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COMPARATIVE OPERATING COSTS OF PETROL AND COMPRESSION IGNITION ENGINED BUSES FOR PASSENGER TRANSPORT.*

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Synopsis.

In this paper on the operating costs of oil- and petrol-engined omnibuses the author has emphasized the fact that the main incentive to the use of alternative fuels or types of prime mover is economy in operation combined with ease of handling of the fuel. The rapid progress made by the oil engine in the last decade is shown to be due to the excellent manner in which it fulfils these requirements.

The saving on a 56-seater double-deck bus is stated to be 1·152*d*. per bus mile, or £216 per annum on annual mileage of 45,000 miles. This is a nett saving after making due allowance for additional overhead and maintenance charges.

The difficulty of Municipal undertakings in dealing with peak loads and the effect of taxation is illustrated graphically, and the summary of replies to a questionnaire by twenty-six undertakings shows that although the conditions vary greatly in different towns, there is ample evidence of the preference for the oil-engine vehicle.

Finally, the author does not contend that the present oil engine has reached finality, and mentions experiments which are now being made with the injection of gas and the alternative use of producer gas, although it must be remembered that any alternative must comply with the requirements already emphasized, of economy in operation and ease of storage and handling of the fuel.

In preparing this paper, I realized that it would not be sufficient to present figures based solely on the operation of motor omnibuses in any one city. I therefore drew up a Questionnaire which was sent to the General Managers of twenty-six undertakings in Great Britain, and I am grateful to them for the care with which they have completed the Questionnaire, and it is on the experience of these various municipalities that I have based my figures.

Among the many varied items which go to make the total cost of operation of a passenger-transport service, the fuel bill is one of the highest. In Manchester, the cost of petrol represents 21½ per cent. of the total running cost of the petrol vehicle, and with the compression-ignition engine the fuel cost is equal to 14 per cent. Further, many of the other items, such as loan charges, licence costs, and the payment of wages—rigorously controlled by the Trade Union Agreements—can only be reduced by running greater mileages per vehicle, which in large cities with high peak loads is sometimes very difficult. The chart in Appendix No. 1 shows very clearly the morning and evening peak loads, and it will be noticed that 60 per cent. of the licensed buses are in use for only a comparatively short time in the morning and evening.

The fuel costs, as I have pointed out, represent high percentages of the working expenses, and they therefore present an attractive field to the operating engineer in search of economy. These high percentages are,

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of course, due to taxation. When one considers that the nett price of fuel oil, for instance, is something under 4*d*. per gallon, one gallon of which is sufficient to propel a double-deck vehicle 8½ miles, it represents a remarkable achievement on the part of the Oil Refiners and Distributors that it can be refined, imported, and distributed all over the country to consumers at a price which, but for taxation, would be approximately 4*d*. per gallon. We have, however, to deal with things as they are, and as taxation at present increases the price of petrol by something like 216 per cent. and fuel oil by approximately 232 per cent., the need for economy in fuel consumption becomes apparent. The importance of this may be judged by the following :—

An extra quarter of a mile per gallon to the owner-driver of a private car may to him appear a matter of no great importance. Let us, however, see what this apparently very small economy means to the P.S.V. operator. In Manchester during the financial year which closed on 31st March last, over 26,000,000 bus-miles were run, the consumption of petrol being 847,000 gallons and of fuel oil 2,615,000 gallons. If the average m.p.g. could have been raised by just this quarter of a mile per gallon, the resultant economy in fuel would have reduced the working expenses by £6685. Within the next two or three years this annual mileage may be almost doubled, so it will be seen that when I said fuel presents an attractive field for the engineer in search of economy, maybe I should have said that economy in fuel consumption is a matter of paramount importance, provided that economy in the one direction is not more than cancelled out by heavier expenses in another.

In the years following the War many experiments were made with alternative fuels to petrol—paraffin oil and mixtures of petrol and paraffin oil being tried without great success. The next stage was the use of a creosote distillate in an ordinary spark-ignition petrol engine, the engine being started on petrol and then run on the creosote fuel when warmed up. It was found necessary with these engines to increase the compression ratio to 6 to 1 and to fit special heating apparatus to the induction pipe. In order to vaporize the creosote, the inlet manifold was totally enclosed in the exhaust manifold, the latter being protected by a shield from the cooling-draught caused by the fan. With such a design there was very little control of the heating of the inlet manifold, the temperature of which had a most important bearing on the running of the engine. If too cold, a rapid deposition of carbon took place in the manifold and round the valve, which ultimately caused throttling of the gases. If too hot, cracking of the creosote oil took place, causing deposition of carbon compounds in the cylinder, which ultimately reached and contaminated the sump oil. Overheating of the inlet gases also caused a drop in the volumetric efficiency of the engine. Great care was also required in the setting of the controls, in order to get a satisfactory change-over from petrol to creosote.

The lubrication of the engine presented certain difficulties, owing to dilution and contamination caused by the creosote and asphaltic compounds formed during combustion. Castor oil was used with success owing to its property, not so much of dissolving the compounds mentioned above, as of keeping them in suspension and preventing them separating out and causing sludging. The high cost of castor oil, however, made its use uneconomical, and certain mineral oils were used with fair results. In service the engine "pulled" well, but occasional oiling up of plugs took place. It was necessary to have the engine thoroughly warmed up before leaving the garage. To facilitate starting, the engine had to be allowed to idle on petrol for a short time before shutting down at night, in order to clear the cylinders of the products of creosote combustion which caused gumming up of the pistons. Due to the carboning up of the cylinders, frequent docking was required, and general running maintenance was rather higher than for a petrol engine. Overhaul costs also tended to be higher.

The following figures show the results of the running of a double-deck vehicle operating on a route with frequent stops and equipped with a petrol engine modified for running on creosote. Castor oil was not used as a lubricant, but a special mineral oil at 1*s.* 8*d.* per gallon, which gave fairly good results :—

Miles.	Petrol.		Creosote.		Lub. Oil.	
	Galls.	M.P.G.	Galls.	M.P.G.	Galls.	M.P.G.
4279	411	10·4	659	6·5	32½	132

Petrol	1*s.* 1½*d.* per gall.
Creosote	7½*d.* ,,
Lubricating oil	1*s.* 8*d.* ,,
Cost of fuel and lubricating oil	2·595*d.* per mile.
Cost of petrol for similar petrol engine	3·176*d.* ,,
Cost of lubricating oil for petrol engine (200 m.p.g. at 1*s.* 8*d.* per gall.)	0·100*d.* ,,
Total cost of petrol and lubricating oil for petrol engine	3·276*d.* ,,
Saving shown by creosote engine	0·681*d.* ,,

On an annual mileage of 35,000 the saving would be approximately £100 per bus per annum. However, much difficulty was experienced with the running of the two buses which were fitted, owing to the impossibility of maintaining a constant temperature in the inlet manifold, due to the frequent starting and stopping, and the cost of maintenance was such that the experiment was abandoned after about eighteen months.

In 1929 one or two oil-engine chassis were introduced from the Continent, and English manufacturers began to consider the fitting of the so-called diesel engine to commercial vehicles. In 1930 Messrs. Crossley Motors of Manchester, in collaboration with Messrs. Gardners of Patricroft, supplied three oil-engined double-deck omnibuses—one for Leeds, one for Sheffield, and one for Manchester. These buses were fitted with a marine type of engine adapted to fit in a standard chassis. The maximum speed of the engine was governed to 1300 revolutions per minute, which gave the bus a maximum road speed of 28 miles per hour.

The early experiments with these oil engines were so immediately promising that operators demanded more, and the engine-builders responded by designing and producing an engine specially for road-transport work, with a higher maximum engine speed than the marine engines which were first tried.

At this point it may be of interest to direct your attention to a return prepared by Mr. Mackinnon in his paper read at the meeting of the Union Internationale de Tramways in 1935 (extract below), from which you will see that whereas at 31st May, 1931, there were only eleven diesel-engine units in municipal bus service, by 31st December, 1934, there were no fewer than 1144.

Date.	Number of Municipal Undertakings Operating Diesel Engines.	Total Number of Diesel Engines in Service.
31st May, 1931	8	11
31st March, 1932 . . .	14	54
May, 1933	33 (approx.)	214 (approx.)
30th Sept., 1933	47	389
30th June, 1934	59	780
31st Dec., 1934	72	1144

The figures at 30th June, 1938, for vehicles owned by members of the Municipal and Transport Association (see Appendix II) were as follows :—

	Single Deck.	Double Deck.	Total.
Petrol . . .	1433	1904	3337
Oil	935	4486	5421

from which you will see that out of a total of 8758 single- and double-deck motor omnibuses, no fewer than 5421 are operated by compression-ignition engines.

Dealing with the whole of the country, the figures taken from the Ministry of Transport return (given in Appendix III) show that the maximum number of hackney vehicles licensed during the quarter ended 30th September, 1938, operated by petrol vehicles of over eight seats capacity, had fallen by 7539, as compared with three years ago, whilst at the same time the number of similar vehicles driven by heavy oil had increased by 11,781, this latter figure being an increase of 212·62 per cent. on the figure for September 1935. Comparing this with the goods vehicles, there was a reduction of 3345 in the " over 2½-ton " class and an increase of 3135 in the heavy-oil vehicles, this latter figure being equal to 57·8 per cent. increase over the figure in September 1935.

Table III, Section C, of the Ministry of Transport Returns for 1938 gives the number of vehicles registered for the first time during the twelve months ended September 1938. Looking at double-deck passenger vehicles from forty-eight to sixty-four seats, it is noticeable that in this year only ninety new petrol-engine buses were licensed, as against 1989 oil-engine buses of the same capacity. From these figures it will be seen that as regards large passenger vehicles, the oil engines now rank supreme. The position with goods vehicles is scarcely the same, as, owing to the imposition of the 20-miles-per-hour speed limit for vehicles weighing over 2½ tons, the application of the oil engine to goods transport has received a setback, it being difficult to keep the weight of the oil engine sufficiently low to enable the vehicle to qualify for the high-speed category.

From the foregoing brief historical review it will be seen that the compression-ignition engine has firmly established itself as a prime mover in municipal passenger transport, and it is my purpose to show in this paper that the chief reason for the rapid rise in popularity of the compression-ignition engine is the saving in fuel cost over the petrol-driven engine.

I now propose to deal with the cost of operation under the following headings: (1) Capital Cost; (2) Operation and Maintenance Cost.

(1) Capital Cost.

In the early days of development of the high-speed diesel engine the capital cost of a vehicle so fitted was £200–£250 over and above that of the corresponding petrol-engine chassis. This is understandable when it is remembered that the engines were built in smaller numbers and were distinctly of an experimental nature. To-day the additional capital cost of the oil-engine vehicle over the petrol-engine vehicle is approximately £100 per chassis.

The difference in the annual charges between an oil-engine bus and a similar petrol-engine bus amounts to £19, based on an estimated extra charge of £100 per chassis. On an annual mileage of 45,000 this represents 0·101*d.* per vehicle-mile.

In the case of municipal undertakings it is necessary to make application to the Ministry of Transport for sanction to borrow the money upon the security of the City Rate for the purchase of motor omnibuses, and the repayment of the loan is spread over a period of eight years, in addition to the payment of interest on the money borrowed. Experience in Manchester has proved that the life of a motor bus does not always reach the full limit of the loan period of eight years, so additional provision is charged annually in order that the whole capital outlay is provided in six-and-a-half years. This additional provision is set aside to pay off the outstanding debt whenever a bus is prematurely taken out of service and scrapped. The additional provision on buses that remain in service for the full loan period is thus available for the purchase of, say, new bodies, or for general renewal purposes (see Appendix IV).

Some undertakings are in the fortunate position of having a reserve fund available so that new vehicles may be purchased out of accumulated profits from previous years. In this case a sum equal to the loan debt repayment could be charged against revenue each year and credited to the Reserve Fund, so that by the time the vehicles are worn out, the amount in the reserve fund would again be available for buying more vehicles.

Capital costs are greatly influenced by the conditions under which the vehicles operate. The life of a bus in Manchester, for instance, with frequent stops, congested traffic, and sett roads (which cause constant vibration), is naturally shorter than it would be in a town with light traffic and smooth tarmac roads. This increased cost, together with a higher maintenance cost, may be counteracted to some extent by the "density-of-traffic" factor shown in an increase of revenue for more passengers carried per vehicle-mile. Nevertheless we have in Manchester 170 buses still running which have exceeded their eight years' life. These vehicles are still being operated on the peak-load services, as it would be obviously uneconomical to purchase brand-new vehicles for the operation of the part-day services, the loan charges per week on a double-deck bus being £8 (see table on Comparative Operating Costs).

(2) Operation and Maintenance Cost.

In considering operating costs there are certain factors which do not vary whatever method of propulsion is used for the vehicle. These are: the traffic charges (which include the wages of drivers and guards, cash-clerks, and inspectors, ticket-printing, equipment on routes, uniforms, and cleaning of vehicles), general expenses (which include salaries and wages of officials, rents, rates, printing and stationery, compensations—accidents and employers' liability—health, pensions, unemployment, fires and other insurances, and telephones and postages), licences (there is, of course, now no difference between the licence paid on the petrol-engine vehicles and the heavy-oil-engine vehicles). All these items per bus-mile only vary according to the use made of the vehicles, and in large towns, where there is a large peak load, it is extremely difficult to obtain a satisfactory mileage from all the vehicles in the fleet.

This leads to complications when attempting to compare the costs to-day of a petrol-engine and an oil-engine vehicle. During the last few years most municipalities have purchased oil-engine vehicles only, with the consequence that the older petrol-engine vehicles have been relegated to the peak-load services. As a result the average mileage of a petrol-engine bus is much lower than that of a corresponding oil-engine vehicle. In calculating the cost of a petrol-engine vehicle I have therefore had to assume that it is working under conditions identical with those of the oil-engine vehicle. Coming now to repairs and maintenance there is no appreciable difference in such items as bodywork, painting, electrical repairs, maintenance of tyres or fire appliances, and these items have been treated as non-variable costs. With regard to the two remaining items under this heading—chassis and engine—there is a difference. In the early days of the oil engine, overhauls were much more expensive than at present, owing to the higher price of materials. Crankshafts, crankcases, etc., have to be considerably stronger in the oil engine owing to the higher stresses with which they have to deal. This difference in cost has now been considerably reduced, due to increased production, but nevertheless the opinion of the municipalities replying to the Questionnaire is definitely that there is a higher cost in the overhauling of the oil engines. This varies from a few pounds to £20 per engine, with the exception of one undertaking, who state a cost of £46 more than a petrol engine, although at the same time two other undertakings claim that the oil engine is cheaper to overhaul than the petrol; but, taking the average, the cost of the heavy overhaul of the oil engine is 0·08*d*. per bus-mile more than that of the petrol engine. It is difficult to assess the difference in day-to-day running maintenance, but the general opinion of the different undertakings appears to be that, if anything, the advantage lies with the oil engine, the fuel-injection pump causing far less trouble than the combination of magneto and carburettor fitted to the petrol engine.

The following table shows the comparative working expenses and final operating costs of two double-deck buses operating under normal conditions and running an annual mileage of 45,000. The non-variable costs are abstracts from the Manchester Revenue Account to date (5th February, 1939). The variable costs are average costs obtained from a summary of the Questionnaire, and again Manchester figures are used for interest, loan charges, and additional provision.

Comparative Operating Costs of Two Double-deck Buses (48–56 *Seats*) *Running an Annual Mileage of* 45,000.

Type of Vehicle :		Petrol Engine.	Heavy-Oil Engine.
Cost of complete vehicle		£2,100	£2,200
	Pence per Bus-Mile.		
Non-variable costs :			
Traffic expenses	5·462		
General expenses	0·939		
Buildings and fixtures	0·104		
Machinery and tools	0·088		
Superannuation fund	0·343		
Labour costs of fueling and lubricating	0·066		
Repairs and maintenance :			
Bodywork and painting	0·816		
Electrical			
Tyres and fire appliances			
	7·818	£1,466	£1,466
Excise licence		86	86
P.S.V. licence		2	2
		£1,554	£1,554
Variable costs :			
Repairs and maintenance :			
Chassis and engine	1·333	250	
,, ,,	1·413		265
Fuel (consumption only)	2·800	525	
,, ,, ,,	1·443		271
Lubricating oil (consumption only)	0·057	11	
,, ,, ,, ,,	0·081		15
Comparative working expenses :		£2,340	£2,105
Interest on loan		73	77
Redemption of debt		236	247
Additional provision for renewals		87	91
Comparative operating costs		£2,736	£2,520
Difference in favour of heavy-oil buses		£216 = 1·152*d.* per bus-mile.	

Repairs and maintenance cover all the costs of both the day-to-day maintenance in the garages, regular dock overhauls, and complete overhauls. From the returns made by the different undertakings it appears that everybody has now adopted a more or less similar system. Engine and chassis are light docked every 20,000 miles, and this dock generally consists of the removal of the cylinder head, attention to valves, decarbonizing, dropping of the sump, and inspection of the bearings, cleaning of oil filters and oil system generally, refilling with fresh oil, and the checking of the fuel-pump timing. With some undertakings the fuel-pump calibration is also checked at the same time.

Up to a few years ago it was the custom to put all vehicles through a complete overhaul after 60,000 miles, but owing to the improvements in material and design, this figure has gradually been increased, until now 100,000 is looked upon as being an appropriate mileage at which to carry out a complete overhaul. Unfortunately on fast City services, where engines are subject to very severe treatment, it is not generally advisable to let the engine run for such a period, and in many undertakings it is customary therefore to carry out a semi-overhaul at 50,000–60,000 miles or to change the engine unit for a thoroughly overhauled unit.

