric Oxide and Propylene. L. S. Echols and R. N. Pease. *J. Amer. chem. Soc.*, 1939, **61**, 1024–1027.—Both nitric oxide and propylene inhibit the *n*-butane decomposition. The inhibition reaches a limit as the inhibitor concentration increases. It fades out as the reaction proceeds, the rate eventually becoming nearly equal to that of the normal decomposition. This phenomenon is attributed to the reversible formation of an intermediate.

These results are compared with the normal reaction, and the inference is drawn that there are two chain processes involved with only one type of carriers, or one mechanism concerned with the reversible inhibitor reaction. T. C. G. T.

1214. Density and Transition Points of Dotriacontane (Dicetyl). W. F. Seyer and W. Morris. *J. Amer. chem. Soc.*, 1939, **61**, 1114–1117.—Accurate measurements of the transition points of solid paraffin hydrocarbons, such as dicetyl, may be made by use of the dilatometer.

Pure dicetyl can be prepared from cetyl alcohol if sufficient recrystallizations are made.

The dicetyl prepared had a melting point of 69·6° and transition points at 69·5 and 63·5°. T. C. G. T.

1215. Dehydrogenation of *cyclo*-Octene. S. Goldwasser and H. S. Taylor. *J. Amer. chem. Soc.*, 1939, **61**, 1260–1263.—Catalytic dehydrogenation of *cyclo*-octene with chromium oxide gives styrene and not, as previous workers report, *cyclo*-octatetraene. *cyclo*-Octane is a secondary product, presumably by hydrogenation of the *cyclo*-octene with the hydrogen from its dehydrogenation. Up to 94% styrene was obtained.

Eight-membered rings tend to form six-membered rings at temperatures of 300° and over.

The apparatus used for the catalytic study of the vapours of hydrocarbons in the gasoline range is described. T. C. G. T.

1216. Catalytic Dehydration of C_6–C_8 Aliphatic Alcohols. S. Goldwasser and H. S. Taylor. *J. Amer. chem. Soc.*, 1939, **61**, 1751–1761.—Hexanol-1, 2-ethylbutanol-1, 2 : 4-dimethylpentanol-1, 2 : 4-dimethylpentanol-3, and 2-ethylhexanol-1 have been dehydrated using alumina, chromic oxide gel, and thoria catalysts. Uranium oxide was found to be inactive for dehydration.

The apparatus and procedure to separate the isomers resulting from the dehydration are described.

The ease of dehydration is shown to be correlated with the number of secondary hydrogens on the carbon second from that having the hydroxyl group. The elimination of water in this position causes the formation of an activated intermediate stage with the configuration of a 3-membered ring, and this in turn breaks down.

The effects of rate of passage and change of catalyst have been investigated and interpreted. T. C. G. T.

1217.* Viscosity of Gases Handled in Distillate Plants. W. L. Nelson. *Oil Gas J.*, 13.7.39, **38** (9), 50.—Data on the viscosity of high-pressure gas and of light liquids have been correlated and a chart drawn up showing the viscosity of normal paraffin hydrocarbons at different "reduced" temperatures and pressures (*i.e.*, actual temperatures and pressures in absolute units divided by the critical temperature and pressure, respectively). C. L. G.

1218.* Presence and Determination of Acetone and Methyl Ethyl Ketone in the Products of Low-Temperature Carbonization of Coal. E. A. Coulson and E. C. Holt. *J. Soc. chem. Ind.*, 1939, **58**, 267–270.—Samples of crude gas spirits from various low-temperature carbonization plants were examined with the object of determining the nature and amount of ketones present and the best method of rapid estimation of them. A successful method for the determination of the purity of acetone was found to be formation of the bisulphite compound by treatment with considerable excess of *N*-sodium bisulphite, removal of unused bisulphite with excess of iodine, and back-titration with thiosulphate. This gave results about 7% low for methyl ethyl ketone, but was used for comparing one sample with another. The different plants showed ketonic contents of 0·80–1·27%, made up of about 51% acetone, 33·4% methyl ethyl ketone, and 4·5% methyl *n*-propyl ketone containing ethyl propionate. The ketones were obtained by recovery from the bisulphite complex followed by fractionation. No ketones were found in the aqueous liquor from low-temperature carbonization. R. D. S.

1219.* Variations in the Physical and Chemical Properties of Castor Oil Due to Thermal Treatment under Different Conditions. F. Hawke and B. Segal. *J. Soc. chem. Ind.*, 1939, **58**, 270–272.—In order to ascertain the conditions of treatment to render castor oil completely miscible with mineral oils, samples were heated alone at different temperatures and pressures. The chief change occurring in such circumstances appeared to be one of decomposition, and not polymerization. Density did not change, but the V.I. was raised from 82 to, in one case, 128. It was observed that only heat treatment at 325° C. rendered the resultant oil (acetyl value 45–50) miscible with mineral oils. Above or below this temperature complete miscibility was not possible. Above 275° C. the residual oils showed an increase in acidity, decrease in the mean molecular weight of the fatty acids, increase in unsaturation, and decrease in acetyl value. Polymerization, which occurs extensively above 325° C., causes a greater tendency to oxidation. The authors observe that treatment must be carried out within strictly controlled temperatures and pressures to ensure complete miscibility with mineral oils, and that the products, although possessing excellent viscosity characteristics, are more liable to sludge and gum than the raw castor oil, and are therefore poorer lubricants.

R. D. S.

1220.* Mechanism of Catalytic Phenylation and its Inhibition by Iron. H. H. Hodgson and E. Marsden. *J. Soc. chem. Ind.*, 1939, **58**, 290–292.—It has been previously shown that iodine and aniline phenylate α-naphthylamine by initial production of hydriodic acid, resulting in the formation of a complex which decomposes to give phenyl-α-naphthylamine and ammonium iodide. The latter then immediately dissociates to hydriodic acid, thereby enabling the reaction to continue. The authors here show that hydriodic acid is superior in catalytic powers to sulphuric and hydrochloric acids, but that these two acids are more efficient than hydrogen iodide in the phenylation of peri-acid. Quantitative phenylation experiments conducted with various mixtures of α-naphthylamine, aniline, and aniline hydriodide, with and without iodine, showed that the reactions were unimolecular.

Iron, whether in the form of iron vessels or introduced into the mixture as iron filings, definitely inhibited the action, but when the iron was rusted, phenylation occurred. Anhydrous ferrous oxide did not catalyse phenylation, whereas hydrated ferrous oxide was effective, due to its hydrolysis; wherefore it is suggested that clean iron forms ferrous iodide by withdrawing the catalyst (hydriodic acid), and so preventing phenylation, but that rusted iron forms ferrous iodide and water, so regenerating the catalyst and allowing the reaction to proceed. R. D. S.

1221.* Apparatus for Taking an Average Sample of a Variable Flow of Gas. A. Blackie. *J. Soc. chem. Ind.*, 1939, **58**, 293–296.—A description of an apparatus for obtaining an average sample of a flow of gas varying in velocity, pressure, density, and temperature. Two forms are proposed, one for small samples and one for larger samples.

