A STUDY OF OIL OXIDATION AS RELATED TO LUBRICATION.* PART I.—APPARATUS, TECHNIQUE, AND PRELIMINARY RESULTS.

By Paul G. Exline, M.S.,† W. E. Kramer, B.S.,†
and John R. Bowman, Ph.D.†

The possibility that the surrounding atmosphere may influence lubrication was suggested by the explorations of Gilson,[1,2] but the rôle of oxidation in lowering friction was first pointed out by King.[3]

It was he who showed that oxidation of a lubricating oil can alter its behaviour in a journal bearing to extend the range of operation beyond that normally secured from the same oil before oxidation. More recently Jakeman and Fogg[4] investigated this effect, using the same machine and following the same procedure, but concluded that " the increase in seizing temperatures and decrease in minimum friction produced by running a bearing periodically up to seizing temperature in oxidizing conditions, are not due to any great extent to a change in the oil, being almost entirely accounted for by changes in the form and surface finish of the bush bearing." In view of the known influence of the higher fatty acids in reducing friction, and of the further known tendency of petroleum lubricating oils to form high-molecular-weight acids on mild oxidation, it appeared that a positive effect of oxidation was to be anticipated. It was believed also that the mechanical variables mentioned by Jakeman and Fogg could be controlled if a sufficiently refined test method could be devised.‡

Several changes were felt necessary in the procedure in order to facilitate rigid control of all conditions.

1. In order to avoid distortion in the bearing and its associated parts due to temperature changes, all such parts should be maintained at a constant temperature.

2. Means should be available for controlling the rate of oxidation of the oil.

3. Under constant-temperature operation of the bearing, the periodic approach to incipient seizure must necessarily be through a steady increase of load or decrease of journal speed. The increasing load method was chosen for reasons of convenience.

4. The point of incipient seizure should have a definite reproducibility and should occur under conditions which would least affect the bearing surface and shape.
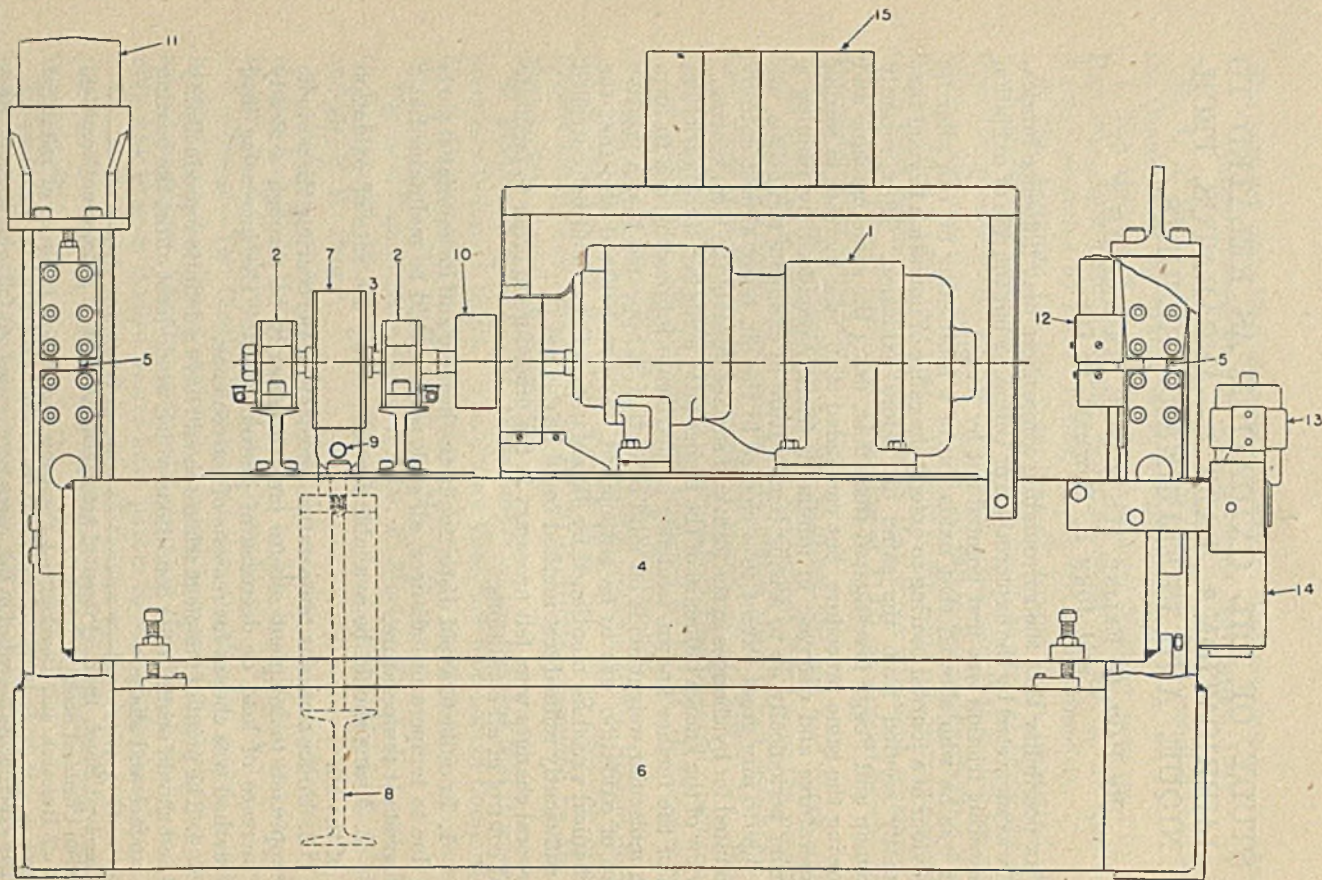
Y
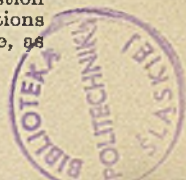
Fig. 1.

SIDE ELEVATION OF BEARING TEST MACHINE.

DESCRIPTION OF APPARATUS.*

The machine constructed for this purpose applied a load to a bushing in which a journal was driven at constant speed. This load is periodically increased from zero to incipient seizure, while it and the torque are recorded continuously. The atmosphere and temperature of the oil system were under control at all times, and the operation of the machine was entirely automatic.

The instrument, shown in Fig. 1, consists of two parts : the frame and the moving system. The moving system comprises a rigid box-section beam or cradle (4), which is suspended at each end by thin steel tapes (5), and which carries the constant-speed driving motor (1) with an output speed of 107 r.p.m. obtained by gearing, two self-aligning ball bearings (2), the test journal (3), a magnetic clutch (10), and counter-balancing weights (15). The supporting tapes are accurately aligned with the axis of the journal, so that the entire moving system is free to rotate about this axis with a small amplitude.

All electrical connections to the cradle are made through a group of steel pins attached to the frame at (12) which dip into a corresponding group of mercury cups which form part of the moving system.

BALANCING AND TORQUE RECORDING SYSTEM.

The frictional torque on the journal is measured by determining the restoring torque applied to the cradle to hold it in a horizontal position. The balancing system is mounted on the rear of the cradle, and consists essentially of a balancing weight (14) on a horizontal screw at right angles to the axis of the cradle and driven by a reversible motor (13). The motor is controlled through a suitable electrical circuit by spring contacts which are closed when rotation of the cradle approaches an angle of 15 seconds. In this manner, torques applied to the journal can be balanced to an accuracy of 0·02 in./lb.

Uninterrupted motion of the balancing weight in one direction for one second of time causes a resistance in series with the motor to be shunted out; this more than doubles its speed. This prevents " hunting " oscillations when the torque is changing slowly, and permits the weight to follow the more rapid change near the end of each cycle.

A continuous record of the torque is obtained on a 10-inch-wide strip chart driven at the rate of 2 in. per hour by a small synchronous motor. Arms projecting from the cradle support the chart drive carriage, which is directly behind the balancing weight, to which is attached the recording pen arm.

At incipient seizure the torque is increasing so rapidly that the balancing weight is unable to maintain the cradle in its zero position. Flexure of the spring contact takes place, and a third or " breakdown " contact is closed when the torque applied to the journal reaches a definite value greater than that of the restoring torque applied by the weight. This contact then acts to stop the journal almost instantaneously by de-energizing the magnetic clutch and reducing the bearing load to zero by the method to be described

---

* The test equipment was designed following suggestions by Mr. R. J. S. Pigott, Chief Engineer, Gulf Research and Development Company.

later. It has been observed that at incipient seizure the rate of increase
of torque is so rapid that the absolute value of the seizing load is little
influenced by the speed of travel of the balancing weight.

LOADING SYSTEM.

A rear cross member on the frame carries the upper or fixed portion of
the rear tape suspension. A front cross member supports a frictionless
hydraulic loading device (11) which carries the upper half of the front tape
suspension. Oil pumped into this loading cylinder applies a vertical force
to the front tape, about 40 p.s.i. being required to hold the cradle in a hori-
zontal position. An auxiliary device is used for introducing oil into the
cylinder at a constant rate. Oil is exhausted from the cylinder through a
solenoid valve, which is opened when the breakdown contact is closed and
which is closed again by a pressure-operated switch when the cylinder
pressure is reduced to 40 p.s.i. This pressure switch also energizes the
magnetic clutch, thus starting a new cycle.

The test-bearing housing (7) is supported from the cross member (8)
which is attached to the side channels (6) of the main frame. A pin (9)
assists in maintaining accurate alignment of the bearing with the journal.
The upward pull of the loading device forces the journal against the top of
the bearing. This force is zero for a pressure of 40 p.s.i. in the loading
cylinder, while the maximum capacity of the machine, 4000 lb., is obtained
with 690 p.s.i. in the cylinder. Fig. 2 shows a record of the pressure in the
loading cylinder during 37 cycles of a typical run.

TEST BEARING.

The test bearing (3) shown in longitudinal section in Fig. 3 is a bronze
sleeve 1 inch inside diameter and 2 inches outside diameter pressed into the
steel housing (4). The sleeve is $1\frac{1}{2}$ inches long, but is counter-bored to a
depth of $\frac{1}{4}$ inch at each end, to secure an effective bearing length of 1 inch.
The bearing load in pounds is thus numerically equal to the bearing pressure
in pounds per square inch projected area.

Oil is carried to the bearing through a horizontal duct which intersects
the bearing surface 135° from the crown on the " on " side. Labyrinth
seals at each end of the bearing prevent escape of oil along the shaft, yet
have clearance enough to cause no frictional torque. Oil escaping from
the ends of the bearing is drained out of the end spaces by ducts which
permit it to return to a sump by gravity.

Holes are also drilled through the housing into the tops of the end spaces,
so that any desired gas can be passed out through the oil system and the
labyrinth seals, thus permitting control of the atmosphere in contact with
the oil.

Ring heaters (6) are clamped in grooves on each end of the housing;
the housing temperature is controlled by a thermostat placed in a horizontal
hole just below the bearing. A thermocouple is introduced into the top of
the bearing in a hole drilled to within $\frac{1}{32}$ inch of the bearing surface. A
continuous temperature record shows that the variation from the controlled
temperature is rarely more than $\pm 2°$ F. An operating temperature of
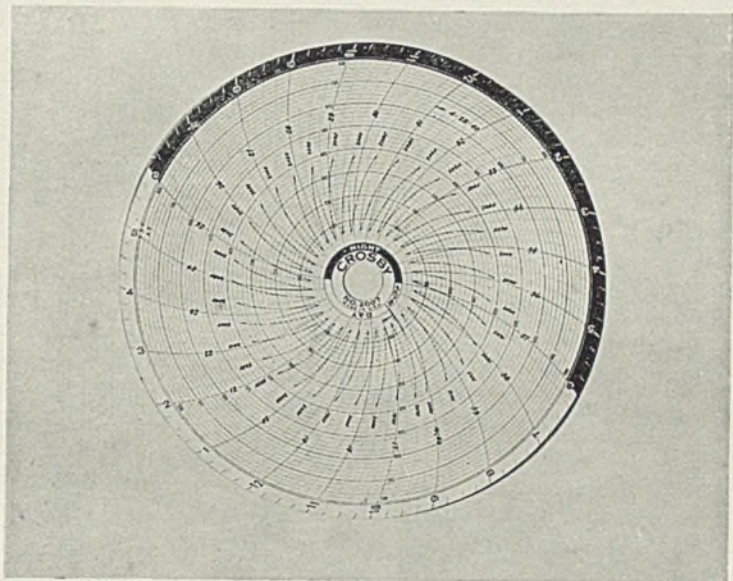250° F. was chosen for this work, in order to permit ready oxidation of the

Fig. 2.

TYPICAL CHART SHOWING LOAD RECORD OVER 24-HOUR PERIOD.
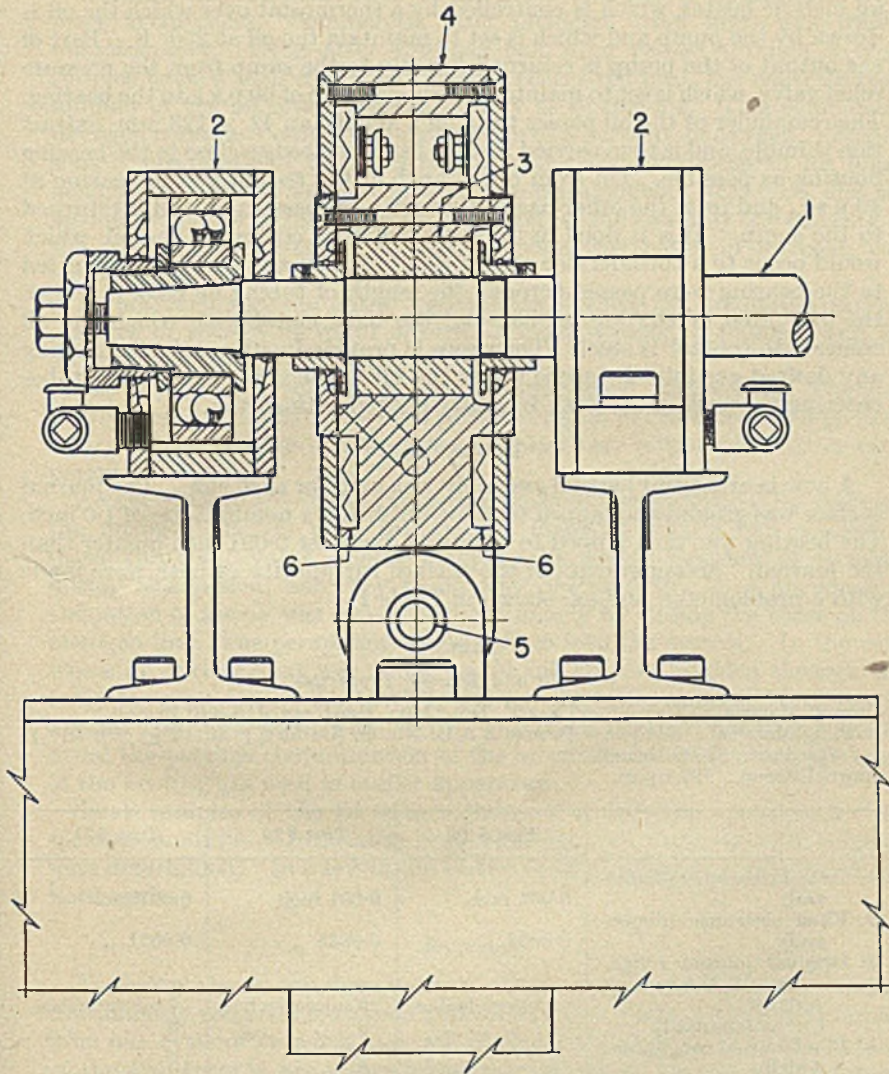
FIG. 3.

LONGITUDINAL SECTION THROUGH TEST BEARING AND HOUSING.

oil when exposed to air, to facilitate the temperature control by operating well above the point which the bearing would reach if no heat were added, and to reduce the lubricant viscosity so that excessive loading would not be required to enter the boundary region.

LUBRICATING SYSTEM.

The lubricating oil is contained in a large flask, from which it is lifted by a rotary pump having a capacity of 3 gallons per minute.   The flask rests on

an electric heater, which is controlled by a thermostat over which the oil is drawn by the pump and which is set to maintain the oil at 250° F. Part of the output of the pump is returned directly to the sump from the pressure relief valve, which is set to maintain a feed pressure of 60 p.s.i. to the bearing. The remainder of the oil passes through a Whatman 43 × 123 mm. extraction thimble, and is then carried to a tee fitting placed as close to the bearing housing as possible. Oil from one branch of the tee enters the bearing at 40 p.s.i., and from the other passes through a by-pass valve and is returned to the sump. This is done in order to minimize cooling of the oil, which would occur to a considerable extent if only the small amount which is fed to the bearing were passed through the length of tubing necessary. With the exception of the bronze bearing, the only metal with which the oil comes into contact is steel. The sump is provided with a tube for passing any desired gas into the space above the oil. The space around the tubes entering the neck of the flask is tightly packed with cotton.

PROCEDURE.

A new bearing and journal assembly was used for each run. The journal surface was ground and lapped to a fine finish and a nominal size of 1·0 inch. The bearing was then lapped to an inside diameter 0·001 inch greater than the journal. Measurements of the surface irregularity of both were made with a profilometer, and are shown in Table 1.

TABLE I.

Journal and Bearing Properties.

Journal Material : Nickel Steel S.A.E. No. 2340; Hardness, 415–440 Brinell.
Bushing Material : Sand-cast Bronze S.A.E. No. 64 (Cu 80%; Sn 10%; Pb 10%); Hardness, 65–80 Brinell.
Journal Speed : 107 r.p.m.

	Test #28.	Test #29.	Test #31.
1. Initial clearance (diametral)	0·001 inch	0·001 inch	0·001 inch
2. Final clearance (diametral)	0·0023 ,,	0·0025 ,,	0·0021 ,,
3. Original journal roughness (R.M.S.);			
Axially	5 micro inches	6 micro inches	4 micro inches
Circumferentially	5 ,, ,,	6 ,, ,,	3 ,, ,,
4. Final journal roughness :			
Axially	6 ,, ,,	8 ,, ,,	10 ,, ,,
Circumferentially	5 ,, ,,	5 ,, ,,	4 ,, ,,
5. Initial bearing roughness :			
Axially	15 ,, ,,	15 ,, ,,	12 ,, ,,
Circumferentially	15 ,, ,,	15 ,, ,,	12 ,, ,,
6. Final bearing roughness :			
Axially	6 ,, ,,	8 ,, ,,	12 ,, ,,
Circumferentially	6 ,, ,,	6 ,, ,,	6 ,, ,,

Each oil sample was vacuum distilled to remove last traces of dissolved oxygen before use, and was transferred to the sump in an atmosphere of oxygen-free nitrogen. All parts of the system through which the oil flowed were first blown out with this nitrogen.

Mention may be made here of the great difficulty of obtaining a truly inert atmosphere. Commercial tank nitrogen, tried first, was wholly unsatisfactory. Even after this gas had been passed through a large furnace packed with copper turnings at cherry-red heat, the neutralization number of the oil rose nearly as rapidly as in free air. This commercial nitrogen contained only a minute fraction of a per cent. of oxygen. Finally some " pre-purified " grade nitrogen, such as is manufactured for filling incandescent lamps, was purchased; two consignments were used, and the second proved to be far superior to the first, as indicated by the stability of the neutralization number of the oil when this batch of nitrogen was employed.

Before each run the entire system was flushed by circulating several changes of solvent ($\frac{1}{3}$ ethyl alcohol, $\frac{1}{3}$ ethyl acetate, $\frac{1}{3}$ toluene) and by scouring the tubing with a test-tube brush.

The machine was started at room temperature; temperature was then slowly increased to 250° F. over a period of 20–30 hours, in order to prevent injury to the bearing due to distortion, and also to provide a running-in period.

Access of air to any of the exposed oil surfaces was prevented by applying the nitrogen blanket until the load at incipient seizure had reached a reasonably stable value. Some unexplainable variations generally occurred during this period, but they in no way obscured the later phenomena. Oxidation of the oil was usually secured merely by closing the valve on the nitrogen line, thus permitting air to diffuse into the system. In the case where an anti-oxidant was added to the oil, air was bubbled through the sump for some time. The periods during which the nitrogen blanket was applied can be seen in Figs. 6–10. Electrical heating was employed to avoid the possible contamination of the lubricant by combustion products of the heating gas used in earlier apparatus.

Small samples of the oil were withdrawn at frequent intervals for inspection analysis. Ordinarily, only viscosity and neutralization number were determined. In a few of the earlier runs more complete examinations were made.

RESULTS.

As shown above, the data product of the machine comprises complete, continuously recorded load-time and torque-time charts; typical examples from one cycle of an actual run are illustrated in Fig. 4. The time scales of the two records are accurately synchronized, so that the load–torque curves may readily be constructed if desired. Practically, however, this is not necessary, because the loading is so nearly linear that the torque-time record may, for the purposes of the experiment, be considered identical with the load–torque curve.

In Fig. 5 is shown the relation between the coefficient of friction and the dimensionless variable ZN/P calculated from the data of Fig. 4. The minimum on this curve is conventionally taken as the condition of operation intermediate between thick and thin film types of lubrication. The curve is exhibited here to indicate the relative extents of the two regions in a typical cycle of the machine.

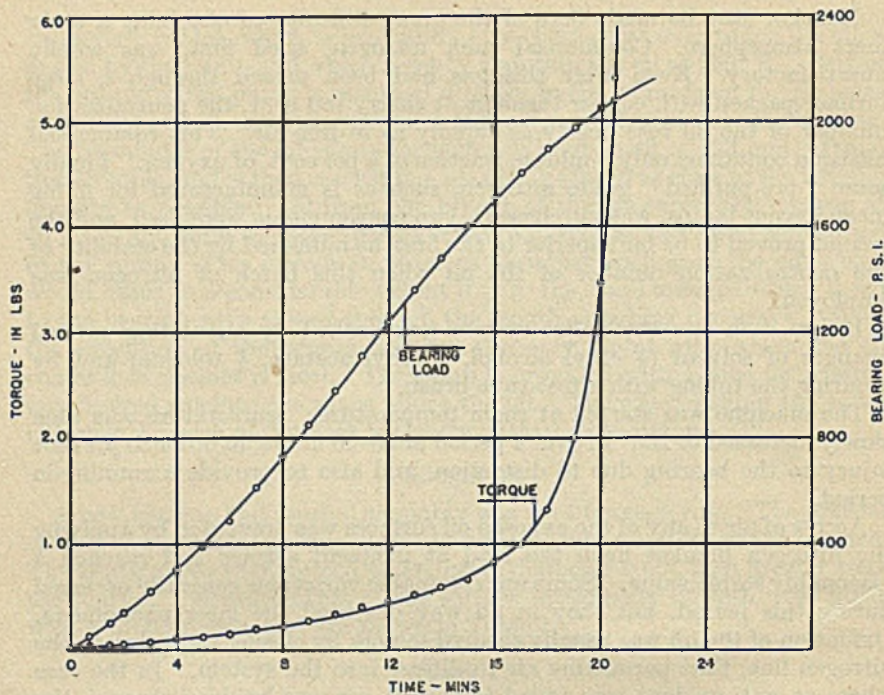The principal interest in the results, however, lies not so much in the

Fig. 4.

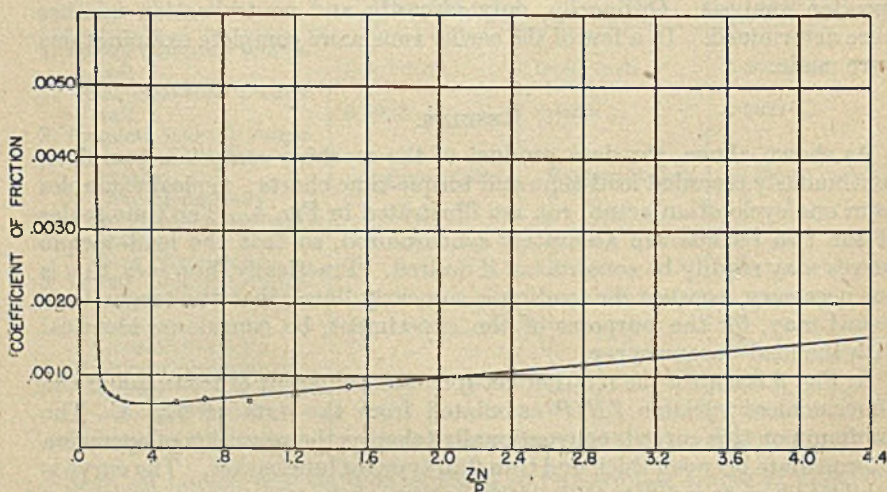TYPICAL LOADING AND TORQUE CURVES (TEST NO. 31 AT 210 HRS.).

Fig. 5.

TYPICAL ZN/P VS. COEFFICIENT OF FRICTION CURVE (TEST NO. 31 AT 210 HRS.).

analysis of the data from single loading cycles, as in the change in the incipient seizure peaks of the cycles with the state of the lubricant. Five typical runs of this type are illustrated in Figs. 6–10, showing peak load and torque values, *i.e.*, incipient seizure values, together with other relevant data.

Results with a Paraffinic Oil.

Figs. 6 and 7 are duplicate runs on the same oil, a light, highly refined, paraffinic material; the inspection data for this oil are listed in Table II.

Table II.

Inspection Data for Paraffinic Oil.

Sp. Gr. : 0·8534.
Viscosity at 100° F. : 16·30 centistokes; Viscosity at 210° F. : 3·45 centistokes.
K.V.I. : 120.
Colour, N.P.A. : 1⁻.
Pour point : +10° F.
Flash point : 380° F.
Fire point : 420° F.
Carbon residue : 0·01%.
Ash : 0·00%.
Neut. number : 0·01.
Aniline point : 221° F.

The most striking phenomenon exhibited is the large increase of load-carrying capacity of the oil during oxidation, the value frequently becoming

Fig. 6.