At the complete overhaul of the engine it is usually necessary to either re-grind the sleeves or cylinder bore and fit oversize pistons, or, alternatively, re-sleeve back to standard size. The crankshaft will require re-grinding, and all the bearings, both main and big-end, will require renewal. It will also be found that certain of the valve-seats will require new inserts. In the larger undertakings the engine, after such an overhaul, is thoroughly bench-tested and ready to start a fresh life, as good as new. The costs given for this overhaul vary from £30 to £90, but in comparing the costs of the overhaul of the petrol and oil engine, I have used the Manchester figures, which are comparable with similar undertakings, and the cost of overhaul of the oil engine is approximately £20 more than the petrol engine. Certain engine-manufacturers undertake the overhaul of their engines for users, and we in Manchester have had oil engines overhauled by well-known makers at a cost of £75 nett. Our own price for this job over twelve months has worked out at £74 8*s*., so that I think we may say that the figures I have used are fair and reasonable. Some undertakings claim, in their replies to the Questionnaire, to have carried out their overhauls for considerably less than this, but you will appreciate that circumstances alter cases, and there may be particular reasons which result in the engine not needing such heavy repairs as are required after 60,000 miles' arduous service in heavy city traffic.

The distinguishing unit between the oil engine and the petrol engine is the fuel-injection pump which takes the place of both carburettor and magneto on the petrol engine. This pump is remarkably efficient, and in fact it is largely due to this pump efficiency that the high-speed compression-ignition engine has made such progress. In the maintenance of the pump we find it advisable to check the calibration at every light dock (20,000 miles), but the actual repair and replacement required by the pump—even at 100,000 miles—are very small. Most of the large undertakings now have an electrically driven machine for testing and calibrating fuel-injection pumps, and these have proved of great service, inasmuch as the fuel consumption has been improved as a result of a periodic calibration on the machine. The following table shows the pump-settings which have been standardized in Manchester, and the effect of using and maintaining these settings has been an improvement in the fuel consumption of the fleet of half a mile per gallon :—

Calibration Letter.	Code.	Overload Setting, C.C.	Full-load Setting, C.C.	Governor Springs.	Governor R.P.M.		Max. M.P.H.
					Min.	Max.	
A	A.2M7E	9·4	7·7	7023/84	180	770	30·4
	B.2M7E	9·4	7·0	7023/78			
B	A.2M6E	9·4	7·0	7023/36	180	870	30·4
	B.2M6E			7023/75			
				7023/38			
C	C.3M7E	9·4	8·4	7023/84	180	770	30·4
				7023/78			
D	C.3M6E	9·4	7·7	7023/36	180	870	30·4
				7023/75			
				7023/38			
G	A.2S7K	9·4	7·7	7023/84	180	770	32·2
	B.2S7K			7023/78			
				7023/38			
H	A.3S7H	9·4	7·9	7023/84	180	770	30·7
	B.3S7H			7023/78			
L	—4L4E	9·3	8·6	7023/84	180	800	33·5
				7023/78			
M	—4L6E	9·3	7·6	7023/84	180	900	31·5
				7023/78			
				7023/38			
N	—4T5F	9·3	8·2	7023/84	180	800	32·9
				7023/78			

KEY.

First (letter).	Heads.	Second (Number).	Engine.
A	A type	2	4·7/16 × 6
B	B ,,	3	4·7/16 × 5½
C	C ,,	4	4½ × 5½
D	D ,,		

Third (letter).	Chassis.	Fourth (Number).	Differential ratio.
M	Type x D.D.	4	5·4
S	Type x S.D.	5	5·5
L	Type z D.D.	6	6·5
T	Type z S.D.	7	5·75

Fifth (letter).	Tyre Size.
E	9·00 × 20
F	230 × 20
H	8·25 × 22
K	8·25 × 24

I cannot too strongly urge engineers to pay most careful attention to the settings and calibration of the fuel-pumps.

FUELS.

The type of fuel used has obviously a very important bearing on the question of operating costs. Some years ago in Manchester we were put to a great deal of unnecessary expense through using an unsuitable petrol, and we have since taken particular care to have samples regularly tested. The petrol which gave trouble had a final boiling point of 239° C., with a result that crankcase dilution was excessive and engine trouble followed. As a result of our experience we consider that a petrol with a final boiling point of over 200° C. is unsuitable for our purpose. The following is an average test of a petrol which has been found suitable :—

Specific gravity	0·741
Distillation test :	
First drop collected at	41·0° C.
Between first drop and 105° C.	37·5%
,, 105° C. and 150° C.	38·0%
,, 150° C. and 180° C.	16·5%
Above 180° C.	6·5%
Loss on distillation	1·5%
	100%

Maximum temperature of distillation—199·5° C.
Sulphuric-acid test—Acid layer assumes light orange-yellow coloration.
Effect on bright copper—Nil.
Doctor test—Negative.
Colour—Water-white.

This test can be carried out by the chemical laboratory of the Corporation, and in fact frequent test-samples are taken and tested during the period of a contract. The octane number of the spirit is given by the suppliers as 69·5.

The oil used for our compression-ignition engines, which the general public will insist on calling " crude " oil, is, as you are well aware, a high-grade gas oil. It is much more difficult for the users to make certain that the fuel is up to specification, the engine test being, I think, the only real criterion. From the replies to the Questionnaire, the majority of undertakings are using well-known standard gas oils, of which the following is a typical specification :—

Specific gravity at 60° F.	0·845
Flash-point (P.M.)	220° F.
Viscosity (Redwood) at 70° F.	42 seconds.
,, ,, ,, 100° F.	36 ,,
Calorific value	19,500 minimum B.T.U.
Spontaneous ignition temperature	240° C.
Carbon residue	0·01%
Ash	0·003%
Sulphur	0·13%
Cetane number	57·5 minimum.
Initial boiling point	240° C.
10% over at	263
20% ,,	272
30% ,,	278
40% ,,	285
50% ,,	291
60% ,,	298
70% ,,	306
80% ,,	318
90% ,,	340
95% ,,	362
Final boiling point	Below 370° C.
Recovery	97%
Residue	1·5%
Loss	1·5%
Pour-point	10° F.

This specification is, in my opinion, better than the British Standard Specification for high-speed diesel fuel No. 209, published July 1937, the latter permitting a maximum viscosity of 45 secs. (Redwood) at 100° F. Our experience in Manchester leads us to think that the viscosity we are now using—about 36 secs. (Redwood)—is much more suitable, as there are difficulties in supplying a higher viscosity fuel to the engine.

I have made some experiments with a view to comparing different gas oils as regards startability in our engines. An auxiliary tank filled with a mixture of ice and salt was connected in series with the engine-cooling system, and an independently driven circulating pump used to circulate the brine mixture through the engine until the temperature of the cooling water was brought down to 15° F.

These tests showed the necessity of using lubricating oil with a good cold test, as it was necessary to turn the engine at 80 r.p.m. to be certain of a start, under these conditions of extreme cold.

Comparative fuel tests are also made with engines on the test-bench at the Works, where we have two Heenan and Froude electro-dynamic engine-testers, the following being the result of a typical test :—

Fuel " A "—Average of 5 runs of 15 mins. each :—
1400 r.p.m., 76·64 b.h.p., 0·603 pt. per b.h.p.

Fuel " B "—Average of 5 runs of 15 mins. each :—
1400 r.p.m., 78·75 b.h.p., 0·581 pt. per b.h.p.

These tests are of value as a comparative test only, due to the fact that our flowmeters are calibrated for petrol and this test was taken on an oil engine. The performance of the engine was better in every way when running on fuel " B."

Whatever method of grading or rating the fuels is ultimately decided on, one of the most important points to the user is that the ignition delay angle should be as small as possible, and it has been found that there is a direct relationship between the anti-knock value and the delay angle, zero knock or the best possible smooth running being equal to 3·5° of ignition delay.

Good ignition qualities, low viscosity, freedom from impurities, and absence of wax separation are all desirable in a fuel oil for compression-ignition engines. Ease of starting on both oil and petrol engines has a direct bearing on cost, for unless the engine will start easily after standing all night, it is necessary to have either special gangs of men going round starting up, or self-contained portable petrol-engine-driven starters, or even, in many instances, it becomes necessary to tow the vehicle with another one, adding considerably to the running costs.

A direct-injection oil engine normally has a better start than a similar petrol engine, but with some of the indirect type there are starting difficulties, particularly in cold weather. We have found that by using double pole-heater plugs connected direct to the 12-volt lighting and starting battery, it is nearly always possible to get a cold start. The heater-plug is controlled by a special switch, which, when turned into the first position, heats the plugs, including a tell-tale plug in the driver's cab. When this is glowing brightly, the switch is moved into the second position which operates the starter-motor. We have also developed in some of our garages a system of radiator heating, whereby low-pressure steam is allowed to bubble through the radiator throughout the night, the steam-pipe being connected to a special tap at the bottom of the radiator-tank.

This has proved very satisfactory and economical for both petrol and oil engines, as the temperature of the engine is maintained at over 100° F. throughout the night.

In Manchester it is our practice to centrifuge all fuel oil before delivery to the buses, oil being received from the contractor into the large storage-tank, from which it is pumped through a centrifuge into the service-tank. Although there are only two other undertakings who have reported that they also use the centrifuge, we have formed a definite opinion that this process is a profitable one. The actual cost of centrifuging, including all capital charges of the plant and labour, is less than 0·1*d.* per gallon, and it has been noticeable when one of the centrifuges has been temporarily out of service, complaints from the buses belonging to that garage regarding black smoke, etc., have immediately increased. The majority of the undertakings have reported that they now get very few complaints from the police or public regarding fumes, this being due to the better attention to the pump and atomizer systems. Seventeen of the undertakings replying have installed power-driven testing machines for calibrating the fuel-pumps, and report savings of from 5 to 10 per cent. In Manchester it is now our practice to check every pump at 20,000 miles, and this has resulted in an improvement of 5 per cent. in the fuel consumption of the fleet.

LUBRICATION.

The question of lubrication is one on which, as you know, many papers have been written, and many more will be written. Most engineers hold very decided opinions, some believing in the cheapest oils, and others in the very highest quality. From the returns made by the undertakings it appears that most municipal operators take the middle course, using a lubricant of a reasonable price and making no attempt to reach phenomenal oil-consumption figures in miles per gallon. Tests have been carried out with all types of oil, and in our opinion the better consumption obtained from the higher-quality oils was not sufficient to offset the increased cost. Provided an oil of good cold test and as low a viscosity as can be used with safety is specified, no harm will result, and the wear figures will not be excessive. In fact in Manchester with a medium-priced oil and the following specification :—

Specification No. 1. (*Diesel lub. oil.*)

	Winter.	Summer.
Specific gravity at 60° F.	0·905	0·907
Closed flash	440° F.	440° F.
Open flash	460° F.	460° F.
Viscosity (Redwood) at 70° F.	1120 secs.	1450 secs.
,, ,, ,, 140° F.	136 ,,	165 ,,
,, ,, ,, 200° F.	56 ,,	62 ,,
Viscosity index	85	85
Cold test pour I.P.T.	5° F.	5° F.
Demulsibility number I.P.T.	3	4
Fatty oil, %	Nil	Nil
Carbon residue Ramsbottom A	0·19%	0·25%
,, ,, ,, B	1·12%	1·22%
Colour	Deep pale	Very light red

cylinder-wear figures as low as 12,000 miles per 0·001 inch for petrol engines, 15,000 miles per 0·001 inch for direct-injection oil engines and

33,000 miles per 0·001 inch for indirect-injection oil engines are regularly obtained. These figures are not isolated cases, but are averages of a large number of engines.

Twenty-two undertakings have given details of the specification of the lubricating oils which they use. It is not necessary to give all these in detail, as fifteen of them are similar to that already given for Manchester.

Three undertakings are using oil similar to Specification No. 2 (below), the price of this being approximately 60 per cent. more per gallon than the oil in the Manchester Specification.

Three undertakings are each using special oils. Specification No. 3 (*a*) is apparently a solvent-refined oil of a low viscosity with a very high viscosity index (108), and the price is slightly higher than that of the previously mentioned solvent oils. A specially treated oil with a graphite content is shown in Specification No. 3 (*b*) and this has the highest viscosity index of any oil reported—viz., 111. The third undertaking which is using special oil reports that it is using lubricating oil which has been electrically treated, but it does not pass any comment on the results obtained.

Specification No. 2.

Specific gravity at 60° F. . . .	0·880–0·885
Closed flash	440–450° F.
Viscosity (Redwood) at 70° F. . . .	2200–2300 secs.
,, ,, ,, 140° F. . . .	255–260 ,,
,, ,, ,, 200° F. . . .	80–83 ,,
Cold test pour I.P.T.	15° F.
Demulsibility number I.P.T. . . .	—
Carbon residue Ramsbottom A . .	0·30–0·35%
,, ,, ,, B . .	0·80–0·90%

Specification No. 3.

	(*a*).	(*b*).
Specific gravity at 60° F. . . .	0·873	0·882
Closed flash	405° F.	430° F.
Open flash	415° F.	450° F.
Viscosity (Redwood) at 70° F. . . .	660 secs.	1450 secs.
,, ,, ,, 140° F. . . .	107 ,,	185 ,,
,, ,, ,, 200° F. . . .	53 ,,	71 ,,
Viscosity index	108	111
Cold test pour I.P.T.	15° F.	0° F.
Demulsibility number I.P.T. . . .	1	4½
Fatty oil, %	Nil	1½%
Carbon residue Ramsbottom A . .	0·42%	0·52%
,, ,, ,, B . .	—	1·35%

Finally there is one other interesting point, and that is that one municipality with a fleet of over 100 buses has entered into a mileage contract for the lubrication of their vehicles, the contractor apparently being responsible for all the lubrication of the fleet and being paid so much per bus-mile.

TAXATION.

The question of taxation has a great bearing on the development of any new type of prime mover for road-transport work. The absence of additional taxation undoubtedly assisted the early development of the oil engine, the position in 1932 being that whereas petrol was carrying a tax of 8*d*. per gallon, gas oil was free of tax, and the licence for the oil-driven vehicle was exactly the same as the petrol vehicle. In 1933, however, there was an additional tax of 1*d.* per gallon on both gas oil and lubricating oil, and the licence of a double-deck fifty-two-seater bus was increased from £86 8*s.* to £148 if driven by an oil engine. In 1935 the additional Road Fund tax was removed, and the 8*d.* per gallon fuel tax put on gas oil in the same way as on petrol. Finally, in 1938 there was an additional 1*d.* per gallon, making 9*d.* on both petrol and fuel oil. This is shown clearly in the following table :—

52-*Seaters.*

	Petrol.		Heavy Oil.	
1932.				
	Tax	8*d.*	Tax	Nil
	Lubricating oil	—	Lubricating oil	—
	Licence	£86 8*s.*	Licence	£86 8*s.*
1933–34.				
	Tax	8*d.*	Tax	1*d.*
	Lubricating oil	1*d.*	Lubricating oil	1*d.*
	Licence	£86 8*s.*	Licence	£148
1935–36.				
	Tax	8*d.*	Tax	8*d.*
	Lubricating oil	1*d.*	Lubricating oil	1*d.*
	Licence	£86 8*s.*	Licence	£86 8*s.*
1938–39.				
	Tax	9*d.*	Tax	9*d.*
	Lubricating oil	1*d.*	Lubricating oil	1*d.*
	Licence	£86 8*s.*	Licence	£86 8*s.*

It is interesting to note that the amount paid for motor-omnibus licences in Manchester for the financial year (1937–38) was as follows :—

Road Fund licences	£45,955
Traffic Commissioner's licences	2,555
	£48,510

The amount paid in tax on petrol and heavy oil for the financial year (1937–38) was £104,716. The amount paid in tax on lubricating oil was £385. Thus the total taxation paid was £153,611.

The table in Appendix V illustrates the effect of the varying taxation on the running costs and savings in favour of the oil engine.

The average fuel cost per mile of the undertakings replying to the Questionnaire were as follows :—

Average Cost per Mile.

	Double Decks.		Single Decks.	
Petrol	2·889	2·889	2·441	2·441
Heavy oil, direct	1·423		1·220	
,, indirect		1·569		1·367
Saving in favour of oil engine (in pence per bus-mile)	1·466	1·320	1·221	1·074

To conclude, it will be noted from the summary of the Questionnaire that there are now very few complaints against the oil engine. It has the advantage that the brake thermal efficiency is approximately 32 per cent., as against 22 per cent. for the petrol engine and, further, it runs most economically at about 60 per cent. of full load, which is the condition under which the engine is mostly running in service. The performance on the road is generally admitted to be a gear better than a petrol-driven bus, and experiments are now being made with over-speed gear-boxes so as to give a higher road speed and take advantage of the good torque with the diesel engine at low speeds. Further, there is less risk of fire, and no restriction on the storage and handling of the fuel.

The oil engine to-day runs comparatively quietly, and in fact many passengers cannot tell the difference. There remains, then, the saving in fuel, which averages 1·357*d*. per mile for a double-deck bus (see p. 579), from which must be deducted the slight extra maintenance cost of 0·080*d*. per mile, the higher lubrication cost of 0·024*d*. per mile and the additional debt redemption charges of 0·101*d*. per mile, leaving a nett saving per bus-mile of 1·152*d*., equivalent to £216 per vehicle per annum on a basis of an annual mileage of 45,000.