R. D. S.

1222.* Thermochemical Aspects of Hydrogenation. R. Michel. *Oel u. Kohle*, 1939, **15**, 455–459.—On the hydrogenation of an unsaturated compound, changes of free energy content take place which are reflected in the heat of combustion. The share in the molar heat of combustion of a particular atom grouping is its heat value. For example, the heat of the $-CH_3$ group in ethane is 185 Cals., half the molar heat of combustion; similarly that of the CH_2 group in ethylene is 172·5 Cals. On the other hand, the heat value of a CH_2 group in a straight-chain paraffin—*e.g.*, decane or dotriacontane—comes out at 155 Cals. The difference between this value and that obtained from ethylene must be attributed to the presence of a double bond in the latter. Similarly the heat content of a CH group in dimethylpentane or dimethyloctane is 125 Cals., whilst in benzene it is 130·2 Cals. For the carbon atom itself, in the aliphatic series—*e.g.*, in trimethylbutane or hexamethylethane—the heat value is 95 Cals. Since the value for aliphatic CH is 125 Cals., the heat value of hydrogen is 30 Cals.; this confirms the independently derived values for CH_2 and CH_3, so in the aliphatic series we have the values: C, 95 Cals.; CH, 125 Cals.; CH_2, 155 Cals.; CH_3, 185 Cals.

On the other hand, the heat values for C in ethylene and in benzene are 112·5 and 100·2 Cals., respectively. Consequently, on hydrogenation, the carbon atom of the hydrogenated group will, in general, have a lower heat content than before, the addition of hydrogen resulting in evolution of energy. Thus the heat value of the carbon atoms is characteristic of the ability of an organic compound to take up hydrogen.

Examples are given showing the change in heat values of the carbon atoms as benzene is hydrogenated to *cyclo*hexane, and reasons put forward to explain why, in the successive hydrogenation of the poly*cyclo*pentadienes, the second two hydrogen atoms are added to the same ring as the first.

In the case of mixtures such as gasoline, a guide to the degree of hydrogenation possible can be obtained by determining an average heat value for the carbon present. This is calculated thus: the product of the number of gram atoms of hydrogen per 100 gms. sample and the heat value of hydrogen, is subtracted from the heat of combustion of 100 gms. sample, and the result divided by the number of gram atoms of carbon in 100 gms. sample.

The author shows how this method can be extended to coals, the elementary analyses and heats of combustion of which are known, and gives as examples a sample of Silesian coal and a lignite. In the former case the heat value is 101·3 Cals., and in the latter 96·25 Cals., showing that the coal contains unsaturated carbon, whilst the lignite is already largely saturated. T. T. D.

Analysis and Testing.

1223.* Accelerated Oxidation Test for Oils. W. Francis and K. R. Garrett. *J. Inst. Petrol.*, 1939, **25**, 561–565.—A new method for determining the oxidizability of oil is described, using a solution of alkaline potassium permanganate under standard conditions as the oxidizing agent. It is claimed the method can be used to ascertain the state of oxidation of an old oil. G. R. N.

1224.* Colour Density and Acid Vapour Indicate Oil Performance. (Vide *Proceedings 12th National Meeting of the Oil and Gas Power Divisions*, The American Society of Mechanical Engineers, June 1939.) W. F. Weiland. *Nat. Petrol. News*, 9.8.39, **31** (32), R.334–R.338.—It is stated that the performance of a motor oil may be predicted and its useful service life determined by the determination of the colour density ratio, or oxidation number, and the minimum acid-vapour temperature. The colour density ratio is obtained by comparing the depth of colour of an oil before and after oxidation under controlled conditions, or before and after normal use. The minimum acid–vapour temperature is that at which the oil first produces acid vapours when placed under a slight vacuum in a bath at 350–360° F., the acid vapours being detected by litmus. The minimum acid–vapour temperature is stated to fall rapidly as oxidation proceeds, and to be closely related with the rate of visible sludge formation and oil breakdown. Graphical data for a number of typical oils are presented. H. G.

Motor Fuels.

1225.* High-Octane Fuel Containing *iso*Propyl Ether. E. I. Zabryanski. *Neft. Khoz.*, June 1939, **20** (6), 39–42.—Baku and Koschagil gasolines blended with 40% *iso*propyl ether have an octane number of 97–98 (C.F.R. Motor Method). Volatility and vapour pressure of blends are within the limits of American standards for aviation gasolines. Starting properties of Baku B-70 gasoline are improved by the addition of *iso*propyl ether.

When 30–40% *iso*propyl ether and 3·0 cu. cm./kgm. T.E.L. are added to Baku B-78 residual gasoline, an octane number of 95–97 (Motor Method) is obtained with satisfactory volatility. By addition of 30–40% *iso*propyl ether and T.E.L. to Grosny aviation gasoline or desulphurized Ishimbaevo gasoline, 91–95 octane fuels are obtained. Maximum octane number improvements result when *iso*propyl ether is added to low octane fuels. L. R.

Lubricants and Lubrication.

1226.* Service Tests with Lubricants for High Speed Oil Engines. A. T. Wilford. *J. Inst. Petrol.*, 1939, **25**, 607–622.—A paper with discussion on lubricating oil tests carried out by the London Passenger Transport Board during the past seven years with special reference to the quality of lubricating oil required for oil-engined buses. G. R. N.

1227.* Lubrication of the Modern Commercial Vehicle Chassis. F. C. Whitehouse. *J. Inst. Petrol.*, 1939, **25**, 623–628.—A paper, presented for discussion, relating to the lubrication problems that have been encountered in the development of the light fast commercial vehicle. G. R. N.

1228.* Automobile Manufacturer's Selection of Lubricants. K. Brozyna. *J. Inst. Petrol.*, 1939, **25**, 629–642.—A paper, which, after discussing the desirable qualities of car lubricants, gives an approved selection of the various types required.

G. R. N.

1229.* Function of Colloidal Graphite in Special Purpose Lubes. R. Szynanowitz. *Nat. Petrol. News*, 9.8.39, **31** (32), R.340–R.342.—Colloidal graphite, electric furnace graphite, is now available in stable suspension in low viscosity carriers such as dilute glycerine, benzol, carbon tetrachloride, triethanolamine, etc. Such materials find extensive use as penetrating oils to help solve lubrication problems where ordinary lubricants are not completely satisfactory. Colloidal graphite is occluded in the surface and functions as an efficient lubricant after the rupture of the lubricant film in the usual sense. Dispersed in glycerine, colloidal graphite is a good lubricant for rubber, and in a volatile carrier solves many problems of high-temperature lubrication where full-film lubrication with a mineral oil is not possible. Used as an additive to mineral oil in " running-in," danger from film rupture is reduced. Being " truly colloidal," this graphite introduces no difficulties that might be attendant upon a tendency to settle out. H. G.