EFFECT OF OXIDIZING AND INERT ATMOSPHERES ON THE PERFORMANCE OF A LUBRICATING OIL.
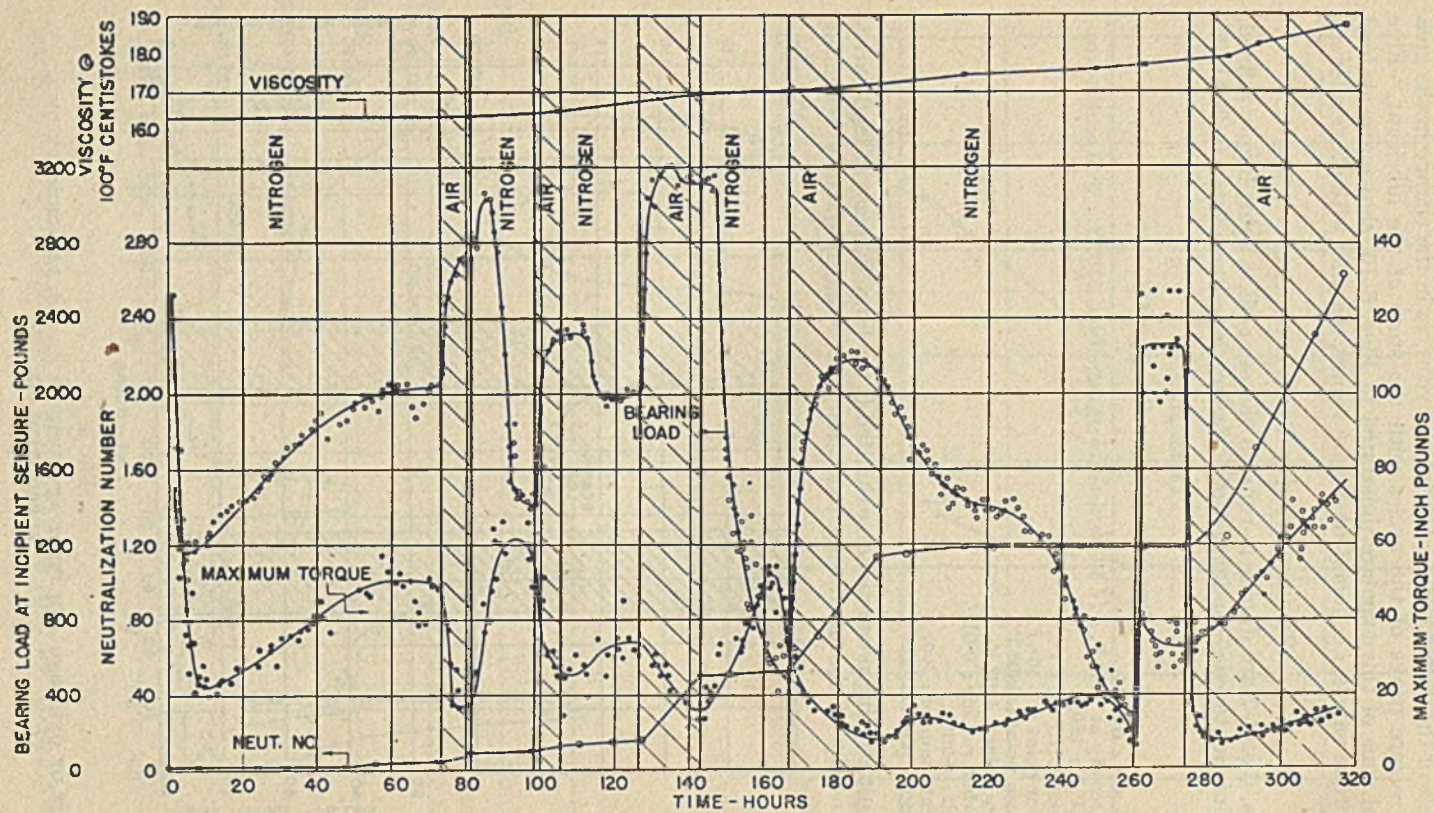
Fig. 7.

EFFECT OF OXIDIZING AND INERT ATMOSPHERES ON THE PERFORMANCE OF LUBRICATING OIL.

AIR NITROGEN AIR

INTENTIONAL OVERLOAD

VISCOSITY AT 100°F CENTISTOKES

TORQUE AT INCIPIENT SEIZURE - IN. POUNDS

40 36 32 28 24

140 120 100 80 60 40 20 0

260 270 280 290 300
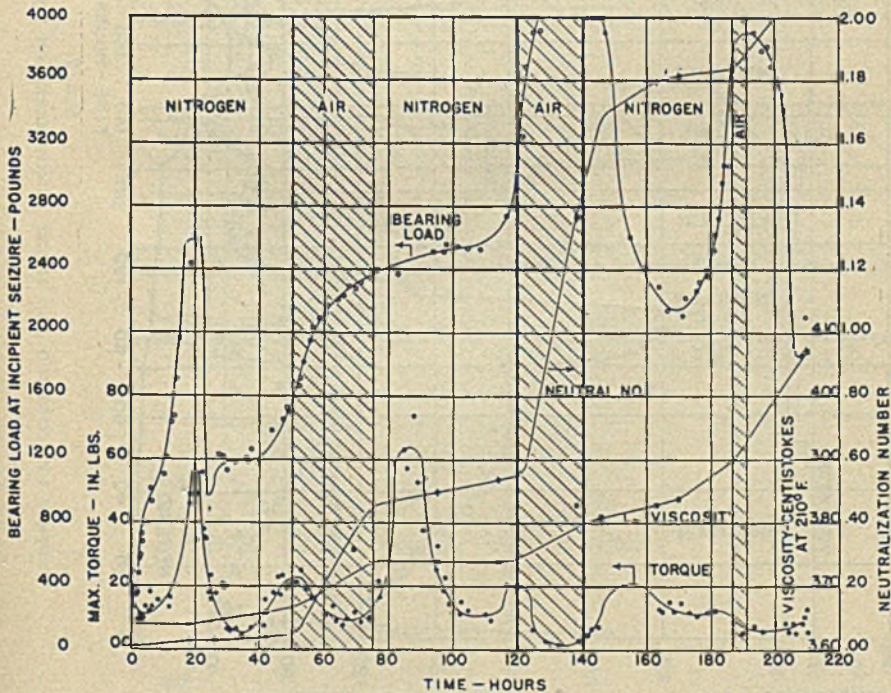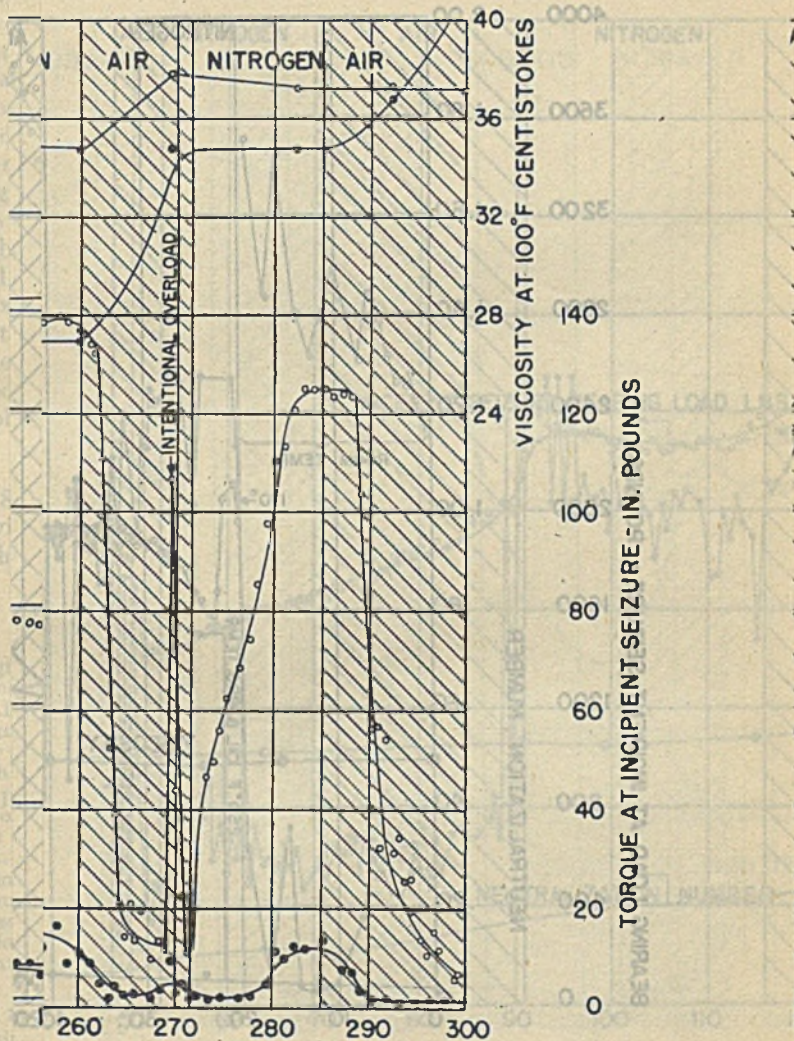
FIG. 8.

EFFECT OF OXIDIZING AND INERT ATMOSPHERES ON THE PERFORMANCE OF LUBRICATING OIL OF LOW V.I.
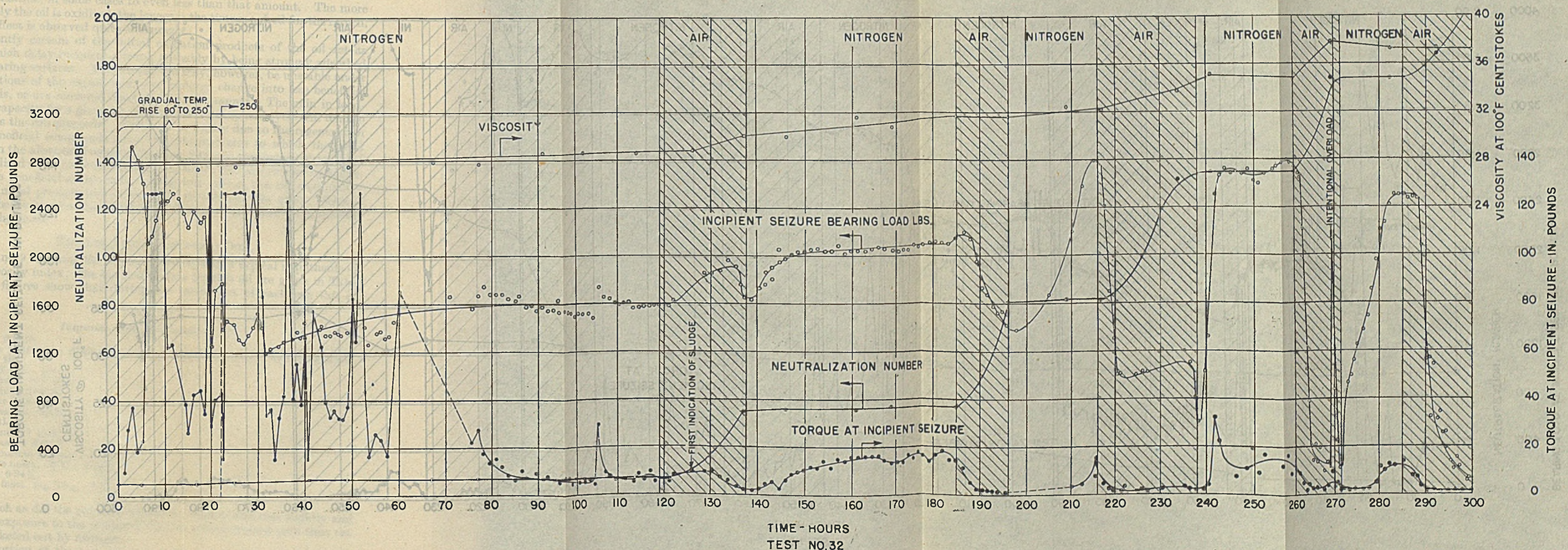
twice that of the unoxidized oil.   Even more remarkable is the indication that the effect is temporary; displacement of the oxidizing air with an inert nitrogen blanket causes the seizure load to decrease to near its value before oxidation, in some cases to even less than that amount.   The more extensively the oil is oxidized, the longer is the time required for the return, but the effect is observed quite as strongly.

Apparently certain of the initial oxidation products of the oil act as agents which delay incipient seizure, probably by being strongly adsorbed on the bearing surfaces.   These materials may, however, be unstable under the conditions of the experiment, and undergo change into less beneficial compounds, or are rendered inactive in some manner.   The gain in load-carrying capacity for a given air phase of the atmosphere cycle will tend to increase as the run proceeds.   This may be partly due to the regeneration of the beneficial compounds from the intermediates to which they had reverted in the absence of oxygen, together with the continued oxidation of the unoxidised oil; this would result in a steady increase in the concentration of the beneficial compounds.   A marked gain in the response occurs with the initial precipitation of insoluble material in the sump.   This is discussed below in connection with related phenomena observed in the case of a naphthenic oil.

Results with Naphthenic Oils.

Figs. 8 and 9 illustrate the results obtained with a typical naphthenic oil of low viscosity index; the inspection data for this oil are given in Table III.   The figures show that during the early part of each run this oil

Table III.

Inspection Data for Naphthenic Oil.

Sp. gr. : 0·9230.
Viscosity at 100° F. : 27·69 centistokes; Viscosity at 210° F. : 4·06 centistokes.
K.V.I. : 29.
Colour, N.P.A. : 2+.
Pour point : −30° F.
Flash point : 310° F.
Fire point : 350° F.
Carbon residue : 0·01%.
Ash : 0·01%.
Neut. number : 0·03.
Aniline point : 309° F.
Steam emulsion number, sec. : 86.
Refractive index, $n_D^{20°}$ C. : 1·5078.
Sulphur : 0·24%.
Naphtha insol., mg./10 g. : 0·7.

behaved much as did the paraffinic product; seizure load rose slightly and slowly with exposure to the oxygen of the air, and decreased each time the air was blanketed out by nitrogen.

In that portion of the test, however, following initial precipitation of sludge, the effects were reversed.   The seizure load now decreased when air was admitted and rose when it was excluded.   The reason for this is not clear.   A possible explanation may be found in postulating the deposition of a sticky layer of insoluble oxidation products which exhibit a specifically different friction behaviour.   When air is excluded, the formation of these products ceases and they are worn off the bearing surface

mechanically; this allows the seizure load to increase toward its original value.

This phenomenon is in marked contrast with that pointed out above for a paraffinic oil. In that case, precipitation of insoluble material was accompanied by a marked increase in seizure load. Again, a possible explanation may lie in a postulated difference in the character of the insoluble material precipitated on oxidation from the one type of oil and the other. It is strongly suspected that the first precipitates from an oxidized paraffinic oil are of soap type and those from a naphthenic oil of asphaltene type. The soap-type precipitate either does not adhere to the metal surfaces or does not decrease seizure load. The formation of soaps should, it can be assumed, be preceded by the formation of soap-forming acids; such compounds are known to decrease coefficient of friction. On the other hand, the asphaltene oxidation product of a naphthenic oil, if deposited on the bearing surface, might serve to decrease seizure load.

TABLE IV.

Results of Comparative Tests on Seizure Load, or Load-Carrying Capacity of Some Commercial Oils.

Tests run in nitrogen in the order below on the same bearing.

| Order of Test.	Oil.	Seizure Load (pounds).		
		Minimum.	Average.	Maximum.
1	A	1812	2248	2520
2	B	765	1631	2737
3	C	1197	1487	1937
4	D	1075	1275	1443
5	E	1168	1470	1675
6	B *	1380	1646	2452
7	A *	1692	1991	2327
8	F	1745	2080	2522
9	G	1493	1573	1660

* Duplicate tests.

Note.—Operating temperature was adjusted to equalize viscosity of all oils, to obtain an absolute viscosity of 3·88 centipoises. Temperature range 261–275° F.

The above explanation may agree with the possibility that the oxidation products of a paraffinic oil would be more polar than those from a naphthenic oil.

In order to obtain an indirect confirmation of the influence of oxidation on seizure load, a run was made in which 1 per cent. of a proprietary inhibitor was added to the low viscosity index naphthenic oil. The results are shown in Fig. 10. The inhibitor is believed to have anti-oxidant and detergent properties. It will be seen that the seizure load, except for the run-in period, remained quite constant for almost 200 hours, irrespective of the atmosphere to which the oil was exposed.

The torque data as a whole were far more erratic than the seizure data collected in the runs, particularly as regards the peak values. It must be borne in mind here that *seizure*, in the sense used throughout this paper, is really incipient seizure, the state at which the rate of increase of torque
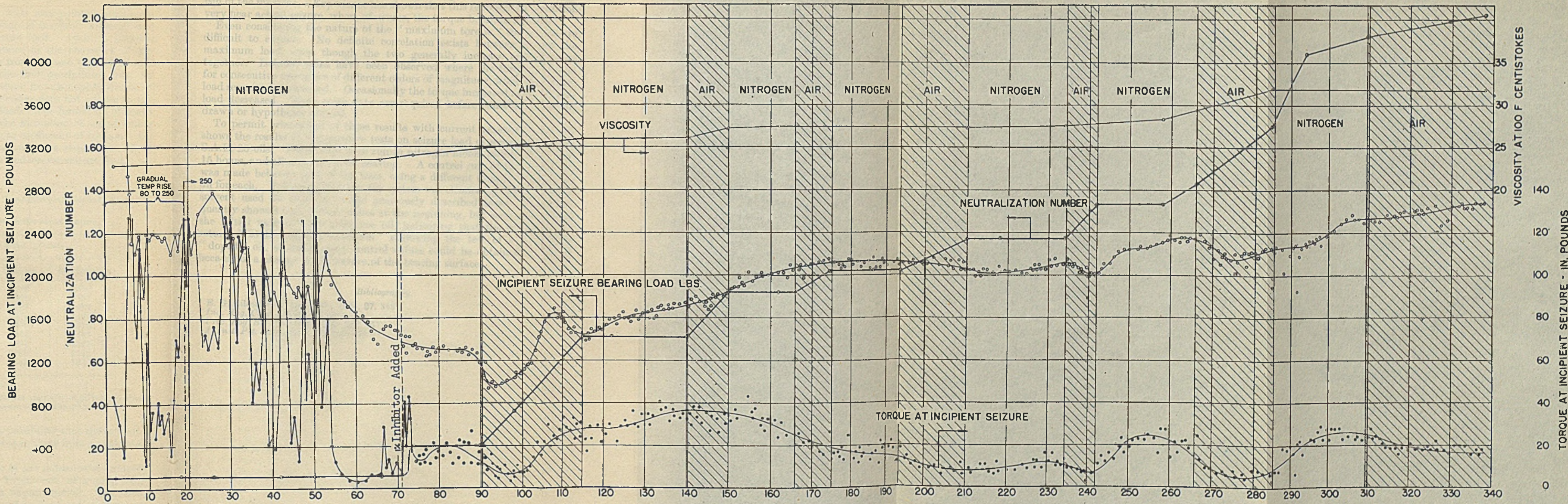
TIME - HOURS

TEST NO. 36

Fig. 10.

EFFECT OF OXIDIZING AND INERT ATMOSPHERES ON THE PERFORMANCE OF LUBRICATING OIL OF LOW V.I. + 1% INHIBITOR.

becomes large enough over a sufficient time to trip the breakdown mechanism of the machine.   Experience has shown that this represents a condition very near actual seizure, when, of course, the torque becomes infinite.

Even considering the nature of the " maximum torque," the results are difficult to explain.   No definite correlation exists between it and the maximum load, even though the two generally increase and decrease together.   Isolated cases have been observed where the torque maxima for consecutive cycles are of different orders of magnitude, while the seizure load remained unchanged.   Occasionally the torque increased as the seizure load decreased.   Much more data are required before conclusions can be drawn or hypotheses formed.

To permit orientation of these results with current practice, Table IV shows the results of comparative tests on seizure load of some commercial S.A.E. 20 oils.   These tests were run in nitrogen alone, lasted only about 15 hours, and all used the same bearing.   A control run, of about 4 hours, was made between each of the tests, using a different sample of the same oil for each.   Following each run the system was cleaned by circulating the solvent used for flushing in the previously described tests.   These frequently showed high or low values at the beginning, but soon approached the initial value for the reference oil, indicating that the machine had returned to its original condition.   Following the test of a drastically " doped " oil, no satisfactory control values could be obtained, probably because of a change in the nature of the bearing surfaces.

Bibliography.

[1] E. G. Gilson, *Gen. Elec. Rev.*, 1924, **27**, 318.
[2] *Ind. Eng. Chem.*, 1926, **18**, 467.
[3] *Proc. Roy. Soc. (London)*, 1933, **139**, 447.
[4] *J. Inst. Pet. Tech.*, 1937, **23**, 350–365.

THE INSTITUTE OF PETROLEUM

A MEETING of the Institute was held at the Royal Society of Arts, John Adam Street, Adelphi, London, W.C.2, on Thursday, 25th March, 1943, Mr. C. Dalley, President, occupying the Chair.

A discussion on the subject of "Petroleum as a Source of Synthetic Materials" was opened by Dr. A. E. Dunstan, Professor F. H. Garner, and Mr. J. A. Oriel, M.C.

DISCUSSION.

DR. A. E. DUNSTAN, before opening the discussion, said that the Council of the Institute was doing its best to continue the monthly meetings, and he urged Fellows and Members to provide more material for the *Journal*. Good papers and other material for publication were very much needed, in order to keep the Institute not merely alive, but flourishing.

The subject of the discussion on the present occasion was, in effect, the production of material from the basic products of the degradation of petroleum.

Some years ago he had invented the expression "petroleum bricks" and had raised the question of how to obtain them and what to build with them. No one in these days who read the literature on the subject could fail to realize that those petroleum bricks were a very real entity in modern chemical affairs. Those who were engaged in the oil industry to-day were inclined not to have too much regard for what had happened in the past, but those happenings had built up the present structure, and he proposed to deal for a few moments with the history of the subject.

The first utilization of petroleum bricks had probably been brought about by the revered founder of the Institute, Sir Boverton Redwood, many years ago, when he and the late Sir James Dewar had achieved the cracking of petroleum. The word "cracking" was perhaps inappropriate; what really happened was that, by the impact of high temperature, heavy oils were split or broken down into bricks. With those bricks, at that very early stage, long before the last war, Redwood and Dewar had inadvertently built up aromatic hydrocarbons.

He had had the good fortune, a quarter of a century ago, to be associated with the late Professor Wheeler in attempting to go a stage further than Redwood and Dewar, had gone, and they had been able to show that from the ordinary, plain, recalcitrant hydrocarbon, methane, aromatic hydrocarbons could be produced. They had been able to show that, by the impact of temperatures of the order of $1000°$ C., 1000 cubic feet of methane, for example, would give $1\frac{1}{2}$ gallons of liquid, and that that liquid was in effect quite similar to coal tar. It was a somewhat curious fact that one could start with coal, petroleum, straw, or wood, and, given the temperature, could obtain almost the same products. A "coal" tar could be obtained from all those starting-out materials if the temperature was sufficiently high.

He thought it must be assumed that, in the long run, one came down to the ultimate radicals associated with the thermal decomposition of hydrocarbons; to CH, CH_2, and CH_3, and those radicals really were the bricks with which the present meeting was concerned. The very early work carried out showed that from those simple radicals complicated structures could be built up. With those simple bricks houses and edifices could be built, and he would like to direct attention to some of those edifices : plastics, synthetic rubber, solvents, and so forth.

The point that he wished to emphasize was that petroleum had ceased to be a simple crude raw material for half a dozen every-day products; it had ceased to be a raw material for kerosine, gasoline, gas oil, lubricating oil, bitumen, and so forth. It had begun to resemble coal tar a hundred years ago; it had begun to be the fount of starting-out materials for the whole range of synthetic chemistry. That was admittedly a very big claim to make, but assuredly the present members of the Institute would see the time when coal tar would take a second place in the development of the great industries now in their infancy.

It would be remembered that cracking began to be a serious problem because of the demand for more and more liquid motor spirit. It was not a question of quality then,

but a question of quantity. It was not possible, twenty-five years ago, to obtain a sufficient amount of motor spirit from crude oil by direct distillation to cope with the demand unless a vast amount of ancillary products were produced for which there was no particular need, such as kerosines, gas oils, and heavy residues. A little later on the question of quality arose, and cracking became a process for the vast improvement of performance in the engine as compared with the performance of the straight-run material. The United Nations would have been in a very unfortunate position to-day had they been dependent on straight-run gasoline from ordinary crude oils. The question of quality became super-important, so much so that straight-run gasoline had to be cracked to obtain the super-characteristics demanded by the engine. That necessarily brought about the production of greater and greater quantities of by-products, so that one had to contemplate, in drastic thermal treatment, that a third of the initial oil would come out in the form of hydrocarbon gases. Therefore the industry, having to provide super-quality, had to produce a vast amount of material which in effect was the new material for a great new series of industries.

He did not propose to deal in great detail with the subject under discussion at the present meeting, but rather to open a debate, which he hoped would be very profitable, on the developments which were likely to occur in the very near future in the building up of structures. Professor Garner and Mr. Oriel would deal at much greater length than he could with these obvious developments of applied science, but he would wish to mention one or two somewhat striking examples which had occurred in the last few years.

He would refer first to the building up of *iso*-octane from the butenes. Not very many years ago butene, like methane and the rest of the lower hydrocarbon gases, was indeed a waste product, but, based on the pioneer organic chemistry of Butlerow and Ipatieff, it was shown that the butenes were capable of polymerization and that from two molecules of *iso*butene one could build up an octene with the 2 : 2 : 4-trimethyl-pentene structure, and from that particular octene, by simple hydrogenation, *iso*-octane could be derived. That was the starting-point, from the point of view of the petroleum industry, of all modern development in the chemistry of the lower hydrocarbons.

He could remember very well a meeting in Chicago, about fifteen or sixteen years ago, at which Graham Edgar first announced his scheme for the comparison of liquid fuels for the automobile engine, when he indicated, for example, that the substance of poorest performance was n-heptane, which he obtained by the distillation of certain resins from the Californian pine, and that the best of all was *iso*-octane, produced then in the laboratory by somewhat difficult methods. Those two substances, *iso*-octane and n-heptane, were fixed as the standards of performance not very many years ago.

It was astonishing how in the meantime the organic chemist had solved the problem of the utilization of the lower hydrocarbons. Month by month advances had been made in the application of those substances to synthetic treatment, and he would like to remind members of one or two of them.
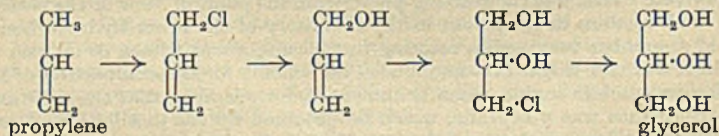
If one wanted to make *iso*-octane to-day, the starting-up materials were an olefine and a C_4 *iso*paraffin, *iso*butane, and any of the butenes; in fact, *iso*butane and the propenes or the ethylenes. *iso*Butane was essential for the purpose, but there was a deficit of it. Natural petroleum did not produce the quantity that the chemist wanted. He had often contemplated the extraordinary lack of foresight in Nature's Chemistry. One would have thought that Nature would have foreseen all the present difficulties and have produced *iso*butane in place of n-butane, but that had not been the case, so to-day it was necessary to make *iso*butane for synthesizing the C_8 hydrocarbons. By a process of isomerization, n-butane could be converted into *iso*butane, and in turn the *iso*butane could be converted into high-anti-knock materials. He had often thought that the reaction of the *iso*paraffins with the n-olefines or the *iso*-olefines was one of the prettiest in the organic chemistry of petroleum. The simple reaction of the tertiary carbon atom of the *iso*paraffin with the alkenes was outstanding in its importance in the industry. He remembered talking some years ago to Ipatieff, who had been a pioneer in this sort of work, and in the course of conversation they arrived at the somewhat fundamental point that the tertiary carbon atoms in *iso*butane were not very dissimilar from the tertiary carbon atoms in the aromatic series. Ipatieff had at one time been concerned with the addition of ethylene to benzene, and one of the tertiary carbon atoms in the benzene ring took up ethylene under the influence of a catalyst and ethylbenzene was formed. It was a natural development of that work to

discover that *iso*butane reacted very similarly with the butenes, under the impact of an effective catalyst, to produce the 8-membered structures, the *iso*-octanes.