As to the future, we look forward to a reduction in the power-weight ratio of the compression-ignition engine and a further reduction in the first cost. There is also a possibility of further economies with the introduction of super-charging and the two-stroke engine.

Experiments are actively in progress with the Erren system of injecting a percentage of hydrogen gas into the compression-ignition engine, which it is claimed can produce a further economy of 30 per cent. provided hydrogen can be purchased at a reasonable price. It is stated that if hydrogen could be purchased at 8*d*. per 1000 cu. ft., it would be equivalent to diesel oil at 3*d*. per gallon or petrol at 2*d*. per gallon. The Erren system is claimed to give smoother running and a clean exhaust, in addition to fuel economy.

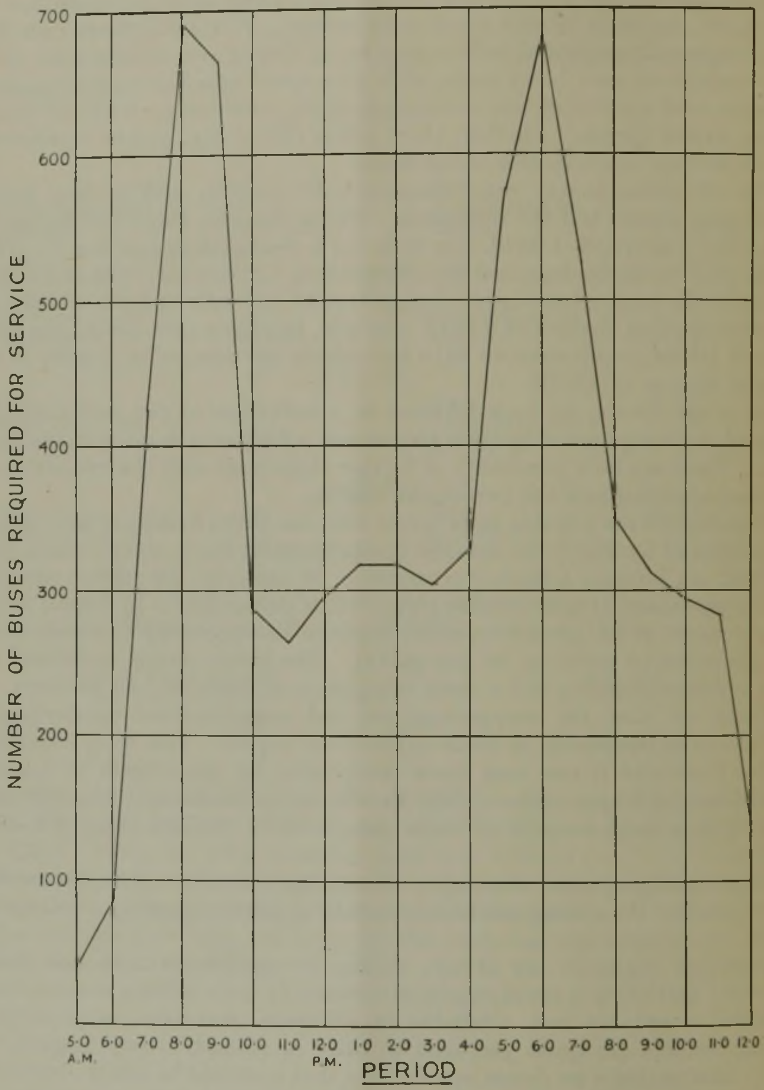
There are also the compressed-gas and self-contained producer-gas vehicles to be considered as rivals to the diesel engine. In certain countries on the Continent it has been made compulsory for the owners to operate a minimum of 10 per cent. of their fleet on home-produced fuels, and this has led to a large number of these gas-producer vehicles being put into service.

Experiments are again starting in this country, and it will be interesting to see whether the system can be successfully applied to passenger-transport work.

Transport engineers are always willing to experiment with new fuels provided that there is some reasonable chance of their being a success, and provided a suitable fuel, available in sufficient quantities, is produced, engine-builders are quite prepared to alter or re-design their engines to suit. The qualities we desire in a fuel are that it should be easily obtained, safe to store and handle, and stable under normal storage conditions. It should give easy starting, smooth running, and clean combustion, leave no undesirable residue in the cylinders, be stable in price, and cheap. It is the author's contention that at the moment the compression-ignition engine using standard gas oils stands unchallenged as the cheapest, safest, and best method of propelling a road passenger-transport vehicle.

APPENDIX I.

Buses Required for Service.



APPENDIX II.

Particulars of Passenger Vehicles Operated by Members of the M.T. and T.A.

At :	31st December, 1934.	30th June, 1935.	31st December, 1935.	30th June, 1936.	31st December, 1936.	30th June, 1937.	31st December, 1937.	30th June, 1938.
Motor omnibuses :								
Petrol :								
Single-deck	2343	2206	2063	1960	1805	1688	1583	1433
Double-deck	2613	2512	2490	2447	2361	2174	2026	1904
Total	4956	4718	4553	4407	4166	3862	3609	3337
Oil :								
Single-deck	225	328	450	521	605	699	853	935
Double-deck	919	1379	1813	2065	2708	3252	4034	4486
Total	1144	1707	2263	2586	3313	3951	4887	5421
Total motor-buses :								
Single-deck	2568	2534	2513	2481	2410	2387	2436	2368
Double-deck	3532	3891	4303	4512	5069	5426	6060	6390
Total	6100	6425	6816	6993	7479	7813	8496	8758

APPENDIX III.

Mechanically Propelled Road Vehicles—Great Britain.

Vehicles for which licences were current during quarter ended 30th September, 1935, 1936, 1937 and 1938.
Compiled from Ministry of Transport Returns.

A.—HACKNEY VEHICLES.

	Number of Vehicles.				Per cent. of Total.				Increase or Decrease in Three Years.	
	1935.	1936.	1937.	1938.	1935.	1936.	1937.	1938.	Number.	Per cent.
Internal-combustion engines :										
Light oil :										
(*a*) Up to eight seats . .	38,331	36,893	34,784	34,723	39·75	38·32	36·45	35·90	− 3,608	− 9·412
(*b*) Over eight seats . .	40,499	38,981	35,860	32,960	42·00	40·49	37·58	34·08	− 7,539	− 18·61
Heavy oil, etc. . . .	5,541	8,547*	12,997	17,322	5·75	8·88	13·62	17·91	+11,781	+212·62
Electrically-propelled (trolley vehicles)	1,176	1,588	2,125	2,725	1·22	1·65	2·23	2·82	+ 1,549	+131·72
Tramcars	10,872	10,260	9,657	8,988	11·28	10·66	10·12	9·29	− 1,884	− 17·33
Total . . .	96,419	96,269	95,423	96,718	100·00	100·00	100·00	100·00	+ 299	+ 0·31

* Includes 1 petrol and coal-gas fuel vehicle.

B.—GOODS VEHICLES.

(Excluding agricultural vans, etc., showmen's special vehicles.)

	Number of Vehicles.				Per cent. of Total.				Increase or Decrease in Three Years.	
	1935.	1936.	1937.	1938.	1935.	1936.	1937.	1938.	Number.	Per cent.
Internal-combustion engines :										
Light oil :										
(*a*) Up to 2½ tons . .	360,309	382,777	401,450	415,842	85·31	85·93	86·47	86·80	+55,533	+ 15·41
(*b*) Over 2½ tons . .	52,644	52,251	50,988	49,299	12·46	11·73	10·96	10·30	− 3,345	− 6·35
Heavy oil, etc. . . .	5,417	6,149*	7,107†	8,552	1·28	1·38	1·6	1·78	+ 3,135	+ 57·87
Coal gas	14	7	12	18	—	—	—	—	+ 4	+ 28·57
Steam-driven . . .	2,018	1,671	1,283	986	0·5	0·38	0·26	0·20	− 1,032	− 51·14
Electrically propelled . .	1,885	2,600	3,320	4,397	0·45	0·58	0·71	0·92	+ 2,512	+133·26
Total . . .	422,287	445,455	464,160	479,094	100·00	100·00	100·00	100·00	+56,807	+ 13·45

* Includes 5 petrol and coal-gas vehicles.
† Includes 7 petrol and coal-gas vehicles.

APPENDIX IV.

Schedule showing the Annual Sum Required to be Set Aside and to Accumulate at 3 per cent. Compound Interest, in Order to Repay a Loan of £2200 in Eight Years.

Year. 1.	Annual Payment into the Fund. 2.	Annual Interest on Accumulations. 3.	Total, Columns 2 and 3. 4.	Total in Fund at End of Each Year. 5.
	£ s. d.	£ s. d.	£ s. d.	£ s. d.
1	247 8 1	—	247 8 1	247 8 1
2	247 8 1	7 8 5	254 16 6	502 4 7
3	247 8 1	15 1 4	262 9 5	764 14 0
4	247 8 1	22 18 0	270 6 11	1035 0 11
5	247 8 1	31 1 0	278 9 1	1313 10 0
6	247 8 1	39 8 1	286 16 2	1600 6 2
7	247 8 1	48 0 2	295 8 3	1895 14 5
8	247 8 1	56 17 6	304 5 7	2200 0 0

Statement showing the Additional Provision required Each Year to Reduce the Period to 6½ Years.

Year.	Amount as per Col. 4 Above.	Additional Provision.	Total.
	£ s. d.	£ s. d.	£ s. d.
1	247 8 1	91 1 2	338 9 3
2	254 16 6	83 12 9	338 9 3
3	262 9 5	75 19 10	338 9 3
4	270 6 11	68 2 4	338 9 3
5	278 9 1	60 0 2	338 9 3
6	286 16 2	51 13 1	338 9 3
6½	147 14 1	21 10 5	169 4 6
7	147 14 2	—	—
8	304 5 7	—	—
	£2200 0 0	£451 19 8	£2200 0 0

It will be seen that should the vehicle last the full period of eight years, there is £451 19*s*. plus interest accrued in the Renewals Fund available for other purposes.

APPENDIX V.

Schedule showing the Effect on Power and Lubricating Costs of Taxation on a Standard D.D. Bus (48–56 Seats) Running an Annual Mileage of 45,000.

COST PER BUS-MILE.

(Market fluctuations ignored.)

	1932.				1934.				1936.				1938.			
	Petrol Engine.		H.-Oil Engine.		Petrol Engine.		H.-Oil Engine.		Petrol Engine.		H.-Oil Engine.		Petrol Engine.		H.-Oil Engine.	
		Pence p.b.m.		Pence p.b.m.		Pence p.b.m.		Pence p.b.m.		Pence p.b.m.		Pence p.b.m.		Pence p.b.m.		Pence p.b.m.
Licence amount .	£86 8*s.*	0·461	£86 8*s.*	0·461	£86 8*s.*	0·461	£148	0·789	£86 8*s.*	0·461	£86 8*s.*	0·461	£86 8*s.*	0·461	£86 8*s.*	0·461
Petrol or fuel oil per gall. . . .	4·16*d.*	0·885	3·625*d.*	0·414	4·16*d.*	0·885	3·625*d.*	0·414	4·16*d.*	0·885	3·625*d.*	0·414	4·16*d.*	0·885	3·625*d.*	0·414
Petrol or fuel oil tax per gall. . .	8·00	1·702	—	—	8·00	1·702	1·000	0·114	8·00	1·702	8·000	0·914	9·00	1·915	9·000	1·029
Engine lubricating oil per gall. . .	13·20	0·053	15·200	0·076	13·20	0·053	15·200	0·076	13·20	0·053	15·200	0·076	13·20	0·053	15·200	0·076
Engine lubricating oil tax per gall. .	—	—	—	—	1·00	0·004	1·000	0·005	1·00	0·004	1·000	0·005	1·00	0·004	1·000	0·005
Comparative costs .		3·101		0·951		3·105		1·398		3·105		1·870		3·318		1·985
Difference in favour of C.I. engine .	2·150				1·707				1·235				1·333			

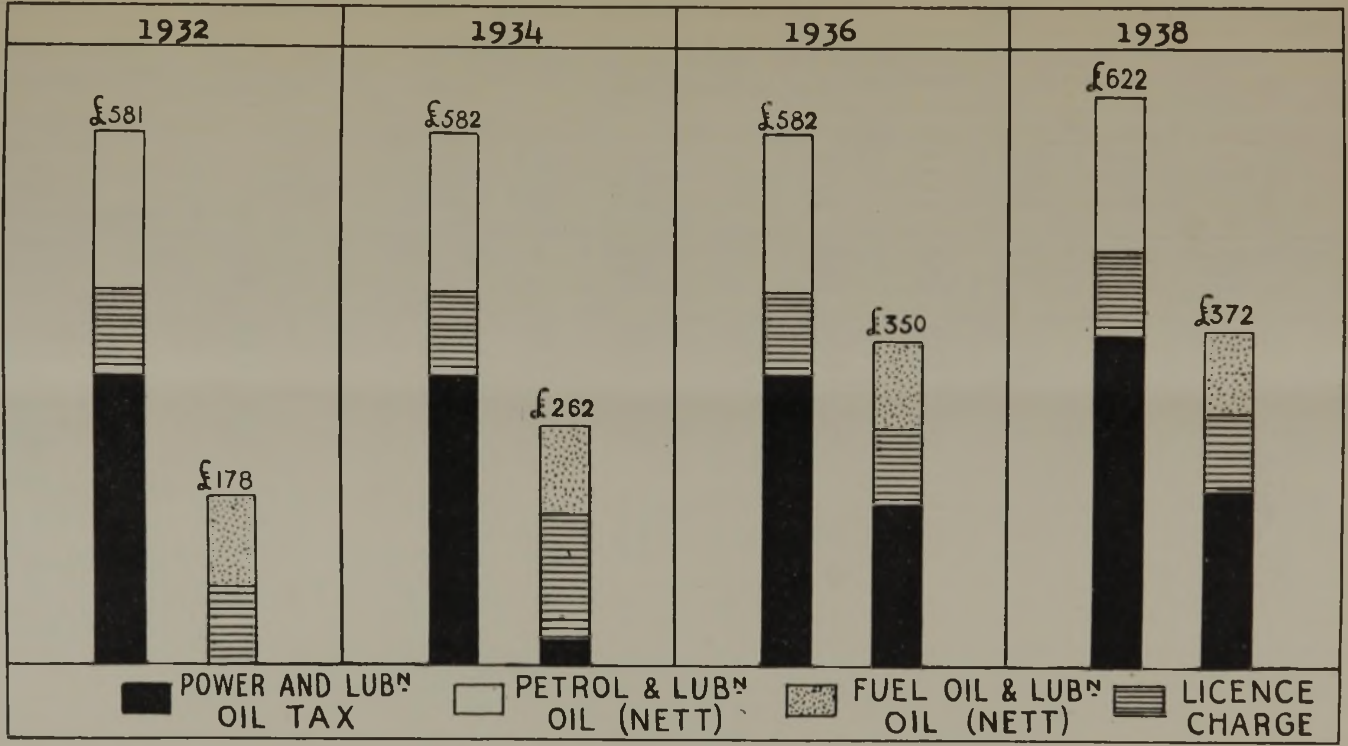
APPENDIX V (*continued*).

Nett Power and Lubrication Costs and Taxation.

(Calculated to the nearest £.)

	Nett.	Tax.	Nett.	Tax.	Nett.	Tax.	Nett.	Tax.	Nett.	Tax.	Nett.	Tax.	Nett.	Tax.	Nett.	Tax.
Licence . . .	—	£86	—	£86	—	£86	—	£148	—	£86	—	£86	—	£86	—	£86
Petrol or fuel oil .	£166	£319	£78	—	£166	£319	£78	£21	£166	£319	£78	£171	£166	£359	£78	£193
Engine lubricating oil	£10	—	£14	—	£10	£1	£14	£1	£10	£1	£14	£1	£10	£1	£14	£1
Totals . . .	£176	£405	£92	£86	£176	£406	£92	£170	£176	£406	£92	£258	£176	£446	£92	£280
Aggregate costs .	£581		£178		£582		£262		£582		£350		£622		£372	
Difference in favour of C.I. engine .	£403				£320				£232				£250			

APPENDIX VA.


1932
1934
1936
1938
£581
£178
£582
£262
£582
£350
£622
£372
POWER AND LUBN OIL TAX
PETROL & LUBN OIL (NETT)
FUEL OIL & LUBN OIL (NETT)
LICENCE CHARGE

Summary of Information from Twenty-six Undertakings.