1230.* Studies in Non-Fluid Lubrication. Pt. I. S. Kyropoulos. *Refiner*, 1939, **18** (7), 273.—By means of a simple apparatus and microscopic observation, the dependency of surface wear and polish on the characteristics of the lubricant was studied. An electrical effect was found to be responsible for wear in contrast to polish in the presence of solid (*e.g.*, wear) particles. The lubricating efficiency of an oil may be increased by excluding the electric effect and its resulting effects. This may be done by direct electrical connection of the surfaces and/or by discharging the surfaces and particles by means of imparting electrical conductivity to the oil. Polar substances, added to the oil, perform this discharge directly or indirectly. Their effect is in low concentrations proportional to the resulting conductivity of the oil. The magnitude of the electrical field strengths is such that it may lead to the building up of field currents at the peaks which will tend to promote seizure. The electrical effect originates in fluid lubrication and leads to local non-fluid lubrication in small clearances. G. R. N.

1231.* Effect of Fatty Acid Derivatives on Lubricants. A. W. Ralston, E. J. Hoffman, and E. W. Segebrecht. *Nat. Petrol. News*, 26.7.39, **31** (30), R.320–R.322.—Using the technique previously described, (*Nat. Petrol. News*, 3.11.37, Abstract No. 62 (1938)), the effect on the lubricating efficiency of hydrocarbon oil to which sundry fatty acid derivatives were added was examined. The alkyl esters of saturated and unsaturated fatty acids and sundry thio esters were used. The results indicated that all the additives reduced frictional forces, that the saturated fatty acid derivatives were superior to those of unsaturated fatty acids, and that the thio esters were less efficient than the corresponding oxygen esters. It is assumed that the esters function by virtue of their adsorption at the metal surface, and that the point of attachment is the carboxyl group. It is further assumed that the greater the difference between the radicles R and R^1 in the ester $R{\cdot}COO{\cdot}R^1$, the greater would be the polarity and the greater the efficiency as a lubricant additive. These assumptions were not borne out by the results. Indeed, often the reverse is true. H. G.

Asphalt and Bitumen.

1232.* Development in Bitumen Plastics. W. H. Cambden. *Chem. & Ind.*, 1939, **58**, 867–868.—A review of the uses of bitumen for moulded articles for electrical purposes. The incorporation of fillers, such as asbestos, has, in the opinion of the author, opened considerable new fields, and it would appear to be wrong to assume that bitumen is losing ground in the plastic industry. T. C. G. T.

1233.* Measurement of the Flow Properties of Bitumens. D. C. Broome. *J. Inst. Petrol.*, 1939, **25**, 509–530.—The use of routine apparatus in determining flow criteria is adversely discussed and some modifications are suggested. Of the various viscometers the rotating cylinder type is preferred, and data obtained with it are examined in the light of the conceptions of plasticity, thixotropy, age hardening, and elastic recovery. G. R. N.

1234.* Bitumen Emulsions. L. G. Gabriel. *J. Inst. Petrol.*, 1939, **25**, 531–557.—The development of and various problems in the manufacture of bituminous emulsions are sketched. Sedimentation behaviour and physico-chemical factors underlying the viscosity/concentration relationships of these emulsions are discussed. Various uses of the emulsions in industry are described and the mechanism of breakdown in various circumstances is analysed. G. R. N.

1235.* Production of Bitumen from Residue of Ishimbaevo Crude. G. P. Grigoryev and N. S. Ruzankin. *Neft. Khoz.*, March 1939, **20** (3), 53–55.—The process of conversion of Ishimbaevo residue into bitumen is carried out at temperatures above 240° C. After 7 hr. air-blowing, active bitumen formation begins. Temperature has a decisive effect on the oxidation of the residue. The high content of sulphur compounds in Ishimbaevo residue has a very beneficial effect on the process of bitumen formation, the sulphur compounds acting as catalysts.

Optimum conditions for bitumen formation are: Temperature, about 300° C.; air consumption about 5 litres/min. per 1 kgm. oxidized residual oil. Yield figures, when producing from Ishimbaevo oil goudron, are as follows: 19–20% of the crude, and 31–32% of the residual oil. When the oil residue is oxidized directly, 37–38% of the crude or 61–62% of the residue are obtained.

Roofing felt prepared with the bitumen obtained showed satisfactory weathering resistance and had good waterproof qualities. L. R.

1236.* Soil Stabilization by Heat Treatment. G. W. Eckert. *Chem. & Ind.*, 1939, **58**, 846–851.—The problem of producing a reasonable road surface by heat treatment of the soil has received attention in the U.S.A. and in Australia. Experiments were carried out in America prior to 1890. Generally the procedure has been to remove strips of clay from the surface and roast it by various means, such as roadside fires, and replace the roasted clay and roll it in.

A machine has been developed by L. R. H. Irvine in Australia for the direct heating of surface soil to make a durable road surface which offers great promise. The Australian machine which has been in operation in Queensland for four years consists of a furnace suspended within a wheeled chassis. The heat is obtained by the burning of a gas generated by a producer using wood fuel. The flame, under pressure from a fan, is directed on to the soil. The machine has an overall length of 33 ft., width 9 ft., and weighs about 25 tons. It is claimed that this machine heats the surface effectively to a depth of about 6 in., and that the cost of one mile of road construction with it is $3500.

Temperatures of 400–700° C. are necessary in the successful treatment of soil, as at these temperatures the crystal lattice structure of the clays is disrupted with release of OH ions.

If the soil is heated sufficiently long at the higher temperature, a hard, compact, and only slightly brittle product ensues. Its binding strength will be due to interlocking crystallization films of glassy silicates and oxides of iron and alumina.

Bitumen binders are desirable mediums for binding and waterproofing the soil.

T. C. G. T.

1237.* Gilsonite. F. R. Jones. *Chem. & Ind.*, 1939, **58**, 800–801.—A brief review of the origin, mining, properties, and uses of Gilsonite. T. C. G. T.

Special Products.

1238. Synthetic Fatty Acids. Developments in the Paraffin Oxidation Method. Anon. *Chem. Tr. J.*, 4.8.1939, 105–107.—The production of fatty acids for soap-making or edible purposes from the oxidation of Fischer–Tropsch residues is rendered difficult in practice by the incompleteness of the oxidation, necessitating recycling, and by the formation of undue amounts of oxy-fatty acids. E.P. 506,104 of 1938 granted to Vereinigte Oelfabriken Hubbe und Farenholtz of Magdeburg describes a method of overcoming these difficulties, based on the fact that the presence of volatile oxidation reaction products accelerates the oxidation reaction. A multi-stage process is accordingly used in which a current of air or other oxidizing gas is passed through the several reaction vessels, addition amounts of air, etc., being introduced throughout the different stages. It is believed that there is an optimum hydrogen ion concentration (within the slightly acid range) for the production of fatty acids, and this is maintained by the introduction, primary formation, and removal of the more readily volatile oxidation products. The consumption of air, owing to the more effective utilization of oxygen, is also reduced. Using 0·3% of magnesium stearate catalyst, oxidation of Fischer–Tropsch paraffin at 120° to 125° C. for 36 hr. in a three-stage process gave products of acid value 93, 111, and 125 respectively, in the three vessels, with initial boiling points under 14/16 mm. pressure of 151–157° C. C. L. G.