Another point had arisen which he thought would seem reasonably obvious to the chemists who were present. It was well known that the aromatic hydrocarbons had properties which the straight-chain hydrocarbons did not possess; they were very much superior in engine performance from the standpoint of their oxidation reactions. When the organic chemist contemplated the difference between ordinary straight *n*-heptane and toluene, it might have raised in his mind a great many possibilities and problems. For instance, how could a substance like *n*-heptane, which from the point of view of the chemical industry was a comparatively useless substance and from the point of view of the petroleum industry was useless as a motor fuel, be got into ring structure; in other words, into toluene ? Therefore, with the effort to build up the chemical bricks into high-anti-knock bodies of the *iso*-octane type, a parallel set of researches was made to build them up into ring structure, into materials such as benzene, toluene, and so forth, and hence arose the modern development of cyclization, in which the straight-chain hydrocarbons bent round into ring structure, with loss of hydrogen and then with still further loss of hydrogen, right into the aromatic derivative; in other words, from *n*-heptane into toluene.

It would therefore be seen that the impact of organic chemistry on the petroleum industry, with its development of exceedingly high-anti-knock material, and the transformation of straight-chain paraffins into *cyclo*paraffins, and *cyclo*paraffins into aromatic hydrocarbons, had gone steadily on, but there were many other aspects which must not be disregarded.

He was inclined to think that one of the most delightful examples of the impact of plain organic chemistry on the petroleum industry was the work of E. C. Williams in synthesizing glycerol from propylene. Starting with propylene, allyl chloride was obtained by the addition of the halogen. Hydrolysis led to allyl alcohol which, on hydrochlorination, yielded the chlorhydrin, and this readily hydrolysed to glycerol.

$$
\begin{array}{ccccccccc}
CH_3 & & CH_2Cl & & CH_2OH & & CH_2OH & & CH_2OH \\
| & & | & & | & & | & & | \\
CH & \rightarrow & CH & \rightarrow & CH & \rightarrow & CH\cdot OH & \rightarrow & CH\cdot OH \\
|| & & || & & || & & | & & | \\
CH_2 & & CH_2 & & CH_2 & & CH_2\cdot Cl & & CH_2OH \\
\text{propylene} & & & & & & & & \text{glycerol}
\end{array}
$$

As Williams had very truly said, this synthesis would be a curb on any great increase in the price of the natural glycerol derived from fats.

He had referred to the impact of temperature on the lower hydrocarbons and had mentioned the work he had done with Professor Wheeler in producing aromatic hydrocarbons from methane. Fig. 11 in " Chemistry and the Petroleum Industry," by Dr. A. E. Dunstan, *J. Inst. Petrol.*, July 1943, 29 (235), 163, showed a modern pyrolysis plant. Actually the plant did not use methane, but surplus lower hydrocarbon gases under the impact of temperature and pressure were processed, producing material of a high aromatic content.

The most important aspect of the new synthetic chemistry was the development of catalysis. Fig 13 in *loc. cit.* showed a simple unit in which the lower hydrocarbon olefines, ethylene, propylene, butylene, and so forth, were subjected to the influence of a contact medium. Under the impact of catalysis the lower hydrocarbon olefines united and built up aggregates; C_2 became C_4 and C_4 became C_8. From what was at one time a waste product a building-up material of great value had been found.

PROF. F. H. GARNER said that when the present meeting was arranged it was proposed that those who opened the discussion should spend only a few minutes in introducing the subject; in fact, they were merely to provide an opportunity for discussion. He had prepared a very short note on the subject of synthetic rubber.

The most important individual product synthesized from petroleum would appear to be synthetic rubber, although *iso*-octanes for the manufacture of aviation gasolines would come as a close second. The task of making synthetic rubber—Buna S, Butyl Hycar, Neoprene, and Thiokol—would again appear to be one of the most formidable manufacturing tasks in the present war, and one of the most important from the point of view of winning the war.

According to the Baruch Committee, which it would be remembered was appointed by President Roosevelt to give a decision on some of the rubber problems in the United States, an overall production of 850,000 tons of Buna S, 130,000 tons of Butyl rubber, 70,000 tons of Neoprene, and 60,000 tons of Thiokol were required. Buna S was made by co-polymerizing butadiene and styrene, Butyl rubber was made by co-polymerizing butylene and a diene, Neoprene was made from chloroprene, which was the chlorinated butadiene, and Thiokol was made from sodium polysulphide and ethylene dichloride. All the amount required would not be made from petroleum, as of the butadiene for the manufacture of Buna S about 240,000 tons were to be made from grain alcohol which was available. The programme for the manufacture of butadiene had to be very carefully co-ordinated with the programme for the manufacture of butylenes for the *iso*-octane manufacture in aviation gasoline production, and there had apparently been some conflict in the steel requirements, *i.e.*, in the requirements of steel for the manufacture of the plants, although the Baruch Committee had considered that the conflict need not be serious.

The very large requirement of the C_4 fractions for the manufacture of Buna was originally based on butanes, which, of course, were available in large amounts in natural gas and also in cracked gases and other gases from refineries, but it was soon seen that the plants for the manufacture of butylenes from butane (an intermediate step in the manufacture of butadiene) would require too much steel. Attention was therefore concentrated on cracking operations which would give large proportions of butylenes, and modifications of known cracking processes and developments of new processes followed, amongst which the Fluid Catalyst Process and the Houdry Process were particularly important.

For the conversion of butylene and butylene–butane mixtures into butadiene, some 280,000 tons were said in November last to be in process of construction or planned, and some 110,000 tons by direct thermal cracking of mixed petroleum hydrocarbons. A new Houdry process was introduced in the meantime for the cracking of butane directly into butadiene, with yields claimed to be as large as 67 per cent., and an additional 60,000 tons had been agreed, making a total of 420,000 tons of butadiene from petroleum. In addition to that quantity, another 100,000 tons was contemplated from a group of small companies participating in a refinery conversion programme.

In addition, styrene was required in the proportion of about one part to three parts of butadiene, and some of that might be made from ethylene derived from petroleum.

The yield of Buna was 1·1 long tons from 1 short ton of butadiene. It was rather interesting that co-polymerizing capacity was based on long tons, that being the normal method of expressing weight of rubber, and that butadiene and butylene production was based on the short ton of 2000 lb.

This programme appeared to be the most important ever undertaken in the petroleum industry, and was based on the extensive research work carried out in the various petroleum companies' laboratories in recent years, which had been applied to full-scale manufacture under the extreme stress of war conditions.

Mr. J. A. ORIEL said it was a terrifying prospect for him to try to say anything on the subject of the discussion, following as he did the greatest expositor on petroleum chemistry in the country and a professional professor of the subject, but, as the third and junior member of the trinity (he hoped he would be allowed to call it a trinity without any invidious comparisons being made by the audience), he was left to deal with the odds and ends on which the two previous speakers had not touched. He was sure everyone must be wondering what there was left for him to deal with, and he himself was wondering about that. He had been told by Dr. Dunstan that he was to speak for only about ten minutes, as many of the members present would wish to speak on the subject of the chemistry of petroleum.

Dr. Dunstan and Professor Garner had dealt very clearly with what he might call the chemistry side of petroleum as distinct from its fuel side, and Dr. Dunstan had made quite clear the development of the use of the chemical activity of the olefines from cracked gases, so that he himself was left not so much to deal with the chemistry of petroleum as to fill in a few gaps on chemicals derived from petroleum. It was a little difficult to do that without laying himself open to the criticism that he was merely giving a catalogue of the chemicals which could be derived from petroleum, but he would try to avoid doing that, and would merely mention a few things, so as to provoke

Z

a certain amount of discussion on those products. He was sure that some great man had said at some time or other that the subject of a lecture could be made to mean whatever one wanted it to mean, and he was going to take advantage of that on the present occasion.

Some people had wandered from the path of pure chemistry in the course of their association with the petroleum industry, and had become more concerned with the chemical engineering side than with the purely chemical side, and the subjects which Dr. Dunstan had introduced in his address had become rather terrifying to them. In his youth it had been the custom to deal with such things as methane, ethane, and propane, and to dismiss everything else as higher homologues, and those were the substances, he thought, which it was now necessary to look into much more closely. Therefore he would prefer to go back for a few minutes to certain somewhat hetero-geneous mixtures, rather than to deal with the pure chemicals which could be built up of Dr. Dunstan's bricks.

Before doing so, he wished to refer to one or two interesting chemicals that were not usually mentioned; they were not chemical compounds, but were elements of great importance which were derived from petroleum. The first and most obvious of those was carbon black, which was formed by the incomplete combustion of petroleum gases and by the rapid cooling of those gases. It was very important during the war to realize the contribution that carbon black had made to the rubber industry. The bulk of the carbon black was incorporated in the production of rubber tyres, and that incorporation increased the life of tyres from about 4000 or 5000 miles to 20,000 or 30,000 miles. It was very interesting to see how the petroleum industry had come to the aid of the internal-combustion engine industry, not only in the provision of fuel, of which it was the main source, but also in the provision of material for tyres.

Another element which was of interest in the petroleum industry was helium. It was not often that attention was directed to the fact that the petroleum industry was the main source of that element, but it was so. All the members were familiar with the use which had been made of helium in airships, owing to its low density, lightness (it was the next lightest element to hydrogen) and safety. The fact that the petroleum industry in America was responsible for the production of the bulk of the helium had in the past almost led to international complications. It was interesting to note that the largest production of helium outside the United States, which was from a spring in Alsace, would provide helium only at such a rate that it would take 1400 years to fill a Graf Zeppelin. The pre-war implications o that were, he thought, obvious. Helium, however, had been used recently in a much more interesting way—namely, in connection with diving. The trouble known as " divers bends," which was a serious matter, was brought about when divers had been down to 200 or 300 feet and were then brought up too suddenly; it was due to the solution of nitrogen from the air in the blood and the sudden release of it. The bubbles, pressing on nerve centres, brought about very unpleasant results, which caused convulsions and sometimes death. It was found that helium, being much less soluble than hydrogen in water, could be supplied to the divers as helium air instead of nitrogen air, and would get rid of that trouble. Not only were men able to go down to greater depths and to carry out more work when they were down there, but the unpleasant results which had formerly been experienced were completely abolished. The first time helium was used in this connection was in saving the lives of several men on the American submarine *Squalus* in 1939. Helium was so often mentioned in connection with airships and its use as a life-destroying agent that he thought he would like to mention its use as a life-saving agent.

Having dealt with those two elements, carbon black and helium, he proposed to refer briefly to some of the more intricate mixtures, with which those engaged in the petroleum industry were much more conversant than they were with normal pure compounds, and he wished to refer first to plastics.

The coal-tar industry had contributed, up to the present, a great deal more raw material to the plastic industry than had been contributed by the petroleum industry, but, as was obvious from what Dr. Dunstan had already said, there were in the petro-leum industry very many good starting-points for plastics. The coal-tar industry at present accounted for about 70 per cent. of the raw material for plastics, 15 per cent. coming from cellulose and the remaining 15 per cent. being other raw materials, in which were included the raw materials from petroleum. During the war period the

petroleum industry was devoting a great deal more attention to the production of synthetic rubber than to plastics, but unquestionably when peace came again the industry would be able to turn its attention more actively to the production of plastics, and there would be a great deal of equipment available in the refineries to turn over to that very great industry.

The plastic industry was not a very old one, being about the same age as the chemical industry based on petroleum. With all due respect to Dr. Dunstan, the real building up of the bricks that he had mentioned had been done at refineries during the last fifteen or twenty years, and the plastic industry had been in existence for about the same length of time. He did not suggest that the chemistry of the high polymers had been known for only that short time, but he thought it was only within that time that it had been found possible to elucidate the molecular structure of the high polymers and to prepare them in the laboratory and the plant. The same point had been reached in the polymer industry as had been reached in many other industries, and it was very characteristic of chemical development. An attempt had been made to imitate nature in the production of a naturally occurring product, and now, with further knowledge of the product itself and its chemical composition, the point had been reached when it was possible not only to imitate nature, but to improve on it and to find similar but different materials with special uses which had not been even imagined when the investigation was first undertaken.

Without generalizing too much, he thought it could be said that a high polymer which consisted of a chain which fitted badly into a lattice shape and would tend to return to its normal shape gave synthetic rubber, a high polymer which fitted easily into a lattice structure gave fibrous materials, and the high polymers which were in between those two types gave plastics, and therefore were quite closely related to the subject of which Professor Garner had spoken.

He would like to mention a few types, first the phenolic type, derived from phenol and formaldehyde, which was by far the most important of all. The phenols were derived from coal, either direct or from benzene, and, while the benzene might be produced in the United States from hydroforming in the petroleum industry, in this country there was no doubt that it would always be produced from the coal-gas industry. The formaldehyde would probably be produced by the dehydrogenation of methanol or, in the petroleum industry, by the catalytic oxidation of methane. Apart from the fact that these were the first resins to be produced on a really large scale, their pre-eminence was due to their cheapness, their ease of moulding, and their structural strength. One of their disadvantages was that they were rather dark in colour, but that had been improved within the last year or eighteen months. The products from the phenolic type of plastic included moulding powders, laminated products with paper or fibre base, castings for further working and solutions in drying oils for the paint and varnish industry.

There were also the alkyd type, the amino type, and the acrylic and the polystyrene types of plastics, all derived, partly at least, from the petroleum industry, and he was quite sure that, as time went on, more and more plastics would be built up from the starting gases of the petroleum industry.

Aromatic petroleum extracts were again mixtures in the petroleum industry formed when lubricating oils were extracted; they were used partly as drying oils and partly as fillers. Naphthenic acids were other materials which were made on a large scale, as were also sulphonates, but he had not time to refer to those substances at any length.

In conclusion, he would like to direct attention to the different meaning which the chemistry of petroleum had for the present audience as compared with members of the Institution of Petroleum Technologists fifteen or twenty years ago. In those days, the early days of cracking, those engaged on the refinery side used to have a very useful little item at the end of their balance sheets, known as " gas and loss." Who in those days ever dreamed that that item would really be the beginning of an enormous chemical industry ? The gases were now almost the sole source of *iso*-octane, and very soon, he suggested, aeroplanes would be running on nothing but what was made out of those gases.

An enormous vista was opened out to the petroleum industry. Looking back on the last ten years, would anyone present like to suggest that the research on the chemistry of petroleum or petroleum products was approaching its zenith, let alone its end? Whether the production of various products from petroleum or the various uses to

z 2

which those products could be put was considered, the road which was being opened up was, to his mind, only at its beginning, and no indication could be given as to which way the road would branch. Petroleum, the raw material for this chemical industry, was only beginning to be understood. In the past far too much of it had been burned, and it was high time that research workers considered more and more closely how this precious raw material could best be conserved so that not one cubic foot of it was lost to the service of mankind. There was too great a tendency at present to squander raw-material resources. He had recently seen in a paper the suggestion that the roofs of houses in the future should be made of stainless steel. Why should such precious materials be used except in places where there was no alternative ? He hoped that those engaged in the petroleum industry would get rid of any nonsense of that sort in their industry. They should ensure that the greatest and the best possible use was made of the precious raw material which had been entrusted to their care.

In conclusion, he would like to urge the members not to feel that their industry and the coal industry were rivals, but rather that between them they could continue to use for the benefit of mankind two valuable fuels and very precious raw materials, neither of which was inexhaustible.

Mr. Harold Moore said he thought all the members present should be very grateful to the openers of the discussion for having brought such an interesting subject before them, but there was one point which had not been mentioned, i.e., that the whole of the synthetic petroleum industry was entirely dependent on refinery by-products, and unless refining was carried out in this country, he did not know how the raw material could be obtained. With a home consumption of petroleum of 12,000,000 tons a year, there should be about 500,000 tons of C_3 and C_4 hydrocarbons available and 500,000 tons of other gas, which would be sufficient to build a very large industry, as well as providing a certain amount for aviation purposes. He thought that the new development should result in a reconsideration of the attitude which had been adopted so far, which was, he thought, unfavourable to refining in this country and in favour of refining at the fields. The new development ought to alter the whole outlook on the subject.

The field for research opened out to physicists and chemists by the new development was a most entrancing one, and he was sorry to find, from watching the papers carefully for some time, that British physicists and chemists had had much less to do with recent developments than had been the case twenty years ago. It appeared that most of the work on the subject was being done in other countries at the present time.

He had been associated with one particular experiment recently. This experiment had now reached the pilot-plant stage, and was being carried on in equipment somewhat similar to a commercial unit. The plant was engaged in aromatization, a reaction which had been known for a considerable time. In this case the charge was naphtha and other liquid fractions, not gases. A very complete aromatization had been obtained, the liquid product containing approximately 98 per cent. of aromatic hydrocarbons. This process opened up a new field, in that, whereas benzole and toluol were quite easily extracted from coal-tar products, and could be purified simply, some of the higher bodies existing in coal tar were very difficult to isolate and purify. By the process to which he referred, an approximate yield of 10 per cent. of benzole, 10 per cent. of toluene, and 10 per cent. of a mixture of ethyl benzene and xylenes were obtained, and could be purified with little other treatment than simple distillation. Higher aromatic compounds, such as naphthalene, anthracene, acenaphthene, and phenanthrene, were easily isolated from the higher fractions, as there were practically no olefines, oxygen, sulphur, or nitrogen derivatives present in the finished mixture. Sulphur left the reaction as H_2S. Whereas coal tar could be made to yield the simple hydrocarbons at economical costs, it was very expensive to isolate the higher compounds from coal tar, and refined naphthalenes, anthracene, and higher hydrocarbons are very expensive, in spite of being present in considerable quantity in the relatively cheap coal tar. By the aromatization of petroleum these higher bodies could be obtained with much less difficulty. In addition to the liquid aromatic products, C_3 and C_4 fractions were given in the gaseous state, and were largely unsaturated. The pitch yield was about 4 per cent. He did not consider the process as a substitute for coal tar, but it was particularly advantageous for making higher hydrocarbons, and made available an extra supply in case the demand for benzole and toluol exceeded the quantity

available from coal tar. The amount of phenol extracted from coal tar might prove insufficient in view of the development of the plastic industry. Even when phenol was made from coal-tar benzene, the yield might still be insufficient. The method he described provided another way of obtaining increased production over and above the coal-tar production.

DR. BRANCKER said he did not agree with Mr. Moore that most of the research on petroleum was being done outside this country. He thought that a considerable amount of it was being done in this country, but, owing to the necessity for secrecy, the results of the research were not available. He himself had been engaged on research and, although he could mention what he had been doing, he was prevented from giving full details about it. In time of war he thought there should be a pooling of knowledge, and if that took place Mr. Moore would be shown to be incorrect in his opinion as to the amount of research that was going on in this country.

The question that he wished to discuss was that of aromatic petroleum residues. Dr. Dunstan had said that the coal-tar industry would be superseded by the products obtained from petroleum, and he did not think anyone present would disagree with that. Dr. Dunstan had outlined the manner in which he was building up very interesting bodies, but, besides being built up, they could also be obtained by the process of breaking down, and he wished to direct attention to the fact that aromatic petroleum residues contained a considerable percentage of aromatics, naphthenes, and paraffins. A considerable amount of work had been done in Manchester on the constitution of aromatic petroleum residues, with the use of what was known as the Vlugter, Waterman Van Westen method of analysis. That method of analysis had certain limitations, and there might be criticisms of it, but he thought it gave a very fair approximation of the chemical constitution of the aromatic petroleum residues. Those residues were being used extensively for rubber and for drying oils, but they were used at present in the dark, in a "hit-and-miss" way. Sometimes they were successful and sometimes they were unsuccessful. It was desirable to have more knowledge on the subject of what particular aromatic petroleum residues would suit a particular purpose, and with that in view their chemical constitution had been ascertained at Manchester, about thirteen oils altogether having been dealt with. The research workers there had concentrated on three main extracts. The first one showed on analysis that it contained three benzene rings in the form of an anthracene nucleus, to which was attached one *cyclo*pentane ring and a C_8 paraffin, but it was not known just how the rings were combined. The raffinates which corresponded to the extracts contained a low percentage of aromatics and high percentage paraffins. In the first case it contained one benzene nucleus, as compared with the three in the extract, a *cyclo*naphthene C_8 and a paraffin chain C_{17}. It was found that the extracts were not unsaturated in an aliphatic sense, but neither had they what was called a diene number. There were anthracene, benzene, and naphthalene nuclei in the extracts; therefore why had not the extracts a diene number? The answer given was that the paraffins were distributed around the nuclei masking the double bonds, but the research workers at Manchester could not be sure about that; all that they could advance at present was the constitution of the extracts in percentages of aromatics, paraffins, naphthenes. They suspected that the aromatic petroleum residues had a certain structure from molar volumes, but further than that they could not go at present. It was possible that, if the results of the research were published, someone more academically minded might be able to say what particular fraction of an extract could be used for rubber manufacture, etc., from a knowledge of molecular structures.

With regard to the use of aromatic petroleum residues as drying oils, what it was desirable to do now was to make the extracts more unsaturated, introducing if possible the double bonds which were so essential in organic chemistry, and that could be done, for example, by chlorinating the extract and then drying off the hydrochloric acid, in effect dehydrogenation. The oil then had an entirely different physical nature; it was viscous and tenacious before, and if put on a glass plate nothing happened, but if the dehydrogenated extract was put on a glass plate, it formed a kind of film, which he thought indicated a drying product. It was along lines such as these that a drying oil could probably be made.

He thought it would be agreed that a fairly good advance had been made in the subject.

DR. UNDERWOOD said that he would like to emphasize a point which had been brought up by Mr. Moore. It had to be admitted that the bulk of the work described in the discussion that afternoon had been done abroad, particularly in America, although there were, of course, notable exceptions. One such exception with which all the members were familiar was the pioneer work carried out by Dr. Dunstan and his colleagues on the alkylation process. It must not be taken as a sign of the inferiority of British scientists and technicians that this position had arisen. It resulted from the absence in this country of a vigorous refining industry to provide an adequate training-ground for technicians in the processes in question. It might be argued that it would be uneconomic and impracticable to have such a training-ground in this country, because the oil was not found here and the refining should be done where the oil was found, but, if that argument was carried to its logical conclusion, there would not be a cotton industry in this country because cotton was not grown here, there would be only a very small woollen industry because not much of our wool was produced here, and even the iron and steel industry in this country would be a very insignificant one. Without a flourishing industry as a training-ground technicians could not be trained, just as people could not be taught to swim without a swimming-bath. Facilities for practical experience were essential.

The opening contributions to the discussion had to cover such a wide field that it was almost inevitable that there should be omissions. No reference had been made to the development of the nitroparaffins. This was still in its infancy, but might well lead to an industry comparable in magnitude with that based on the nitro-aromatics. Another important process which had not been mentioned was the conversion of methane and other lower hydrocarbons into acetylene. This had been carried out on a modest scale before the war, and was being carried out on a larger scale to-day. It was obviously a very important development, not merely because it produced another substance to add to the list but also because it produced a substance which was the starting-point of a very large number of well-established industries. When the petroleum industry produced a material like acetylene, which was the starting-point of a number of existing and important industries, that development was much more important than if there was produced merely another product which in itself might be useful but which was not the starting-point for many other processes of manufacture. The same argument applied to the aromatization processes for producing the aromatic hydrocarbons in pure form from petroleum, because that meant in effect that anything which was now produced from the coal-tar hydrocarbons could be produced from petroleum hydrocarbons if they were converted to benzene, naphthalene, anthracene or any of the other hydrocarbons which were at present based on coal tar.

DR. R. C. FISHER said he would like to touch upon one point, which had not been mentioned by any of the previous speakers, in connection with the modern developments under discussion. So far it was essentially the chemical aspect of the subject which had been discussed, but he would like to say a few words on the engineering aspect, because obviously the chemical developments must be assisted by adequate engineering. Engineering, he thought, was both a handicap, to a certain extent, and a great help to the modern developments in question. It might be surprising to hear engineering referred to as a handicap, but, when Dr. Dunstan criticized Nature for producing butane instead of other more useful compounds, one wondered whether it was not the human mind, more particularly that of the engine designer, which was at fault. If the engine designer could produce a mechanism which would burn the products as they were available in Nature, it would not be necessary to correct Nature and make them better fuels. Engineering could also be a help to the modern developments in question. In the laboratory it was a relatively simple matter to isolate pure hydrocarbons by distillation, but it was a very different matter to isolate pure hydrocarbons on an industrial scale, and he suggested that the fact that it had been possible on a large scale to separate those basic compounds was the reason why it was practicable to proceed along the wide road ahead. The problems to which the oil engineer who had been educated in the old style of refinery processes involving simple distillation and possibly simple cracking, had become accustomed were rather basically changed in the modern field. Not only were the temperatures and the pressures encountered considerably different, but the materials themselves were also very different from an engineering point of view. For instance, the viscosity of all the

light modern products was considerably lower than the viscosity to which one was accustomed in connection with " old style " petroleum products. The net result was that the pumping problems and the lubricating problems were much more difficult. The economic side also required most careful study. For instance, in a refinery where one has available large amounts of waste, the gases, the combustion problems, and combustion engineering were not very difficult; on the contrary, the more one burned of those gases the better; whereas now the chemists laid their hands on most of the constituents of the gases and it was difficult to find anything that one was allowed to burn in a furnace : in other words, higher efficiency was of great importance.

He wished to point out that, unless very great care and research were devoted to the mechanical engineering side, it would be rather difficult for the fuel, chemical, and scientific development to make practical use of the theoretical investigations that could be carried out in the laboratory on a small scale.

THE PRESIDENT suggested that a paper might be read before the Institute on the subject brought forward by Dr. Fisher, and also that another meeting might be held for the further discussion of the question of petroleum as a source of synthetic materials.

DR. DUNSTAN agreed, saying that another meeting might well be held for an open debate on the subject which had been introduced on the present occasion by the openers of the discussion. It was obviously impossible to deal with it adequately at one meeting.

A vote of thanks was accorded to the openers of the discussion, and the meeting then terminated.

THE INSTITUTE OF PETROLEUM.

A MEETING of the Institute was held at the Royal Society of Arts, John Adam Street, London, W.C.2, on Tuesday, 8th June, 1943, at 5.30 p.m. Mr. C. Dalley, the President, occupied the Chair.

PETROLEUM AS A SOURCE OF SYNTHETIC MATERIALS.

The discussion on the subject of "Petroleum as a Source of Synthetic Materials," which had been opened by Dr. Dunstan, Professor Garner, and Mr. Oriel, at the meeting of the Institute held on 25th March, 1943, was resumed.

DISCUSSION.

MR. ASHLEY CARTER said he would be interested to know what were the uses of petroleum for thermo-plastics and for thermo-setting plastics.

MR. W. W. GOULSTON said that, in the making of plastics from petroleum, the unsaturated hydrocarbons which were present in petroleum would be used. Those unsaturated hydrocarbons would polymerize, either in the presence of a catalyst or by just being allowed to stand, into various resin-like compounds. Another method was to react some of the unsaturated hydrocarbons with other bodies, and thus make plastics in the same way as synthetic plastics were made in the ordinary chemical industry. Styrene, for example, which was one of the unsaturated hydrocarbons present in some of the petroleum gases but was more often manufactured by reacting ethylene with benzene and dehydrogenating, polymerized to a plastic. It also combined with other substances to form plastic materials, *e.g.*, it was combined with butadiene to give a particular type of plastic material—namely, synthetic rubber. Buna S was made in that way. One merely needed to indicate the presence of the unsaturated hydrocarbons in the petroleum gases, especially the cracked gases. Cracked materials were the starting-points for various chemical synthetic bodies, including, of course, resins.

DR. A. E. DUNSTAN pointed out that styrene had been identified in the products of the pyrolysis of methane, and that the late Professor Wheeler, Mr. W. H. Cadman and he had drawn attention to this occurrence many years ago.