	1.		2.		3.		4.		5.		6.	
	D.D.	S.D.	D.D.	S.D.	D.D.	S.D.	D.D.	S.D.	D.D.	S.D.	D.D.	S.D
No. of buses in fleet :												
Petrol	—	—	3	12	35	—	15	27	31	6	10	25
Oil	25	7	52	8	78	12	17	34	59	10	49	—
Fuel consumption, m.p.g. :												
Petrol	—	—	5·00	6·25	4·36	—	5·06	5·60	4·55	5·90	—	—
Direct-oil . . .	8·75	—	9·25	11·50	10·13	10·50	10·69	10·58	9·32	9·61	9·46	—
Indirect-oil . . .	8·75	—	8·50	—	9·05	—	8·25	8·20	8·63	—	7·78	—
Lubricating-oil consumption :												
Petrol :												
5,000 m. . . .	1000	—	600	1929	1400	—	1000	1200	—	—	—	—
20,000 m. . . .	1000	—	394	1760	1200	—	700	770	—	—	—	—
40,000 m. . . .	800	800	380	1240	700	—	600	600	—	—	—	—
Direct-oil :												
5,000 m. . . .	1000	—	3397	2600	3037	3586	4000	4500	—	—	16,713	—
20,000 m. . . .	800	—	1700	2100	2014	2332	3000	2250	—	—	13,641	—
40,000 m. . . .	600	—	725	1918	1229	1413	1700	1750	—	—	8,889	—
Indirect-oil :												
5,000 m. . . .	1000	—	600	—	1793	—	2500	565	—	—	516	—
20,000 m. . . .	750	—	360	—	1218	—	1080	350	—	—	301	—
40,000 m. . . .	550	—	348	—	575	—	430	190	—	—	200	—
Average yearly mileage :												
1st year . . .	—	—	50,096	47,154	51,000	—	—	—	39,000	31,000	—	—
2nd year . . .	No figures given.		45,482	49,483	50,000	—	—	—	39,000	31,000	—	—
3rd year . . .			33,296	44,562	49,000	—	—	—	39,000	31,000	—	—
4th year . . .	—	—	31,807	40,317	35,000	—	—	—	39,000	31,000	—	—
Schedule speed, m.p.h. .	11		12·89		11·39		13·7		10		95	
Nature of routes ? . .	Chiefly hilly.		Average.		Mainly city services.		Hilly.		Flat.		Flat and easy	
Comparative cost of overhaul ?	Oil £12 more than petrol.		Petrol £2 more than oil (labour only).		Not comparable, mostly oil engines.		Oil £20 10*s.* more than petrol.		Costs the same.		No figures.	
Excessive wear ?	Occasional crankshaft and one gudgeon pin.		Mostly piston-ring trouble. Top ring, excessive wear.		Piston-ring grooves. Governor units.		No.		No.		Depends on type.	

Type of bearing.	Mains—white metal.	Aluminium alloy, lead bronze and chromet top half big end.	100% lead bronze, changing to lead bronze rods, top mains, bottom.	Direct, 100% white metal. Indirect, 100% lead bronze.	Mains—white metal. Rods—aluminium alloy and lead bronze alloy.	Chromet, few with lead bronze.
Many bearing failures ?	No.	No.	No.	No.	No.	Earlier type—yes.
Crankshaft hardened ?	No.	One make only.	No.	No.	Yes.	One only.
Pump : check calibration ?	Annual, work sent out.	Every 20,000 miles.	Every 20,000 miles.	Every heavy dock.	Every heavy dock.	When engine is taken down for mechanical failure.
Delivery setting ?	—	7·5/8·0 c.c. at 100 r.p.m.	—	As specified by makers.	10·5 c.c at 600 r.p.m.	—
Power machine ?	—	Yes—home-made.	Yes.	No.	Yes.	No—hand.
Consumption improved ?	—	No figures available.	Yes—0·750 m.p.g.	—	Yes—0·002 m.p.g.	—
Atomizers cleaned regularly ?	Yes.	Yes—every 5000 miles.	Yes—every 5000 miles.	Yes—every 5000 miles.	Every light and heavy dock.	Yes—every 5000 miles.
Centrifuge filters ?	No.	No.	No.	No.	No.	No.
Exp.-oil inhibitors ?	No.	No.	Yes—cleaner and gives best wear figures.	Yes—wear considerably less.	No.	No.
Reclaim ?	No.	Yes.	Yes.	Yes.	Yes.	Yes.
Sumps drained ?	Every 3000 miles.	Every 3000 miles.	Every 5000 miles.	Every 5000 miles.	Every 5000 miles.	Every 3000 miles.
Saving of oil p.b.m. over petrol ?	⅛*d*. per mile.	Estimated 0·38*d*. per mile.	Fuel—1·3*d*. per mile.	—	Chief saving on petrol.	About 1·00*d*. per bus-mile.
Starting difficulty ?	No.	No.	No—Whipple to save battery.	Yes—converting to direct injection.	Occasionally—cold. Whipple starter.	No—Carrier-Ross system.
Breakdowns—less with oil engines ?	Yes.	Yes.	Yes.	Yes.	Yes.	Yes.
Pump and injection system more reliable than mag., carb., etc. ?	Yes.	Yes.	Yes.	Yes.	Yes.	Yes.
Drivers' preference ?	No.	Yes—oil engines.	Yes—oil engines.	Yes—petrol engines.	Yes—oil engines.	Wilson gearbox and fluid transmission.
Complaints about oil engines ?	No.	No.	Odd one or two from police. Direct inject., not since mod. pistons and injectors fitted.	No.	Remote comments.	No.

Summary of Information from Twenty-six Undertakings (continued).

	7.		8.		9.		10.		11.		12.		13.	
	D.D.	S.D.	D.D.	S.D.	D.D.	S.D.	D.D.	S.D.	D.D.	S.D.	D.D.	S.D.	D.D.	S.D.
No. of buses in fleet :														
Petrol	27	19	7	4	7	14	4	—	19	—	23	4	—	—
Oil	80	—	57	9	77	20	10	24	41	—	68	10	50	16
Fuel consumption, m.p.g. :														
Petrol	4·80	6·00	4·40	5·55	3·50	4·50	5·12	—	4·70	—	4·52	6·01	—	—
Direct-oil	9·35	—	8·55	10·23	9·25	11·00	9·50	11·50	9·00	—	9·20	11·54	10·90	11·50
Indirect-oil	—	—	—	—	8·50	—	—	—	8·60	—	—	—	—	—
Lub.-oil consumption :														
Petrol :														
5,000 m.	—	—	500	540	No useful data. 8/10 years old.		1000	D.D. & S.D. Falls rapidly after this.	240 average. Sump drainings included.		443	2774	—	—
20,000 m.	—	—	450	540			900				340	2000	—	—
40,000 m.	—	—	420	520			600				326	1982	—	—
Direct-oil :														
5,000 m.	1125	—	710	1100	—	—	2000	Keeps steady after this.	350 average. Sump drainings included.		2571	1867	Average : 800	1200
20,000 m.	700	—	690	1060	—	—	1900				984	1326		
40,000 m.	341	—	500	1000	—	—	1800				984	1442		
Indirect-oil :														
5,000 m.	—	—	—	—	1090	—	—	—	350 average. Sump drainings included		—	—	—	—
20,000 m.	—	—	—	—	510	—	—	—			—	—	—	—
40,000 m.	—	—	—	—	480	—	—	—			—	—	—	—
Average yearly mileage :														
1st year	40,000	—	37,100	30,500	50,000	50,000	57,000	50,000	40,000	—	62,789	54,000	—	—
2nd year	40,000	—	37,400	31,700	50,000	50,000	46,000	44,500	40,000	—	61,490	53,758	—	—
3rd year	35,000	—	29,100	33,500	50,000	45,000	45,000	35,000	40,000	—	49,546	43,309	—	—
4th year	30,000	—	31,000	26,700	40,000	40,000	49,000	—	40,000	—	47,375	35,122	—	—
Schedule speed, m.p.h.	9·5		10		9·6		10·97		9		11·18		8·6	
Nature of routes ?	Flat, many stops. Short routes.		Comparatively flat —8 stops per mile, town and suburban.		Hilly.		Mainly flat.		Flat, many stopping-places.		Town and suburban, some hilly.		Generally flat, max. grad. 1 in 8.	
Comparative cost of overhaul ?	Oil £10 more than petrol.		—		Oil £13 more than petrol.		Oil £10 more than petrol.		Oil £10 more than petrol.		Oil £5 more than petrol.		—	
Excessive wear ?	Cylinder wear. Piston wear.		Pump fibre couplings and few Duralumin rods, none since replaced steel.		Crankshafts.		No.		Breakage of bearings.		No.		No	
Type of bearing ?	Lead bronze top. White metal bottom.		White metal and lead bronze.		Lead bronze, alum. alloy and white metal.		Top, alum. alloy. Bottom, bronze shell, white metal.		White metal.		Mains, white metal. Top, alum. alloy. Bottom, white metal.		White metal, steel backs.	

Many bearing failures ?	No.	Very few.	Yes—one make only.	No.	No.	No.	No.
Crankshaft hardened ?	Yes.	Yes.	Yes—except where bearing trouble is experienced.	Case-hardened.	Yes.	Yes.	No.
Pump: check calibration ?	Every 80,000 miles.	Every 10,000 miles.	At heavy dock and complete overhaul.	Sent to makers at at overhaul.	Every 60,000 miles.	Every 30,000 miles.	Sent to makers at overhaul.
Delivery setting ?	7·8 c.c. at 100 r.p.m.	19·5 c.c.—250 strokes at 500 r.p.m.	48 c.c. full throttle at 600 r.p.m.	—	8·5 c.c. at 100 r.p.m.	7·8/8·3 c.c. at 100 100 r.p.m.	—
Power machine ?	Yes.	Yes.	Yes.	No.	No—hand.	Yes.	—
Consumption improved ?	No.	Little improvement, black smoke eliminated.	Yes—0·50 m.p.g.	—	Not noticeable.	—	—
Atomizers cleaned regularly ?	Every 6000 miles.	Approx. 3000 miles.	Yes.	Rarely necessary between docks.	Yes—15,000 miles.	Yes—3000 miles.	—
Centrifuge filters ?	No.	No—" Oweco " filter on supply tank.	No.	No.	No.	Yes—Hopkinson's.	No.
Exp.-oil inhibitors ?	No tests.	—	Yes.	No.	No.	No.	No.
Reclaim ?	No.	Yes.	Yes.	Yes.	Yes.	Yes.	Yes.
Sumps drained ?	Oil engines 4500 miles.	10,000 miles.	5000 miles.	5000 miles.	15,000 miles.	15,000 miles.	3500 miles.
Saving of oil p.b.m. petrol ?	—	1·6*d.* gear-box, 1·43*d.* torque converter.	1·5*d.* p.b.m.	Just over 1*d.* p.b.m.	No figures available.	—	—
Starting difficulty ?	No.	Yes—Whipple starter. Hot water in rad. Portable batt.	Yes—portable charger on part-day buses.	Not much difficulty.	No.	No.	No.
Breakdowns—less with oil engines ?	Yes.	No difference.	Yes.	Yes.	Yes.	Yes.	Yes.
Pump and injection system more reliable than mag., carb., etc. ?	—	No difference.	Yes.	Yes.	Yes.	Yes.	Yes.
Drivers' preference ?	Oil engines.	Oil engine—probably due to starter and torque.	Oil engines.	Oil engines.	Oil engines.	Oil engines.	Oil engines—due to fluid flywheel and Wilson gear-box.
Complaints about oil engines ?	Smoking until calibration machine installed.	No.	Occasional.	Not directly.	No.	No.	No.

Summary of Information from Twenty-six Undertakings (continued).

	14.		15.		16.		17.		18.		19.	
	D.D.	S.D.	D.D.	S.D.	D.D.	S.D.	D.D.	S.D.	D.D.	S.D.	D.D.	S.D.
No. of buses in fleet:												
Petrol . . .	68	6	15	34	11 buses only for workmen.		188	14	44	4	28	19
Oil	103	—	84	24	100	15	705	45	162	5	123	11
Fuel consumption, m.p.g.:												
Petrol	5·55	—	5·76	7·27	—	—	4·80	5·60	4·94	—	4·86	5·10
Direct-oil . . .	9·04	—	10·52	11·74	7·74	10·04	10·10	11·10	9·43	—	9·85	—
Indirect-oil . . .	—	—	—	—	—	—	7·68	—	8·37	—	8·53	10·66
Lub.-oil consumption:												
Petrol:												
5,000 m. . . .	1135	—	1500	1250	—	—	600	1200	1198	—	185	385
20,000 m. . . .	947	—	1200	1000	—	—			956	—		
40,000 m. . . .	286	—	950	775	—	—			632	—		
Direct-oil:												
5,000 m. . . .	946	—	1200	1000	1121	1230	1600	2500	1550	—	1466	—
20,000 m. . . .	787	—	1100	900	780	900			550	—		—
40,000 m. . . .	359	—	900	800	340	405				—		—
Indirect-oil:												
5,000 m. . . .	—	—	—	—	—	—	431	—	2056	—	359	388
20,000 m. . . .	—	—	—	—	—	—		—	729	—		
40,000 m. . . .	—	—	—	—	—	—		—	518	—		
Average yearly mileage:												
1st year . . .	45,000	—	Fleet figures given.		41,000	61,000	Fleet figures given.		44,000 (S.D. & D.D.)		59,100	63,203
2nd year . . .	46,000	—			46,000	55,000			43,000 ,,		58,800	63,191
3rd year . . .	43,000	—			47,000	50,000			40,500 ,,		47,100	58,307
4th year . . .	40,000	—			50,000	42,000			39,000 ,,		48,900	60,513
Schedule speed, m.p.h. .	11·57		10·15		11·49		10·5		9·591		14·5	
Nature of routes?	Mixed.		Town centre to suburban areas.		Local and suburban services.		Average.		50% flat.		Local—town services.	
Comparative cost of overhaul?	No figures.		Oil £25 more than petrol.		No figures.		Oil £5 more than petrol.		Oil £46 more than petrol.		Oil £6 less than petrol.	
Excessive wear?	Holding down bolts, cyl. hd. some broken cranks.		Oil pipes, top piston-rings, grooves on pistons.		Clutch centre splines. Con. rod bearings crack.		Cylinder bores.		Timing chain, worm-wheels, brake liners.		No.	

Type of bearing ?	Mains—white metal. Rods—lead bronze tops.	Mains—steel backed. Rods—duralumin tops.	Duralumin and steel backed metal.	Steel back white metal.	Main—50/50 lead bronze and white metal.	Chromet, lead bronze and white metal.
Many bearing failures ?	No.	No.	Frequently cracked.	No.	No.	No.
Crankshaft hardened ?	Yes.	Yes.	Yes.	No.	No.	Yes.
Pump : check calibration ?	25,000 miles.	15,000 miles.	—	25,000 miles.	30,000 miles.	Every dock or as required.
Delivery setting ?	7·9 c.c. for 100 revs.	—	8·0 c.c. for 100 revs.	8·0 c.c. for 100 revs. at 800 r.p.m.	—	9·9 c.c. for 100 rev. at 600 r.p.m.
Power machine ?	Yes.	Yes.	Yes.	Yes.	Yes.	Yes.
Consumption improved ?	Machine new.	Yes—0·13 m.p.g.	Yes—0·25 m.p.g.	Cannot say.	Yes—10–12½%.	—
Atomizers cleaned regularly ?	Every 25,000 miles.	Every 5000 miles.	Every 5000 miles.	Every 10,000 miles.	Yes.	Yes.
Centrifuge filters ?	No.	No.	No.	No.	No.	No.
Exp.-oil inhibitors ?	No.	No.	No.	Yes—no advantage.	No results. Exp. stage only.	No.
Reclaim ?	Yes.	Yes.	Yes.	Yes.	Yes.	No.
Sumps drained ?	Every 25,000 miles.	Every 7500 miles.	Every 5000 miles.	—	Oil, 5000 miles; petrol, 25,000 miles.	Every 7000 miles.
Saving of oil p.b.m. over petrol ?	Fuel cost only 0·647*d.* p.b.m.	0·40*d.* p.b.m.	Estimated 1½*d* per mile.	1·65*d.* p.b.m.	1·5*d.* p.b.m.	—
Starting difficulty ?	Petrol-Whipple, oil-immersion heater and Whipple.	No.	Portable machine for cold starting.	No.	Pre-combustion oiler—yes. " Radright." Steam heating.	No.
Breakdowns—less with oil engines ?	Yes.	Yes.	Yes.	Yes.	Yes.	Yes.
Pump and injection system more reliable than mag., carb., etc.	Yes.	Yes.	Yes.	Yes.	Yes.	Yes.
Drivers' preference ?	Speediest and torque converters.	No.	Oil engines.	No.	Oil engines.	Oil engines.
Complaints about oil engines ?	No.	No.	No.	No.	No.	No.

Summary of Information from Twenty-six Undertakings (continued).