1239.* Trends of Progress in Oils and Fats (Other than Edible) and Detergents. P. W. Tainsh. *Chem. & Ind.*, 1939, **58** (25), 587–591.—Although hardened whale oil is an almost perfect substitute for tallow in soap-making, its future is considered uncertain because of the rapid depletion in the stock of whales. In the season 1937–1938, 46,039 whales were caught, and these produced 557,000 tons of oil. This is classified according to free fatty acid content and colour in four grades, Nos. 1–4. Next in importance is palm oil, with an annual world production of about 500,000 tons. The plantation system is now in operation in W. Africa, Dutch East Indies, and Malaya, the last two localities accounting for almost 50% of the world's output. The oils in the nut-oil class, mainly coconut oil and palm-kernel oil, account for 20–25% of the oils used in soap-making. They give to soap special properties connected with lather, solubility, and texture. As regards soya-bean oil, a member of the soft oil class which includes cottonseed oil and groundnut oil, 500,000 tons were produced in 1938. Cultivation has increased enormously in the U.S.A., but in England efforts to find a bean suitable for cultivation have not been very successful. Of other alternatives, chief interest is in fatty acids from the oxidation of selected petroleum fractions, or from materials amongst the products of the Fischer–Tropsch synthesis, or from coal as the raw material. In Germany it is expected that a full-scale plant for producing synthetic fatty acids will be in operation by the end of 1939. Progress in the methods of treating oils and fats by bleaching and hydrogenation is seen in the use of activated earths and of selection of suitable catalysts and controlled temperatures. Progress in transport has witnessed the replacement of barrels by bulk methods, and the consequent almost complete disappearance of the melting process. A problem at present receiving attention is the research into anti-oxidants, necessary owing to the removal or destruction of natural inhibitors in the oil or fat when heated. Incidentally an anti-oxidant is considered to work by absorbing energy liberated in the reaction chain, thus preventing further activation of the autoxidizable fat. The Lea test for rancidity measures the peroxide content of oxidized fats and is considered to have stimulated research in the field of anti-oxidants. So far efforts to replace the old batch process of soap-making by a continuous process have not been very successful. The mechanism of saponification is considered to be a homogeneous reaction taking place in solution. The soap itself, on account of its micelle nature, is the solvent for the oil and the alkali. Improvements in processing include the use of centrifugal and filtering methods and of cold air or running cold water in cooling bars and slabs of soap or thin films in drums. Drying has been improved in the direction of utilizing both the forward and return motion of the net or band carrying the soap, and also in reheating and re-circulating the air used for drying. Milling for soap flakes is now done in temperature-controlled chilled cast-iron drums having precision ground surfaces and producing flakes of a thickness of between 0·001 and 0·002 in. Toilet soaps and soap powders and bleaching soaps have likewise been improved, the first named to retain colour and perfume. Of more than passing interest are the soapless detergents now being developed for use with hard water to overcome the objection of the precipitation of insoluble calcium and magnesium soaps. Use of preparations from sulphonated castor oil was not encouraging, as detergent properties were not good. Other compounds prepared and used are the so-called Gardinols, obtained from the sulphation of aliphatic alcohols derived from C_{12}–C_{18} straight-chain hydrocarbons, also condensation products of fatty acids with isethionic acid, *e.g.*, the oleyl ester of the sodium salt of isethionic acid, also compounds from the reaction between fatty acid chlorides and methyl taurine, and lastly the Igepons obtained by the sulphonation of the products of reaction of high-mol.-wt. phenols and ethylene oxide. For general purposes the soapless detergents are still inferior to soap, but find special application in the treatment of woollen fabrics and for shampooing. J. L. T.

1240. *Chemistry of Solid Carbon. H. L. Riley. *Chem. & Ind.*, 1939, **58** (17), 391–398.—This detailed study gives an account of the X-ray diffraction methods of analysis of the various forms of black carbon. In graphite, the carbon atoms are arranged hexagonally in flat layers, and when graphite salts are formed, the hexagonal layers remain intact and the anion penetrates in between them. A description, based on X-ray data, is given of the process of carbonization, and from these are obtained the structures of cokes which are confirmed by chemical investigations into the properties of the cokes at various temperatures. When the carbonizing temperature is about 700° C., changes occur which greatly affect the resulting cokes. The effects at this temperature (which are enumerated) are responsible for the differences between low-temperature and high-temperature cokes. The factors determining the mechanical strength of coke provide further confirmation of such interpretation of results.
R. D. S.

Detonation and Engines.

1241.* New Laboratory Method for Rating High Octane Aviation Fuels. R. Stansfield and H. B. Taylor. *J. Inst. Petrol.*, 1939, **25**, 566–572.—A cathode-ray oscillograph and an indicating unit showing rate of change of pressure diagrams were employed with the C.F.R. engine in devising running conditions from which a measure of the rating of aviation fuels of high octane number (87 +) could be obtained.
G. R. N.

1242.* New Stream-Line Oil Filter. Anon. *Chem. & Ind.*, 1939, **58** (25), 601.—In announcing the M.C.7 type filter for fitting actually on to the engine of a commercial vehicle, the familiar claims for minimum attention and longer life of the lubricant are stressed.
J. L. T.

1243.* Automotive Type Engine Drives. J. C. Albright. *Refiner*, 1939, **18** (5), 212.—At the Fairfax, Oklahoma, gasoline plants of the Skelly Oil Co. well-known makes of motor-car engines have been adapted to run on plant gas and provide motive power for water and absorber oil circulation pumps. A short account is given. G. R. N.

1244.* Operating Costs of Petrol and Compression Ignition-Engined Buses. W. C. Whalley. *J. Inst. Petrol.*, 1939, **25**, 573–606.—A lecture, with discussion, showing the saving effected when C.I engines replaced petrol engines as the prime mover in buses.
G. R. N.

Economics and Statistics.

1245.* Review of the Trinidad Petroleum Industry During the Period 1934–1938. V. Bryan. *Monit. Petr. roum.*, 1939, **40**, 1251–1254.—During 1934 the Trinidad petroleum industry showed the first signs of recovering from the 1930 depression. In that year the island achieved its record production, to that date, of 1,492,528 tonnes. Each year since has seen an increase in this record, until, in 1938, the production was 62·8% higher than in 1934, at 2,430,000 tonnes. 95·3% of this production was processed during the year.

Other interesting statistics of the industry in Trinidad are: (1) The total area of the island is 4300 sq. km., of which 2295 are petroleum concessions. (2) The production of natural gas in 1938 was 523,900,000 cub. ms. (3) 2641 wells have been drilled in Trinidad, of which 1304 are in production. Of these 428 are under pressure and account for 69·7% of the annual production, 516 are being pumped and yield 19·8% of the production, whilst other means—*e.g.*, gas lift—account for the remaining 10·5%. Drilling was started on 279 wells in 1938. (4) The oil produced is of asphaltic base, and ranges in gravity from 47° to 14°. (5) Annual internal consumption of petroleum products is 13,342 tonnes of spirit and 3150 tonnes of lamp oil.

Petroleum to the value of $23,656,561 was exported in 1938, and this represents 69% of the island's trade. Bunker fuel is at the head of petroleum exports, with a value of $11,348,699.

The island has four deep-water jetties for loading tankers, and has a storage capacity of about 600,000 tonnes, which is being increased to 700,000 tonnes.