MR. HAROLD MOORE said that experiments were being carried out at Manchester on the aromatization of petroleum naphthas, and a mixture of xylene, styrene, and benzene was obtained. The benzene and styrene were obtained by dehydrogenating ethyl benzene. The proportions were very difficult to ascertain, and there was some difficulty in the conversion to styrene of ethyl benzene. Quite reasonable yields were obtained; the total production, he thought, was about 9 to 10 per cent. of the naphtha, and about two-thirds of it was either ethyl benzene or styrene. In the catalytic treatment the temperature used was below 700° C.

THE CHAIRMAN said that in the last number but one of the *Journal* he had seen a statement by Dr. Gustav Egloff that all synthetic materials discovered in organic chemistry could be made from methane and that there were half a million of them.

MR. HAROLD MOORE said he had happened to get the catalogue of Carbide Chemicals of the United States recently, and it was surprising to see the large number of synthetic products made from petroleum. The list gave one some idea of what was happening in the United States at the present time with regard to the manufacture of synthetic products from petroleum, especially petroleum gases. There were about fifteen alcohols in the list, up to heptadecanol—methyl, ethyl, *iso*propyl, and so forth. There were six glycols, and there were ethers and oxides, there being a range of about eight glycol ethers, and there were also butyl ethers, and so on. There was a range

of about eight esters, which included some of the glycol esters, and there were also about ten ketones, six aldehydes, and four organic acids. The firm had not listed such things as formic acid and acetic acid. There were four anhydrides, eight chloride compounds, such as butyl chloride, a range of about thirty amino-compounds, including quite complex ones, a series of sulphates and a range of pure hydrocarbons. The whole list comprised about 120 products, all in commercial production and made in large quantities. The Company had another list of chemicals made in research quantities.

He thought the main plastics made from petroleum were those made from ethylene, isobutylene, butadiene, and styrene, the two most important of those being styrene and butadiene.

Carbide Chemicals were specializing particularly on the vinyl resins, and they sent out a notice with their catalogue saying that one could put sticky fingers on it and wipe it with a wet cloth and it would be perfectly all right, because it had vinyl polymer on the outside.

Mr. J. S. Jackson thought the hope of the future was that either formaldehyde or acetylene would be produced from methane. Methane was a substance that was available in enormous quantities, whereas the other basic materials under consideration usually involved manufacturing processes such as cracking. He had seen references in the literature to the practical possibility of producing formaldehyde from methane by oxidation and acetylene by heat treatment.

Mr. W. W. Goulston said that the question of manufacturing acetylene or formaldehyde from methane was an economic and commercial one, the cost of that method of manufacture having to be compared with the cost of other methods. He had no doubt that very large sums of money were being spent in supporting research work, particularly in the United States, for finding an economic commercial method of manufacturing acetylene and formaldehyde from methane. As Mr. Jackson had pointed out, methane was available in enormous quantities, and acetylene and formaldehyde were extremely useful materials as starting-points for a very large range of synthetic products.

Mr. Harold Moore said that the Cities Service Company had a large plant manufacturing formaldehyde from methane, but he did not know of any large-scale manufacture of acetylene from methane, the latter being a more difficult process.

Mr. J. S. Jackson said he believed that at present the Americans depended to a considerable extent upon natural gas for their domestic heating, but it seemed to him that in a very short time everything that would burn would be regarded as a basic material for the manufacture of synthetic resins or chemicals and people would then have to freeze, but they would have nice chairs to sit on and pretty rooms to freeze in.

Dr. A. E. Dunstan said that the amount of petroleum produced in the whole world was about the same in weight as the amount of coal produced in Great Britain —i.e., about 250,000,000 tons a year. The methane problem was exceedingly intriguing. There might be, he thought, about 10,000,000 tons of methane produced in a year. He had been assured many years ago by Lord Cadman that, apart from petroleum methane, there was a colossal amount of methane wasted in the gases pumped out of coal mines in the ordinary ventilation from mines, and the opinion had been expressed that there was probably more methane associated with coal than there was with petroleum.

Methane was a most recalcitrant hydrocarbon. It was so symmetrical that one did not know where to attack it, but he was inclined to think that methane to acetylene was the best line of attack, acetylene being a convenient source of many valuable products.

There was another aspect of synthetic petroleum chemistry which might be of interest to the members—namely, the synthetic chemistry of food. It was a well-known fact that in the last war Germany produced a certain amount of fatty acids by the oxidation of waxes, and it was also well known that, as Professor

Williams had shown, the production of glycerol from propylene was straightforward enough. Having obtained glycerol and stearic acid, one found the way to food substances fairly open, and he had heard it suggested that it was not beyond the bounds of possibility for organic chemists to synthesize materials of the vitamin type. With glycerine, stearic acid, and a certain modicum of synthetic vitamins, one would have a first-class foodstuff.

Mr. Harold Moore said that the present production of gas was over 70 million tons a year, but that, of course, was not all methane, as it included ethane, propane, butane, etc. He believed it had been recently said that the United States production of gas was about 30 per cent. of the production of oil (he presumed that applied generally to the rest of the world), and that the reserves of gas were something approaching 100 per cent. of the reserves of oil in tons. The largest consumption for plastic at the moment was for rubber, which should take about 1 million tons.

Mr. H. L. West, referring to Dr. Dunstan's remarks about making glycerol from propylene, said he thought they gave rise to the question whether it was not desirable to use the petroleum gases available for synthesis in the best possible way. Glycerol could be made quite easily by fermentation, and he thought it would be better to make it in that way and to use propylene for other purposes.

Another point that struck him was that in order to produce the unsaturated gases it was usually necessary to employ a relatively large proportion of raw petroleum as a heating medium; the process was a somewhat wasteful one in its consumption of petroleum as a raw material. He thought one of the main lines of investigation now should be to find a method of producing the unsaturated gases without such a waste. He looked forward to an advance being made in biochemical processes whereby it would be possible to produce some of the gases required, probably saturated, in sufficient quantities to augment the production from petroleum, utilizing materials not so exhaustible as petroleum.

He thought it was time that the gas industry started to use some of the knowledge that was available from the petroleum industry in order to conserve some of the materials that were at present burned in coal gas. He believed there was a small proportion of ethylene burned in coal gas which, if removed, might make a very useful starting material for synthetic rubber.

He believed it had been stated recently that the rate of consumption of petroleum at the moment was so high that some of the fields in the United States were beginning to become exhausted.

Mr. W. W. Goulston said that the suggestions made by Mr. West were quite sound. A number of products could be made by fermentation, and he had no doubt that many new processes would be worked out in the future which at present were not even dreamed of, but up to the present most of the starting materials for fermentation processes were foods and substances which could be used for food. In the United States very large quantities of grain were being used for manufacturing butadiene, and the farmers there were very anxious for it to be used for that purpose, but he thought it was quite wrong. At present, of course, the situation was very difficult, and food could not always be taken to the places where it was wanted, so there was probably an excess of food in certain parts of the world, but when the times were more normal food should be used for food, and not as a starting material for synthetic products.

With regard to Mr. West's point that it was wasteful to produce unsaturated hydrocarbons from petroleum, because a great deal of petroleum was required to make a very small quantity of unsaturated hydrocarbons, he thought Mr. West had probably lost sight of the fact that the process also resulted in the production of commercial petroleum products.

Mr. Harold Moore said he did not agree that it was wasteful to make glycerol from propylene. The cost of propylene was about £2 a ton, whereas none of the fermentation products was in that range at all. Most of the propane used to-day was used as a substitute for fuel. As far as the thermal efficiency of the change-over from propane to propylene was concerned, the reactions were not very wasteful ones. The fermentation industry used a colossal amount of fuel in the preparation of ethyl

alcohol in order to get it distilled to the concentration required, and he believed the amount of heat recovered was very small in proportion to the amount used in the distillation process. Glycerol was about £100 a ton, most of the synthetic materials being £50 to £100 a ton. The gases, even when extracted, were only £2 a ton, and when sold in bulk the price was much lower; yet it was suggested that they should be burned and not used for making glycerol.

DR. A. E. DUNSTAN said that Williams had authoritatively stated that the price of glycerol made synthetically compared very favourably indeed with the price of glycerol made by fermentation. To obtain glycerol by the ordinary fat-splitting methods involved the utilization of foodstuffs, whereas the synthetic manu-facture made use of what was in effect largely a surplus product.

He would like to point out to Mr. Goulston that the unsaturated hydrocarbons used in synthetic chemistry were almost invariably products of petroleum which were incidental to the main purpose of making motor spirit.

PROFESSOR F. H. GARNER said that, with reference to the general question of natural products competing with petroleum products, one very important point which would have to be considered was what would happen to all the rubber planta-tions in Malaya and other places when rubber was made from petroleum or alcohol. There was a large population concerned in the rubber industry, and their future means of livelihood would have to be taken into consideration. He believed that question was being studied at the moment by a Colonial Products Committee.

With regard to the question of the most economical source for the various synthetic materials, that would be settled in due course. It resolved itself into a question of the cost of labour and the various processes which were involved. The point as to whether alcohol should be derived from agricultural products or from petroleum would have to be settled on a world-wide basis in the long run.

It should be remembered that when petroleum was cracked the whole of the pro-ducts were utilized. It was not cracked specifically for the production of butadiene, for instance. The process was modified so that butadiene could be produced in large quantities, but the other products produced at the same time were, of course, utilized for fuel and other purposes.

THE PRESIDENT said that the oil companies in Trinidad had to pay a subsidy to assist the sugar industry in that country, so if it was necessary to rely for alcohol made from sugar produced in Trinidad there would have to be financial assistance from some source other than oil companies.

MR. H. L. WEST thought his remarks had been somewhat misunderstood. His point was that the petroleum supply was definitely exhaustible. It appeared that in about two hundred years' time, with the increasing consumption of petroleum for different purposes, mainly as a fuel, there would be a definite shortage. Therefore he thought that, as a long-range policy, the oil companies should institute research to see whether the raw materials for making synthetic products could be derived from other sources, such as vegetable material.

DR. A. E. DUNSTAN suggested that when that unhappy time came when petroleum was becoming scarce there would be illimitable amounts of shales. The Americans had made a very accurate survey of the shale resources in the United States, and they were gigantic. When the shales were exhausted he imagined that the coal industry would step into the breach.

MR. HAROLD MOORE suggested that if the supplies of petroleum were likely to become exhausted it would be better not to use it in ships and motor cars, but to reserve it for synthesis, where any given quantity went so much further. A million tons of petroleum was a very large amount from the point of view of making synthetic materials. If a man was short of petrol and butter he would probably prefer to have a gallon of butter than a gallon of petrol, because a gallon of petrol would not go very far, but eight or nine pounds of butter would.

THE PRESIDENT said that just before the war maize was being burned under boilers in Venezuela. There was a possibility of employing vegetable materials or edible

materials when it was economic to do so and to utilize petroleum when it was economic to do so.   Edible materials might even be cultivated for the specific purpose.

He was sorry that Mr. Dewhurst was not present, because he could have dispelled the bogey that was so often raised about the end of petroleum being in sight.   It had been shown, for instance, that the Athabasca tar-sands of Canada would last for a very long time.   He did not think there was any need to be alarmed about the supplies of petroleum coming to an end, and there were vast areas in many places which could grow corn, maize, and so on, which could be utilized if and when it was economic to do so.   The Russians were using grain for the purpose of making butadiene on a large scale, but they were very anxious to produce large quantities of foodstuffs also.

Mr. ASHLEY CARTER said he would like to ask Professor Garner a question on the subject of rubber production from the tree.   He had been fortunate enough to see rubber trees planted in the early years of the present century, and he thought it took about three years from the time of planting for a rubber tree to reach the tapping stage—i.e., the stage when the latex could be tapped from the tree.   After three years the girth of a rubber tree was about 9 inches.   How would the cost of the rubber produced from them compare with the cost of synthetic rubber ?

PROFESSOR F. H. GARNER said he could not answer Mr. Ashley Carter's question about the girth of the rubber trees, but, with regard to the question of cost, he thought it was estimated that the cost of producing natural rubber was about the same as that of producing synthetic rubber.

The important point to bear in mind, in his opinion, was that some of the new synthetic rubbers would be very superior to natural rubber in a number of respects. Some of them, as was well known, were far superior from the point of view of oil resistance, and others were said to be superior from the point of view of wear when used for tyres.   That made the competition with natural rubber more severe than it would be if the synthetic product was identical with natural rubber.

Mr. HAROLD MOORE said that the price of butane was £2 to £5 a ton and the price of rubber was about £100 a ton, and between those two limits a technical and very new process had to be carried out.   He thought that if engineers and chemists were left long enough with a proposition of that kind they would finally be able to work with a very much narrower margin than at the present time.   The controlling factor was how great the margin was between raw butane and butadiene rubber.   In other synthetic processes the cost of production had decreased very rapidly after the first period of testing out production, and it looked as if the petroleum product would be a very severe competitor with the natural product in so far as it fulfilled the requirements.

DR. A. E. DUNSTAN said that the synthetic production of indigo was a case which illustrated very clearly Mr. Moore's remarks.

ESTIMATION OF MERCAPTAN SULPHUR ALONE OR IN PRESENCE OF ELEMENTARY SULPHUR IN PETROLEUM PRODUCTS.*

By E. R. H. Davies, Ph.D., A.I.C. (Member), and
J. W. Armstrong, B.Sc.

Introduction.

The publishing of this method is sponsored by Sub-Committee No. 3 of the Institute of Petroleum, having in mind the possible inclusion in later editions of the Handbook.

No originality is claimed for the method—in fact, it is understood that in a modified form it is in use in the Emeryville (and probably other) laboratories of the Shell Development Co. and in Universal Oil Products, Ltd.

It was felt that publication in the *Journal* would lead to possible constructive criticism out of which could be evolved a method considerably more satisfactory than the present qualitative "Doctor" test. The method has been in constant use in the laboratories of the authors and has given every satisfaction.

Available Methods.

(a) *Iodometric Method* [1, 2].—This method depends on the oxidation of mercaptan to disulphides by iodine solution :

$$2 \text{ RSH} + \text{I}_2 = \text{RSSR} + 2\text{HI}$$
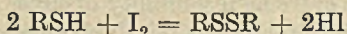
This method, however, fails in the presence of olefins and oxidizing and reducing agents interfere.

(b) *Lamp Method before and after Sweetening.*—This method has been used in conjunction with various sweetening processes,[3, 4, 5] but is rather time-consuming, and not too reliable in presence of organic sulphides and disulphides.

(c) *Mercuric Chloride Method* [2].—This method is based on the reaction :

$$\text{RSH} + \text{HgCl}_2 \longrightarrow \text{RSHgCl} + \text{HCl}$$
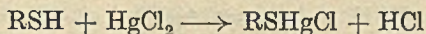
the HCl being titrated. It has been shown, however, that mercuric chloride reacts with olefins to liberate acid.[6]

(d) *Cupric Chloride Method* [7].—Here the mercaptans are quantitatively oxidized to disulphides with cupric chloride. $2 \text{ RSH} + \text{CuCl}_2 \longrightarrow \text{RSSR} + \text{Cu}_2\text{Cl}_2 + 2\text{HCl}$. The cuprous chloride is titrated with potassium permanganate. The chief limitation to this method is that it must be carried out in the absence of air. It is also not applicable to coloured solutions.

(e) *Cupric Oleate Method.*[8]

$$4 \text{ RSH} + 2 \text{ Cu(OL)}_2 \longrightarrow 2 \text{ CuSR} + \text{RSSR} + 4\text{H(Ol)}$$
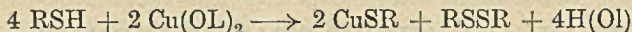
This method is not suitable in the presence of peroxides nor in coloured solutions.

(f) *Silver Nitrate Method*[4].—The precipitation of silver mercaptide would seem to be the most favoured method. This method is still rather tedious, as the tendency of the silver mercaptide to pass into the hydrocarbon phase and carry with it adsorbed silver nitrate necessitates lengthy washing. The principal objection, however, is that excess silver nitrate is used, and in consequence all anions whose silver salts are insoluble are precipitated, along with the mercaptans. It is also unsuitable for coloured solutions. Some improvement may be obtained by adding methanol,[9] which decreases the tendency of the solutions to form emulsions.

(g) *Potentiometric Methods*[10].—Tamele and Ryland found that using alcohol to dissolve the sample and titrating with an alcoholic solution of silver nitrate, the separation of phases, the formation of emulsions, and the resulting adsorption are completely eliminated. Furthermore, to avoid excess silver nitrate at the end of the precipitation, the end-point is determined potentiometrically with a silver electrode, thus making the method applicable to coloured solutions. Also on account of the very low solubility of silver mercaptide, the method is applicable in the presence of substances, which normally react with silver nitrate, but form compounds more soluble than the silver mercaptide.

PRINCIPLE OF PROPOSED METHOD.

The method is an adaptation of that proposed by Tamele and Ryland.[10] It depends on : (a) the extreme insolubility of silver mercaptides and silver sulphide in alkaline solution and the relatively greater insolubility of silver sulphide compared to silver mercaptides; (b) the interaction of elementary sulphur, mole for mole, with mercaptan sulphur producing silver sulphide through an intermediate sodium alkyl disulphide as shown by the equations below. The end-points of titration are determined by measuring the change in potential of a silver electrode immersed in the titration vessel by a potentiometric procedure.

For mercaptans alone, the mechanism can be represented by :

$$\text{RSH} + \text{Ag}^+ \rightleftharpoons \text{AgSR} \downarrow + \text{H}^+$$
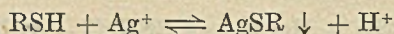
Sodium acetate is used as an alkaline buffer to prevent loss of mercaptan and to neutralize the hydrogen ion formed during titration of the mercaptans. For mercaptans plus elementary sulphur the suggested mechanism is the formation of mixed sodium alkyl disulphide which reacts with the silver ion to yield finally silver sulphide and alkyl trisulphide thus :

$$\text{S} + \text{RSNa} \rightleftharpoons \text{NaSSR}$$
$$2 \text{ Na SSR} + 2 \text{ Ag}^+ \rightleftharpoons \text{Ag}_2\text{S} \downarrow + \text{R}_2\text{S}_3 + 2\text{Na}^+$$
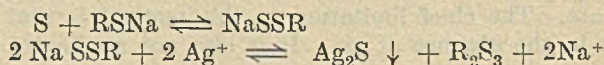
SCOPE.

The method is applicable to the determination of mercaptan sulphur and elementary sulphur in colourless, or coloured petroleum products. It is

not affected by olefins, aldehydes, peroxides, inert sulphur compounds, dyes, phenols, naphthenic acids, fatty acids, nitrogen bases, or chloride ion. Hydrogen sulphide must be removed before making the determination.

APPARATUS.

A simple arrangement for the potentiometric titrations is shown in Fig. 1. The cell consists of a silver half-cell, which is sensitive to changes in silver ion concentration and a mercury half-cell which serves as the reference electrode. The silver half-cell consists of a silver wire, 2 mm. in diameter, with its lower half immersed in a beaker containing 50 mls.
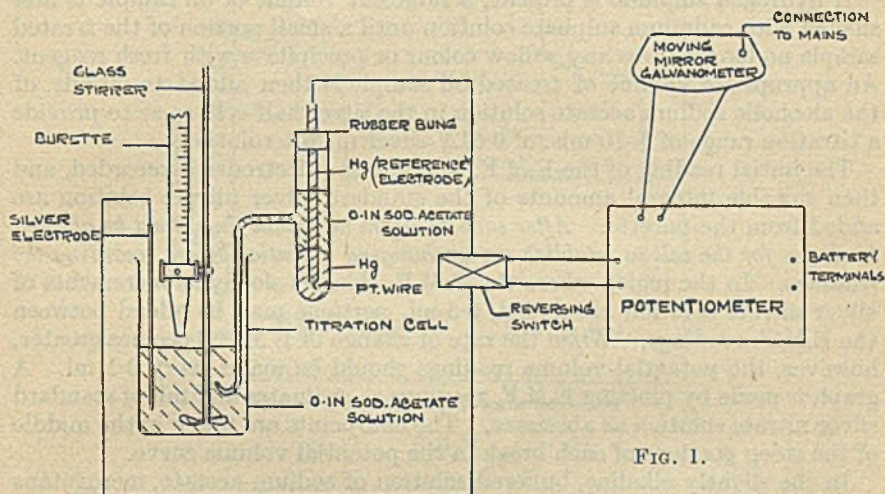
FIG. 1.

of $0.1N$-sodium acetate in 95 per cent. ethyl alcohol. The mercury half-cell consists of a glass tube closed at one end and bearing a side-arm midway along its length, bent as shown in sketch to form the bridge. The end of this side-arm is drawn out to a very fine orifice, terminating beneath the surface of the solution in the titration cell. The mercury half-cell contains a layer of mercury approximately $1\frac{1}{2}$ inches deep, with the standard $0.1N$-sodium acetate solution above it. The level of the sodium acetate solution is adjusted so that it is about $\frac{1}{2}$ inch above the side-arm when the bridge is full of the solution and the rubber bung tightly in position in the top of the cell (see Fig. 1). The reference electrode consists of a suitable piece of soda glass tube closed at one end with a small length of platinum wire sealed in, the tube being filled with mercury. The electrical lead makes contact by dipping into the top surface of the mercury.

A reasonably sensitive potentiometer arrangement is required that will measure potential differences of one millivolt.

A suitable assembly is made by connecting a moving mirror galvanometer in series with a " Unipivot " Potentiometer supplied by Cambridge Instrument Co., Ltd.

The apparatus also includes a glass stirrer, 10 ml. burette calibrated in 0.05-ml. divisions, and a reversing switch.

REAGENTS.

0·1N-sodium acetate solution in 95 per cent. ethyl alcohol.

0·01N-silver nitrate solution in ethyl alcohol, containing 10 per cent. water. This solution is prepared from a stock solution of 0·1N strength by diluting 10 mls. of 0·1N-silver nitrate solution (aq.) to 100 mls. using absolute alcohol.

Acid cadmium sulphate solution, containing about 15 gm. cadmium sulphate and 1 ml. 12N-sulphuric acid per 100 mls. of solution.

PROCEDURE.

If hydrogen sulphide is present, a sufficient volume of oil sample is first shaken with cadmium sulphate solution until a small portion of the treated sample no longer gives any yellow colour or precipitate with fresh reagent. An appropriate volume of treated oil sample is then added to 50 mls. of the alcoholic sodium acetate solution in the silver half-cell, so as to provide a titration range of 5–10 mls. of 0·01N-silver nitrate solution.

The initial reading of the E.M.F. between the electrodes is recorded, and then suitable integral amounts of the standard silver nitrate solution are added from the burette. *After each addition sufficient time must be allowed to elapse for the cell to establish an unchanging potential before recording the readings.* In the region where the E.M.F. changes slowly as increments of silver nitrate solution are added, 0·5-ml. portions may be added between the E.M.F. readings. When the rate of change of E.M.F. becomes greater, however, the potential-volume readings should be made every 0·1 ml. A graph is made by plotting E.M.F. readings as ordinates and ml. of standard silver nitrate solution as abscissae. The end-points are taken in the middle of the steep portions of each break in the potential volume curve.

In the slightly alkaline, buffered solution of sodium acetate, mercaptans react mole for mole with elementary sulphur to form sodium alkyl disulphide. If no elementary sulphur is present the initial E.M.F. of the cell (before any silver nitrate is added) is approximately—400 millivolts and a curve like that labelled (*a*) in Fig. 2 is obtained.

In this case, RSH as S % by wt. $= \dfrac{(\text{mls. AgNO}_3 \times \text{normality} \times 32 \cdot 06)\,*}{\text{gm. oil sample} \times 10}$

If elementary sulphur is present along with the mercaptans, however, the initial E.M.F. will be approximately −600 millivolts. When mercaptan sulphur is in excess of the elementary sulphur, two end-points will be found, as in curve (*b*), Fig. 2. The first represents the end of the precipitation of alkyl disulphide ion, since the corresponding silver compound is less soluble than silver mercaptide.

In this case, elementary S (% by wt.) =

$$\dfrac{(\text{mls. AgNO}_3 \text{ to first break) (N) (32·06)}}{\text{gm. oil sample} \times 10}$$

RSH as S (% by wt.) $= \dfrac{(\text{total mls. AgNO}_3 \text{ to second break) (N) (32·06)}}{\text{gm. oil sample} \times 10}$.

---

* One equivalent of silver nitrate is equal to one equivalent of sulphur.

When the elementary sulphur is in excess, only one end-point will be obtained, in which case a measured amount of a standard solution of n-propyl mercaptan must be added to the sample before titration. The procedure and conditions are then the same as in the previous case. Sufficient mercaptans must be added to give a distinct mercaptan break in the volume-potential curve.

(a)   FIG. 2.   (b)
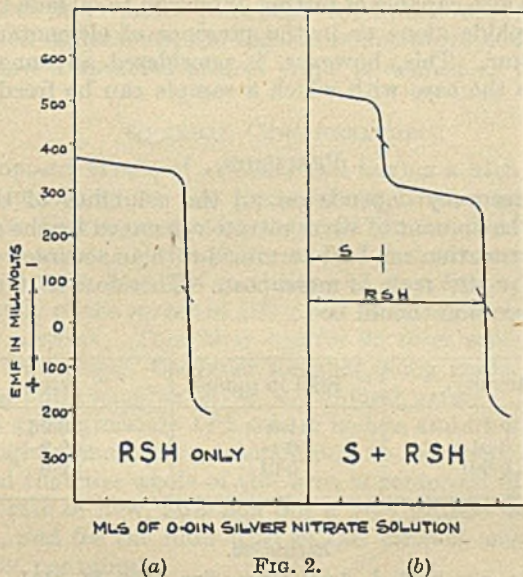
In this case, elementary S (% by wt.) =

$$\frac{(\text{mls. AgNO}_3 \text{ to first break}) (N) (32 \cdot 06)}{\text{gm. of oil sample} \times 10}$$

RSH as S (% by wt.) =

$$\frac{(\text{total mls. to second break} - \text{mls. for added RSH}) (N) (32 \cdot 06)}{\text{gm. of oil sample} \times 10}$$

NOTES.

The importance of keeping the silver electrode perfectly clean cannot be too strongly stressed. The electrode should be cleaned with potassium cyanide and washed carefully with distilled water.

Although rapid equilibrium is generally attained during the titration, the equilibrium becomes slow at the stage of the titration where a " break " occurs in the potential-volume curve. During this stage of the titration it is generally necessary to wait several minutes before adding the next increment of silver nitrate solution. Erroneous values will result if an additional increment is added before an unchanging potential is obtained.

The precipitation is made in alcohol solution because this eliminates the tendency of the silver mercaptide to occlude silver nitrate—as it does in water solution—and leads to high results.

The apparatus described here, although simple, has been found to be very effective, and the results are reproducible.

The method may be extended to the determination of mercaptans in liquefied petroleum gases, by externally cooling the titration beaker to $-15°$ C. by the use of " drikold "; the sample, depending on its mercaptan content, being quickly weighed into the chilled beaker on a trip scale or by means of a previously chilled pipette.

The method is also capable of further extension to include the estimation of hydrogen sulphide alone or in the presence of elementary sulphur or mercaptan sulphur. This, however, is considered an unnecessary complication, due to the ease with which a sample can be freed of hydrogen sulphide.

PRECISION.

The relative accuracy depends on (a) the solubility of the sample in alcohol, and (b) the amount of silver nitrate consumed by the sample. The end-point of the titration can be determined with an accuracy of ± 0.02 c.c. This indicates 2×10^{-7} mole of mercaptan. Therefore if 10 c.c. of sample are taken, the precision should be :

Molality.	% RSH in sample.	% error.
0·1	1·0	± 0.02
0·01	0·1	± 0.2
0·001	0·01	± 2.0

References.