	20.		21.		22.		23.		24.		25.		26.	
	D.D.	S.D.	D.D.	S.D.	D.D.	S.D.	D.D.	S.D.	D.D.	S.D.	D.D.	S.D.	D.D.	S.D.
No. of buses in fleet :														
Petrol	12	29	7	9	—	52	88	—	70	2	103	57	—	31
Oil	82	18	138	12	51	91	543	—	119	—	527	81	143	—
Fuel consumption, m.p.g. :														
Petrol	4·14	5·45	4·70	6·70	—	5·68	4·00	—	4·52	6·35	4·04	4·17	—	6·00
Direct-oil	9·29	9·48	9·10	10·82	8·81	10·93	9·00	—	7·30	—	9·18	11·28	10·9	—
Indirect-oil	8·80	—	7·20	—	—	8·66	—	—	—	—	8·74	10·80	9·90	—
Lub.-oil consumption :														
Petrol :														
5,000 m.	No useful figures.		1021	1260	—	125	All petrols over 4000 m., average 300 m.p.g.		Average for 1938, 200 m.p.g.		534	468	—	—
20,000 m.			470	680	—	81					399	376	—	—
40,000 m.			168	253	—	59					226	277	—	—
Direct-oil :														
5,000 m.	1200	—	1496	2820	2900	2873	3000	—	Average for 1938, 386 m.p.g.		651	739	4000	—
20,000 m.	825	—	850	2073	2500	2210	1900	—			559	624	2700	—
40,000 m.	425	—	423	1077	1375	1250	900	—			468	550	1500	—
Indirect-oil :														
5,000 m.	750	—	485	—	—	778	—	—	—	—	440	384	4000	—
20,000 m.	280	—	291	—	—	670	—	—	—	—	316	268	2500	—
40,000 m.	200	—	292	—	—	322	—	—	—	—	225	245	1300	—
Average yearly mileage :														
1st year	Continuous yearly average 45,460	49,070	45,369	65,024	56,000	50,000	Fleet figures given.		Fleet average 35,861		54,907	61,637	Fleet figures given.	
2nd year			33,234	61,669	51,000	49,000					50,655	54,445		
3rd year			18,126	56,828	48,000	41,000					44,341	50,924		
4th year			10,993	50,652	46,000	39,000					33,553	24,648		
Schedule speed, m.p.h.	Local 10·61 Country 14·67		Local 9·5 m.p.h. Ltd. stop 14·0 m.p.h.		10·5		11·3		9·177		10·8		12·5	
Nature of routes?	Mostly town services.		Steep gradients.		Hilly.		Almost all city work.		Hilly.		Mostly flat, town services.		Normal road conditions.	
Comparative cost of overhaul?	Oil-engine figures only.		Oil £3 14*s*. less than petrol.		Oil £20 less than petrol.		Oil £2 14*s*. 6*d*. less than petrol.		Oil £8 less than petrol.		No figures.		No figures.	
Excessive wear?	No—a number of crankshafts broken.		No.		Cylinder wear 0·001 in. per 4000 miles.		Early type cranks. Main bearing housings.		No—main bearing studs and cranks have broken.		—		No.	

Type of bearing?	White metal and lead bronze.	White metal alum. alloy, chromet and white metal.	White metal.	White metal or lead bronze.	Duralumin and white metal.	White metal or lead bronze.	White metal and bronze.
Many bearing failures?	No.	No.	No.	Not excessive.	No.	No.	No.
Crankshaft hardened?	Yes.	Yes.	No.	Yes.	Yes.	Yes (some fescolised).	No.
Pump: check calibration?	Every dock overhaul.	Every 40,000 miles.	Every 60,000 miles.	10,000/15,000 miles.	At engine overhaul.	Every 20,000 miles.	Every 25,000 miles.
Delivery setting?	—	—	—	—	—	—	7·0/8·0 c.c.
Power machine?	Yes.	Yes.	Yes.	Yes.	By manufacturer.	Yes.	Yes.
Consumption improved?	—	Difficult to say.	No definite results.	—	—	Yes—5%.	Max. figures are maintained.
Atomizers cleaned regularly?	Yes—3000 miles.	Yes—5000 miles.	Yes.	Yes—9000 miles.	Yes.	20,000 miles.	Every 3000 miles.
Centrifuge filters?	No.	No.	Yes.	Experimenting.	No.	Yes.	No.
Exp.-oil inhibitors?	No.	No.	Yes.	No.	No.	No.	Yes.
Reclaim?	No.	No.	Yes.	Yes.	Arranging to instal.	Used oil sold and brought to original spec.	Yes.
Sumps drained?	Every 9000 miles.	Every 5000 miles.	Every 3000 miles.	7500/9000 miles.	4000/5000 miles.	—	Every 6500 miles.
Saving of oil p.b.m. over petrol?	No comparable figures.	No comparable figures.	1·43*d.* p.b.m.	Difficult to estimate.	—	1·333*d.*	—
Starting difficulty?	No—excess fuel delivery device.	No.	Tow to start indirect.	Petrol-towed to start. Oil-plug and batteries.	Abnormal weather only.	Carrier–Ross and double pole htr. plugs.	No.
Breakdowns—less with oil engines?	Yes.	Yes.	Yes.	Yes.	Yes.	Yes.	Yes.
Pump and injection system more reliable than mag., carb., etc.?	Yes.	Yes.	Yes.	Yes.	Yes.	Yes.	Yes.
Drivers' preference?	Oil engine torque convert. and starters.	Oil engines.	Oil engines.	Doubtful.	Oil engine. Probably due to torque converter.	Oil engines.	Oil engines.
Complaints about oil engines?	No.	No.	No.	Buses withdrawn if reported engine smoking.	Minor from public, due to narrow streets.	Isolated complaints regarding black smoke.	No.

DISCUSSION.

Mr. T. C. E. Rowland said, with regard to the operation of engines on creosote oil, that they had experienced the same difficulty, particularly with the abnormal carboning up around the valves. This took place to such an extent that the machine would operate only for a matter of a week or ten days before it had to be taken down and thoroughly cleaned. They had not persevered with the experiment, as there was great difficulty in obtaining two consignments of creosote oil alike; he understood that the total supply for the country was very limited, and even had the experiment proved successful, there might be great difficulty in obtaining the fuel requirements.

He was very interested to see that at Manchester they were able to obtain 20,000 miles per 0·001 in. wear in cylinder bores. This was a phenomenal figure, and he would be glad to know how this was obtained. Most operators had to be content on heavy city services with something like 3500 miles per 0·001 in. wear. They had, however, been able to obtain figures up to 11,000 miles per 0·001 in. wear with some experimental chromium-plated liners, and this figure they considered very satisfactory.

On page 577 of the paper, under "Capital Cost," the author spoke of repayment loans being spread over a period of eight years, and in some cases the vehicles had been scrapped at about six and a half years; these were very low figures to-day. They had extended theirs to ten years, and in some cases they might have to run beyond that. He understood that one of the largest operating companies had extended their period up to fifteen years.

The author appeared to lay great stress on the centrifuging of fuel oil as being a means of reducing dirty exhaust. They had never centrifuged their oil, but on the advice of some of the fuel suppliers they applied a heavy type of filter in the main pipe-lines, and it was true to say that they had never experienced any trouble through impurities getting into the engine. The small filters in the fuel-oil system were cleaned on dock, which was at approximately 10,000 miles intervals, and it was seldom that anything was found in them; it was more a question of routine. They had found that the best way of keeping the exhaust clean was by recalibrating the fuel pumps at 25,000 miles intervals. This not only effected saving, but also kept the exhaust clean.

On page 587 the author stated that experiments were actively in progress with the Erren system of injecting a percentage of hydrogen gas into the compression-ignition engine. He would be very pleased to hear the author give some further information with regard to this, as it was a question all transport operators were anxious to hear about, particularly at this juncture, when so much was being talked about the use of home-produced fuels. The author also referred to producer-gas vehicles being considered as rivals to the diesel engine. Perhaps he had more information than was available to the average operator, as up to the present he (Mr. Rowland) knew of only one producer-gas vehicle that had been operating on passenger service. He thought it would be true to say that this had been run more in the nature of an experiment, and he would be glad to have any further information on this subject.

In conclusion, he would like to compliment the author on such an interesting paper.

Mr. Wilford prefaced his remarks by stating that although it was not within his province to discuss the paper from the aspect of costs, he would like to comment on certain other points raised.

In respect of the use of creosote, the London General Omnibus Co., Ltd., had also carried out service tests with some measure of success, castor oil being employed as lubricant. Amongst the factors which led to the abandonment of the experiments was the realization that not only were the available supplies of the fuel limited, but that material from different sources, and possibly even from the same source, was likely to be of very variable character. It appeared, therefore, that it would have been impossible to employ creosote for any appreciable number of vehicles, and that adjustments would have been required to suit the different characteristics of individual deliveries.

The paper contained a tabulation of the fuel-pump settings standardized in Manchester. To enable a comparison to be made with those employed by the London Passenger Transport Board, he asked for details as to the pump speed and number of revolutions at which the outputs were obtained.

He referred to the fact that the London Passenger Transport Board had not found it necessary to centrifuge the fuel before use, and suggested as a reason that they had commenced their development work with indirect-injection engines, which in the early days were very much less troublesome than the direct-injection type in respect of exhaust smoke. The contention that a centrifuged fuel was less prone to cause wear, due to elimination of iron oxide derived from rust formation in the storage tanks, was not supported by work carried out by the I.A.E. Research Department with used lubricating oils supplied by the London Passenger Transport Board. In these tests it had been found that the only oil which gave rise to any measurable increase in cylinder wear was one which contained an appreciable amount of silica, derived, of course, from road dust.

The London Passenger Transport Board used a lubricating oil of viscosity similar to that of the Summer grade of Specification No. 1. The viscosity of the oil complying with Specification No. 3 (*a*) seemed unusually low, and it would be interesting to know if it were used for any special reason—as, for example, a tendency in the engines concerned to production of excessive carbon deposits derived from incomplete combustion of the fuel.

With regard to the use of producer gas for passenger transport vehicles, he felt that this was not a practical proposition at the moment. He was given to understand that a producer-gas-driven vehicle was about equal to a C.I. engine-driven one in respect of fuel costs, but that its operation was much more difficult. Moreover, both the exhaust-smoke and carbon-monoxide problems were real objections, particularly in the case of vehicles running in congested city streets.

MR. H. J. YOUNG said he had listened to the author's remarks concerning the low rate of cylinder-wear on his fleet with much interest, because it happened that the firm with which he (Mr. Young) was connected supplied the liners which gave the good results on those buses. Other fleet-operators, however, could take heart in the knowledge that the very atmosphere of a city appeared to have a profound effect on the wearing-rate. It would be an instructive research to determine the abrasive properties of samples of dusts obtained from air-filters of vehicles functioning in various parts of their largest cities. Moreover, the most intimate details of service conditions and of combustion-zone conditions could exert a controlling influence upon cylinder-wear. It was by no means all a matter of petrol or oil; and the fact that superheated steam engines could suffer from severe bore-wear established that argument beyond doubt.

He (Mr. Young) had heard with some astonishment the reiterated appeals made at the Conference for engineers to co-operate with petroleum technologists by designing engines to suit modern petrols, the latter being described in detail for the engineer's benefit. That had recalled to his mind an incident of recent happening. Approaching a petrol station where there were fifteen pumps, he was slowing down when his wife asked quite seriously : " What are you going to have ? " If that was an accurate portrait of motoring to-day, it suggested that engine designers had already co-operated with petroleum technologists to the extent of producing engines which work well and remain healthy no matter which of fifteen or more diets may have been selected for his steed by the owner driver.

In conclusion he directed attention to the unusual nature of the paper by Mr. Whalley. It was full of valuable practical facts and figures so presented that it could be read by all. It was the type of paper eagerly sought and seldom found by technical bodies.

DR. E. R. REDGROVE said he thought that the excellent cylinder-wear figures on the C.I. engines were largely, if not entirely, attributable to the fact that the fuel was centrifuged. One only had to see the material—particles of rust, silica, fibre, etc.—removed by a centrifuge, to realize that when bound together by the lubricating oil film, it would form a most undesirable grinding paste.

He would like to inquire whether the lubricating oil also was centrifuged, either before issue to the vehicle or by batch treatment during service.

MR. C. I. KELLY recalled the old saying " What you gain on the swings you can lose on the roundabouts," in view of the surprise expressed by some people concerning Mr. Whalley's low figure for cylinder wear—namely one-thousandth part of an inch every 20,000 miles. It was rather applicable to the point under discussion, for if Mr.

Whalley's bus engines experienced so little liner wear—and that was quite believable—then one might presume that something else was taking the wear, possibly the piston rings. The answer might be that piston-ring wear and piston-ring replacement charges might be higher with those 900/950 Brinnell liners which experienced so little wear themselves. Would Mr. Whalley please clarify the issue by submitting figures on those points and letting them know the effects on oil-consumption, if any?

Mr. Whalley, in replying to the comments of Mr. Rowlands and Mr. Wilford, said that Manchester experienced trouble both with knocking and sludging in the creosote engine. Castor oil was tried as a lubricant and also a special mineral oil, but the vehicle was more often off the road than on, and the experiment was abandoned after 12 months.

Producer gas was under consideration, but no actual step had so far been taken to equip a vehicle.

With regard to the "Erren" engine, Mr. Whalley had seen an oil engine working the previous week on this system, and it appeared quite satisfactory. Under certain conditions it was claimed that a thermal efficiency of 41 per cent. was obtainable.

With regard to the figures for cylinder wear, these were not unusual in Manchester, and could be verified by anyone who cared to inspect the records. It must be admitted, however, that no attempt was made to reach phenomenal oil-consumption figures, a medium-priced oil of the lowest possible viscosity consistent with safety being used, it being considered better to sacrifice a little lubricating oil to ensure that the mechanical parts reached as good a mileage as possible before overhaul.

The use of the centrifuge ensures as far as possible that only clear fuel oil is put into the bus tanks.

An experiment was made at one garage, where the use of the centrifuge was discontinued for a month.

Much trouble was subsequently experienced with the fuel-feed system of the buses at this depot, mileage being lost for defective autovacs. This convinced them that centrifuging was worth while; furthermore, the machine acted as a check on the oil suppliers, the gravity setting being very sensitive, and change in the specific gravity of the fuel being shown up immediately.

In reply to Mr. Wilford, the table of Fuel Pump Settings was based on 250 revolutions at 600 r.p.m. tested on a C.A.V. Bosch Motor-driven Machine.

With regard to Dr. Redgrove's remarks, the lubricating oil was not centrifuged, but the crankshaft drainings were returned to the suppliers, streamlined and reblended with new stock to bring the viscosity in line with new oil.

SERVICE TESTS WITH LUBRICANTS FOR HIGH-SPEED OIL ENGINES.*

By A. T. WILFORD,† B.Sc., A.R.C.S., A.I.C., M.Inst.P.

SUMMARY.

An account is given of certain lubricating-oil tests carried out by the London Passenger Transport Board during the past seven years, covering a period of intensive development in the application of oil engines to passenger vehicles. Steps leading to the drafting of a first specification for lubricating oil for this type of engine are described, and data are quoted pointing to a close relationship between hard asphalt produced in an oil during use and that generated in an oxidation test of the Air Board type.

Reference is made to investigations involving determination of the optimum periodicity of oil changes, the efficiency of a flushing oil for cleaning engine-bases, and the useful life of engine-oil by-pass filters.

Results of tests with solvent-refined oils are summarized. It was established that, compared with the lubricant originally standardized in 1932, oils complying with the specification quoted in Appendix II increased engine mileage by 11 per cent., reduced oil consumption by nearly 7 per cent., reduced cylinder wear by 13·5 per cent., and decreased engine failures due to seizures and bearings by 60 per cent. The oil has been adopted despite its much higher cost, it being estimated that there will be a net yearly economy of a few thousand pounds. Experience to date indicates that engines are in a cleaner condition internally than was previously the case, and although "lacquering" has been observed, no trouble attributable to it has been encountered.

INTRODUCTORY.

THE introduction of high-speed oil engines for passenger-transport vehicles raised a number of problems which could not be solved by drawing an analogy with the petrol engines which they were displacing. One of these problems was that of the lubricating oil, involving not only a decision as to the most suitable type, but also a train of subsidiary investigations. The opinion has been freely expressed that the C.I. engine demands a better grade of oil than that used for petrol engines, on the grounds that the lubricant is continuously subjected to an oxidizing atmosphere, in contrast with the relatively reducing conditions encountered in the petrol engine. This may be true enough, but the adverse effects of oxidation are to some extent neutralized by the lower temperature of the oil-engine cycle, and it is the author's opinion, and also his experience, that the main incentive to the use of a relatively high-grade oil arose in the first instance from a very justifiable determination to ensure that the suitability of the lubricant should not be called into question every time engine troubles were encountered. This "safety-first" policy has proved to be a correct one in so far as the London Passenger Transport Board is concerned, in that, whereas the lubricant has come under suspicion more than once, a general change in grade has never been made without prolonged investigation.

Unlike a fuel, the suitability of a lubricating oil cannot be finally determined by engine-bench tests, since it is difficult, if not impossible, to reproduce the varying factors of load and speed, weather conditions,

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† London Passenger Transport Board.

deterioration of both engine and lubricant between docking periods, and the effects of extended engine life, which are encountered on the road. Recourse must therefore be made to service tests, conducted under properly controlled conditions and employing a representative number of vehicles. It is the purpose of this contribution to give an account of the more important work of this nature carried out during the past seven years, which covers a period of continuous expansion in the numbers of oil-engined vehicles operated by the Board. Reference will also be made to certain subsidiary investigations bearing upon lubrication problems.

Experiment Procedure.

It may be of interest at the onset to describe the procedure employed in carrying out tests under service conditions; the principles apply not only to experiments with lubricating oils, but to all investigations involving the observation of engines and vehicles over a lengthy period. Sanction to commence an experiment must first be obtained from a Technical Committee which sits monthly; the experiment may be originated by the Committee itself or arise as a recommendation from a Sub-Committee. Following approval by the Chief Engineer, an Experiment Procedure Sheet is prepared. This is a carefully drafted document specifying the number and type of vehicle involved, and setting out in precise terms the action required by the various sections co-operating. The Procedure Sheet also describes briefly the purpose of the experiment, the manner in which the costs are to be allocated, and embodies a note of any special information required to be communicated verbatim to the garage or garages concerned. An experiment seldom covers less than six vehicles in its initial stages, and is extended as circumstances dictate. Data in respect of mileage performed and oil and fuel consumption are collected weekly; samples of used oil, where required, are taken at regular intervals; inspectors are detailed to watch the progress of the experiment, and the units concerned are submitted to a full examination at the end of their service life. To ensure that the latter are not lost sight of at this or any other stage, vehicles bearing experimental features carry a special card, whilst the units involved are identified by means of metal labels. Finally, a report is compiled, the recommendations being made effective following consideration by the authorizing Committee and subsequent approval. Experimental work as a whole is directed by the Technical Officer, but certain items, amongst which are lubricants, are handled completely or in part by the laboratory, close co-operation being maintained with the Technical Section.