With increasing evidence of vast petroleum reserves, it is apparent that the industry in Trinidad has a very bright future. T. C. G. T.

BOOK REVIEWS.

Famous Cities of Iran. By Dr. L. Lockhart. Pp. 115. Illustrations 65 + 2 maps. Walter Pearce & Co., The St. George's Press, Brentford, Middlx. Price 7*s*. 6*d*.

Translation of a Review in French by M. Maurice Mercier.

No one could be better qualified than Dr. Laurence Lockhart to give us an historical sketch and description of the most famous towns of Iran, that will satisfy at the same time the demands of the bibliographer and the curiosity of the ordinary traveller.

It is true that the *Naft* Magazine has already given us the first publication of the various chapters describing these enchanting cities, the very names of which are enough to plunge us into the realms of fantasy and imagination: Tehran, Isfahan, Tabriz, Meshed, Shiraz, Qazvin, Nishapur, Hamadan, Kermanshah, Yezd, Kerman, Kashan, Qum, Shushtar, Ardabil, Bandar'Abbas; but the publication in one volume of so many monographs is of particular interest, and will be welcomed by all who have enjoyed the original articles.

Dr. Lockhart's long residence in Iran, his knowledge of the inhabitants and of their customs and history, his numerous bibliographical references, and his notes, have enabled him to produce within the covers of a moderately sized book a work of the first order. If it is further stated that his book is illustrated in a most delightful way, one will already have some idea of what this publication is like, coming after so many others by the same author.

Reference to the bibliography shows that Dr. Lockhart has not been content merely to consult the accounts of European travellers such as Chardin, Sir Thomas Herbert, E. Herzfeld, Sir A. H. Layard, G. Le Strange, James Morier, Samuel Purchas, Sir P. M. Sykes, not to mention the fundamental works of J. de Morgan and of Sir J. Malcolm, but he has also referred to Arab and Persian travellers such as Hamdullah Mustaufi, Ibn Battuta, Al Istakhri, Al-Muqaddasi, Nasir-i-Khusrau and finally Yaqut.

It must have been difficult to combine in a work collected together in such a concise way so much charm and real quality. If the preparation of this book has been only a form of recreation for Dr. Lockhart, it is a great joy for the reader, and let us remember that it is often the light books which are the most difficult to produce.

I feel that Dr. Lockhart, with his alluring descriptions, has given us his " rubai 'at " after Omar Khayyám, and I do not think that from the point of English literature a greater measure of praise could be accorded to it: moreover, the foreword by Lord Cadman is in itself an incomparable testimony to the merit of this book.

M. Mercier.

A.S.T.M. Standards on Petroleum Products and Lubricants. Prepared by Committee D-2 on Petroleum Products and Lubricants September 1939. Pp. ix + 336. American Society for Testing Materials, 260 S. Broad Street, Philadelphia, Penna. Price $2.

The A.S.T.M. Standards on Petroleum Products and Lubricants, prepared by Committee D-2 of the American Society for Testing Materials, and issued in September 1939, includes a number of modifications of previous methods of test. The more important of these are the introduction of new tentative standard methods of Test for Carbon Residue of Petroleum Products (Ramsbottom carbon residue), for Gum Stability of Gasoline, and for Tetraethyl Lead in Gasoline. In the report it is stated that better reproducibility was obtained with the Ramsbottom method than with the Conradson method. Technical Committee A on Gasoline reports an investigation of three methods of test for determining gum stability, the bomb method, low-pressure-induction method test, and the copper-dish test. Correlation with storage tests were carried out, and the work described has extended over the last five years. It is considered that the copper-dish test gives unsatisfactory reproducibility, and the tentative method of test recommended is based on the induction period measured in the bomb test, as this method of test is more generally used in the industry. The method for tetraethyl lead is a modification of one originally devised by the Imperial Oil Company of Canada.

There are a number of revisions of tentative standards, including the tentative method of test for Kinematic Viscosity, 445/39-T, in which any apparatus of a capillary type capable of measuring viscosities with an error not greater than 0·2 per cent. is now permitted; pure distilled water is to be used as the primary viscosity standard, but oil samples may be used as secondary standards.

Amongst the standard methods of test which have been revised is the burning test of burning oils D 181-39 for which a method of test is also under consideration by the Kerosine Sub-Committee of the Institute which should be issued shortly.

Three tentative methods have been advanced to standard, including the method of test for knock characteristics of motor fuels.

In so far as petroleum products are concerned the A.S.T.M. D-2 Committee now includes proposed specifications for aviation gasoline and tentative specifications for fuel oils, gasoline, Stoddard solvent and petroleum spirits in addition to emulsified asphalts. The 1938 Report also included a diesel fuel classification.

There is also included in the report of A.S.T.M. D-2 Committee for 1938, Standard Definitions of Terms relating to Petroleum D288-39, which have been advanced to Standard from Tentative Standard. F. H. GARNER.

BOOKS RECEIVED.

The Hydrogenation-Cracking of Tars. Part V. The Operation of a Semi-Technical-Scale Plant. D.S.I.R. Fuel Research Tech. Paper No. 51. Pp. 30. H.M. Stationery Office, London. Price 1*s*.

This report describes the results obtained in a semi-technical-scale plant at the Fuel Research Station, designed to treat from 200 to 400 gal. of raw materials per day. The raw materials consist of hydrogen, and low-temperature tar from the Fuel Research Station's narrow brick retorts, to which is added a controlled proportion of "recycle oil." The amounts and analyses of the materials produced under different operating conditions are given, and comparisons are made with the corresponding results from the small-scale converters. The operation of the plant appears to have been very satisfactory, and has shown that the results of treating low-temperature tar are similar to those obtained in small-scale experimental plants.

Technology, Employment, and Output per Man in Petroleum and Natural-Gas Production. Works Project Administration National Research Project and Department of the Interior, Bureau of Mines. Report No. E.-10. 1939. Pp. 347. Federal Works Agency, Works Project Administration, 1734 New York Avenue, N.W.

This report presents a detailed examination of the past record and present status of the industry in question, with a view to indicating the future trends of output and man-power requirements. The long-time trends of production are first developed to indicate whether these trends are likely to continue or change their present course. The trends of employment are next examined for an understanding of significant influences that have affected the size and character of the industry's working force. Technology is then studied to determine the labour-saving that has attended successive technical advances in the past, and to ascertain possible effects of impending technical improvements.

INSTITUTE NOTES.

November 1939.

ADDRESS OF THE INSTITUTE.

The address of the office of the Institute will be as follows until further notice :

The Institute of Petroleum,
c/o The University of Birmingham,
Edgbaston, Birmingham, 15.
Tel. No. : Selly Oak 1181 (Dept. of Oil Engineering).

The office and library at the Adelphi are not available.

NEW MEMBERS.

The following elections have been made by the Council in accordance with the By-Laws, Section IV, Para. 7.

Elections are subject to confirmation in accordance with the By-Laws, Section IV, Paras. 9 and 10.

Fellows.

Doughty, Walter David	London.
Ekonomopoulos, N. P.	Athens.
Hutchison, Arthur Gilbertson	Trinidad.
Steinitz, Ernst W.	London.