[1] Kimball, Kramer, and Reid, *J. Amer. Chem. Soc.*, 1932, **54**, 3404.
[2] Sampey and Reid, *ibid.*, 1932, **54**, 3404.
[3] Faragher, Morrell, and Monroe, *Ind. Eng. Chem.*, 1927, **19**, 1281.
[4] Borgstrom and Reid, *Ind. Eng. Chem. (Anal. Ed.)*, 1929, **1**, 186.
[5] Youtz and Perkins, *Ind. Eng. Chem.*, 1927, **19**, 1247.
[6] Hofman and Sand, *Ber.*, 1900, **33**, 1349.
[7] Schulze and Chancy, *Nat. Petrol. News*, 1933, **25**, (34), 37.
[8] Bond, *Ind. Eng. Chem. (Anal. Ed.)*, 1933, **5**, 257.
[9] Malisoff and Anding, *ibid.*, 1935, **7**, 86.
[10] Tamele and Ryland, *ibid.*, 1936, **8**, 16.

Imperial Chemical Industries, Ltd.,
    Billingham.

THE FILTER FREEZING TEMPERATURE OF AVIATION FUELS.*

By J. M. A. Court, B.Sc., A.I.C.

Definition.

When a fuel flows under controlled conditions through a wire gauze filter of defined dimensions, the highest temperature at which the rate of flow falls below a specified critical value is defined as the filter freezing temperature.

General Considerations.

Certain proposed blends of aviation fuel having a high water solubility, tend to precipitate ice at low temperatures, with resultant freezing or blocking of the filter screens of aircraft fuel filters. This method provides a means of determining the tendency of such fuel to cause filter freezing.

The type of gauze and the conditions of flow chosen for this test are based on a study of the standard 200-g.p.h. filter, which is one type of filter now used in aircraft. This filter has for its filter screen two concentric cylinders of wire gauze, the inner member being made of 80 × 80-mesh gauze, and the outer member of 100 × 120-mesh gauze. The total effective gauze area is approximately 17·2 square inches, and for simplification, and to impose slightly more severe conditions on the laboratory test, it has been assumed that the whole of this area is composed of 100 × 120-mesh gauze. The rate of flow, although not a very critical factor, is based on these figures, and for the filter used in this method amounts to approximately 50 mls. per minute.

Apparatus.

Fuel Container.—Shall be a suitable bottle having a capacity of approximately 1300 mls. and dimensions close to those shown in the diagram (Fig. 1). It should be closed by a tightly fitting rubber bung having three holes for the thermometer, the air-vent and the outlet tube. It shall be supported so that the fuel level is 2 feet 6 inches above the delivery jet when flow commences.

Cooling Bath.—Shall be a suitable Dewar flask of 6 inches inside diameter and 11 inches deep, into which the fuel container can be placed for cooling.

Air Drying Tube.—Any suitable tube containing calcium chloride may be used, provided that the latter is not so tightly packed as to cause any back pressure on the fuel flow.

Wire Gauze Filter.—Shall consist of a brass tube of dimensions indicated in the diagram (Fig. 1), with wire gauze securely soldered over one end. The gauze shall be soldered on the outside only of the brass tube, and there shall be no blockage of the effective area of the gauze by solder. The thimble thus formed shall be a sliding fit on glass tube of dimensions 10 mm. outer diameter and 7 mm. inner diameter, and shall be secured in

---

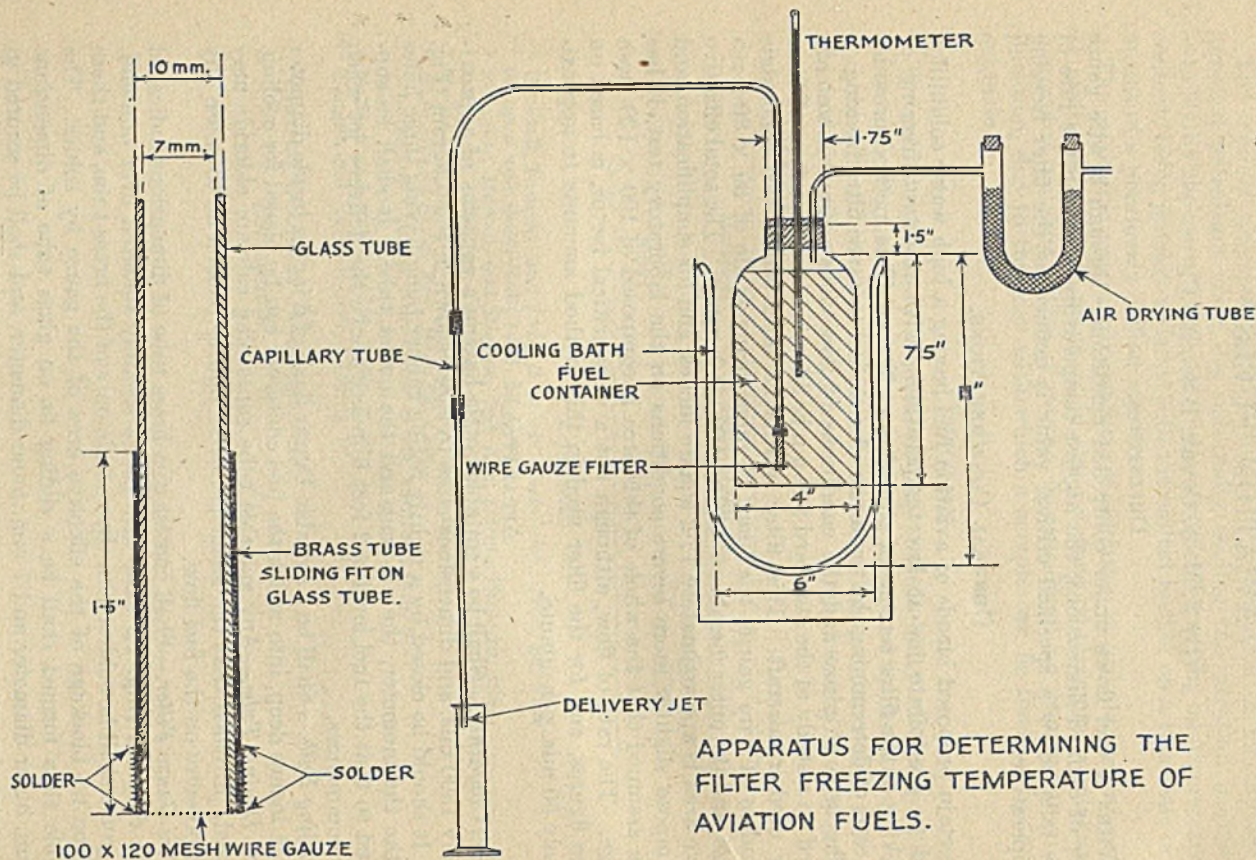APPARATUS FOR DETERMINING THE FILTER FREEZING TEMPERATURE OF AVIATION FUELS.

FIG. 1.

position with the end of the glass tube in contact with the gauze by means of a petrol-resisting rubber or a suitable jointing compound.   The filter shall be constructed with brass gauze of the following dimensions :—

100 × 120 mesh.   100 mesh to be of 41-s.w.g. wire (0·0044 inch dia.).
                  120 mesh to be of 40-s.w.g. wire (0·0048 inch dia.).

Thermometer.—Shall be an alcohol thermometer reading in units of 1° C. from +30° C. to —80° C.   The alcohol column shall be visible to —50° C., with the bulb at least 3 inches below the fuel level in the container when the latter is full.

Capillary Tube.—The delivery jet offers little restriction to fuel flow, and control of the latter shall be obtained by inserting a capillary tube in the circuit.   This capillary tube shall be of such a bore and length that with a head of 2 feet 6 inches of fuel on the delivery jet, the flow through the latter shall be 50 mls. per minute at laboratory temperature.

PROCEDURE.

About 1500 mls. of the fuel to be tested shall be saturated with water by shaking with the latter in a Winchester quart bottle for 15 minutes at laboratory temperature.   The sample shall be allowed to stand 24 hours until it is free from suspended water, and it shall then be transferred to the fuel container by syphoning through a 100 × 120-mesh wire-gauze filter to ensure that no solid material enters.

The fuel shall be cooled gradually over a period of 2 hours to the desired temperature in the cooling bath with alcohol and solid carbon dioxide. When the fuel has been maintained at this temperature for 15 minutes, the flow shall be started by applying suction to the delivery jet, after which it shall be allowed to proceed by syphoning.   The rate of flow shall be checked and recorded at 5-minute intervals by measuring the volume in mls. collected per minute in a measuring cylinder.

The rate of flow will decrease slightly, due to the drop in gravity head of fuel, but the onset of filter freezing is indicated by a marked and sudden decrease in flow, which may eventually cease completely.   The fuel fails if at any time during the test the flow falls below 25 mls. per minute.

Tests shall be carried out first at 0° C. and thereafter in decrements of 10° C. down to —50° C., using a freshly water-saturated sample of fuel for each test.   The highest temperature at which the flow falls below the critical value of 25 mls. per minute shall be reported as the filter freezing temperature.   Immediately after each test the filter shall be removed from the fuel container and examined for the presence of ice.

PRECAUTIONS.

The highest points of the glass tubes leading from the fuel container to the delivery jet are liable to trap air bubbles which may be hidden by the coating of ice which is formed on the outer walls when testing at low temperatures.   These air-locks, if allowed to persist, will cause a large decrease in flow which will confuse the results.   Care must therefore be taken to remove the trapped air and to prevent further locking.

A A

ABSTRACTS.

AUTHOR INDEX.

The numbers refer to the Abstract Number.

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

Geology and Development.

1027. Kansas : Rapid Development of Carmi Field Opens Important Area on South Flank of Arch. C. Hoot. *Oil Gas J.*, 29.7.43, 42 (12), 177.—The outstanding development of the northern Mid-Continent in the first half of 1943 was the rapid expansion of the Carmi pool. The field is nearly 3 ml. long, with 2000 acres proved. The average initial well potential is 2800 brl./day, from the Arbuckle at 4305–4329 ft.

217 wildcats were completed in Kansas during the first half of 1943, compared with 146 in the first half of 1942. 35 discoveries were made in the first half of this year. Most of the wildcats were on the Barton Arch, and the discoveries were generally within 3–5 ml. of proven areas, as during the past three years. The Studley pool of Sheridan County was, however, 12 ml. from the nearest field, and its discovery well gave 689 brl./day from the Lansing–Kansas City lime at 3808–3817 ft. The Deerhead field off the Barton Arch play came in with a well yielding 2785 brl./day from the Viola at 5005–5014 ft. The Hunter pool of Saline County produces from the Mississippian chat at a depth of 2674 ft. Major developments have merged the Zenith and Peace Creek pools, both of which produce from the Viola. The producing area runs northeast–south-west for 15 ml., and it gave 2,042,000 brl. in the first half of 1942 and 2,682,000 brl. during the same period of 1943.

Tables summarize the completions in the first half of 1943 by fields, and also summarize the wildcats, as well as giving the completions by months.   G. D. H.

1028. Nebraska : Forest City Basin. Anon. *Oil Gas J.*, 29.7.43, 42 (12), 178.—Production in the Forest City Basin has declined steadily during the first half of 1943, and the hoped-for Bartlesville sand development in Atchison County, Missouri, has faded from the picture. Seven dry holes were drilled in Missouri, and Nebraska had nine dry

holes and one oil-well from which 10 brl./hr. was swabbed from the Hunton lime at 2170–2180 ft.

The completions in Nebraska and Missouri during the first half of 1943 are summarized by months.   G. D. H.

1029. Kentucky's Production Rises Following Wildcat Campaign. Anon. *Oil Gas J.* 29.7.43, **42** (12), 204.—A 100-brl. well at a depth of 2346–2369 ft. opened the Robards pool in Henderson County, while the Utley pool in the same County came in with a 200-brl. McClosky well at 2576–2581 ft. The Anthoston pool produces from the Aux Vases at 2184–2189 ft. In May the Morganfield field was opened by a 122-brl. well in the Mansfield sand at 1428–1445 ft. The Poole field produces from the Tar Springs at 1961–1976 ft., and the Cairo pool from the Waltersburg at 1890–1907 ft. In Daviess County the Panther pool was opened in the Bethel sand at 1833–1837 ft.

The completions are summarized by counties for the first half of 1943, and monthly completion totals are also given.   G. D. H.

1030. Ohio : Penn Grade Field in Muskingum County. Anon. *Oil Gas J.*, 29.7.43, **42** (12), 204.—A large Pennsylvanian-grade oil well has been completed in Falls Township, Muskingum County, and together with scattered wells in the eastern part of Newton Township and Madison Township, Perry County, and extending south to the Clayton pool, opens up a large potential producing area. Few Clinton sand wells were drilled outside of this area and the Clayton pool, and no important discoveries were made.

Gas is in demand in Ohio, and one of two wildcats in Ashland County found gas. Two pools were opened in Holmes County east of the present production, and there were successful tests in Jackson and Knox Counties. Gas was also found in Lorain, Medina, and Eastern Morgan Counties. Two Clinton and one shallow discovery were made in Perry County, and the Sandyville field, Stark County, and the Hinckley pool were extended. The Muskingum–Morgan gas-field has been extended to the north, east, and south.

The completions during the first half of 1943 are summarized by counties, and the monthly completion totals are also listed.   G. D. H.

1031.* Good Well Is Completed in Turner Valley Field. Anon. *Oil Wkly*, 2.8.43, **110** (9), 47.—British Dominion Oil and Development Company's No. 5 new North Turner Valley well may receive an allowable of nearly 1000 brl./day. No. 6 is to be drilled ¼ ml. east of No. 5 and No. 7 ¼ ml. north of No. 5.

Deca 2, the first of a series of wells to be drilled in the Athabasca sands, is being tested. Taber-Providence 3 in the Taber field near Lethbridge is being tested. The Taber area has some good wells and dry wells. Taber, Vermilion, Ram River, and Athabasca are comparatively shallow areas.   G. D. H.

1032.* Prolific Well Completed in Turner Valley North End. Anon. *Oil Wkly*, 2.8.43, **110** (9), 47.—British Dominion No. 3 at the north end of Turner Valley was reported to be flowing at the rate of 4800 brl./day on July 16th, and may become one of Turner Valley's largest wells. The lower porous limestone zone produced at 130–150 brl./hr., and the upper porous zone at 55–60 brl./hr. The structure is narrow at the site of the well. In May the Turner Valley production fell to a record low.

Shell's Jumping Pound test has reached a depth of 10,624 ft.

The Turner Valley Devonion test has settled down to produce at the rate of 200 brl./day, having been plugged back to the Madison after encountering a fault. G. D. H.

1033.* Crude Oil Production at New High For Year. Anon. *Oil Wkly*, 16.8.43, **110** (11), 102.—The U.S.A. oil production has risen to a new high for this year, and averaged 4,229,185 brl./day in the early part of August. This production is within 108,000 brl./day of the all-time peak reached in January 1942.

The daily outputs of the different states are given.   G. D. H.

1034.* Commercial Gas Field in Athabasca Area. Anon. *Oil Wkly*, 16.8.43, **110** (11), 103.—Deca No. 2 in the Athabasca area has revealed a new gas-field in Alberta. The original flow is estimated at 15,000,000 cu. ft. of gas/day, but in a Government test the flow is reported to have been 22,000,000 cu. ft./day. Part of a core from 1654–1663 ft.

showed oil saturation, but this is cased off by casing set at the top of the Grand Rapids sandstone at 1674 ft.

A site for Deca No. 1 has been chosen 6 ml. east of No. 2, and a site for Deca No. 3 2¼ ml. south-west of the discovery well.

The Deca gas-well is 80 ml. from Edmonton which draws its gas supply from the Kinsella and Viking fields 125 ml. away. G. D. H.

1035.* Will Complete Old Deep Test South of Calgary. Anon. *Oil Wkly*, 16.8.43, **110** (11), 103.—The fifteen-year old Ranchmen's well, 25 ml. south of Calgary, is to be completed. This well has been standing for a considerable period in the Dalhousie sand at 7240 ft. It struck many showings of oil and gas.

New Ranchmen's-Snider 1 well, now at 1700 ft., will also be completed. G. D. H.

1036.* Production Increasing in North-West Canada. Anon. *Oil Wkly*, 16.8.43, **110** (11), 103.—During the first five months of 1943 Canada produced 4,211,751 brl. of crude, as compared with 4,383,292 brl. in the same period of 1942. Alberta gave 4,074,469 brl. in the 1943 period, against 4,313,292 brl. in the 1942 period. The New Brunswick output this year was 11,335 brl., and 9165 brl. in the first five months of 1942, while the corresponding figures for Ontario were 53,420 brl. and 60,689 brl. respectively. The North-West Territories yielded 146 brl. of oil in the first five months of 1942, and 72,527 brl. in the corresponding period of 1943, the monthly figures being: January, 9107 brl.; February, 11,556 brl.; March, 17,374 brl.; April, 19,692 brl.; and May, 14,798 brl. G. D. H.

1037.* Crude Oil Production Up 9% in Peru. Anon. *Oil Wkly*, 16.8.43, **110** (11), 103. —For the first quarter of 1943 the Peruvian oil production was 3,627,127 brl., compared with 3,327,318 brl. in the same period of 1942. 275,644 brl. of natural gasoline were obtained, against 272,733 brl. in the first quarter of 1942. G. D. H.

1038.* Canadian Production Down in First Five Months of 1943. Anon. *Oil Wkly*, 16.8.43, **110** (11), 103.—In May the Canadian output of crude oil and natural gasoline was 872,812 brl., the April figure being 837,072 brl., and that for May 1942 892,034 brl. Alberta's output was 843,431 brl. of which 832,219 brl. came from Turner Valley.

During May the natural gas production was 3,115,270,000 cu. ft., compared with 3,659,984,000 cu. ft. in April, and 3,076,658,000 cu. ft. in May 1942. The total gas output for the first five months of 1943 was 21,760,864,000 cu. ft., against 21,083,130,000 cu. ft. in the same period of 1942. G. D. H.

1039.* Italian Oil Fields Small, but Important to Axis. Anon. *Oil Wkly*, 23.8.43, **110** (12), 10.—The Albanian crude production is believed to be about 3700 brl./day from some 550 wells in the Devoli field. The oil is about 16 gravity, and comes from depths of 2000–3000 ft. Italy's several small fields give a total daily output of roughly 125 brl., mainly from the region of the Po river.

Generally the Italian wells are small and shallow. In the early 1930's the daily output was around 600 brl./day, but later it declined. Six of the fields were south of the Po in the Apennines foothills, principally in the province of Emilia, south of Parma and west of Bologna. The oil is in fractures or sand lenses and sandstone blocks in the Argille Scagliose (variegated shales). This shale is highly fluid when wet, and has been observed to be intruded into joints, bedding planes, and broken anticlinal crests. The formation may be of Eocene age or transitional between the Cretaceous and Eocene. Heavy crude is produced from some twenty wells in a field midway between Rome and Naples.

Several areas in Albania, in addition to Devoli, are reported to show heavy crude.

At Ragusa, in Sicily, is the second largest asphalt deposit in the world, second only to the Pitch Lake of Trinidad. The asphalt impregnates a limestone. Sicily has numerous oil and gas seeps, nearly all associated with the Argille Scagliose. G. D. H.

1040.* July Discovery Record Best So Far This Year. L. J. Logan. *Oil Wkly*, 23.8.43, **110** (12), 20.—As in earlier months the July discoveries were predominantly of mediocre or poor quality, but the record number of discoveries made the total of crude discovered represent a substantial addition to the reserves. The outstanding discovery was the

development of Tensleep production in the Elk Basin field, Wyoming. This added about 135 million barrels of reserves, while all the other July discoveries may account for only 40–70 million barrels.

The present rate of production is about 120 million brl./month, and on the average the monthly discoveries have been falling below this figure in estimated reserves.

In July 296 exploratory wells were completed, about the same number as in June. During the first seven months of 1943 there were 1777 strict wildcat completions, compared with 1810 for the corresponding months of 1942. The percentage of successful wildcat wells has been lower than in 1942.

The Tensleep well at Elk Basin is on the south-west flank of the structure and well outside the Frontier producing area. Tensleep saturation was found at a depth of 5409 ft., 32 ft. below the top of the Tensleep. The initial production was 1440 brl./day of 31-gravity oil. The well may prove 6000 acres of Tensleep production.

The Atlanta field in Arkansas has been extended 1½ ml. by a well which produces from the Cotton Valley sand and the Smackover lime. Illinois has had three new small oil-fields, new pay horizons in four fields and eleven field extensions. Five oil- and one gas-field were found in Kentucky, while Kansas had five new oil-fields. North Texas had six new oil-fields, and new pays in three fields. On the Lower Texas Gulf Coast new pay horizons were proved in three fields, and a gas-field and two oil-fields were extended. The Stratton field with its prolific sands has been extended 2 ml. to the west.

Tables summarize by States and districts the results of wildcatting in July and during the first seven months of 1943. A list is given of the discovery wells completed in July 1943, with the name, company, location, completion and starting dates, depth, producing formation, initial production, oil gravity, structure and method of discovery, and a preliminary estimate of reserves where an estimate has been made.   G. D. H.

1041.* Wildcat to be Drilled East of Turner Valley. Anon. *Oil Wkly*, 23.8.43, **110** (12), 42.—Drilling is expected to be resumed soon on the New Ranchmen's site, 18 ml. east of Turner Valley. At the site of the No. 1 well the Madison limestone is probably 8000 ft. deep. The Old Ranchmen's well in the same area was not completed because of operational difficulties. It went to 7200 ft. and had definite oil shows at six points in the last 1000 ft., without reaching the Madison, which is several hundred feet deeper. A seismic survey preceded the locating of the New Ranchmen's well.

G. D. H.

1042.* Canadian Oil Trickle Outside Turner Valley. Anon. *Oil Wkly*, 23.8.43, **110** (12), 44.—Turner Valley gave 95·3% of the crude oil and natural gasoline produced in Canada in May. An additional 1·3% was produced by other Alberta fields. The remaining 3·4% came from Ontario, New Brunswick, and Fort Norman. The total May output was 872,812 brl. In May 1942 Canada produced 892,034 brl. and in the first five months of 1942 4,383,292 brl., against 4,211,751 brl. for the same period this year.   G. D. H.

1043.* Alberta's Crude Output Is Down This Year. Anon. *Oil Wkly*, 23.8.43, **110** (12), 44.—In the first six months of 1943 Alberta produced 4,643,264 brl. The output in the same period of 1942 was 4,988,473 brl.   G. D. H.

1044.* Doing Geological Work West of Fort St. John. Anon. *Oil Wkly*, 23.8.43, **110** (12), 44.—Several geological parties are searching for oil in territory west of Fort St. John, British Columbia. The Hudson Hope area is believed to be favourable. Several years ago in the Pouce Coupe district, west of Dawson Creek, and south of Fort St. John, a large flow of oil was struck but not developed. Recent prospecting and drilling are believed to have located oil and gas.   G. D. H.

1045.* Canada's Largest Producer Completed at Turner Valley. Anon. *Oil Wkly*, 23.8.43, **110** (12), 44.—British Dominion 5 well is reported to have produced at the rate of 4500 brl./day, making it probably Canada's largest producer. It is the most northerly producer in the proven area of Turner Valley.   G. D. H.

1046.* Sharply Expanded Production Rates Feature of Recent Petroleum Trends.
L. J. Logan. *Oil Wkly*, 30.8.43, **110** (13), 12.—In spite of curtailment of civilian oil consumption the over-all demand for petroleum continued to increase during August. P.A.W. production certifications for September call for 4,552,100 brl./day. The June figure was 4,218,900 brl./day. During the past three months the producing ability of Districts 1 and 2 has declined, and only nominal production increases have been possible in Districts 4 and 5. Hence the main increase has come from District 3, and especially from Texas.

Crude oil production in the first seven months of 1943 was 5·5% above the figure for the same period of 1942, and runs to stills were 3·4% higher. Last year the industry drew heavily on stocks of refined products, and so this year refinery runs have been closer to current demands than they were last year.

The main rises in production above the 1942 levels have been in California (20%), Kansas (19%), Texas (13%), New Mexico (21%), Louisiana (4·5%), Colorado (5%), Wyoming (4%), Kentucky (68%), Arkansas (1·6%) and Michigan (0·3%). Compared with the output in the first seven months of 1942 production in 1943 declined in Illinois (27%), Indiana (25%), Mississippi (37%), Oklahoma (14%), Ohio (9%), Nebraska (45%), New York (4·6%), Pennsylvania (10%), West Virginia (5%) and Montana (6%).

During the first seven months of 1943 790,350,000 brl. of crude was run to stills in U.S.A. In California the runs were 151,316,000 brl., against 122,191,000 brl. in the first seven months of 1942.

Recently the gasoline production has been increasing, and the kerosine production is 7% above that for the first seven months of 1942. The residual fuel oil production has risen by 15%.

Data on production, stocks, demand, and refinery runs are tabulated. G. D. H.

1047.* Non-Marine Wasatch Vast Rocky Mountain Potential Oil Source. J. B. Crapo.
Oil Wkly, 30.8.43, **110** (13), 32.—The Wasatch formation of north-eastern Utah, north-western Colorado, and south-western Wyoming contains many extensive beds of tar-saturated sandstone. The largest and most extensive deposits are in the Uintah Basin and the Roam Cliffs in Utah and Colorado.

Over twenty-five years ago the White River structure, 20 ml. west of Meeker, Colorado, yielded gas, and in 1924 oil and gas were found at LaBarge, Lincoln County, Wyoming, in these beds. In the latter case the oil is 650–1000 ft. deep, in lenticular sands. The wells have had initial outputs of 5–300 brl./day, and to date the total production is about 8,000,000 brl. Gas was found at Hiawatha, Moffat County, Colorado, in 1925, and oil has been produced from some of the deeper sands. 25 ml. to the south-east the Powder Wash Dome has given oil and gas. In 1938 gas was discovered on the Big Piney Creek anticline, 16 ml. north of LaBarge, and later an oil-well was completed.

The above Wasatch discoveries seem to indicate that oil and gas in quantity are present and indigenous to these beds, and Nightingale states that there is no sign of faulting or fracturing on the Powder Wash Dome which would permit migration into the Hiawatha member of the Wasatch.

20,000 sq. ml. of Eocene beds await exploration in this region. G. D. H.

1048.* Several Alberta Wildcats Have Important Shows. Anon. *Oil Wkly*, 30.8.43, **110** (13), 49.—Sparky 1, south of Lloydminster, is reported to have struck oil, and Ram River 2 is being acidized after giving 33 brl./day. 20 ml. south-east of Wainwright Edgerton 1 is reported to have an oil and gas showing.

Several Turner Valley wells are nearing the producing level. G. D. H.

1049.* Crude Production Lower but Still Near Peak. Anon. *Oil Wkly*, 30.8.43, **110** (13), 49.—In the week ending 28th August, U.S.A. produced an average of 4,225,585 brl./day of crude, 7010 brl./day less than in the previous week. The decline was caused by the rises in production in California, Illinois, Indiana, Kentucky, Texas, West Virginia, and Wyoming failing to offset the falls in Kansas, Michigan, Oklahoma, Pennsylvania, Arkansas, Louisiana, and New Mexico. G. D. H.