Lubricating Oil Specifications.

The main purpose of a lubricating oil test is, of course, to determine the suitability of the material. In the event of a positive result being obtained, the next step is to prepare a specification, and this may necessitate further experimental work.

The desirability or otherwise of compiling rigid specifications is a matter of controversy, and it is probably true to say that suppliers as a whole are averse to them. The large user takes the opposite standpoint, and there is a continued urge from purchasing departments to cover as many items as possible by specifications, which preferably should be more than a description of the performance required. For a concern of the Board's magnitude it is essential to be able to take lubricating oil from a number of sources of supply, and from the point of view of standardization, as well as purchasing, it is equally necessary that the oils shall comply with specifications. The alternative is to approve branded oils; this course is open to the objection of having to carry out protracted service tests on a number of lubricants, not only once, but every time the character of the oils is changed. It has been contended that a rigid specification precludes full advantage being taken of improvements introduced by the suppliers. It is the Board's experience, however, that suppliers are not slow in calling attention to advances considered likely to be of benefit, and in such circumstances service tests are carried out, the results of which have a mutual value. It is possible that the time is approaching—the author has in mind the increasing use of " doped " oils—when it may be difficult for a user fully to describe his requirements by means of specifications of the present type and co-operation of suppliers would be welcomed to assist in revision, where necessary. It is appreciated that there may be difficulties in complying with this suggestion, in which case users will have to devise means for maintaining their position both in respect of access to variety in sources of supply and ability to invite proper competition in purchasing.

Service Tests Leading to First Specification for C.I. Engine Lubricating Oil.

The first oil engines placed in service were lubricated with an oil which has proved to be quite suitable for petrol engines, and which possessed a viscosity of 210–225 seconds at 140° F. It was soon apparent that, due to accumulation of suspended matter, the oil thickened to an undesirable degree, and recourse was had to one of lower viscosity (150–170 seconds at 140° F.), which was employed at the works for first filling of engines following overhaul. Further observations showed that this oil became contaminated with " carbon " at the rate of about 1 per cent. per 1,000 miles, whilst oxidation was rather marked, up to 0·9 per cent. of hard asphalt being found after a few thousand miles in service. Although it was improbable that bearing failures being experienced at the time were attributable to the lubricant, it was considered desirable, on the " safety-first " grounds already mentioned, to commence an investigation with the view of standardizing a better grade of oil, so that one variable at least might be eliminated.

It is of interest to record the wide range of oils which were put forward from various sources during 1931–1932 as being the most suitable for A.E.C.-type oil engines. Specific gravities ranged from 0·878 to 0·932, although only one oil was above 0·916, whilst viscosities at 140° F. varied from 95 secs. to 330 secs., no less than twenty oils having a viscosity of over 180 secs. Our early experience had shown that an oil of 210 secs. viscosity was too thick, and even when, due to improvements in engine design, the rate of accumulation of carbon was much reduced, it was again established that no advantage was to be gained by the use of an oil of this viscosity, or by one of about 190 secs. at 140° F. The viscosity range finally chosen was 160–175 secs., and has been maintained up to the present time. It may be remarked in passing that the engine with which we were dealing was of the air-cell type, and in consequence there was no dilution of the lubricating oil with fuel.

For the purpose of the service tests six oils were selected, one being that already in use; a second complied with the same specification, but was obtained from a different source, whilst the remaining four were of distinctly higher grade; certain of their characteristics are given in Table I.

TABLE I.

Characteristics of Oils Tested.

Code letter of oil . .	A	B	C	D	E	F
Specific gravity at 60° F. .	0·918	0·884	0·906	0·896	0·900	0·919
Closed flash point, ° F. .	425	425	405	415	395	385
Viscosity (Redwood) :						
Viscosity at 140° F.—secs.	165·5	164	167	168·5	165	160
Viscosity at 200° F.—secs.	59·5	63	61	63	59·5	58
Pour point, ° F. . .	Below 15					
Initial coke value, % .	0·37	0·57	0·28	0·52	0·33	0·26
Increase in coke value after oxidation, % . .	1·84	1·68	0·89	1·12	0·92	1·32
Asphalt after oxidation, %	4·25	1·77	2·01	1·46	1·24	3·05
Ratio viscosity at 140° F. after/before oxidation .	2·26	1·93	1·73	1·79	1·68	2·21

Each oil was used in thirty engines for a period of four weeks, the complete test thus lasting for nearly six months. Tests carried out in recent years have generally occupied a much longer period, but at the time there was an incentive to arrive at some conclusion with the minimum of delay. A record was kept of engine failures during each four weeks test, and three engines were earmarked for special examination both prior to and following the use of a particular oil; of necessity, however, considerable reliance had to be placed on the condition of the oils after use, and in this connection some one hundred and eighty samples were examined.

Over the limited period during which each oil was in use only one of the six appeared to react adversely on engine life, this being one of the two lower-grade lubricants involved (Oil " F "—Table I). In the circumstances existing, the data would not have been regarded as conclusive had it not been for the fact that this oil also exhibited a greater degree of deterioration during use than did the remaining five, although in this respect it was closely followed by the other lubricant of the same specification—(Oil " A "). On the other hand, the most expensive oil tested (Oil " B "), did not show to any advantage over the other three improved-quality oils, there being little to choose between the four in respect of performance or condition after use. Examination of the used oils revealed one point of considerable interest, in that a quite good relationship was found to exist between the amount of hard asphalt generated during use and that produced by an Air-Board oxidation test on the corresponding fresh oil; this is shown graphically in Fig. 1. Considering that the asphalt figures were derived from samples of used oils taken from a number of engines, and that average oil consumption was not the same in each test, it must be conceded that a laboratory oxidation test has some value. This at least was the author's conclusion, and when drafting a specification based on the results of the investigation, it was reasonable to include an oxidation test, the fixing of a maximum limit on the hard asphalt content of the oxidized oil being, it is believed, novel at the time.

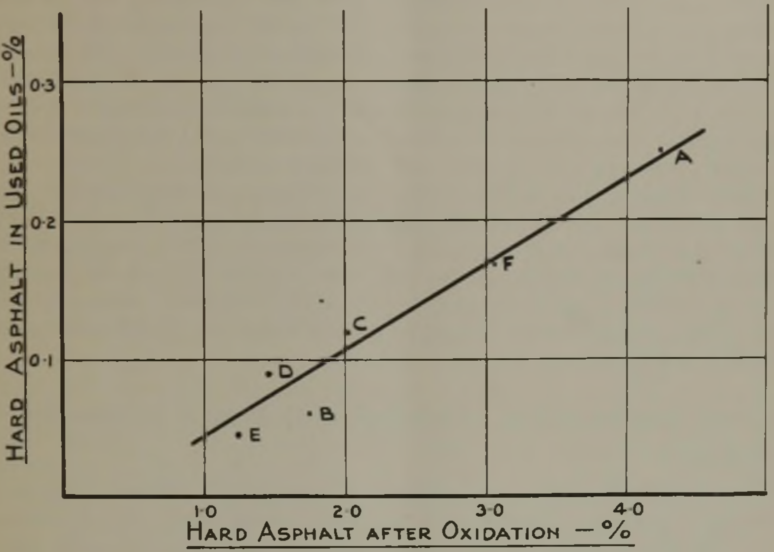

Fig. 1.

The specification is given in Appendix I. That it was on the right lines may be taken as proved by the fact that oils complying with it were used in the C.I. engines operated by the Board for a period of over six years, whilst a similar oil has been used in A.E.C.-type engines in various localities. It was not, however, in any sense regarded as the last word, and prior to the introduction of oils refined by the solvent-extraction process, service tests were carried out with various lubricants which were claimed to possess advantages in respect either of improving engine life or of cheapness, without detriment to engine life. The results of these tests did not lead to any modification of the specification, and in one instance there was definite evidence that any marked relaxation would have been a retrograde step. The oil in question possessed the following characteristics as compared with the specification then in force.

	Experimental Oil.	Specification.
Viscosity at 140° F.	135 secs.	160–175 secs.
,, ,, 200° F.	55 ,,	60 secs. min.
Asphalt after oxidation	Up to 3·3%	2·2% maximum

The service test involved six newly overhauled engines, the usual precautions being taken to ensure that they were filled and topped up only with the experimental oil. Samples of the used oil were taken at regular intervals, and on removal the engines were examined in respect of cylinder wear and general condition. The used oils were found to contain much higher amounts of suspended matter than was normally encountered with the standard oil. A further abnormality of the used oils was the presence of a small amount of diluent, this being quite exceptional with the type of engine concerned; it was suspected that the "diluent" was in reality evidence of a breakdown of the oil. Five of the engines failed for various reasons at mileages considerably below those ordinarily obtained, the diminution in life being equivalent to about 35 per cent.; cylinder wear at this stage was of the same order as that usually found after a normal service life. The ultimate life of the sixth engine was not observed, since the test results as a whole were sufficiently conclusive.

Quite recently, and as the result of investigations extending over nearly three years, the Board has adopted a solvent-refined oil as the standard lubricant for high-speed oil engines, but before describing the various steps which have led up to this change, it may be of interest to give an account of certain ancillary work in connection with lubricating oils and which chronologically fall within the period during which the oil, first standardized in 1932, was in use.

Maintenance Problems Associated with Engine Lubricating Oil.

Oil Changes.

The system of vehicle maintenance adopted by the Board provides for docking at garages at regular intervals based on mileage. Midway between two consecutive docks the vehicles receive an intermediate dock, and the various operations which must be carried out on each of these occasions are covered by schedule.

When oil-engined vehicles were first placed in service, the docking period was 8000 miles, the engine lubricating oil being drained and bases refilled with fresh oil every 4000 miles. With improvements in engine design and maintenance it was found possible to increase the period between full docks to 12,000 miles, and in the case of indirect-injection engines, oil changes were extended to this interval also. In respect of the few experimental direct-injection engines in use from time to time, the periodicity of oil changes was, after investigation, fixed at 6000 miles, and it is only recently that it has been considered wise to alter this ruling.

A mild epidemic of failures amongst the standard type of engines attributable to choked oilways, and accompanied by a marked thickening of the lubricating oil, led, amongst other things, to a reconsideration of the policy of changing the oil so infrequently. It is typical of experience in the development of oil engines that these failures were by no means general, and that the individual measures taken to overcome them seemed inadequate, and yet were successful. The truth of the matter is that when troubles are encountered in service, circumstances do not permit a systematic investigation of the effects of one remedy after another. All possible remedies are applied at the same time, and when the desired result has been achieved, any that can be proved to be superfluous are discontinued. One of the steps taken in the particular instance under discussion was to institute a system of oil changes after each 6000 miles at the garages where sludging of the lubricating oil was most prevalent.

Examination of these thickened oils showed them to possess the peculiar property of increasing in apparent viscosity when heated—the effects being actually observed at about 140° F. Samples of the oil in circulation taken at regular intervals over a period indicated that a " carbon " content of 8 per cent. was critical, and that an engine seizure was very probable if as much as 10 per cent. of " carbon " was in suspension. (It may be mentioned that throughout this paper the term " carbon " is used to denote suspended organic matter insoluble in pure benzene.) Data were also obtained in respect of the condition of the used oils in a number of engines after performing their first 6000 and 12,000 miles, respectively, two sets of conditions being studied, one in which the oil was changed at the lower mileage, whilst in the other the oil was used for the full dock period. It was found that, whereas the amount of " carbon " in the oil at 12,000 miles was often higher than that present at 6000 miles, even if the oil had been changed at the intermediate period, there was a marked reduction in ash content relative to " carbon " present as compared with oils which had been in use for the full dock period. This result indicated that contamination of the oil with inorganic matter occurred at a greater rate during the first 6000 miles of engine life than in subsequent periods, a conclusion which might, in fact, be anticipated. On this basis an initial oil change at 6000 miles was considered likely to be beneficial, since the inorganic matter must be regarded as having some influence on engine wear. It was, of course, also evident that organic suspended matter removed with the oil when draining bases after 6000 miles must reduce the total contamination of the oil during the next 6000 miles. That the benefits of this were not always apparent is mainly attributable to the fact that it is impossible to empty the base completely, with the result that the second charge of fresh oil starts its life already appreciably contaminated.

It was finally decided to standardize on an initial oil change after the first 6000 miles, the oil being again changed at 12,000 miles and subsequently at full docks only. Oil changes after each 6000 miles were continued for a time at certain garages, but it was not possible to prove that any increase in engine life was obtained thereby.

Cleaning of Engine Bases.

The observation that the fresh oil was immediately contaminated by dirty oil remaining in the bases after draining led to further investigation. An extreme example of the extent of this contamination is illustrated in Fig. 2, which shows the " carbon " content of the used oil from an experimental type of direct-injection engine at intervals of about 1000 miles from 5000–27,000 miles, when a seizure occurred. The three marked decreases in contamination correspond with oil changes. It will be observed, however, that not only did the fresh oil start its life in an appreciably dirty condition, but that the adverse effects of oil left in the base were greater at the second and third than at the first oil change. The few instances in which there was a slight decrease in contamination instead of an expected increase were undoubtedly due to inaccuracies in sampling, and do not affect the argument.

The progressive contamination of the oil was, of course, very much less in the case of the standard engines, but it was felt that some benefit might result from an endeavour to give the fresh oil a clean start. The most positive method was to drop the bases, and this was tried for a time, but was eventually discontinued for a number of reasons, amongst which was the considerable increase in labour involved. Another line of approach was to use a flushing oil. The method employed was to drain out the dirty oil while the engine was still hot, and to fill up with an equivalent quantity of the flushing oil. The engine was then allowed to idle quietly for from 2 to 3 mins., following which the oil was again run out, carrying the sludge with it. The efficiency of this treatment was studied in a quantitative manner.

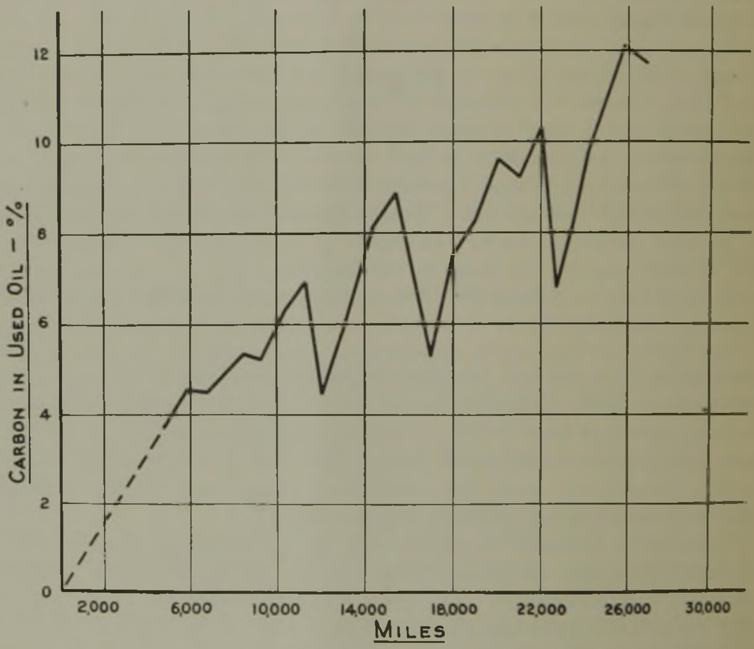

FIG. 2.

The way in which this was done is illustrated by the data in Tables II and III. In each case the figures in column (*a*) relate to the suspended " carbon " in the used oil drained from the engine bases at first semi-dock. Column (*b*) shows the " carbon " content of the oil in the same engines a few days afterwards. The figures given in the last column represent the proportion of " carbon " in the fresh oil attributable to its having been contaminated with dirty oil remaining after draining; the percentages are calculated from a knowledge of the rate of contamination of the oil during the semi-dock period, it being reasonably assumed that this rate held good over the subsequent seven days. It will be appreciated that it was necessary to employ new or newly overhauled engines in this investigation, so that the data in the two tables refer to two different groups of engines, all, however, being of the same type. Table II concerns the group of engines, bases of which were drained at intermediate dock in the normal manner, while Table III refers to the engines submitted to the flushing oil treatment. From a comparison of the figures in the last column of each table, it is evident that no benefit was derived from the use of the flushing oil sufficient to justify its adoption as a normal maintenance procedure.

TABLE II.

Engine.	(a) " Carbon " in Used Oil when Drained, %	Period after Draining, days.	(b) " Carbon " in Used Oil, %	Proportion of " Carbon " in (b) due to Contamination with (a), %
1	1·68	6	1·13	78
2	2·02	5	2·16	89
3	1·47	4	0·83	83
4	1·46	1	0·67	94
5	1·70	6	2·25	90

TABLE III.

Engine.	(a) " Carbon " in Used Oil when Drained, %	Period after Draining, days.	(b) " Carbon " in Used Oil, %	Proportion of " Carbon " in (b) due to Contamination with (a), %
6	2·84	7	1·80	74
7	2·11	7	1·31	61
8	2·54	7	1·44	65
9	1·25	7	0·98	79
10	1·61	7	3·07	90
11	1·75	7	1·17	70

No further action has been taken in regard to more effective draining of bases. A combination of factors, amongst which may be included improvements in design of injectors, improved methods of maintenance, and a change in grade of lubricating oil, have resulted in the complete elimination of sludging trouble, and at the present time the amount of " carbon " in oil drained at intermediate or full docks averages less than 1·5 per cent.