Members.

Bowmer, John James	Birmingham.
Brooking, Miles	Cheshire.
Fincham, Arthur Joseph	Venezuela.
Harris, Robert	Bombay.
Pilat, Mrs. Eve Neyman	Lwow.
Ransone, William Robert	Texas.
Williams, John Henry	Iraq.
Ueda, Hirosi	London.

Associate Members.

Edwards, Revill	Stafford.
Ellis, Dennis Wilson Villiers	Johannesburg.
Evans, Archibald	Ellesmere Port.
Ferner, Robert Reuben	London.
Firth, Maurice Murrowood	London.
Gilbert, Stanley William Terrence	Calcutta.
Hidson, John	Venezuela.
Lee, Colin Alfred	Leicester.
Poppy, Edgar	London.
Richardson, George	Tunbridge Wells.
Shen, Gann Jin Tai	China.
Walker, Laurence Harry Thomas	Bahrein Island.

Transfers to Associate Member.

Cameron, Alexander Bryce	Iran.
Davies, Thomas Trevor	London.
Kane, John	London.
Wellings, Frank Richard	Trinidad.

Students.

Baxter, Ian Lionel	London.
Gottesmann, Manfred	Palestine.
Wygard, Edward Jan	Leeds.

TRANSFERS.

The following transfers have been approved by the Council :

From Member to Fellow.

Allen, R.
Comins, D.
Crichton, R.
Glendinning, D. M.
Howard, A. H.
Howes, D. A.
Jackson, B. R.
Jameson, J. A.
Lamb, M. F.
Le Mesurier, L. J.
Mitchell, W. C.
Ormandy, W. R.
Parker, J. S.
Rankine, A. O.
Spearing, C. E.
Sprake, C. H.
Stansfield, R.
Thompson, A. Beeby.

From Associate Member to Member.

Grindle, G. A. F.

From Associate to Member.

Grant, E. G.
Smith, H. F.

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.

FARTHING, Vernon Lambert, Consulting Engineer (*V. L. Farthing & Co.*), 528, Tower Building, Water Street, Liverpool, 3. (*J. S. Parker ; J. C. Wood-Mallock.*)

IJDENS, Rente Albert, Student, Bilderdijk Iaan 94, Rijswijk (Z.H.) Holland. (*H. I. Waterman.*)

JAMES, John Edmund, Chemist (*Snowdon Sons & Co., Ltd.*), "Theseus," Moor Lane, Cranham, Upminster, Essex. (*E. R. Redgrove ; E. A. Evans.*)

MOORE, Philip Harold, Engineer (*Manchester Oil Refinery*), Woodville, Doctors Lane, Chaldon, Caterham, Surrey. (*R. B. Hobson ; E. Stokoe.*)

NISSAN, Alfred Heskel, Lecturer (*Birmingham University*), 78, Heathfield Road, Handsworth, Birmingham, 19. (*A. W. Nash ; C. E. Wood.*) (Transfer to A. M.)

PEACOCK, William George, Manager, c/o Anglo-American Oil Co., Ltd., King Edward Buildings, New Street, Birmingham. (*H. C. Tett ; C. Chilvers.*)

WARBROOK, Reginald Harold, Refinery Operator (*Munster Simms & Co. (Dublin), Ltd.*), Olney, Westfield Road, Kimmage, Dublin, Eire. (*E. Lumb.*)

ARTHUR W. EASTLAKE,
Honorary Secretary.

ABSTRACTS.

Loan of Periodicals.

Commencing with the present issue of the *Journal* (No. 193), every Abstract of which the original article is available at the Institute's office in Birmingham will be indicated in the *Journal*. The originals of these may be borrowed by members in Great Britain through the post.

Periodicals will be loaned for one week only. Members should send stamps to cover the outward postage. A reply-paid label will be issued for the return postage.

Photostat Copies.

Members either in Great Britain or abroad can be supplied with a photostat copy of any article marked in the Abstracts as so available. The charge for photostat copies is 1*s*. 3*d*. per page photographed. Orders should be accompanied by remittance.

HADFIELD'S

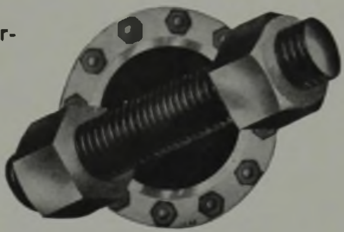
TRADE **ERA 131** MARK & TRADE **HECLA 153** MARK

STEAM PIPE FLANGE BOLTS

HAVE A HIGH CREEP STRENGTH

For use at the highest temperature employed in modern steam practice.

Do not become brittle as a result of operating conditions.



Steel Castings and Forgings of all Kinds.

Area of Works over 200 acres

HADFIELDS LTD.

Buildings cover 61 acres

East Hecla and Hecla Works, SHEFFIELD, Eng.

No. 1666.

SCHLUMBERGER ELECTRICAL CORING

France.—Société de Prospection Électrique, 30, rue Fabert, PARIS.

U.S.A.—Schlumberger Well Surveying Corporation, 2720 Leeland, HOUSTON, Texas.

Local Offices : Long Beach, Oklahoma City, New York, Corpus Christi, Bradford.

Venezuela.—P. Bayle, Villa Proselec, MARACAIBO.

Trinidad, B.W.I.—Schlumberger Electrical Coring Methods, SAN FERNANDO.

Colombia.—H. Rappart, PUERTO-BERRIO.

Argentine.—G. Guichardot, COMODORO RIVADAVIA, Km. 27.

Morocco.—M. Texier, Société de Prospection Électrique, PETITJEAN.

Rumania.—A. Poirault, 18 Strada I. C. Bratianu, CAMPINA, (Prahova).

Germany.—Firma von Flotow, Schillerstrasse 36^{I}, HANOVER.

Dr. B. Paul, Kobenzlgasse 30, VIENNA.

Hungary.—M. Scheibli, Vadaszkürt Tür Istvan U.5, BUDAPEST.

Iraq.—L. Beaufort, QAIYARAH.

British India.—A. Couret, DIGBOI, Assam.

Burma.—L. Bordat, KHODAUNG.

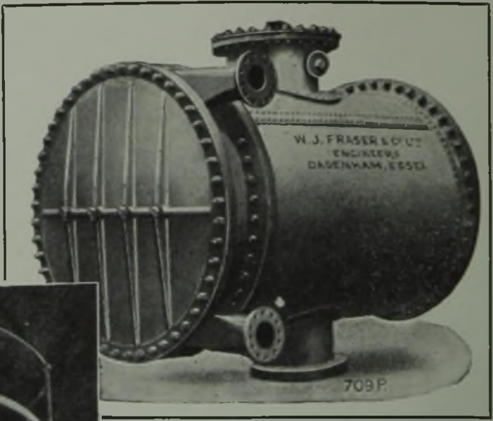
Netherland East Indies.—R. Sauvage, PLADJOE, Sumatra.