1050.* Well Will Be Drilled Under Lake Erie's Bed. Anon. *Oil Wkly*, 30.8.43, **110** (13), 49.—A gas-well is to be drilled in Lake Erie, 1 ml. offshore from the southern end of the Tilbury gas-field. Gas is expected at depths of 1375–1425 ft.

Some years ago several gas-wells were drilled in the lake near Port Alma, but all were under $\frac{1}{2}$ ml. from the high-water mark. It is believed that entry of water into the Tilbury field has " trapped " large amounts of gas beneath the lake. G. D. H.

1051.* Progress Being Made in Western Canada Drilling. Anon. *Oil Wkly*, 30.8.43, **110** (13), 49.—Fourteen wells out of fifty projected by one company have been completed or nearly completed in the Vermillion field. No. 6 pumped 100 brl. in 6 hours, and of the completed wells all except No. 5 have been successful. No. 5 seems to have missed the sand. Elmore 1, the most easterly well, is reported to be giving 70 brl./day.

30 ml. west of Calgary production has been resumed on the Moose Dome Devonian limestone structure. G. D. H.

1052.* Industry Dependent on West Texas for More Production. A. R. McTee. *Oil Wkly*, 6.9.43, **111** (1), 77.—For some time the Permian Basin has had a greater volume of shut-in production than any other part of Texas. It has also been viewed as one of the most favourable areas in which to find new sources of petroleum production, a belief which has been borne out by recent prolific Ordovician discoveries. Since the mid-twenties it has had a high crude reserve, as well as a considerable list of undrilled proven well sites. This condition has arisen largely from oil-outlet limitations. New pipe-lines are to be constructed, thus encouraging the development of proven and wildcat sites.

In September the Texas allowable has been pushed to 1,814,000 brl./day, with the largest increase (73,193 brl./day) assigned to the Permian Basin, making its total 327,642 brl./day. It has been suggested that West Texas could produce about 500,000 brl./day, and at present it is the only area in U.S. which is not producing at its maximum efficient rate. During 1942 the West Texas output fell from 311,300 brl./day in January to 212,600 brl./day in December. Since June 1943 the rate has risen by about 100,000 brl./day.

The capacity of some pipe-lines in West Texas has been increased, and new pipe-lines are to be built.

During 1943 new production has largely been confined to deep fields, and Ordovician discoveries have made West Texas a prominent contributor of new crude reserves in the first half of 1943. The deep tests are very expensive. G. D. H.

1053.* Argentine Oil Demand Only Partially Met : Production Seriously Off. Anon. *Oil Wkly*, 6.9.43, **111** (1), 121.—In 1941 Argentina consumed 33,000,000 brl. of oil and produced 22,500,000 brl. Its production in 1942 was at about the same level, but this year it fell by 23% in the first quarter. It is expected that only about half of Argentina's normal demands will be met this year, due to virtual cessation of imports and the decline in production through shortage of drilling and other equipment.

In 1942 Y.P.F. drilled 72 exploitation wells with a total footage of 335,747 ft. Forty-six old wells were deepened. 15,407,154 brl. of oil were produced, 1,378,364 brl. more than in 1941.

Lack of adequate coal and oil supplies is impeding Argentine industry and transport. The lack of fuel oil is especially marked. The Government has recently agreed to supply 2,250,000 brl. of oil to Uruguay, Paraguay, and southern Brazil in return for drilling machinery from U.S.A. G. D. H.

1054.* Alberta Drilling Active Outside Turner Valley. Anon. *Oil Wkly*, 6.9.43, **111** (1), 124.—Fourteen wells are now being drilled in Turner Valley, and 11 elsewhere in Alberta. The current Alberta production is 25,612 brl./day compared with 27,584 brl./day a year ago. At present Turner Valley gives 23,917 brl./day of crude and 1,186 brl./day of natural gasoline, while 509 brl./day of crude are obtained elsewhere in Alberta. A year ago the Alberta crude production outside Turner Valley was 400 brl./day. G. D. H.

1055.* Production Increasing in Vermillion Field. Anon. *Oil Wkly*, 6.9.43, **111** (1), 124.—During June the Vermillion field produced 6092 brl. of oil without any new wells. The completion of new wells in July and August may be expected to have increased the output in those two months. G. D. H.

1056.* Well Drilling Ahead in Athabasca District. Anon. *Oil Wkly*, 6.9.43, **111** (1), 124.—Deca No. 1 has reached a depth of 350 ft. It lies 6 ml. east of Deca No. 2, which is reported to have flowed 22,000,000 cu. ft. of gas/day. G. D. H.

Geophysics.

1057.* Electrical Logging Through Thick Salt Zones. J. A. Kornfeld. *Petrol Engr*, August 1943, **14** (12), 90.—Continuous circulation of drilling mud through shallower saline beds minimizes and sometimes destroys the spontaneous potential phenomenon when an electrical logging survey is run. This causes difficulties in interpretation, and so has discouraged the use of electrical logging in certain parts of western Kansas.

In practice this difficulty has been overcome by pumping fresh-water mud through the drill-stem from the bottom of the hole, and by using a greater recording range on the recording graph. The fresh-water mud is made up to a higher density than the salt-laden mud fluid in order to prevent mixing.

The troublesome salt beds of Kansas are in the Permian Nippewalla group, Ninnescah shale, and Wellington formation. The most important salt beds are in the Wellington formation, and cover an area 180 ml. from north to south, and 150 ml. from east to west with a maximum thickness of 300 ft.

Two principal effects are involved in the spontaneous polarization phenomenon : (a) electro-filtration and (b) electro-chemical contact effect. The electro-filtration effect arises from the mud filtering from the hole into the formation through the mud cake. The potential so developed is always negative and directly proportional to the mud resistively. It is proportional to the formation permeability. The electro-chemical contact affect depends on the salinities of the mud and formation fluids. It may be positive or negative, and is proportional to the logarithm (Napierian) of the ratio of the chloride concentrations in the two fluids in contact. If the salinity of the drilling mud is greater than the salinity of the formation fluid, the contact potential is positive. In some cases this positive potential may more than offset the negative potential due to electro-filtration, and so yield a positive anomaly.

A case in which the new technique was applied is described in some detail. G. D. H.

1058.* Two-Year Summary of Geodynamic Prospecting Results. S. J. Pirson. *Oil Wkly*, 2.8.43, **110** (9), 23.—During the past two years 2500 stations have been made in over 70 independent geodynamic surveys in 14 different states of U.S.A. and Canada.

Geodynamic prospecting purports to measure the undisturbed rate of hydrocarbon gas diffusion through a measured area of the earth's surface. The permeability of shales and other dense rocks is of the order of 10^{-8} to 10^{-12} Darcy. It is assumed that the ethane and heavier hydrocarbons are not alteration products of organic matter in the soil or sub-soil.

Since methane is the main constituent of marsh gas leakage measurements cannot be based on this gas. Having regard to the nature of the assumptions and the lack of proof or disproof of their validity, the value of the method must be assessed statistically.

Two and often three measurements are made at each station in shallow boreholes 10–20 ft. apart. The precision of a measurement is of the order of 2×10^{-4} c.c. of ethane per day. The rate of flow through an area of half a square foot ranges 5–100 or even 200×10^{-4} c.c./day of ethane. The background values are about $6–8 \times 10^{-4}$ c.c. per day, and only values of 10×10^{-4} c.c./day or more are of interest. So far no well has proved productive in an area within a region of negligible leakage.

The results of wells drilled where geodynamic predictions had been made are tabulated, and some of the contour diagrams of the diffusion rates are presented. G. D. H.

Drilling.

1059.* How to Inspect Drums Used With Wire Rope. A. J. Morgan. *Oil Wkly*. 21.6.43, **110** (3), 31–32.—Three checks are to be made on drums : (1) *Contour*. With plain-faced drums corrugations on the face will cause the same damage to the rope as discussed under sheave materials. Drums which have become corrugated should be

re-machined.   Where the drum shell is too thin it may be lagged with steel plate.   (2) *Symmetry*.   If the drum face is low at one spot the rope will tend to pile up at this point.   The rope coming onto this part of the drum first will wind in too open a wrap, whereas that on the other side of the low spot will wind too tightly, thus causing undue rubbing of adjacent wraps.   (3) *Winding*.   Where grooved drums properly designed for the rope to be used upon them are employed, no winding difficulties are usually encountered when the fleet angles are satisfactory.   Where plain-faced drums are used, however, care must be taken to see that the wire rope winds onto the drum evenly in a continuous loosely closed helix so that one wrap just touched the adjacent wraps. Too-tight winding of rope will cause one wrap to scrub unduly against adjacent wraps, and thereby cause excessive abuse.   With multiple-layer drums too-open winding will allow the upper layers to pull down between wraps of the bottom layers, thus causing scrubbing, pinching, and other excessive abuse of the rope.

Fleet angle is discussed.   This may not exceed 1·5° and not less than 0·5°.   Operating conditions are very briefly discussed.   A. H. N.

1060.* An Instrument for Inspecting Interior Pipe-Wall Conditions.   F. Briggs.   *Oil Wkly*, 12.7.43, 110 (6), 28.—An adaptation of the telescope that was originally designed for inspection of gun barrels now makes it possible to examine the inside walls of tubular goods for defects.   Thus, for example ; it is now possible to determine how each joint of drill-pipe is wearing, thereby continuing much of it for additional service that for reasons of safety might have been discarded previously.   Or, some of the drill-pipe that previously might have been left in service is now junked because of defects revealed by the tubular telescope.

The simple construction of a telescope involves primarily two lenses : the objective or end lens that concentrates the light-beam and the eye-piece lens which magnifies the image.   The instrument for inspecting pipe interiors, familiarly known as the tuboscope, contains both these lenses, plus intervening lenses that tend to maintain the intensity of the light-beam for the length of travel in the telescope tube.   These are known as condensing lenses.   Sections of tube containing three intermediate lenses each can be added to make the tuboscope any desirable length (up to 25 ft.). Just in front of the objective lens is a mercury-vapour lamp attached to the instrument ; this provides light for a longitudinal view of the pipe walls of about 10 ins.   Examination of the entire length of a joint of pipe is accomplished by inserting the lighted end of the instrument into one end for the length of the telescope, and then repeating the same at the other end of the pipe.   Spring centralizers spaced at adequate intervals keep the instrument centred in the pipe.   Right-angle vision of pits and other pipe-wall defects can be obtained by means of a highly polished mirror of stainless steel attached to the instrument between the viewing light and the objective lens, and set at an angle of 45° to horizontal.

Preceding all examinations, the pipe-walls are cleaned thoroughly with rotary wire brushes driven by air pressure.   This air also blows the loose particles from the pipe. After cleaning, the instrument is pushed slowly through the pipe as an inspector examines the inner walls.   If a pit or scar or lap-weld is found, the operator turns the instrument over until he gets the desired object located in the angle mirror.   This permits a vertical view of the affected part, thus giving the operator a closer, more accurate picture.   Should measurements be desired, a small pit-depth gauge can be attached to the instrument.   A. H. N.

Production.

1061.* West Texas Experimental Water Flood Successful.   R. W. Byram.   *Oil Wkly*, 21.6.43, **110** (3), 15–17.—Experimental water-injection operations by Humble Oil & Refining Co. on its Louis Richter lease in the Estes field, Ward County, West Texas, have been sufficiently successful to warrant expansion of the programme.   This conclusion has been reached as a result of tests made during the past year, and is of interest, since it is the first water-flood project of the Permian Basin.   Although only two injection wells have been used, and each of these has put water into different zones, production of the lease has been increased.   Furthermore, tests indicate improvement of bottom-hole pressures in the majority of surrounding wells.   The geology and history of the field's development are given.

The project actually got under way about October 1, 1942, and some favourable results were apparent in recent months. Tests of wells surrounding the injection wells were made in January 1943, and another series of tests was made on 5th April, 1943, or 76 days later. Results of these surveys are indicated. Significantly, fourteen of the eighteen wells tested showed material pressure increases. Pressure losses were indicated in four wells, but two of these were shut in for several days before the first test and for only 48 hrs. prior to the later test. The remaining two were east-edge wells with offset producers, some distance from the injection wells, indicating a normal pressure decline. The average increase in pressure for the 76 days was 70 lbs. or almost 1 lb./day, excluding the two wells which had variation in shut-in time. The results are excellent when it is noted that these are stripper wells producing from a gas-driven reservoir.

While the evidence is not conclusive, it seems probable that if the programme were extended to other leases in the field, productive capacity of the poorer wells would be raised, and the ultimate recovery of the field increased materially. Such a programme would require a regular pattern of injection wells if the most efficient results are to be obtained. Expense of the experimental operation indicates that costs would be reasonable. A total of 123,122 brls. of water had been injected by 1st April, 1943, at a total cost of $1,631.54, or 1.3 cents/brl. This included the cost of electricity generated by the lease plant; without this charge the cost could be reduced to 1 cent/brl.

A. H. N.

1062.* Significance of Secondary Recovery In the United States. P. D. Torrey. *Oil Wkly*, 21.6.43, **110** (3), 18. *Paper Presented before American Association of Petroleum Geologists.*—This paper forms the first section of a symposium on secondary recovery which is to include four papers. Secondary recovery is defined, in accordance with A.P.I. definition, as the oil, gas, or oil and gas recovered by any method (artificial flowing or pumping) that may be employed to produce them through the joint use of two or more well-bores. Secondary recovery is generally recognized as being that recovery which may be obtained by the injection of liquids or gases into the reservoir for the purpose of augmenting reservoir energy; usually, but not necessarily, this is done after the primary-recovery phase has passed.

From this definition it will be appreciated that there are four fundamental requirements for the application of secondary recovery methods : (1) An injection well and (2) a producing well or wells all drilled into (3) a common porous oil-, gas-, or oil-and-gas-bearing formation through which (4) liquids or gases are forced under artificial pressure for the purpose of increasing oil recovery. The importance of secondary recovery is discussed in some detail.

The influences of geological factors are studied. The accumulation of oil in many of the fields in which secondary recovery methods have been employed in the past has been controlled by lenticularity of the reservoir rock—*i.e.*, they are stratigraphic-trap type fields. As such, many of them have not received the benefits of active, natural water encroachment, and the oil has been produced by internal gas-drive, generally regarded as being the least efficient natural reservoir performance. In addition, it should be kept in mind that most of the existing secondary-recovery operations are located in the older fields, which were produced initially at times when little attention was given to the conservation of reservoir energy. In consequence, the solution gas was extravagantly wasted, and when this propulsive agent was dissipated, subsequent production could come only from gravitational drainage. The oil left in the reservoirs by these early, inefficient primary-recovery operations is the oil which is now available for the application of secondary-methods.

Some clue as to the adaptability of a field to secondary-recovery methods can be gained from an analysis of past reservoir performance. If natural water encroachment has been active and uniform, the residual oil content, after the primary period of production has passed, will probably be too low to permit profitable secondary-recovery operations. The effectiveness of natural water encroachment should not be taken for granted unless production records are available to confirm a high degree of recovery efficiency. Frequent instances are known where water has migrated rapidly through relatively thin zones of high permeability, and has drowned out the wells by the formation of water zones, leaving most oil unrecovered in the less permeable strata. A field in which such conditions exist can be regarded as a favourable prospect for the

application of secondary-recovery methods, provided the offending strata of high permeability can be plugged off successfully.

The problem met in fields of divers ownership are briefly indicated. The paper then deals with prospective areas of the U.S. adaptable for future secondary recovery.

A. H. N.

1063.* Flowing Water-Flood Production. T. F. Lawry. *Oil Wkly*, 12.7.43, **110** (6), 46. *Paper Presented before American Association of Petroleum Geologists.*—This is the fourth part of a symposium on secondary-recovery. There are two departures necessary from conventional water-flood operations before flowing may be said to be successful. These are : (1) Delayed drilling of oil-wells, and (2) cementing of packers in both oil- and water-intake wells. Delayed drilling has been a controversial production method, at times highly favoured, and at other times being little regarded. It involves the drilling of water-intake wells first with simultaneous water injection into the sand being flooded. When the intake wells have filled the sand until it may be said to be 10% fluid saturated, the intake rate on the water wells will suddenly fall, giving the operator a signal that the sand has approached complete fluid saturation and is ready for the drilling of producing wells. One objection to delayed drilling is that the oil-wells come in almost wild and may waste substantial quantities of crude. However, this is almost unavoidable, because sand conditions are not uniform enough to permit an even flood-front to be maintained throughout the sand from the time the first water is injected until the oil-well is ready to flow. Consequently, if oil- and water-wells are drilled simultaneously, a back flood of oil or water from the more permeable streaks upon the less permeable streaks will result in the oil-well and delay the entire flood. The reason for the second departure is evident, but is briefly discussed.

The advantages of flowing over pumping are many, but the chief point is economy. Since flowing utilizes some of the energy imparted to the intake water, the mechanical elements for a flowed flood are very simple—just the water-pressure plant. No powers or individual pumping units are required ; there are no jacks and surface rods to be kept greased and aligned, nor is there a string of sucker-rods and working barrels with their valves coming unscrewed, broken, and requiring frequent repair. Aside from the mechanical simplicity of flowing, the lesser cost of materials and the fact that much material is not tied up on one job for a protracted period provide further advantages.

Still another real advantage that flowing has over pumping is the reduction in time and number of men required for installation and maintenance of equipment. It usually requires an experienced crew to build powers and run rod-lines and set jacks. In addition, still another gang is always needed to pull the rods and tubing on pumping-wells. Also, the pumper has to act as nursemaid to a balking engine and oiler to a thousand places that the switcher on a flow job never gives a thought about.

The chief argument against flowing is the back pressure imposed on the sand. Operators who thoroughly appreciate the merits of flowing acknowledge the fact that back pressure on the pay does exist, but, on the other hand, instances are cited where old natural floods, operating at less than hydrostatic head for the depth of the sand, and with low intake rates, permitting prolonged back pressure on the sand, have reduced residual saturation below that possible with the forced water-drive. Some credence is now being given to the idea that limited withdrawal can recover more oil than a normal flood, for the reason that it usually operates at lower intake rates. Certainly the criterion of a successful flowing flood is not that it operates at greater pressure than any other. Another objection to flowing is the necessity for cementing the tubing in the hole. This can be refuted when full realization is given to the fact that nothing mechanical can possibly go wrong down in the hole. If cement-lined tubing is used, there should be no trouble from internal corrosion. If the hole below the packer should cave, an insert string of ½ or ¾-in. pipe can be used to wash the hole, or if mechanical failure of the pipe would necessitate replacement, a companion string of left-hand thread-pipe can be used to fish the faulty pipe out down to the defect, after which the original may be replaced and made whole.   A. H. N.

1064. Fitting Pumping Practices to Individual Wells Yields Best Results. H. F. Simons, *Oil Gas J.*, 15.7.43, **42** (10), 41.—Oil-wells encounter widely different conditions in the pay, and variations in completion methods often cause their response to pumping to

vary from the expected behaviour. A few examples are given which show the losses which may result from absolute conformity to general practice in all cases. Under a number of formational conditions, it may be well to discard, or at least modify, the rule about never exposing the sand-face. As an example, a well with a pay formation containing productive strata alternating with non-productive porous strata or water-productive zones separated by impervious streaks might lose considerable production by not exposing the sand-face. If the non-productive porous zones contain no pressure, the oil can flow into the well-bore and then flow out again. If there is water in one or more of the zones intermingled with the oil-pay strata, the water flows into the well-bore, and, if it carries a slightly greater pressure, movement of oil into the well-bore is retarded. Or, the rate of flow of the water-bearing zone may be slightly higher than the oil-producing zone, and consequently the well fills up with a fluid which is mostly water.

One permian basin superintendent was able to boost his production from a lease from around 7 brls. to 18 brls./well, by recognition of this condition. Gas-lift was being used to produce the wells, and he lowered the standing valve and accumulation chamber to as near bottom as possible. He also decreased the time between injections of lifting gas controlled by the intermitter. By the time ½ brl. of fluid accumulated in the well-bore, opening of the gas-lift valve lifted it to the surface. In this case it was possible to disregard the lifting gas–oil ratio, as the gas supply was obtained from a well on the lease, and after returning to the surface along with the oil it was separated and sold. In other words, there was no charge for the gas, as it was merely used while en route to market.

There are corrective techniques available for shutting off water, thief-zones, caving sections, and sand coming into the well with the production. However, where the well's production is small, the investment required to effect a positive correction is often out of proportion. Another difficulty is the establishment of the true and exact conditions. When one is attempting to shut off either a thief or water-bearing zone, the exact location of the zone must be known. If the zone is only a foot in thickness, several attempts may be required to seal it off with affecting the oil-productive capacity of the well. Because the economic margin is small, the operator is limited in what he can do in the way of actual repair work, whereas alleviation or control steps are within his means.   A. H. N.

1065. Sucker-Rod Pumping System. J. Zaba. *Oil Gas J.*, 15.7.43, **42** (10), 67.— Pumping systems are classified. Sucker-rod pumping is similarly classified, and the pumping motion is analyzed for an ideal pumping cycle. With pump immersed in fluid, which is a necessary prerequisite for its operation, the upward motion of the plunger on the beginning of the upstroke results in closing the travelling valve, because of the weight of the fluid above the plunger in the tubing. At the same time, because of the upward movement of the plunger, a decrease in pressure is created under the plunger in the working barrel, which results in the outside fluid opening the standing valve and entering and filling the space in the working barrel under the plunger. When the motion of the plunger is reversed after the top of the stroke has been reached, the weight of the column of fluid is placed on the standing valve, closing it. At the same time, opening the travelling valve permits the plunger to travel downward, through the fluid, to the point of beginning of the cycle. One of the most important characteristics of this cycle is the transfer of load of fluid in the tubing from tubing to sucker-rods on the upstroke and from sucker-rods to tubing on the downstroke. Deviations from the ideal stroke are discussed.

Loads are next analysed, particular attention being paid to vibrations. In case of sucker-rod strings two sets of vibrations are present : (1) those resulting from the pumping motion of the sucker-rods ; (2) the natural vibration of the sucker-rod string. It is apparent that from the standpoint of the loads involved non-synchronous conditions for these two sets of vibrations are desirable. With velocity of stress transmission in sucker-rods as 15,800 ft./second in mind, Slonneger derives the formula for the frequency of vibration of sucker rods

$$F = 237,000/D$$

where F = frequency in cycles/minute, D = length of rods in feet. For instance, for a sucker-rod string 4000 ft. long the frequency of vibration of the rods would be

$237,000/4000 = 59.25$ cycles/minute. If the frequency of the pumping motion is the same—that is, 59·25 cycles/minute (strokes/minute) conditions of synchronous vibration would exist.

If the impulses are added at intervals which are equal to the natural frequency, then the vibrations are defined as " first-order vibrations." They are most severe, since each wave is augmented by new energy. " Second-order vibrations " are those in which impulses are added with frequency equal to half the natural frequency, etc. In the above example the speeds of 29·62, 19·75, etc., strokes/minute would be synchronous for a 4000-ft. string of sucker-rods and the vibrations would be of second, third, etc., order. Above and below those speeds the vibrations are non-synchronous. A chart, based on Slonneger's formulae, gives the synchronous and non-synchronous speeds with well depths.   A. H. N.

1066. Calculation of Well-Repair Expense. E. H. Short, Jr. *Oil Gas J.*, 22.7.43, **42** (11), 25.—The author compares well-repair expenses calculated in terms of cost/barrel with cost/polished-rod horse-power hour of operation. While pump expense has been used as an example, the polished-rod horse-power hour unit of cost appears to offer also a more accurate method of evaluating well-repair expense than cost/barrel, when applied to the operation of tubing, sucker rods, pumping unit, and engine. In the case of engine operation the loss through the transmission equipment must be added to the polished-rod horse-power.

In subsurface-equipment operation the accuracy of the polished-rod horse-power method is dependent on the application, and a comparison can be only approximate unless the characteristics of the well are the same. Obviously there is a need for an equation which considers both polished-rod horse-power and corrosion. However, at the present time the technique in determining the relative corrosiveness of well-fluid is unsatisfactory and the usual sulphide classifications are shown simply as light, medium, and heavy. Where comparisons in pump expense are to be made on a polished-rod horse-power hour basis, until sufficient data are assembled to arrive at an empirical figure or factor to be used in the polished-rod horse-power equation which will give due consideration to the additional pump wear encountered in wells pumping from a sand horizon, such comparisons must be confined to wells in the same producing classification, *i.e.*, sand or lime.   A. H. N.

1067. Sucker-Rod Load Measurement. J. Zaba. *Oil Gas J.*, 22.7.43, **42** (11), 34.— The three types of dynamometers, hydraulic, mechanical, and electrical types, are briefly described. The ideal card is then discussed, and distortion of the card by friction, deadweight, and vibrations is studied. Finally, the dynagraph is described. The pump dynagraph determines the load on the plunger by recording the stretch of a calibrated rod installed in the sucker-rod string above the pump and coupled to the pull-rod of the pump. The record is made on a thin recording tube, enclosing the calibrated rod and fastened to one of its ends through a nut threaded on to the rod. The record is made by a stylus attached to a rotating tube. This tube encloses a portion of the recording tube, and is set in a bearing on the other end of the calibrated rod. Thus any stretch of the rod causes the stylus to make a vertical line on the recording tube. At the same time the rotating tube, with the stylus, is made to rotate around the recording tube in a horizontal motion, proportional to the vertical recipro-cating motion of the plunger. This rotating motion is caused by two spiral grooves in the rotating tube and two lugs, mounted at the upper end of the third tube, the cover tube. The cover tube, being attached to the pump body, is stationary. With reciprocating motion of the sucker-rods, the lugs of the cover tube ride in the spiral grooves of the rotating tube, causing this tube to rotate in a horizontal oscillating motion. For one complete motion of the plunger, therefore, the stylus makes a horizontal line on the recording tube. The resultant of the vertical motion of the stylus (due to calibrated-rod stretch) and of the horizontal motion (due to rotation of the stylus) is the pump dynagraph card. The card shows loads on plunger in relation to its position. By turning the rods at the well-head, the recording tube may be moved up on the calibrated rod, making possible recording of several cards without pulling the instrument out of the hole. The rotating tube, after being taken out of the instrument, on completion of the test, is flattened into a sheet for inspection and reading of the card.   A. H. N.

1068.* Shallow Wells Cleaned With Air and Water through Tubing. F. B. Taylor. *Oil Wkly*, 2.8.43, **110** (9), 13–14.—Regular equipment for this means of cleaning out includes a two-stage air compressor, preferably driven by a gasoline engine. While the 600–700 lb. usually available with a two-stage compressor is not used in a routine clean-out operation, it is desirable to have this pressure at hand in case of need. A chamber suitable for compressed air storage, either mounted upon the same frame or mounted as a unit, is required. One operator has used a short length (about 16 ft.) of 12-in. casing, orange-peeled at both ends, and with $1\frac{1}{2}$-in. connections set into the welds. This, including $1\frac{1}{2}$-in. pipe swings to afford flexibility in locating the units with respect to each other, is mounted on a light frame and wheels so that it may be trailed to any location.