Cleaning of Filters.

A further point investigated in connection with contamination of the lubricating oil was the periodicity of cleaning external by-pass filters which are fitted to all the later types of oil engines. The filters were at one time of the wrapped-felt type, but the present design is a well-known commercial model, consisting of felt stretched over a wire frame of star-shaped cross section. The filters are cleaned by withdrawing from the housing and carefully scraping the collected sludge from the grooves; they are then washed in paraffin, and after soaking in clean engine oil, are refitted.

At the time the matter was being looked into, the filters were removed after each 12,000 miles, and quantitative tests were made to ascertain whether this period was a reasonable one. The work was carried out with fifteen engines, the filters being removed after periods of from three days to fifteen weeks, a total of forty-four being examined. On withdrawal the filters were immediately placed in specially provided metal containers, and were forwarded to the laboratory, where they were allowed to remain untouched for a week, so that oil, as distinct from adherent oily sludge, could drain away. The filters were then removed and the sludge was scraped off as completely as possible and weighed. The results are shown in chart form in Fig. 3, from which it is clear that the filters were for all practical purposes inoperative after six weeks in service. Although a case might have been argued for cleaning the filters once a fortnight, it was necessary to compromise at six weeks—*i.e.*, at each semi-dock. Cleaning at more frequent intervals would have interfered with normal maintenance schedules, and to justify this it would have been necessary to demonstrate that the proposal would effect a measurable improvement in engine life. Experience indicated that it would be extremely difficult to obtain a conclusive proof, and the truth of this statement will be appreciated when the concluding section of this paper has been read. It is of interest to observe that during six weeks the filters were found to collect nearly 600 grams of oily sludge, and since this contained approximately 25 per cent. of solid suspended matter, no less than 5½ ozs. of this material was taken out of the oil circulating in the engine.

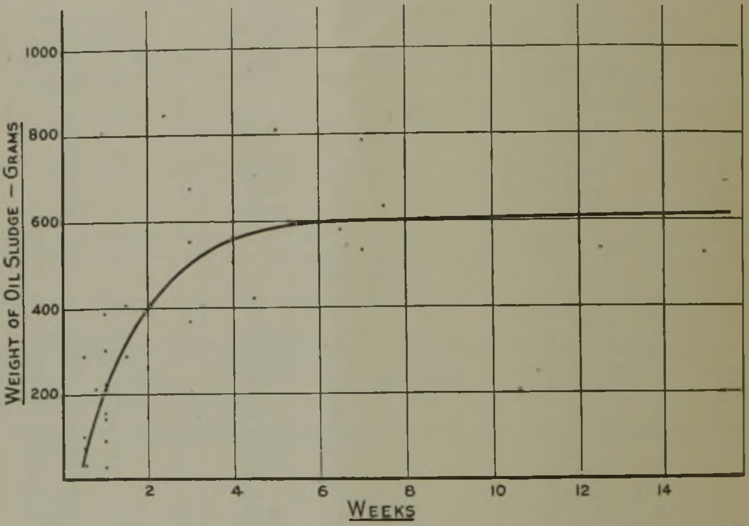

Fig. 3.

The investigation is at present in the course of being repeated, with the view of determining whether the adoption of a solvent refined oil, together with other improvements, justifies any change in procedure. So far only nine filters have been examined, and the data are necessarily incomplete;

nevertheless, the tendency shown in Fig. 4 is sufficiently marked to warrant inclusion in this paper. The results appear to indicate that the filters are not choked even after fourteen weeks use. It is open to argument that this apparently better condition of the by-pass filter when dealing with a solvent-refined oil is in reality due to its inability to retain the " carbon " particles, which, for reasons as yet undetermined, are in a much finer state of division than was found with the oil previously in use. Whilst this may be true, any decrease in retentive power of the filter is not reflected in an increase in the " carbon " content of the used lubricating oil, the tendency being as already mentioned in the reverse direction.

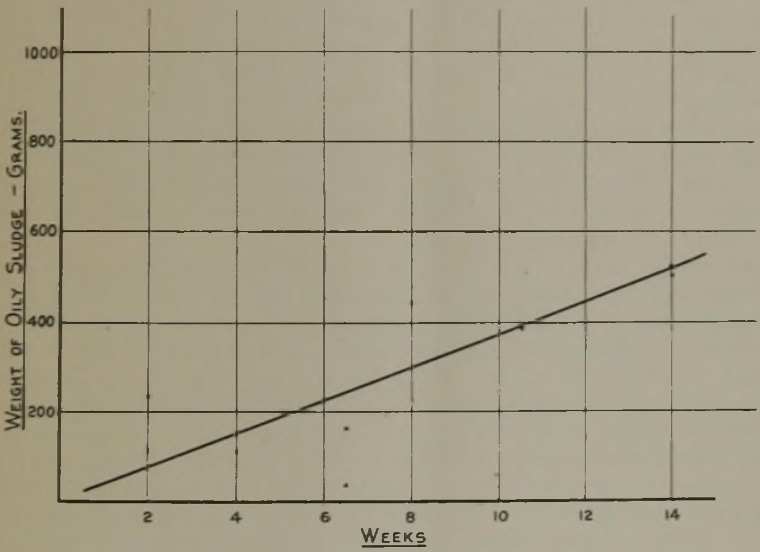

Fig. 4.

Service Tests with Solvent-Extracted Oils.

Service tests with an engine oil refined by a solvent-extraction process were commenced in 1935, and were continued until the middle of last year, when this class of oil was finally adopted for the whole of the Board's oil-engined fleet. As compared with oils conforming to the specification quoted in Appendix I, the solvent oil, when first brought to our notice, was two and a half times the more expensive. Although very considerable reductions in price have since been obtained, the new grade of oil is still much more costly than anything we have hitherto used for engine lubrication. It will be appreciated that very careful investigations were necessary before a substantial increase in the lubricating-oil bill could be justified, it being essential to prove that a net economy could be effected.

The first test was carried out on three engines only, and yielded a most striking result, which was not, however, repeated to the same degree in subsequent large-scale tests; nevertheless, there are at present indications that the considerable improvement in engine life initially obtained may not, after all, have been so far from the mark. The three vehicles concerned in the test were run in comparison with another three, all six being fitted with new engines of the indirect-injection type. The recognized period for oil changes at the time was 12,000 miles, but in a somewhat injustifiable attempt to compensate a little for the high cost of the solvent oil, instructions were given that the latter should not be changed at the normal period, the intention being to determine a suitable mileage from examination of samples of used oil. Unfortunately, there was some lag in obtaining the necessary data, with the result that one of the engines had to be removed on account of bearing failure. The engine had, however, performed nearly 36,000 miles without an oil change, whereas the three comparison engines using the then standard oil had already been removed due to heavy oil consumption, in one instance accompanied by a bearing failure, after an average life of under 22,000 miles. The remaining two engines using the solvent oil continued in service until they had each performed over 60,000 miles; the oil was changed at 36,000 miles, and thereafter at each succeeding 12,000 miles. Examination of samples of used oils from the engines using the special lubricant did not reveal any particular decrease in suspended " carbon "; the proportion of hard asphalt was, however, much lower than that found in the standard oil after use.

The results of the initial test were regarded as so encouraging that arrangements were made for a large-scale test to be conducted at five garages, some of which were operating oil engines exclusively. The performance obtained was apparently very satisfactory, and a strong feeling developed in favour of the solvent oil. The heavy increase in lubricating-oil costs led, however, to a close review of the position, and it was disclosed that various other factors might have, and in certain instances had, contributed to the improvement in engine life obtained. At one garage, for example, the introduction of the solvent oil was found to have coincided with the overhauling of a large proportion of the engines, the engine position being further improved by transfers of new production vehicles from other garages. In two other instances there was evidence that an improvement in oil consumption was at least partly due to the presence of batches of engines which exhibited the peculiarity of commencing life with a quite high consumption of lubricating oil, the miles per gallon figure rising until it reached a normal value after about 12,000 miles, following which low consumption was maintained for a considerable period. There was also reason for suggesting that the benefit attributed to the solvent oil might have been due to a recently introduced reduction in oil pressure, since it had been demonstrated that this had resulted in an improvement in engine life even when the standard oil was used. If the outstanding performance shown by the solvent oil in the original tests had been immediately evident, the various disturbing factors, of which those quoted are only examples, would not have mattered very much; in the circumstances, however, the issue was confused.

It may be asked why this situation should be allowed to arise. The answer is that to minimize periodic depletions of garage fleets due to incidence of overhauls, it is necessary that the fleets shall be composed of vehicles and engines of various ages; new engines, embodying modifications regarded as likely to be beneficial, are therefore usually spread over a number of garages. It was found possible to depart from this principle at one garage, whilst at another the principle could not be applied to a proportion of the fleet which comprised vehicles with bodies specially designed for operation through the Blackwall tunnel. It was decided, therefore, to confine further experiments with the solvent oil to these two garages. At the one where the whole fleet was involved, solvent oil has been used exclusively since oil engines were introduced there, a period of three years. The engines have throughout given a particularly good mileage, and, compared with an adjacent garage at which the alternative oil was in use, it was possible to show that the solvent-refined lubricant was some 18 per cent. the more economical, the comparison being made on the basis of oil costs plus engine overhaul costs per 1000 miles.

As a result of the continued satisfactory performance of the new oil at the two garages mentioned, the restriction imposed on more extended experiments did not last long, further tests being commenced at five carefully selected garages (two in the London area and three in the Board's Country area). On this occasion, however, the oil was purchased to a specification, enabling supplies to be obtained from four distinct sources. This specification, which is the current one for high-speed oil engines, is given in Appendix II.

The position was again carefully surveyed after a year, a detailed comparison being made with the performance of the standard oil at garages selected so as to provide as close a similitude as possible in respect of operating and other conditions. The following points were established :—

(*a*) Mileage obtained from engines using solvent oils was 11 per cent. higher than that from engines using the then standard oil.

(*b*) The use of solvent oils reduced lubricating oil consumption by nearly 7 per cent.

(*c*) There was a reduction of 13·5 per cent. in cylinder wear per 1000 miles in engines lubricated with solvent oils.

(*d*) The proportion of engine failures due to seizures and bearings was 60 per cent. less than the normal at garages using solvent oils.

(*e*) The proportion of engines removed due to cylinder and piston wear and on account of noise was about the same for the two types of oils.

(*f*) The proportion of engine failures due to breakages, such as timing chains and camshafts, was nearly twice as great as normal at garages using solvent oils.

(*g*) Compared with the then standard oil, solvent oil after use exhibited a slight reduction in suspended "carbon," its ash content was at least 15 per cent. lower, whilst the proportion of hard asphalt was reduced by three-quarters.

(In respect of the relatively poor showing of the solvent oil under items (*e*) and (*f*) it may be remarked that the total number of failures due to the causes mentioned was not great, whilst the higher mileage given by the engines using the special lubricant must also be taken into account.)

The results of the extended tests taken as a whole were not so markedly in favour of the solvent oil as were those derived from the single garage at which it had been used longest, and to which reference has already been made. Nevertheless, it was possible to arrive at the definite conclusion that, despite its much higher price, a solvent-refined oil of the type called for by the Specification given in Appendix II could be used without any fear of increasing running costs, whilst there was the probability of a net economy of a few thousand pounds yearly being realized, due to the improved engine-life obtainable. The full effects of the subsequent decision to adopt this class of lubricant are not yet evident, but so far there is every reason for believing that the change has produced the anticipated benefits.

An account of experience with solvent-refined oils for engine lubrication would not be complete without reference to " lacquering," a trouble which appears to have been encountered more particularly in the U.S.A. So far as the Board is concerned, a thin coating of " lacquer " has certainly been observed in a number of engines when dismantled. The coating is, however, very easily removed, and it is regarded as less objectionable than the heavy sludge with which engine parts were often found to be covered when the previous oil was in use; it is quite safe to say that there is at present no evidence of any harmful effects having resulted from the presence of " lacquer." As a whole the engines are in a much cleaner condition than they used to be, whilst the oil in circulation is also less contaminated with suspended solid matter.

There is evidence, however, that the cleaner condition of the oil is not entirely due to the change in grade, and in the case of indirect-injection engines an improved design of injector has undoubtedly had a contributory effect. The influence of design is even more marked with the direct-injection engines now being placed in service, in that, although the quantity of lubricating oil used is much less, its condition, in respect of contamination with " carbon," is much better than that of oil in the indirect-injection types.

It is not suggested that the specification given in Appendix II represents the ideal lubricant for high-speed oil engines, and service tests with two alternatives are already in progress. One of these involves an oil with characteristics similar to those required by the specification, except that its viscosity is 130–140 seconds at 140° F., as compared with 160–175 seconds, which are the limits for the standard oil. This somewhat thinner lubricant has been in use at one garage for nearly eighteen months, and its performance appears to be equivalent to that given by the oil of normal viscosity. The thinner oil is not at present available at any appreciably reduced price, but it offers some attraction, in that it has also been used, without trouble developing, in pre-selective gear-boxes. There is thus the prospect of employing one oil for the two purposes, and an extension of the experiment is in contemplation. The other test in hand is with a " doped " oil which is claimed to eliminate piston-ring sticking, a remedy for which would effect a further improvement in engine life; the experiment has not yet reached a stage at which any opinion can be expressed regarding the efficacy of the oil.

In conclusion, the author would express his thanks to the London Passenger Transport Board for granting permission to present this paper and for allowing full use to be made of the relevant experimental reports compiled in the Department of the Chief Engineer (Buses and Coaches).

APPENDIX I.

LONDON PASSENGER TRANSPORT BOARD
SPECIFICATION U.105
for
LUBRICATING OIL FOR A.E.C. TYPE OIL ENGINE.

Description.—To be a pure hydrocarbon oil, thoroughly filtered to remove all solid matter, and to be entirely free from water, dirt, fibrous particles or any other impurities. The cylinder oil used in the blend to be of the filtered variety.

Free Acid.—The oil not to contain more than a trace of mineral acid, and organic acid not to exceed the equivalent of 0·01 grams KOH per 100 grams of oil.

Specific Gravity.—Determined at 60° F.—not to be below 0·900 nor to exceed 0·910.

Closed Flash Point.—Determined by Pensky-Marten or Gray Apparatus—not to be below 395° F.

Viscosity.—Determined by Redwood No. 1 Standard Viscometer—not to be below 160 secs., not to exceed 175 secs. at 140° F., nor to be below 60 secs. at 200° F.

Asphalt.—Not to exceed 0·010 per cent. To be determined by the method described in the Appendix hereto.

Ash.—Not to exceed 0·010 per cent.

Cold Test.—The pour point of the oil, as determined by the I.P.T. Method G.O.11 (Standard Methods, 1st Edition), not to exceed 15° F.

Oxidation Test.—After blowing for 12 hrs., the viscosity of the oil at 140° F. shall not be greater than 2·0 times the original viscosity at the same temperature.

After blowing for 12 hrs. the asphalt content of the oil shall not exceed 2·2 per cent.

(The blowing is to be carried out in a manner similar to that required by the Air Board Oxidation Test, whilst asphalt in the oxidized oil is to be estimated by the method given in the Appendix hereto.)

Method for Determination of Asphalt.—A suitable weight of the oil to be diluted with forty times its volume of light petroleum spirit, free from aromatic hydrocarbons, and completely distilling between 40° C. and 60° C. The solution, after standing at least 18 hrs. in a stoppered bottle, in the dark, at room temperature, to be shaken and poured through a No. 40 Whatman's filter paper, and the paper washed with petroleum spirit, as specified above, until free from oil. The residue on the filter-paper then to be dissolved by pouring hot benzene (free from thiophene) through the filter paper, collecting the solution in a suitable weighed vessel, the vessel to be reweighed after evaporating off the solvent, and drying.

APPENDIX II.

LONDON PASSENGER TRANSPORT BOARD
SPECIFICATION U.113
for
LUBRICATING OIL FOR HIGH-SPEED HEAVY OIL ENGINES.

Description.—To be a pure hydrocarbon oil refined by the solvent-extraction process, thoroughly filtered to remove all solid matter, and to be entirely free from water, dirt, fibrous particles or any other impurities.

Free Acid.—The oil not to contain more than a trace of mineral acid, and organic acid not to exceed the equivalent of 0·01 gram KOH per 100 grams of oil.

Closed Flash Point.—Determined by Pensky-Marten or Gray Apparatus—not to be below 400° F.

Viscosity.—Determined by Redwood No. 1 Standard Viscometer—not to be below 160 secs. nor to exceed 175 secs. at 140° F., nor to be below 61 secs. at 200° F.

Hard Asphalt.—Not to exceed 0·005 per cent. To be determined by the method described in the Appendix hereto.

Ash.—Not to exceed 0·005 per cent.

Cold Test.—The pour point of the oil, as determined by the I.P.T. Method G.O.11 (Standard Methods 1st Edition), not to exceed 15° F.

Initial Coke Value.—Determined by the Ramsbottom method—not to exceed 0·5 per cent.

Oxidation Test.—After blowing for two successive periods of 6 hrs. at a temperature of 200° C. in a manner similar to that required by the Air Board Oxidation Test :—

(*a*) The viscosity of the oil at 140° F. shall not be greater than 1·5 times the original viscosity at the same temperature;

(*b*) The hard asphalt content of the oil shall not exceed 0·05 per cent. when determined by the method given in the Appendix hereto;

(*c*) The increase in coke value of the oil shall not exceed 0·7 per cent.