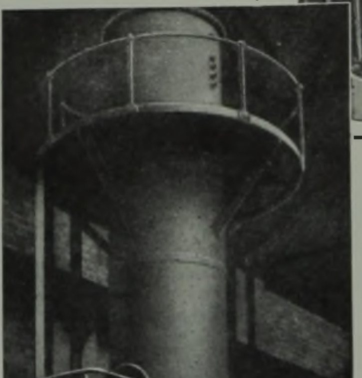
Schlumberger Methods also applied in : U.S.S.R., Japan, Italy, Poland, Yugoslavia, Egypt and British North Borneo.

LIST OF ADVERTISERS.

	PAGE
Aktiebolaget Elektrisk Malmletning	—
Babcock & Wilcox, Ltd.	ix
E. B. Badger & Sons Co.	—
Baker Oil Tools, Inc.	xv
Battersea Polytechnic	—
Bluchalk Co.	—
Cardwell Mfg. Co.	xi
Ceag Ltd.	—
W. Christie & Grey, Ltd.	Inside back cover
A. F. Craig & Co., Ltd.	xii
Charles Dabell & Co.	viii
Duke & Ockenden, Ltd.	Inside back cover
Everett, Edgcumbe & Co., Ltd.	—
Foster Wheeler, Ltd.	—
W. J. Fraser & Co., Ltd.	vi
Geophysical Prospecting Co., Ltd.	v
Hadfields, Ltd.	iii
Hayward-Tyler & Co., Ltd.	xiii
Institute of Petroleum	viii
International Paint & Compositions Co., Ltd.	v
International Petroleum Exposition	vii
Lane-Wells Co.	iv
Lufkin Rule Co.	—
Lummus Co.	xiv
McGraw-Hill Publishing Co., Ltd.	—
Metropolitan Vickers Electric Co., Ltd.	—
National Supply Corporation	—
Oil & Petrolem Year Book	—
Oil Center Tool Co.	—
Oil Well Supply Co.	—
Oxford University Press	—
Security Engineering Co., Inc.	xvi
Sir John Cass Technical Institute	—
Société de Prospection Électrique	iii
Sperry-Sun Well Surveying Co.	—
John G. Stein & Co., Ltd.	x
Stewarts and Lloyds, Ltd.	Back cover
Svenska Diamantbergborrnings Aktiebolaget	viii
John Thompson (Wolverhampton), Ltd.	—
Tintometer, Ltd.	—
University of Birmingham	—
Western Geophysical Co.	—

Kindly mention this Journal when communicating with Advertisers.


W. J. FRASER & CO LTD
ENGINEERS
DAGENHAM, ESSEX
709 P


1223 P

About large Stokers

BABCOCK & Wilcox Ltd. began stoker manufacture over fifty years ago, since when they have built up a wealth of experience in design, construction and operation of all forms of chain and travelling grate stokers, for severe service conditions, and burning the widest variety of fuels.

Below is given an abstract of large travelling grate stokers ordered for five Power Stations only, the first order for each representing a record in size either for width or grate area of B. & W. Style 28 stokers.

The momentary publicity attached to the breaking of a record, in size or capacity, is of little interest in comparison to the constant endeavour to ensure that the best equipment is supplied, and correctly operated, to suit the conditions of each particular job, however large or small.

POWER STATION "A"

Size of stoker
= 29′ 0″ wide × 22′ 0″ long
Grate Area = 638 sq. ft.
No. of Stokers = 12
Total Grate Area = 7656 sq. ft.

POWER STATION "B"

Size of stoker
= 32′ 0″ wide × 20′ 0″ long
Grate area = 640 sq. ft.
No. of Stokers = 5
Total Grate Area = 3,200 sq. ft.

POWER STATION "C"

Size of stoker
= 30′ 0″ wide × 22′ 0″ long
Grate area = 660 sq. ft.
No. of Stokers = 12
Total Grate Area = 7,920 sq. ft.

POWER STATION "D"

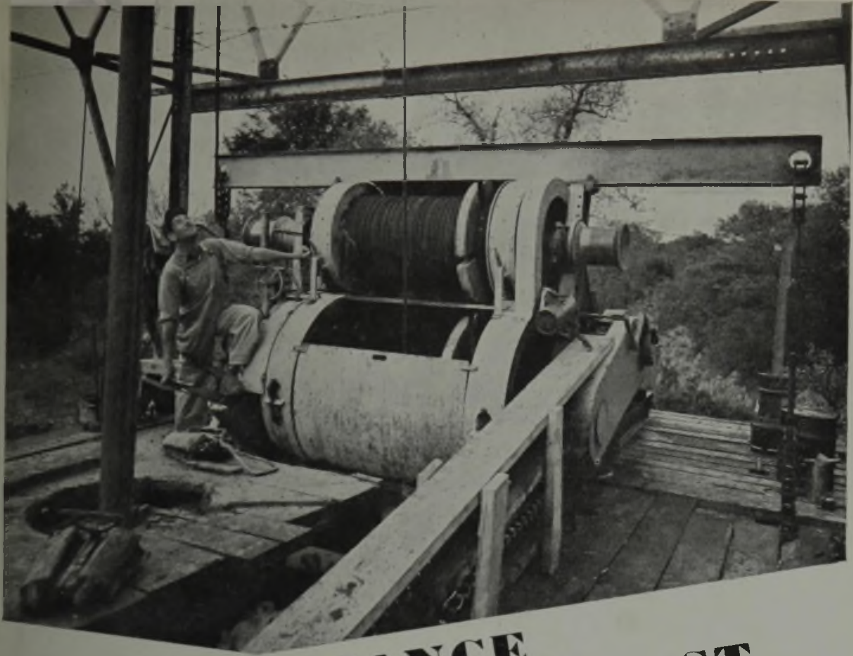
Size of stoker
= 33′ 0″ wide × 20′ 0″ long
Grate Area = 660 sq. ft.
No. of Stokers = 24
Total Grate Area = 15,840 sq. ft.

POWER STATION "E"

Size of stoker
= 37′ 0″ wide × 22′ 0″ long
Grate Area = 814 sq. ft.
No. of Stokers = 6
Total Grate Area = 4,884 sq. ft.

Number of repeat orders in above list = 13
Total number of stokers " " " = 59
Total Grate Area in the 5 Stations = 39,500 sq. ft.

BABCOCK & WILCOX LTD.
34 FARRINGDON STREET, LONDON, E.C.4



PERFORMANCE AND LOW COST

give Steam Rigs a beating

In April 1938, Wiegand Brothers, Drilling Contractors of San Antonio, Texas, who formerly owned steam rigs, purchased a "Cardwell" Model R double drum draw works. Ten months later they purchased another Model R. That's why we say repeat orders are the biggest proof that "Cardwell" rigs make money for their owners. Almost 70 per cent of our sales are repeat orders from satisfied customers.

These are the reasons:

1. "Cardwell" draw works can be converted in the field from rotary to cable tools in three to four hours.
2. Friction clutches speed drilling and enable operator to lift the drill pipe without stopping the rotary table. This decreases the hazard of stuck drill pipe and "twist-offs," saves time at each weight indicator correction, makes it possible to "drill-up" through cave-ins, and makes it easier to ream or straighten the hole.
3. All-steel construction, with selected alloy steels and heat-treated wearing parts, gives light weight with longer life. Built compactly with draw works and engine on one skid, the savings in transportation and rigging-up costs will pay the purchase price of the rig.
4. Day and night parts service is available from our parts stock stores, conveniently located to main oil centres the world over.