A string of $\frac{1}{2}$-in. equivalent to the depth of the well is also needed, as is an adapter between the $1\frac{1}{2}$-in. and the $\frac{1}{2}$-in. This is easily made from a $1\frac{1}{2}$-in. collar, welded in an orange peel and cut through the centre for the insertion of a short, $\frac{1}{2}$-in. nipple. A tee on the $1\frac{1}{2}$-in. above the well-head serves as an outlet for the cleanings from the well. In operation, air pressure at 100–150 lb. is fed into the well through the macaroni string after it has been lowered to a position opposite the face of the pay. There should be some water in the hole, and this is usually available from the formation, of, if necessary, by injection from the surface. Agitation produced by the air pressure escaping through perforation near the bottom of the $\frac{1}{2}$-in. blasts the water against the face of the formation and into any accumulations of cavings. The air escaping up the annular space between the $\frac{1}{2}$-in. and the $1\frac{1}{2}$-in. carries the dirt to the surface. It is usually desirable to keep the bottom of the $\frac{1}{2}$-in. closed, particularly if most of the force is to be directed against the side of the hole. A. H. N.

1069. The Permeability of Porous Solids to Gases and Liquids. L. Grunberg and A. H. Nissan. *J. Inst. Petrol*, August 1943, **29** (236), 193–225.—Permeability to gases is dependent mainly on Reynolds' number, which at small values gives rise to maxima and minima. For higher values of Reynolds' number, but preceding the turbulent regime, permeability assumes a constant value corresponding to viscous conditions. Thus for low rates of gaseous flow in rocks, tests should be carried out at Reynolds' numbers corresponding to those obtaining underground. The " Reynolds' number " may be taken simply as the volumetric rate of flow/unit area of sand, the area being perpendicular to the main line of flow. In other words, the mean linear speed of the gas is taken as the " Reynolds' number." It is further recommended that tests be carried out under a mean pressure equal to that existing underground.

Permeability to liquids is dependent not only on the viscosity, but also on other properties of the liquid which cause a variation in the effective cross-section of the pores under viscous flow. The coefficient of permeability assumes different values for different liquids having different surface-tension values. A single curve was obtained for the different liquids used by plotting against the criterion $\left(\dfrac{\mu^2}{\rho\sigma}\right)$. The permeability also varies with the temperature for the same liquid, but a correction for this can be obtained for each liquid : $K = a - b^\circ t$ C. A. H. N.

1070.* Design of Tapered Sucker-Rod Strings. E. N. Kemler. *Oil Wkly*, 2.8.43, **110** (9), 31–32.—Formulæ are derived and used to calculate the proportion of each size of sucker-rods to be used in mixed strings. The formulae are derived from consideration of acceleration loads. The determination of proper proportions in sucker-rod strings is partly a case of analysis and partly a case of checking performance in the field. Unfortunately, it is not easy to determine proper proportions of sucker-rod strings in all cases from field records, the reason being that a failure in the upper part of the string results in dropping of the entire string. This might cause over-stressing of the upper end of the smaller rods. Such over-stressing might then result in a large number of failures in the smaller rods. An interpretation of the failure record would, under these conditions, indicate that there is an insufficient number of larger rods.

The results of the analysis are tabulated. The proportions are independent of the well-load. A. H. N.

Gas.

1071. Diethylene Glycol Absorbent for Hydrate Removal. Anon. *Refiner*, May 1943, **22** (5), 139.—Removal of entrained moisture and water vapour from natural gas is being successfully and inexpensively accomplished by a large utility company in a small specially designed semi-automatic plant employing diethylene glycol as an absorbent. The gas is produced from a formation carrying large quantities of water around the edges of the field and in the lower sections of the zone, which causes all of the fuel to be wet in the sense that excessive water vapour is suspended or absorbed. Pipe-line drips between the dehydrating station and the wells in the field accumulate the remove condensate and free water, but are, in themselves, not adequate to condition the gas fully for pipe-line transmission.

To prepare the pipe-line to receive the dehydration plant, a section was removed and replaced with a master gate and a by-pass manifold which includes the absorption-column piping. The column acting as the absorber has sufficient baffles and bubble plates to insure adequate contact between the gas and the absorbent. The flow of gas is conventional, entering the base of the column and passing out at the top, both inlet and outlet being served by short lines to prevent excessive use of pipe and fittings. A direct-connected outside-mounted float cage and control valve maintain a level of the absorbent in the column, perhaps one-third the distance from the base to the top, so that a turbulent contact can be obtained between the gas and the diethylene glycol. The glycol is regenerated, freed from water, and recirculated. A. H. N.

1072. Normal Butane. R. C. Alden. *Refiner*, May 1943, **22** (5), 145–147. *Paper Presented before Natural Gasoline Association of America.*—The use of normal butane as a raw material for producing aviation fuels and aviation fuel-blending agents is discussed. A. H. N.

1073. Nomograph for P-V-T Relations of Gases below the Critical Point. G. W. Thomson. *Industr. Engng Chem.*, 1943, **35** (8), 895.—A nomograph is presented which enables the compressibility factor and fugacity of a gas to be calculated from the reduced pressure and temperature. J. W. H.

1074. Volumetric Behaviour of Methane. R. H. Olds, H. H. Reamer, B. H. Sage and W. N. Lacey. *Industr. Engng Chem.*, 1943, **35** (8), 922.—Data are presented for the volumetric behaviour of methane over the temperature range 100–400° F. and at pressures up to 10,000 p.s.i. The results show complete agreement with previously published data up to pressures of 4500 p.s.i. Above this pressure the deviation only amounts to 0·25%. Since the sources of the methane and experimental procedure varied in the several investigations, it is concluded that the behaviour of this gas has now been established. J. W. H.

Refining and Refinery Plant.

1075. Use of Interrupting Devices in the Clearing of Electrical Circuits. W. A. Holland. *Refiner*, July 1943, **22** (7), 211–212.—Because there is always the possibility of a fault, a short circuit, in any electrical circuit, interrupting devices are necessary to clear such faults which might otherwise damage equipment. The interrupting device must have adequate " IC " (interrupting capacity) to clear the circuits safely and quickly, and must also have sufficient momentary capacity to withstand the effect of the maximum short-circuit current the circuit can develop.

It is necessary to know how to calculate the short-circuit current, and the paper described a simple method for doing it. Ratings and reactances of the machines involved must be known (data on generators, transformers, and motors can be obtained from their manufacturer); and also the reactances of circuits (calculated from rules not given in the paper). A. H. N.

1076.* Countercurrent Multitubular Heat Exchangers. M. G. Larian. *Industr. Engng Chem.*, 1943, **35** (8), 840.—The theoretically correct equation for the calculation of heat transfer in exchangers of this type is compared with various methods which have

been proposed, from the point of view of simplicity and accuracy. It is shown that for the prediction of film coefficients the Sieder–Tate graphical correlation should be used for Reynolds' Numbers less than 8000, and that at values above 8000 with this method or the Dittus–Boelter correlation there are serious discrepancies. J. W. H.

1077.* Power Consumption of Propeller-Type Agitators. C. E. Stoops and C. L. Lovell. *Industr. Engng Chem.*, 1943, **35** (8), 845.—A discussion is presented covering the theoretical factors governing the power requirements of agitator systems. By means of an agitator fitted with a torque-type dynamometer, a description of which is given, the effect of the variables, propellor diameter, shaft speed, liquid density, viscosity, liquid depth, and propeller depth have been investigated. It is shown that the experimental data obtained can be correlated in the form of a dimensionless equation the constants of which have been evaluated. Attention is directed to the fact that no critical value is found for the modified Reynolds' number term, and that the Froude factor (wave formation term) may be neglected. J. W. H.

Chemistry and Physics of Hydrocarbons.

1078. Hydrogen Fluoride, The Catalyst. Part 2. J. H. Simons. *Refiner*, July 1943, **22** (7), 189–193.—The catalytic power of hydrogen fluoride must be related to its chemical and physical properties. Those that probably govern its action in organic chemical reactions are its solvent power, its high dielectric constant, its high acidity, its great dehydrating tendency, the insolubility of the other halogen halides in it, and its great tendency to combine with itself and other substances to form molecular complexes.

The effects of anhydrous hydrogen fluoride on glass, wood, paper, human tissues, etc., has been a hindrance to its use. These effects are explained. The effect on siliceous materials is due to the formation of the gaseous silicon tetrafluoride, which escapes the site of the reaction, and thus allows it to proceed. The effect on things like wood and paper is primarily a dehydration, for hydrogen fluoride is a powerful drying agent. On rubber and many unsaturated organic chemical substances the effect is due to the powerful polymerizing action of hydrogen fluoride. The effect on human tissue is due to the fact that this very acidic substance is readily absorbed, and both the hydrogen ions and the fluoride ions are toxic.

In view of the powerful polymerizing power of hydrogen fluoride, it is very surprising that it can be used as a catalyst for organic chemical reactions to prepare desired products in very good yields and without the formation of any appreciable amount of unwanted polymers. As soon as it was demonstrated that this was possible and conditions for doing it were found and described, the way for laboratory experimentation on organic chemical reactions was opened. The advantages of hydrogen fluoride over other agents for the same or similar purposes from an engineering point of view then attracted the interest of industry. One of the reactions for which hydrogen fluoride was found to be an effective catalyst is the one known as alkylation. This is essentially the preparation of a product that contains one or more alkyl or paraffinic groups in its molecules than were in the molecules of the source material. It was found that a great variety of source materials could be alkylated, and also that a great variety of materials to supply the alkyl groups could be used. Among the latter are alkyl halides, olefins, alcohols, esters, ethers, etc. Examples of alkylation are studied to illustrate the chemistry of the reaction. Hydrogen fluoride can be used as the catalyst for certain other reactions which are related to alkylation and acylation. Examples of these are ring closures and rearrangements. An example of the latter is the Fries change. A similar type of reaction is a variation of an exchange reaction. Examples of these as catalyzed by hydrogen fluoride are : *tert.*-butylbenzene reacts with phenol to form benzene and *para-tert.*-butylphenol, benzophenone oxime rearranges to benzanilide, phenyl acetate rearranges to *para*-hydroxyacetophenone, *para*-cresylbenzenesulphonate rearranges to 2-hydroxy-4-methyldiphenylsulphone.

Hydrogen fluoride is also a useful catalyst for reactions not directly related to alkylation and acylation. For example, it is very effective in aiding sulphonation. Benzene reacts with sulphuric acid in the presence of hydrogen fluoride to form benzenesulphonic acid. At higher temperatures dephenyl sulphone is formed. Mixed sulphones can be formed by treating a sulphonic acid with another organic compound

in the presence of hydrogen fluoride. An example of this is the treatment of toluene with benzenesulphonic acid to form the mixed sulphone, *para*-tolylphenylsulphone. Hydrogen fluoride also catalyzes nitration. Nitric acid reacts with benzene at sub zero temperatures to form mononitrobenzene. Further nitration is not accomplished at the low temperature. Benzene is here used as an example of a reactant. Other substances can be sulphonated and nitrated, using hydrogen fluoride as the catalyst.

Hydrogen fluoride is also an effective catalyst in the formation of esters. Esters of acetic and butyric acids have been made by the reaction of these acids with olefins, using hydrogen fluoride as the catalyst. Ethyl acetate was also made by the reaction of acetic acid and ethyl alcohol. The reverse action—that is, the reaction of water with ethyl acetate to form ethyl alcohol and acetic acid—is also catalyzed by hydrogen fluoride. The formation of ethers, carboxylic acids, etc., is studied. The catalytic action of hydrogen fluoride is compared with that of aluminium chloride. A tentative mechanism is postulated. A. H. N.

1079. The Phase Transformations of Normal Paraffins. C. G. Gray. *J. Inst. Petrol.*, August 1943, **29** (236), 226–234.—Pure normal paraffins are found to crystallize in at least four distinct modifications : (α) hexagonal system ; (β) orthorhombic system ; (γ) an uncertain system which may be monoclinic or triclinic ; and (δ) another uncertain system which may be either monoclinic or triclinic, but distinct from (γ). Theoretical considerations lead to the formula $T = A - B/(n - 1)$ for the relationship between melting point and number of carbon atoms in those n-paraffins in which the α form is stable at the melting point. The formula is applicable over the range $n = 20$–36 inclusive, and is in excellent agreement with observed values. Above C_{36} the relationship between melting point and number of carbon atoms is of a different type, and the curve for melting point in this zone continues as a transition ($\alpha \leftarrow \rightarrow \beta$) in the solid phase below C_{36}, suggesting that the β form is stable at the melting point above C_{36}. The upper transition line in the zone $C_{20} - C_{28}$ is probably the continuation, as a transition ($\alpha \leftarrow \rightarrow \gamma$) in the solid phase, of the γ melting-point curve for even paraffins below C_{20}.

An equilibrium diagram is given for the melting point and solid-phase transitions of normal paraffins. A. H. N.

1080.* Design for Hydrocarbon Absorption and Stripping. W. C. Edmister. *Industr. Engng Chem.*, 1943, **35** (8), 837.—A new method is described for the solution of absorption and stripping design problems. This method is more accurate than the Kremser–Brown absorption-factor method when compared with the result obtained from a plate-to-plate calculation. J. W. H.

1081.* Heats of Vaporization. D. H. Gordon. *Industr. Engng Chem.*, 1943, **35** (8), 851.—A correlation is presented which enables the latent heat of any substance at any temperature to be calculated from a knowledge of the ratio of the critical temperature to that of water or other reference substance, the latent heat of which is known. J. W. H.

1082.* Composition of Commercial Hexane. J. Griswold, C. F. Van Berg, and J. E. Kasch. *Industr. Engng Chem.*, 1943, **35** (8), 854.—Data are given for the composition of a commercial hexane cut. These data have been obtained by the removal of benzene by nitration, and a separation of the cut into paraffins and naphthenes by extraction with aniline. The products from this extraction have been distilled in an efficient column to yield close boiling cuts, the physical properties of which have been determined for the calculation of composition. It is shown that the removal of the naphthenes greatly increases the degree of separation obtained. J. W. H.

Synthetic Products.

1083.* Brittle Points of Natural and Synthetic Rubber Stocks. R. E. Morris, R. R. James, and T. A. Werkenthin. *Industr. Engng Chem.*, 1943, **35** (8), 864.—A new apparatus for the determination of the brittle point of synthetic rubbers is described.

The method is considered to be of greater practical significance than previously described slow bend brittle tests.

Comparative results on the new apparatus are given for a large number of synthetic and natural rubbers, and the effect of softeners has been investigated.   J. W. H.

Analysis and Testing.

1084. Developments in the Analysis of Hydrocarbon Gases by Means of Adsorption Fractionation. N. C. Turner. *Refiner*, May 1943, 22 (5), 140–144. *Paper Presented before Natural Gasoline Association of America.*—The method uses an adsorption column to adsorb the gas and a travelling heating device around the column to liberate the gas, which is then measured, and the plotted results give a quantitative picture of the components of the gas. The gas is driven by mercury. The sample of gas is introduced through a flow-meter into the bottom of the column. The flow-meter is used to estimate the quantity of sample taken. The best quantity to use depends somewhat on the nature of the gas, ordinary dry natural gas requiring about a 5-litre sample. After the sample is introduced, the sampling stopcock is closed and the one leading to the mercury reservoir is opened. A single switch on the panel board starts the operation, which, from this point, is fully automatic. The pulling of the switch turns on the heater, which remains stationary until the temperature reaches 750° F. At this point the elevating mechanism goes into operation and the heater gradually rises at a predetermined rate which was set on the instrument panel before the apparatus was put into operation. This rate is such that the heater travels the entire length of the column in about 8 hrs. On reaching the top of the column, the heater remains stationary for 20 mins, during which time hydrogen is introduced in the top of the column to act as a purge for the thermal conductivity cell, volumeter, and connecting tubing. At the end of this time the heater returns to the bottom of the column at an accelerated rate. Also, the mercury level in the column returns to the bottom of the column. Hydrogen follows the receding mercury, and is present in the column when the next sample is charged in. The hydrogen is generated electrolytically by the apparatus. Details of temperatures and other experimental conditions obtaining during measurements are given.

The work thus far has been largely confined to mixtures of hydrocarbons containing nothing heavier than hexane. Analysis of mixtures containing known quantities of hexane have demonstrated that this hydrocarbon can be adsorbed in the column and quantitatively recovered in the distillation. Similar runs made with samples containing known quantities of heptane and heavier hydrocarbons show that these heavier hydrocarbons cannot always be completely distilled from the column. The charcoal used in all of these, however, was full 40-min. activity. Preliminary experiments indicate that the retentivity of the charcoal can be reduced by the deposition of salt on capillary surface of the carbon, so that hydrocarbons as heavy as decane can be quantitatively removed. The work on this phase of the problem is still in progress, and it is too early to reach any final conclusions, but the results so far indicate that there will be no difficulty in handling mixtures containing hydrocarbons as heavy as decane. The highest-boiling hydrocarbons which can at present be actually separated are pentane and hexane. Thus, hexane and heavier hydrocarbons will be determined as a single group.   A. H. N.

1085. Gas Analysis by Means of the Mass Spectrometer. O. L. Roberts. *Refiner*, May 1943, 22 (5), 149–151. *Paper Presented before American Petroleum Institute.*— The paper described very briefly the principles and operation of the mass spectrometer. If each of the molecules of a mixture of gases is electrically charged with a single positive charge, and if each of these charged molecules is set in motion by virtue of the attraction of a nearby negatively charged body. then these moving positively charged molecules or positive ions constitute an electric current. If these positive ions are made to traverse a path through a magnetic field of uniform strength, then each ion will be deflected, and the amount of the deflection will be a function of the mass of the molecule. By this means a stream of molecules of different masses can be separated according to their mass.

In the instrument the gas is admitted into a chamber. A small fraction of the gas is

M M

given a positive charge due to bombardment by electrons which are liberated from a heated filament. The energy of the bombarding electrons is high enough to break some of the molecules into fragments which are also positively charged. The positively charged ions are accelerated towards the electrodes, and after passing through these electrodes enter the semi-circular analyzer tube with a high velocity. The externally applied magnetic field deflects these positive ions, and, by varying the electric field ions of each mass, can be caused to impinge on the collector electrode. At this point the number of ions which reach the collector/unit of time is measured by a recording mechanism. The record produced is a series of peaks which are graphical representations of the relative amounts of ions of each mass. The analysis of the mixture can be determined if the instrument has previously been calibrated with pure compounds. For any given hydrocarbon the particular fragments formed, and the ratio of the amounts of the particular fragments formed, are functions of the number and configuration of the atoms in the molecule. It is imperative that the design and construction of the instrument be such that the spectrum obtained from each component of the mixture be a function of the percentage of each component in the mixture.

Since the record produced by the instrument for a gas mixture is a summation of all the individual components present in the mixture, if the spectrum for a pure hydrocarbon is known, its contribution to the composite gas mixture spectrum can be determined. Interpretation of the composite gas-mixture spectrum involves separating the individual contributions made by each of the components and determining the amount of these contributions. The interpretation of spectra obtained from mixtures containing light hydrocarbons is relatively simple, and the complexity of the interpretation increases as the molecular weight of the hydrocarbons increases. At present the mass spectrometer has analyzed mixtures containing C_8 hydrocarbons, although not all the C_6, C_7, and C_8 hydrocarbons have been determined. Before this can be done pure hydrocarbons must be obtained for calibration purposes. A 10-component mixture containing methane, ethane, ethylene, propane, propylene, normal-butane, iso-butane, iso-butylene, butene-1, and butene-2 requires less effort in interpretation than would a mixture of five isomeric C_6 hydrocarbons. The difference in ease of computation lies in the fact that in the first mixture many of the components can be determined separately, whereas in the latter mixture the determination of the composition of the mixture requires the solution of five simultaneous equations. In general, an experienced operator and computer who is confronted with making gas analyses of all types would average about 2 hrs./sample. This includes the time of running the instrument and computation as well as making the determination. Many samples containing hydrocarbons from C_1 to C_4 inclusive can be analyzed in about $\frac{1}{2}$ hr. One-tenth of a ml. of gas is ample for several check determinations and analyses.

A. H. N.

1086. A Simplified Lubricating Oil Oxidation Stability Test. R. E. Hersh, N. D. Lawson, E. F. Koch, M. R. Fenske, and C. E. Stevenson. *Refiner*, July 1943, 22 (7), 197g205.—A discussion of the requirements to be fulfilled in an oxidation test before it can be considered for general use is made. The importance of making the test and the conditions under which it is made representative of engine deterioration are stressed. The apparatus and the thermostat are described in detail. The oil charge, $100\cdot0 \pm 0\cdot5$ gms. ($0\cdot22$ lb.), is placed in the oxidation tube together with the sheet-iron and copper-wire catalyst prepared as described in the paper. The tube is then placed in a well in the thermostat, the air-inlet tube with two lacquer slides and the thermocouple are then inserted, and 1 hr. is allowed to bring the oil approximately to the oxidation temperature (347° F. or 175° C.). During this time no air is bubbled through the oil. The end of the hour allowed for warming-up is taken as zero time for the start of the run, and the air rate is then adjusted to 10 litres/hr. The oil temperature is measured and recorded at least once in every eight-hour period. In determining the average oil temperature during the run, values measured before the end of the first hour of oxidation are not used. At the end of the oxidation period the air inlet tube and lacquer slides are removed and the effect of oxidation is measured in terms of the following five factors : (1) lacquer formation ; (2) oil-insoluble matter ; (3) oil-soluble, isopentane-insoluble matter ; (4) viscosity increase ; (5) neutralization number.

As a preliminary step in the analysis of the oxidized oil, it is necessary to provide a

clarified oil sample, or one which has been substantially freed from oil-insoluble material. This operation is performed by filtration through Corning fine porosity (F) sintered glass filters (suitably those of 30-millilitres capacity). Filtering is done at least 24 and not more than 72 hrs. after the oxidation has been completed. Just before clarification, the oil is vigorously agitated, so that a representative sample, including oil-insoluble material, may be filtered. About 40 millilitres of clarified oil are required for subsequent tests. This filtered sample will be referred to as the "clarified oil." The determination of the five criteria is discussed fully. Correlation with a Chevrolet Engine Test is also discussed. The correlation obtained in this work appears to be sufficiently satisfactory to warrant the use of the simplified stability test as a supplement to the full-scale engine testing of oils. The proposed use of the laboratory unit would be to classify the oils roughly as to their relative usefulness in the service for which they are tested. Some oils could immediately be judged unsuitable, while for others it may be desirable to impress more severe conditions in order to determine their suitability prior to subjecting them to full-scale engine or similar service tests.

A study is made of the effects of changing certain test conditions, *e.g.*, temperature or time. Finally, the application of the test for other purposes—study of corrosivity of oils on certain metals, or study of effects of oxidation inhibitors—is discussed.

A. H. N.

Motor Fuels.

1087. An Empirical Relation between Octane Number and Molecular Structure. A. Mibashan. *Refiner*, July 1943, 22 (7), 195–196.—A relation was found connecting the octane numbers of paraffin and straight-chain mono-olefin hydrocarbons with their molecular structure. The molecular structure is represented by the centralization index, which varies with the length of the chain, the kind and the position of the side-chains, and the position of the double bond. The method of calculating the centralization index is given, and the relationship between centralization index and octane number for a number of paraffins and straight-chain mono-olefins is demonstrated in tabular form.

A. H. N.

1088. Calibration of C.F.R. Reference Fuels. Sub-Committee No. 5—Engine Tests. Aviation Fuel Knock-Rating Panel. *J. Inst. Petrol.*, August 1943, 29 (236), 235.—The calibration of Secondary Reference Fuel F. 4 + 4 mls. T.E.L./Imp. Gallon and C.12 + 4 mls. T.E.L./Imp. Gallon by C.F.R. Motor Method I.P. 144/42 (T), and the 17° Motor Method I.P. 43/42 (T) is given.

A. H. N.

Gas, Diesel and Fuel Oils.

1089. Creosote Oil as a Fuel in I.C. Engines. R. J. Bramhall. *J. Inst. Fuel*, June 1942, 15 (84), A.3.—This paper gives an account of experiments started in 1932 in the use of creosote in the buses at Rochdale.

First trials were in a spark-ignition engine, a 6-ton Leyland lorry being used. Starting up had to be done by gasoline, and the engine was switched over to the creosote oil when warm. Ordinary mineral lubricating oil was first used, but after 400 miles running excessive dilution and the formation of gummy deposits were noticed. These deposits appeared to be due to the action of the phenols in the fuel and the asphaltic matter in the oil.

Castor oil was next used as a lubricant, and the trouble with deposits considerably lessened. Excessive dilution was cured by distilling the fuel to remove heavy ends and the creosote further improved by washing out the phenols.

Work was then more or less suspended until the outbreak of the present war, when experiments were started on the use of mixtures of creosote oil and petroleum fuel in compression ignition engines. The phenols in this mixture tended to cause gumming, and this was more pronounced in blends containing $< 30\%$ creosote, blends containing 30–50% creosote being somewhat better in this respect. These blends had poorer ignition qualities than straight petroleum oils, and in cold weather gave satisfactory starting only in direct-injection engines.

The whole fleet of buses now uses a creosote–fuel oil mixture with a mineral lubricating oil. The petroleum fuel oil is run into a tank and the correct amount of creosote added. After standing for 24 hrs. the mixture is centrifuged and, provided a washed creosote oil has been used, a satisfactory fuel is produced. Bench tests have been carried out, and have shown some advantages for this blend over straight petroleum fuel. Such a blend is now the standard Diesel fuel for the Rochdale buses, some of which have completed 60,000 miles without trouble. D. L. S.

Lubricants and Lubrication.

1090.* Deterioration of Lubricating Oils. J. J. Jacobs and D. F. Othmer. *Industr. Engng Chem.*, 1943, **35** (8), 883.—The object of the investigation was to examine the effect of Soybean Lecithin (commercially known as Gliddol) as an oxidation inhibitor for lubricating oils. The oxidation test used for this evaluation was the Sohio test, in which the oil is air blown in the presence of steel; a description of the standard apparatus for carrying out this test is given.

It is shown that the addition of up to 2% Gliddol has no effect on the normal inspections except that the V.I. is increased. The results of the oxidation test showed that naphtha insolubles, viscosity increase, and neutralisation number were reduced, and that in this respect it compared favourably with several commercially accepted inhibitors. J. W. H.

1091.* Development and Application of Lubricating Greases. Part I. M. W. Webber. *Petroleum*, September 1943, **6** (9), 136.—A general descriptive account is given of the properties of greases and the special problems which arise in their use. The greater proportion of the greases at present in use are of calcium or sodium soap base, and aluminium and lead soaps are quite frequently employed for special applications. Consideration of the differences between these greases shows the great importance of the metallic radicle, and much work has been done in the search for elements which would produce lubricants of improved quality. Useful results have been achieved with magnesium, zinc, barium, and lithium; the last two show the most promise.

Other developments in the formulation of greases are due to the increasing use of additives. Polymers are used to increase retention and adhesion, while chemical compounds improve anti-oxidant and anti-corrosive characteristics. Extreme pressure agents, such as sulphurized fatty oils, lead soaps, and halogen compounds, are used for the preparation of E.P. greases suitable for the lubrication of highly stressed bearings such as those in rolling-mills, and also for worm drives, steering gears, etc. The polymers used at present in the grease-making industry are nearly all of the polyisobutene type—*e.g.*, " paratac."

Other ingredients which may be considered as additives for greases are graphite, mica, lead oxide, asbestos fibre, and wool yarn. These all serve useful purposes for specific applications, and are not to be considered as mere fillers. Colloidal graphite has proved extremely useful in a number of cases for the reduction of wear, friction, and corrosion, and also for the meeting of conditions of excessively high temperature. Fillers are now used only in cheap axle-greases; they have useful qualities for use on wooden axles.

The principal changes in the actual process of manufacture have been directed towards the use of higher temperatures and pressures. The former help to control the texture, melting point, and consistency of soda-soap greases, as well as ensuring more complete dehydration and saponification. Higher pressures achieved in autoclaves are principally used to expedite the saponification of neutral fats with lime, but if the soap base is highly concentrated, great care is needed to compound with the mineral oil to avoid the formation of lumps or aggregates of soap. Now that fatty acids are in such extensive use it is doubtful if the autoclave presents any serious advantage, especially when bearing in mind the comparatively high cost of the equipment and its maintenance. A. H. N.

Special Products.

1092. Petroleum Drying Oil in Exterior Paint. E. W. McMullen. *U.S. Paint, Oil & Chem. Rev.*, 3.6.43, **105** (11), 30.—A petroleum drying oil, of which 12 million lb. were

produced last year, is in use in baking enamels, porch paints, etc., and other paints in which the dark colour is not vital, and has been examined as a part substitute for linseed oil in exterior paints. The following facts were brought out :—

(1) The incorporation of the petroleum drying oil improved levelling and gloss, even in 10% substitution.

(2) Brushing is unaffected with up to 40% substitution.

(3) Drying is slower, but is brought to normal by doubling the drier concentration, a lead–cobalt combination being preferred.

(4) Up to 40% substitution gives equal, if not superior, hardness and toughness of film.

(5) In white paints 10% substitution gives off white, 20% medium ivory, and 40% dark ivory.

In prime coats, where colour is less important, the petroleum drying oil should be of even greater utility. While complete data on exposure resistance is not available, preliminary results from accelerated and light exposure tests suggest that with substitution up to 40% and proper pigmentation the outdoor life will be satisfactory for the emergency period, resulting in considerable savings in linseed oil and in the final cost of the paint. On the other hand, exposure tests carried out by the New York Paint and Varnish Production Club (Rept. of Committee No. 9 of 12.2.43) on 50% substitution of a petroleum drying oil for 4 months in Florida at 45° F. gave unfavourable results, though these may have been due to the fact that the paints were of the camouflage type, and did not contain active pigments. Promising results are being obtained with the petroleum drying oil mentioned above in interior and emulsion paints.   C. L. G.

1093. Petroleum Refining Processes Adapted to Styrene Manufacture. Anon. *Refiner*, July 1943, **22** (7), 229–231.—A very short description of the plant of Monsanto Chemical Co. is given. The censor would only permit stating that the plant " calls for the cracking of propane to produce ethylene, then alkylation of ethylene and benzol to form ethylbenzene, followed by dehydrogenation of ethylbenzene, to form styrene." Certain details of incidental components are given.   A. H. N.

1094.* Mineral Insulating Oils. A. G. Assaf and J. C. Balsbaugh. *Industr. Engng Chem.*, 1943, **35** (8), 099.—A study has been made of the effect of sulphur compounds, of the type naturally associated with mineral oils, and various addition agents used as oxidation inhibitors, on the oxidation resistance and conductance of insulating oils. It is shown that the inhibitors examined did not produce high electrical losses, and that *tert.*-amyl phenyl phosphite produced the lowest electrical loss. Sulphur compounds in the concentration found in refined oils may increase or decrease the electrical losses, depending on their type.   J. W. H.

1095.* Mineral Oils in Core Compounds. Anon. *Petroleum*, September 1943, **6** (9), 138.—Cores, and the use of mineral oil as binder compound in cores, are briefly discussed. The properties and specifications of oils are listed as follows : specific gravity at 60° F, 0·92–0·94 ; flash point, 155° F. min. ; fire point, 170° F. min. ; viscosity at 100° F. (Saybolt U), 140 min. ; acid value, 48–53 ; saponification value, 190 approx. ; iodine value, 140 min. In addition to this, core oils should also possess good dispersing properties so that an even coating of the sand-grains may be achieved without having to resort to an excessive amount of mixing, and they should also work clean in the core boxes. Furthermore, they should be capable of producing cores of the requisite mechanical strength, with the minimum production of smoke and gas, though this latter property is usually overlooked if it is outweighed by the advantages of using a certain oil. Freedom from objectionable odours during drying and baking of the moulds is by no means the least desirable feature of a good core oil, and in this respect, as well as in their good " shelf-life " properties, most mineral oils will be at an advantage over vegetable and animal oils.   A. H. N.

Detonation and Engines.

1096. Extending Camshaft Operating Life for Increased Engine Power Output. F. Noltimier. *Refiner*, July 1943, **22** (7), 206–210. *Paper Presented before California Natural Gasoline Association.*—The more common forms of cam wear can be divided

as follows : (1) Pock-marks of corrosion are usually most prevalent on the front or lifting-faces having high unit pressures at point of contact with roller followers. As the percentage of total surface area destroyed is usually small, this condition does not necessarily mean that the cams are no longer functioning with a fair degree of efficiency, but, from this point on, an accelerated rate of wear on both cam and rollers may be expected. (2) A more or less smooth and even wear on both sides and top of the cam lobe may occur. This type of wear will cause an appreciable falling off in power with no ready means of ascertaining its cause or even its presence. (3) Wavy, irregularly worn places on cam faces can be easily detected. The common causes are continuous operation with excessive push-rod clearance, sticky valves with a tendency to " hang-up " at certain points, or improper valve-spring tension.

There are three principal methods of checking cam performance. The first two described have the advantage of making camshaft removal from the engine unnecessary, but do not permit such complete examination as does the third. (1) With the engine cold, so that there are no rapidly changing temperatures of parts affecting push-rod clearances, carefully set same to normal operating clearance. Arrange devices on both inlet and exhaust valves which will indicate when they start to open or become completely closed. Then slowly bar over the engine, noting at which points, in terms of degrees of fly-wheel rotation, the valve events take place. Should the fly-wheel be unmarked for valve timing, a steel tape laid around the wheel from the stationary index to H.D.C. or C.D.C. can be used to measure the intervening distance and from this can be calculated the respective valve timing. (2) While maintaining the engine " on the line " and under full load, indicator stop cards or valve cards may be taken. By using a very light indicator spring to magnify the bottom of the conventional power-card, an analysis may be made of the scavenging or exhaust valve action, the inlet or filling strokes, and the beginning of the compression strokes. From these diagrams a diagnosis of valve, air-intake, or exhaust troubles may be made. (3) A third and quite accurate method of cam checking involves the removing the camshaft from engine and placing it in a testing jog. A special dial comprising 720° of flywheel rotation for one complete camshaft rotation with an accompanying adjustable index permits direct reading of valve events as produced by the respective cam.

The paper describes the experimental results on rebuilt cams and the effects observed on engine power output. A short discussion explains certain metallurgical requirements.   A. H. N.

BOOKS RECEIVED.

Handbook of the Scientific Instrument Manufacturers' Association of Great Britain, Ltd., with classified index of instruments. Pp. 53. Scientific Instrument Manufacturers' Association of Great Britain, Ltd., River Plate House, 12 & 13, South Place, London, E.C.3.

Determinacao Quantitativa do Aluminio: sua precipitacao por Meio da Fenilhidrazina. By Wolfrando Carvalho de Moraes Bastos. Pp. 54. Instituto Nacional de Tecnologia, Rio de Janeiro.

British Standard Specification No. 1113 : 1943 for Water Tube Boilers and their Integral Superheaters. Pp. 66. British Standards Institution, 28, Victoria Street, London, S.W.1. Price 7s. 6d.

This specification applies solely to water-tube boiler units, including superheaters, economizers, and to other parts connected thereto without the interposition of a shut-off valve, exclusive of brickwork setting, and insulation.

It does not apply to pressure parts constructed of alloy steels or of carbon steels of different qualities from those stipulated.

British Standard Specification No. 1131 : 1943 for Bronze Oil Retaining Bearings. Pp. 7. British Standards Institution, 28, Victoria Street, London, S.W.1. Price 2s.

This is a war emergency standard applying to bronze bearings having oil retaining characteristics. Its object is to bring about a simplification in the variety of types and sizes of bearings, and so to facilitate more rapid and economic production by concentrating the supply and demand on a simplified range of standard sizes.

This Standard covers cylindrical type bearings ; further specifications to be issued later will deal with flanged bearings and thrust washers.

Standard Methods for Testing Tar and its Products, Revised Sections on Carbolic and Cresylic Acids, Acid Wash Test and Colour Standards of Refined Lower Boiling Products, Notes on the Procedure for the Determination of Anthracene in Unrefined Crude Anthracene, and a special war-time test for the Determination of the Chlorine Content of Creosote Oil. Standardization of Tar Products Tests Committee, 116, Piccadilly, London, W.1. Price 7s. 6d.

The Twenty-fifth Anniversary of the Academy of Science of the U.S.S.R. Pp. 248. Academy of Science of the U.S.S.R., Moscow. *In Russian.*

This book contains a report of the meetings held in connection with the celebration of the twenty-fifth anniversary of the Academy of Science of the U.S.S.R. In his opening speech the President of the Academy, V. L. Komarov, gives an account of the achievements of the Academy and of Russian scientists during the period under review, and in the following speeches this is amplified by a more detailed account of the activities of the various branches.

Of interest to members of the oil industry are sections on Oil Prospecting in the Caucasus and East Russia, the Chemistry of Petroleum, and Synthetic Oil Research. There are also reviews of improvements in technique in various branches of the industry, and mention is made of the new regions of the U.S.S.R. in which oil is being produced.
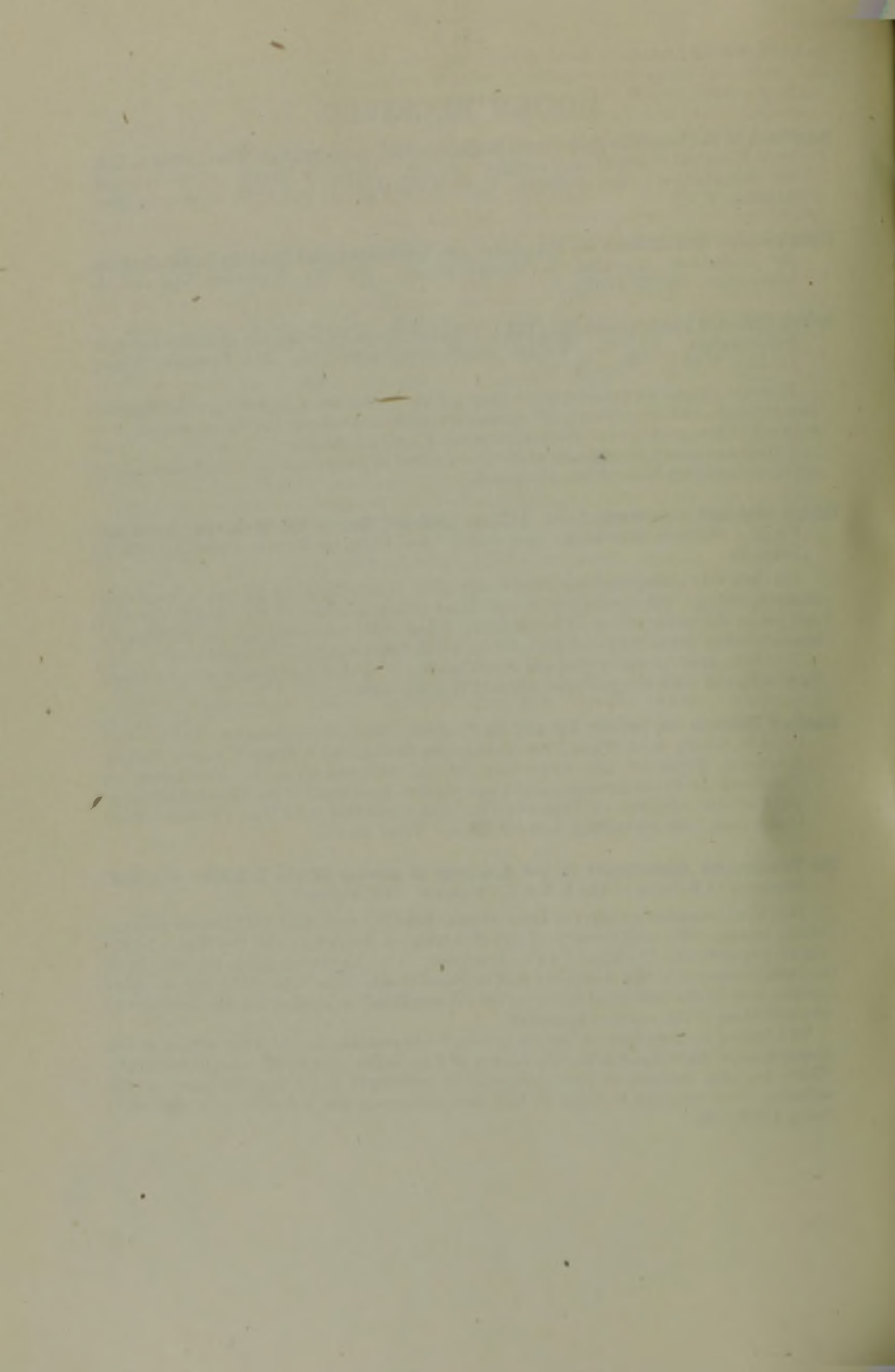
INSTITUTE NOTES.

ELECTION TO COUNCIL.

The attention of Members is drawn to the following extracts from the By-Laws governing election to the Council of the Institute :

(*a*) The Council of the Institute shall be chosen from the Fellows and Members only.

(*b*) Every Fellow, Member, and Associate Member of the Institute may send in writing to the Council the name of a Fellow or Member whom he desires to recommend for election to the Council. This nomination must be signed by at least nine other Fellows, Members, or Associate Members and delivered to the Secretary not later than 30th day of November in any year. No Fellow, Member, or Associate Member may sign more than one Nomination Paper in any one year.

CANDIDATES FOR ADMISSION.

The following have applied for admission to the Institute. In accordance with the By-Laws, the proposals will not be considered until the lapse of at least one month after the publication of this *Journal*, during which time 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 the candidate.

The object of this information is to assist the Council in grading the candidate according to the class of membership.

The names of candidates' proposers and seconders are given in parentheses.

ASTON, Leslie, Chemist, Esso European Laboratories. (*W. E. J. Broom; A. Osborn.*)

BARANY, George Martin, Student, Birmingham University. (*F. H. Garner.*)

CROOK, Lionel James, Production Operator, Anglo-Iranian Oil Co., Ltd. (*D. R. M. Pickard; H. S. Gibson.*)

HULL, Charles, Chemist, Shell Refining & Marketing Co., Ltd. (*G. Davidson; J. Grant.*)

KENZIE, Raphael George, Analytical Chemist, Shell Refining & Marketing Co., Ltd. (*G. Davidson; J. Grant.*)

REES, Vincent R. M., Assistant Works Chemist, John I. Thornycroft & Co., Ltd.

STEPHENSON, Maurice, Petroleum Production Engineer, Capt., R.E.M.E. (*R. B. B. Wrixon; H. de Wilde.*)

TRIPCONY, Donald Frank, Chemist, Esso European Laboratories. (*W. E. J. Broom; A. Osborn.*)

MODERN PETROLEUM TECHNOLOGY.

Early in the New Year the Institute will publish a monograph entitled " Modern Petroleum Technology."

Whilst this volume will be authoritative, and will give an account of recent developments in petroleum science, it will, nevertheless, be simply worded and will be designed for the general reader. It is hoped it will be of particular value to many members who have no particular specialized knowledge of all the subjects described, but who are interested in the multiplicity of ways in which the Industry is developing.

The following will give members some idea of the scope of the new publication :

Section.	*General Editor.*
1. Exploration.	V. C. Illing.
2. Geology.	,,
3. Geophysics.	,,
4. Drilling and production.	C. A. P. Southwell and C. Dalley.
5. Pipe-lines, storage, and transport of crude oils.	C. Dalley.
6. Chemistry of petroleum.	F. B. Thole.
7. Refining :	J. A. Oriel.
(a) Light oils.	
(b) Heavy oils.	
8. Utilization :	F. H. Garner.
(a) Gasolines : (i) aviation.	E. L. Bass.
,, (ii) motor.	E. B. Evans.
(b) Kerosenes, solvents, and white spirits.	F. N. Harrap and E. B. Evans.
(c) Gas oils.	H. Hollings.
(d) Fuel oils.	M. H. Hoffert.
(e) Oils for C.I. engines.	R. Stansfield.
(f) Lubricants and greases.	E. A. Evans.
(g) Waxes.	C. G. Gray.
(h) Bitumen.	J. S. Jackson.
(i) Carbon blacks.	W. H. Cadman.
(j) Insulating oils.	C. Chilvers.
9. Special products, solvents, plastics, rubber, explosives, soaps, etc.	A. E. Dunstan.
10. Transport and measurement.	C. Dalley, assisted by H. Hyams.
11. Economics and legislation.	C. Dalley.
12. Significance of tests.	J. S. Jackson.
13. Research and education.	F. H. Garner.

N.B.—It is hoped that as far as possible these contributions will be read before the Institute.

CHANGE OF ADDRESS.

On and after Tuesday, November 30th, 1943, communicatious should be addressed as follows :—

>   The Secretary,
>   The Institute of Petroleum,
>   26, Portland Place,
>   London, W.1.

Telephone : Langham 2250.
Telegraphic address : Instpetech Wesdo London.

FORTHCOMING EVENTS.

The next meeting of the Institute will be held in November, when Mr. H. L. West will read a paper entitled " Mechanical Testing of Extreme Pressure Lubricants."

Details of place and date of meeting will be notified to members in due course.

A joint meeting of the Institute with the Institution of Chemical Engineers will be held on December 14th, 1943, at 2.30 p.m. at Burlington House, Piccadilly, W.1 (Geological Society of London), when J. C. G. Boot will present a paper on " Petroleum as a Base Materials for Chemicals."

PETROLEUM FILMS BUREAU.

This Bureau issues a series of 35 mm. and 16 mm. sound and silent documentary and instructional films.

The films cover matters of general interest, such as Cargo for Ardrossan—a picture of the uses of oil in two highly contrasted communities—industrial Glasgow and the island of Islay; P.F.B. Cinemagazines; films illustrating how oil is produced and refined; and how motor-cars, etc., work.

The films may be borrowed free of charge by Service units, schools, technical colleges, educational and other organizations.

Both 35 mm. and 16 mm. films are printed on " non-flam." film.

All applications and enquiries should be addressed :—

>   Petroleum Films Bureau,
>   46, St. James's Place,
>   London, S.W.1.

>   ARTHUR W. EASTLAKE,
>   ASHLEY CARTER.
>   *Joint Honorary Secretaries.*

DANGEROUS GASES

IN THE PETROLEUM AND ALLIED INDUSTRIES

A series of 16 Papers reprinted from the

Journal of the Institute of Petroleum

June and July, 1939

**176 pp. 27 Illustrations and Diagrams
Cloth Bound**

7s. 6d.

(including postage)
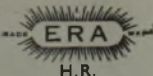
Obtainable from :

THE INSTITUTE OF PETROLEUM

26, PORTLAND PLACE, LONDON, W.1

LIST OF ADVERTISERS.

Kindly mention this Journal when communicating with Advertisers.

Kindly mention this Journal when communicating with Advertisers.

v

Kindly mention this Journal when communicating with Advertisers.

vi

Drums

Hobbing intermediate wheels of speed reducers

for our

12,000 lb. polished rod load Pumping Unit

BUILT TO LAST

Manufactured in Association with David Brown & Sons (Huddersfield) Ltd. and the Power Plant Co. Ltd., West Drayton, Middlesex

●

LEGRAND SUTCLIFF & GELL LTD.

SOUTHALL, MIDDX.   Phone : Southall 2211

Associated with

ENGLISH DRILLING EQUIPMENT CO. LTD.

WALTON-ON-THAMES, SURREY.   Phone : Walton-on-Thames 860

OIL

PLANTS

COMPLETE

FOR :

Atmospheric and Vacuum Distillation

Cracking

Reforming

Reversion

Stabilization

Chemical Treatment

A. F. CRAIG & CO. LTD.

PAISLEY and LONDON

Representing in Europe :

The Winkler-Koch Engineering Co., U.S.A.

FOR OIL-FIRED FURNACES

STEIN
REFRACTORIES

"NETTLE" FIREBRICK
(42/44% Alumina)
"THISTLE" FIREBRICK
35/37% (Alumina)
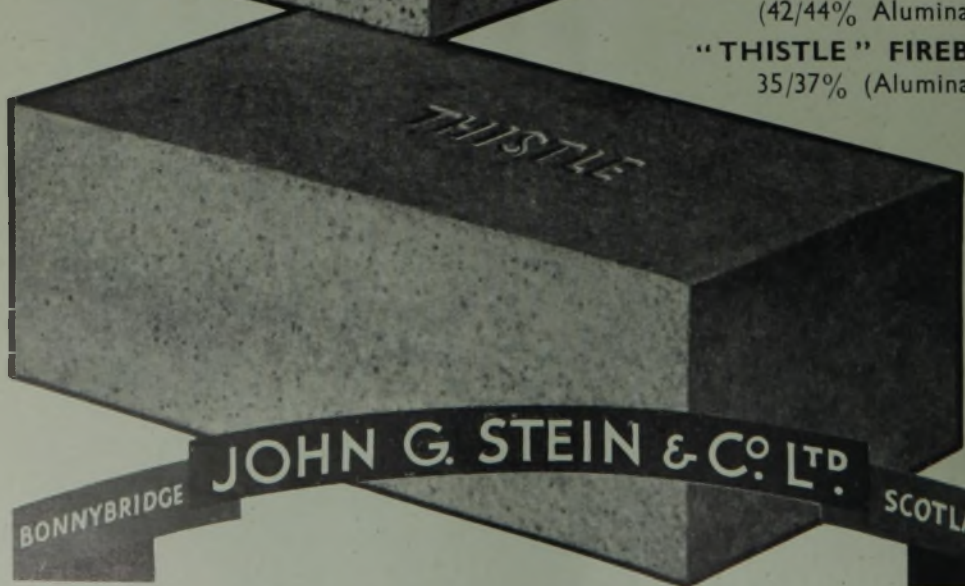
JOHN G. STEIN & Co. Ltd.
BONNYBRIDGE   SCOTLAND

WIGGINS PONTOON FLOATING ROOFS

Welded Products by

WHESSOE

The WHESSOE FOUNDRY & ENGINEERING Cº Lᵀᴰ DARLINGTON & LONDON

DRILLING MUD:

ITS MANUFACTURE
AND TESTING

By

P. EVANS, B.A., F.G.S., M.Inst.Pet.

and

A. REID, M.A., B.Sc., A.M.Inst.Pet.

Price **21s.** post free

(U.S.A. : **$4.25**)

Obtainable from

THE INSTITUTE OF PETROLEUM

26, Portland Place, London, W.I
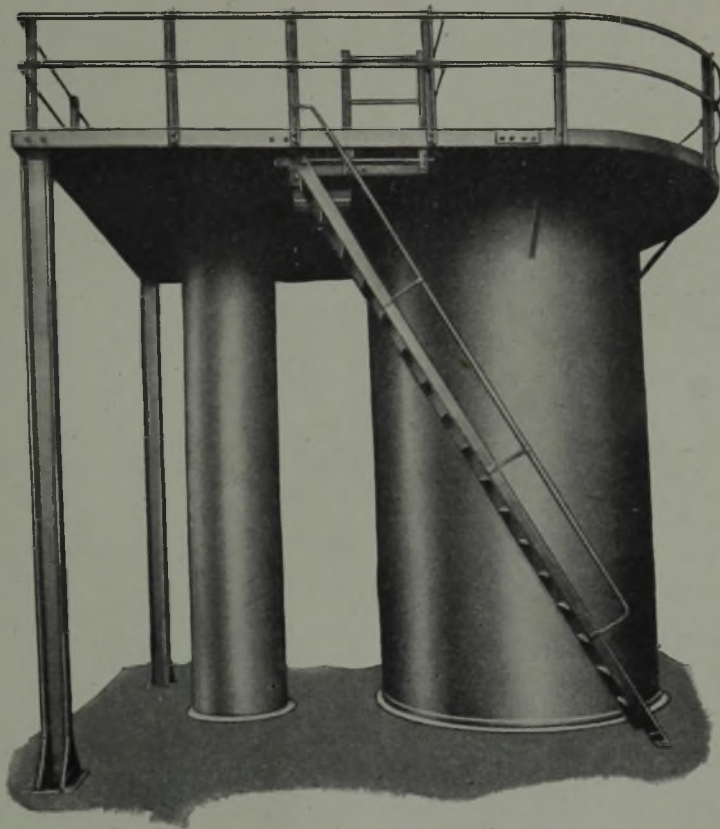
Another...

LUMMUS

CRACKING UNIT

Accepted

This one after 18 days of initial run

For a major oil company Lummus recently completed a Lummus Combination Three-Coil Cracking Unit . . . viscosity-breaking, gas oil and heavy naphtha reforming.» » » Eighteen days after the unit was put on stream it was completely accepted, having met all guarantees. The initial run was continued to 25 days, when the unit was shut down for inspection purposes. » » » This recently completed unit — the ninth consecutive Lummus Cracking Unit to be accepted during initial firing runs of 25 days or more — is equipped with Lummus Floor-Fired, Raised Hearth Heaters, with improved steam generation feature in the convection section. Provision is also made for steam generation from waste heat.

W. H. JONES

Representing: **THE LUMMUS COMPANY**

70 Barn Hill, Wembley Park, Middlesex

Stabilog

MADE THROUGHOUT IN BRITAIN
FAMOUS THROUGHOUT THE WORLD

CONTROLLERS, RECORDERS & INDICATORS
FOXBORO
FOR TEMPERATURE, PRESSURE, LEVEL & FLOW

The Stabilog Control system has made possible the uniform control and stabilisation of entire processes. It has been designed especially for use on continuous processes in petroleum refining and will control the critical temperature, pressure, flow and liquid level applications with the highest precision.
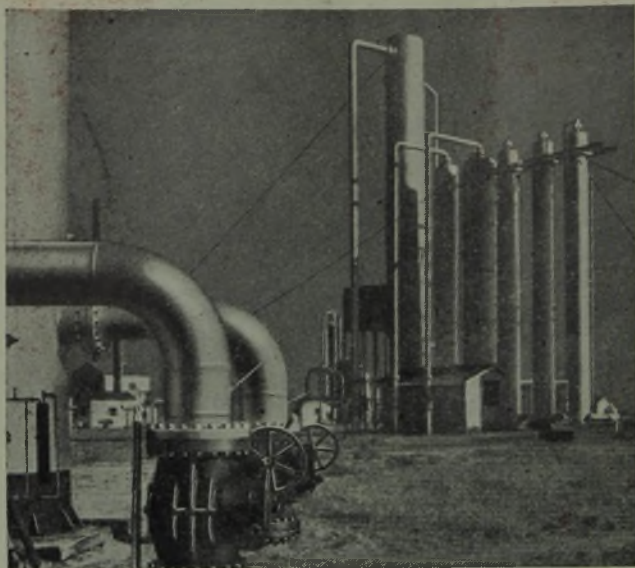
Stabilog and other Foxboro products are manufactured in our factory at Merton, England, from which a complete technical and engineering service is available to refinery engineers.

★

FOXBORO-YOXALL, LIMITED
MORDEN ROAD, MERTON, LONDON, S.W. 19

Kindly mention this Journal when communicating with Advertisers.