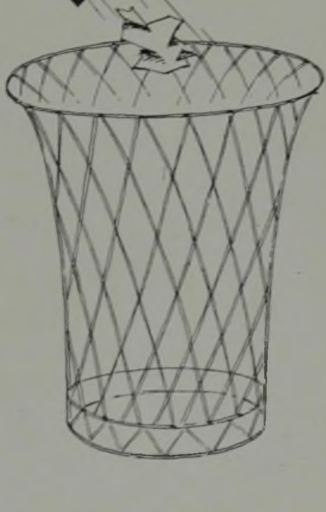
We have four sizes and nine models of slim-hole rigs to fit any depth well, all interchangeable for rotary or cable tool drilling, and modern to the minute. We will gladly send you detailed information.

• We Build 62 Models and Sizes of Servicing Winches and Drilling Rigs—Send your well depths and details of your well equipment for recommended model and size.

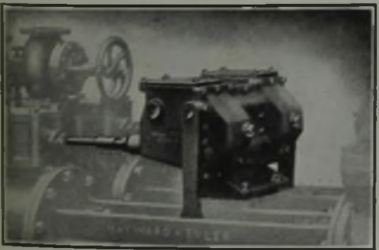
CARDWELL MFG. CO. INC.
FORMERLY ALLSTEEL PRODUCTS MFG. CO.
P. O. Drawer [illegible] · Cable Addresses: "ALLSTEEL", WICHITA · "CARDSTEEL", NEW YORK
Wichita, Kansas, U. S. A.

CARDWELL ALL-STEEL
THIS TRADE MARK INSURES HIGHEST QUALITY AT LOWEST PRICE

F. J. OLSON, Export Manager, 570 Lexington Avenue, New York City. Cable Address: "Cardsteel."
Foreign Representative: JACK GRIZZLE, Continental Hotel, Cairo, Egypt.



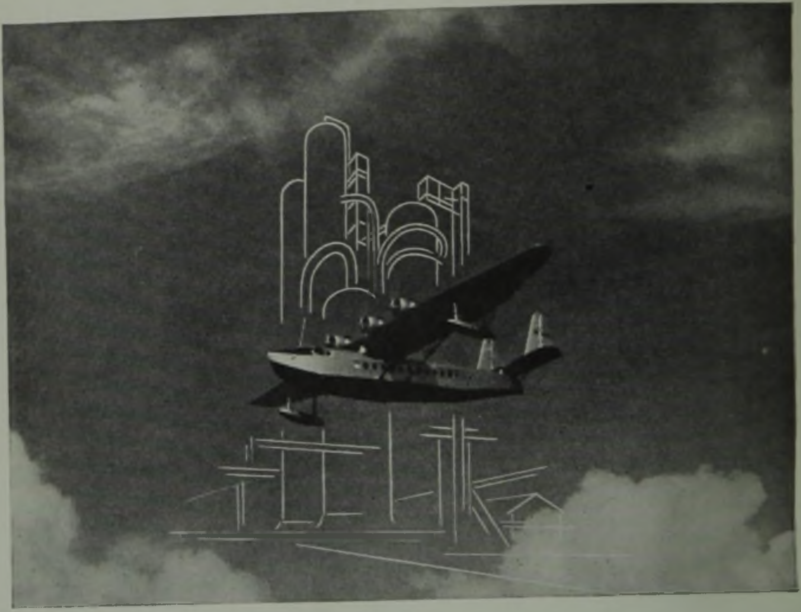
The waste paper basket in our design office holds many more ideas than ever get incorporated in our machinery. This ability to discard ideas is, we believe, one of the hall-marks of a good designer who, unlike the inventor with whom an idea is often an obsession, must be able to sift out the freaks and the fallacies without prejudice. This sort of training makes it difficult for us to sit back and survey our work with pride. There's always some new idea on the way. But in spite of this we do believe that, to take just one example, the ideas which have resulted in a feature such as our patent valve gear to prevent short stroking on Duplex steam pumps will take a lot of beating.

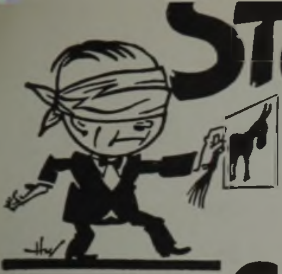


Twells valve gear fitted to a Hayward-Tyler 15 x 12 x 18 Duplex Steam Pump.

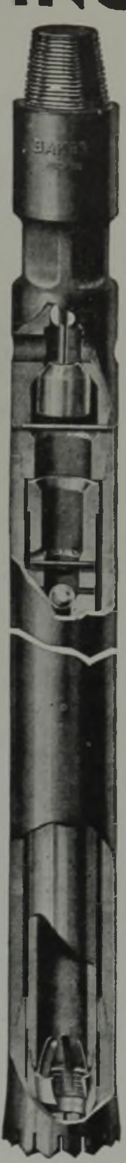
HAYWARD-TYLER

& CO. LTD., LUTON, BEDS. *Telephone: Luton 951.*
LONDON OFFICE: SHELL-MEX HOUSE, W.C.2





STOP GUESSING AND START CORING WITH THE



BAKER CABLE TOOL CORE BARREL

Guessing may be an entertaining parlor game, but it's a mighty expensive pastime in oil well drilling.

With thousands of dollars in equipment and labor at stake, geologists can't afford to guess regarding formation conditions — they have to *know*. The one sure way of obtaining a clear and concise picture of formation structures as they exist down in the hole is to obtain not merely ordinary core fragments or bailer samples, but rather cores that really tell the complete story; cores that are practically 100% perfect; cores that permit an intelligent analysis as a guide to further drilling procedure.

That's why the Baker Cable Tool Core Barrel is the first choice of geologists and experienced drillers by a wide margin. They know that first class cores are going to be taken on every run, in less time, and at less cost . . . with guesswork, the "bogeyman" of drilling procedure, being eliminated.

Literature and detailed illustrated catalog describing the construction and operation of this efficient core barrel will be gladly supplied upon request. *Send for it today—you incur no obligation.*

BAKER OIL TOOLS, INC.

Telephone JEfferson 8211 – HUNTINGTON PARK, CALIFORNIA – 2959 E. Slauson Ave.
Telephone WAyside 2108 – HOUSTON PLANT AND OFFICE – 6023 Navigation Blvd.

MID-CONTINENT OFFICE AND WAREHOUSE:
Telephone 2-8083 – Tulsa, Oklahoma – 312 East Fourth Street

WEST TEXAS BRANCH OFFICE
Odessa, Texas – Telephone 217

EXPORT SALES OFFICE
Rm. 1914 – 19 Rector St., New York City
Tel. Digby 4-5515

ROCKY MOUNTAIN HEADQUARTERS
Tel. 2230 - Casper, Wyoming – Box 1464

BAKER CABLE TOOL CORE BARREL


There's a difference between
DRILLABILITY & REMOVABILITY