Method for Determination of Asphalt.—See Appendix I.

THE LUBRICATION OF THE MODERN COMMERCIAL VEHICLE CHASSIS.*

By F. C. WHITEHOUSE.†

SYNOPSIS.

Development of the light, fast commercial vehicle—Small appreciation of the problems involved in maintenance or operation—Power unit lubrication —" Sludging "—Difficulties in maintaining efficient working temperature—Temperature control devices—Venting of crankcase to get rid of burnt gas—Development of filters—Forced feed lubrication—Necessity for the correct grading of oils—Standardization of oils.

IT would perhaps be well, at the very outset, to state that this paper does not presume to do more than point out how the trend of the design of the modern commercial vehicle has brought into prominence the question of lubrication, and the fact that if progress is to be maintained at the same rate as during the last few years, the engineer will have to enlist the aid of the oil technologist to an even greater extent than formerly.

DEVELOPMENT OF THE COMMERCIAL VEHICLE.

Up to about ten years ago the commercial vehicle was progressing along certain well-defined lines, and, as far as one could judge at the time, the tendency was to develop a machine which was exceptionally robust. Although the elimination of any undue weight was always in the forefront of all design, it was rarely attempted at the expense of a reduction of bearing areas.

Then came the new regulations regarding the taxation of such vehicles, in which any vehicle weighing under 50 cwt. unladen could travel at a speed of 30 miles per hour—which is 50 per cent. faster than its bigger and heavier brother—and, in addition, has a lower taxation rate. This has resulted in the development of the light, fast vehicle, and although it would be foolish to hint that the heavier type of vehicle has ceased to exist, we think it can be stated that in a general sense the type of vehicle having two axles—which, incidentally, must under no circumstances exceed a gross laden weight of 12 tons—is now to a large extent confined to vehicles which come under the 50-cwt. unladen class. The heavier type of vehicle has developed in the direction of a multi-axle job carrying far greater gross loads.

It is obvious that if a vehicle is to be made which is capable of carrying pay-loads of up to 5 or 6 tons at a nominal speed of 30 miles per hour, and which yet, complete with body, shall not exceed 50 cwt. in weight, only the barest necessities can be incorporated in the design. The intensely competitive aspect of the question, which precludes the adoption of any device which, through its complicated functioning, necessitating considerable experimental work in its development, would have the effect of

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† Morris Commercial Cars Ltd.

increasing the selling price of the vehicle, will be left out of consideration. The low weight is obtained only by keeping all parts down to a minimum (consistent of course with the ability to stand up to service conditions), but this must have the effect of increasing the unit loads on the various moving parts.

It is with this type of truck that it is proposed to deal, because it is our contention that the difficulties surrounding the lubrication of all commercial chassis are to a certain extent aggravated with this class of vehicle. To start with, the lower price of the machine has made its use far more universal, and has brought into the ranks of truck-operators large numbers of people using only one or two vehicles, and whose mechanical knowledge and appreciation of the importance of maintenance are most meagre.

It may be urged that a degree of educational effort is here indicated, and with this point we are inclined to agree; indeed, efforts have been for years, and are still being made, in this direction by the firm with which the writer is connected.

By means of instruction books, pamphlets, and lectures, an attempt has been made to impart some idea of the importance of maintenance, and although the results are to some extent gratifying, nevertheless progress is very slow.

Prevention of Sludging.

Most of the troubles that are encountered in the field are concerned with the power unit, and a very large percentage of such cases can be directly or indirectly traced to lubrication. It need scarcely be stated that the bugbear of engine lubrication is sludging. This is so prevalent that it has come to be accepted as inevitable. Members of the Institute of Petroleum are far more competent to express an opinion on this point than we are as engineers, but it is certain that the attempts at its prevention that have been and are being made are many and various. Perhaps the point on which our attention is focussed is the retention of the engine at an efficient and suitable temperature. This is not so easy as it would appear. To start with, the chassis are turned out and distributed with, in the majority of cases, no knowledge of the conditions under which they will eventually have to work. It may be that of two exactly similar vehicles one will be used on long haulage, while the other is used for house-to-house coal delivery, under which latter circumstances the engine will never reach a desirable temperature. Then, of course, there is the usual temperature difference between winter and summer running conditions, all of which add to the difficulty of the designer in adopting a suitable mean rate of engine-cooling. It may be urged that this is an obvious case for engine-temperature control by means of some form of thermostat which short-circuits the water until such a temperature as is desired is reached. Well, that has been done, but no one would claim for it any more than an improvement with regard to the rate of erosion of the cylinder bores.

Again, such a device as the one just mentioned leaves out of account the fact that the radiator under what may be called adverse conditions remains in an over-cool state, which means that any air passing through it also remains cool. This is no great hardship so far as the radiator is concerned, but it does mean that a blast of cold air is impinging on to the timing-chain cover, with the result that if sludging takes place—and unfortunately this occurs in a very large number of cases—it is here that it is formed. Then, it may be asked, why not control the heat-flow from the radiator? Everyone is familiar with the devices that have been used to accomplish this, as such were much in evidence some years ago on pleasure-cars, but as they are not so general now, it must be concluded that the control could scarcely have been so effective as was desired. In any case, the writer can scarcely see such an arrangement being satisfactory under the difficult conditions of truck operation, particularly when working in a sand-pit, stone-quarry, or on a building site.

It might be suggested that if the blow past the pistons could be eliminated, much would be done to cut down the incidence of sludging. Greatly as this is to be desired it is as well to remember that the device of the piston ring is satisfactory so far as it goes, and an enormous amount of research is still going on to determine the correct material and also the optimum unit pressure which shall give the best compromise between wear and retention of pressure, but although much progress has been made in this direction, it cannot yet be definitely stated that no residue from the burnt gases escapes down the cylinder bores. Correct " venting " of the crank-case will reduce the ill effects of such " blow past," but it is a little difficult to see that anything else can be done than to allow the gases to escape, and in doing so to arrange that there are no dead areas where they can collect. The habit, which is general, of enclosing all the valve and tappet mechanism—this, incidentally, has been forced upon designers—by no means improves matters, as the amount of burnt gas that finds its way down the exhaust valve guides is considerable.

Development of Filters.

At present sludge is accepted as a necessary evil and various attempts are made to get rid of it. The straightforward method is obviously to filter it out. In nearly all cases this is accomplished by means of a filter on the pressure or delivery side of the pump, otherwise the filtering element would have to be so large in mesh that its efficiency would be impaired. These pressure-side filters are usually supplied with a by-pass valve, so that when the filtering element becomes choked—which can happen rather quickly when perhaps a mass of impurities which has collected on a certain spot comes down into the oil-stream—the valve opens and by-passes the oil. This is founded on the idea that it is better to have a quantity of dirty oil than no oil at all. Although every book, leaflet, and talk stresses the periodic cleansing of the filter, it is surprising the extent to which it is neglected. The writer has cases in mind where, after addressing meetings of operators and explaining what can happen if such filters are not attended to, the local distributors and dealers have been sold out of filtering elements by ten o'clock the next morning. It should be added that the filters in question were of a highly effective type, using a fabric which, after a time, had to be replaced.

There are, of course, devices which, as it were, refine the oil by by-passing small quantities through filtering material such as Fuller's earth or some similar substance possessing adsorptive properties. Undoubtedly this is effective and satisfactory. There is, however, one drawback. The replenishment of the filtering or purifying cartridge every so often is an additional cost against the running of the engine, and the argument of the operator is obvious. If he is a one-truck operator he feels the loss, and if he owns a hundred, the replenishment of each cartridge, perhaps twice a year, increases the running expenses at the end of twelve months.

These details have been put rather tiresomely before you because it does seem that the impression is present in the minds of oil technologists that sludging is a perfectly well understood phenomenon, and a trouble that is not likely to be eradicated, therefore the sooner the engineer and the operator realise this latter fact, the better.

The engineer does appreciate that aspect of the question, but the operator is more likely to reply that, having bought the best oil (the best oil is always the particular brand he buys), any trouble that has arisen must be due to some fault in the supplier's engine, and not to the oil he is using.

GRADING OF OILS.

Now let us consider another aspect of engine lubrication. It could be stated that for all practical purposes the system of lubrication that is adopted by the majority of makers to-day is of the forced type.

With this system oil is forced to the main bearings of the crankshaft, and from there it usually passes via a hole in the crankshaft to the bottom end. The cam-shaft bearings are also lubricated under pressure. But, generally speaking, the part of the engine that requires as much oil as any is not supplied under pressure—*i.e.*, the cylinder bores, which are usually oiled by the spray of oil which is flung from the bottom ends and the main bearings. However much oil may be flung on to the walls, every movement downwards of the piston-skirt removes the greater proportion, but leaves sufficient for the adequate lubrication of this portion of the piston. This remaining oil is scraped off the cylinder-walls, using the slotted-type scraper-ring for the purpose, leaving behind only the barest minimum to lubricate the top piston rings. As this amount is burnt off during the combustion of the charge, it may be said that when an engine is stopped, one or two at least of the bores are in a comparatively dry condition. It is essential, therefore, that when restarting the engine the oil shall be flung once again on to the cylinder bores in a minimum of time, otherwise much damage will result by scoring due to the pistons running tight. This is one of the reasons why, when starting from cold, the engine should be run at a moderate speed, in order to get the oil through the bearings quickly. Hence the reason why all engineers responsible for such a design would like an oil with as low viscosity as possible, so that it will reach every point in the engine in a minimum of time. Of course, with the heating up of the crank-case and its contents the viscosity becomes still lower, so that more oil passes through the bearings in unit time, and it is this latter quantity that the designer must arrange for his skirt and scraper ring to handle. Obviously, if the viscosity of the oil does not vary to any great degree through the range of temperatures to which the engines are subjected, the parts under review can be designed with greater accuracy. Those of us engaged in the automobile industry are aware of the experimental work that has been carried out to obtain oils having as flat a viscosity curve as possible, and there is no doubt whatever that such results as have been obtained are greatly appreciated by those whose work brings them into contact with operators, but may a suggestion be made that the success so far attained be looked upon as just a happy augury for the future, when curves will be flatter still?

The above remarks refer, of course, to new engines, because when engines are not so new the trouble is aggravated. To start with, the bearings and shafts become worn, allowing a far greater amount of oil to pass through them. The quantity is considerable because in the case of the rear main bearing so much will sometimes pass through as to choke the oil retainer, the inability of which to cope with such an amount will result in a leak. What is happening there is happening all along the engine, and the amount that is sent on to the bores is far too much for the pistons—which incidentally are worn also—to handle. The result is a high oil consumption. It is obvious that when this occurs the bearings should be taken up, but it is unfortunately the case that these finer points of cause and effect are lost on most of the owners with whom we have to deal. The fact which has to be faced by the supplier is that the actual mechanical condition of the unit, provided of course that it is still capable of doing its work satisfactorily, is of far less concern to the owner than the fact that he is spending more on oil than he used to do. If an oil of a higher viscosity could be recommended under such circumstances, the result would be advantageous to all. This can now be done, provided of course that one definitely names the oil that may be used—a proceeding that few makers would ever do, for fear of obvious repercussions. It would appear, therefore, that consideration could be given to what one might term the standardization of engine oils. By this is not meant that all oils should have the same constituents, as obviously that would put an end to all research and progress, but that there should be at the disposal of the engineer three or four *grades* of oil for use in the power unit, each having as flat a viscosity curve as possible, but differing in their viscosities. By this means the operator would be able to keep his oil consumption constant over a much longer period, instead of having to carry out repairs and adjustments of a mechanical nature before they are, from a purely functioning point of view, absolutely necessary.

STANDARDIZATION OF OILS.

While on the same subject, a certain amount of standardizing of oil specifications is at present indicated. Whilst this may be a very thorny subject and a matter on which one is not likely to meet with a ready response, nevertheless it may be pointed out that although there may be many difficulties in the way, it would not appear to an ordinary layman that they are any more numerous than those faced by the steel-makers when such a course was adopted throughout their industry.

The power unit has been dealt with rather fully because the lubrication of the rest of the chassis does not appear to give the same amount of trouble.

There is no doubt that with the improvement in steels, such parts as the gear-box and rear axle have been considerably reduced in weight. This has resulted in high line pressures on gear-teeth. Considerable relief from undue wear on these parts has been obtained by the adoption of the high-pressure oils which have been developed, and which have proved so successful. At present we may be satisfied, but if and when the metallurgist gives us steels or bearing metals that have a higher tensile strength combined with surface hardness, still greater demands will be made on the oil technologist.

In making these few remarks about the lubrication of the commercial vehicle chassis, it certainly has not been the intention to give an impression that the engineer is insensible to the difficulties surrounding the problems facing the chemist and experimentalist who devote themselves to the subject of lubrication. The engineer is deeply appreciative of the progress that has been made, but he has the feeling that after attempting to get over the problems by mechanical devices, perhaps the better way is to ask for the further co-operation of the oil expert, in order that progress shall still continue, and at a rate that shall within a reasonable time bring about a better set of conditions.

THE AUTOMOBILE MANUFACTURER'S SELECTION OF LUBRICANTS.*

By K. Brozyna.†

Synopsis.

Engine Oils. Demands on and characteristics of suitable oils—Preliminary laboratory tests—Fallacy of working to specifications only—Importance of new methods of refining and Addition agents—Oil filters—Final selection of oils, running tests, effect of oils on the engine, etc., cold room tests.

Gear-box Oils. Characteristics of suitable lubricants.

Rear-Axle Lubricants. Extreme-pressure lubricants—Demands on, and characteristics of such lubricants—Attempts to correlate the results of laboratory scoring tests with those under road conditions—Torsion loaded gear-testing fixture—Selection of worm gear lubricants.

Chassis Lubrication. Selection of semi-solid lubricants.

As it is quite beyond the scope of this paper to do justice to all the problems that may arise in connection with the lubrication and selection of suitable lubricants for the various mechanisms in a motor-car, the author has attempted to give only a very brief outline of a number of basic facts and procedures that deserve to be mentioned.

It could be stated that the chief concern of the motor-car manufacturer should be the efficient lubrication of the various units and points of the motor-car that require lubrication, but to achieve this the author considers that the maker must also take into consideration the many theoretical points that arise, have a fair knowledge of the advances made in lubrication technique and the best way to arrange the conduct of his tests, from the results of which he can make his decisions.

Before trying to find the most suitable lubricant for a specific purpose, he must keep in mind that correct lubrication is dependent on two factors: (*a*) the correct lubricant; (*b*) the correct application.

The best lubricant could not fulfil its function if certain mechanical features were not considered, such as correct distribution of the lubricant in the circuit in sufficient quantities, properties of materials in contact, finish of surfaces, dimensions, clearances, etc. Also cooling problems might have to be taken into account. Such items are entirely the car manufacturer's responsibility.

When referring to "correct lubricant," the motor manufacturer must know what is required of the lubricant, always keeping in mind that much greater demands are now made on the lubricating value of the lubricant than formerly, due to increased speeds and higher efficiency of engines, etc.

Motor-car lubricants fall roughly into three general groups: engine crank-case oils, gear oils, and chassis lubricants.

Dealing with the first named: *What are the demands on a good engine oil?*

It must be stable under the widest possible range of operating conditions, have a useful life and reasonably low consumption.

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† Austin Motor Company, Ltd.

Load-carrying capacity must be sufficient for the maximum possible loads at maximum probable temperatures, without permitting metal seizure or undue wear.

It must prevent wear of the metal parts even during the period of boundary lubrication.

It must act as a protective against corrosion from the products of combustion, etc.

It should have the lowest volatility and be non-toxic.

The next question the motor manufacturer would have to ask is, *whether such lubricants are available and commercially produced* and can be distributed to the world-wide markets when needed.

Regarding the means of testing the various lubricants submitted to him, experience has taught the manufacturer that laboratory tests alone, however carefully carried out, do not give sufficient data to enable a decision to be reached—in short, there are no laboratory methods of measuring the true lubricating values which include all the factors entering into the successful lubrication of the mechanisms in question.

Although much has been done to prepare specifications for lubricants, there is no true specification for selecting the lubricant. Specific gravity, viscosity, flashpoint, setting point, carbon residue, etc., do not positively define the quality of an oil in practice.

The capacity to reduce wear and prevent corrosion in service, for example, is a quality which can be determined only by long and expensive tests.

This shows the fallacy of trying to buy lubricating oils by merely quoting specification figures or S.A.E. numbers. It is a fact that oils, on the strength of analysis figures, can meet the same specification but probably not give the same results under service conditions.

Practical tests under running and service conditions have therefore to supply the final answer to the selection of the lubricant, although systematic tests should be carried out in the laboratory to eliminate undesirable products in the first instance, and close co-operation is necessary between the car manufacturer and the oil refiner.

The more essential qualities which the car manufacturer has to look for in such oils are found by laboratory tests in : the viscosity and viscosity index, pour point, stability, carbon residue, and flash point.

It is well to keep in mind that the two main classes of oils possess dissimilar characteristics.

Asphaltic base oils are : good for low pour point and low coke value; bad for chemical stability, viscosity, and low flash point.

Paraffinic base oils are : good for stability, viscosity, and high flash point; bad for pour point and coke value.

By merely mixing the two types of oils, the demanded necessary lubricating values could not be obtained.

If the base oils did not contain in the first place the very substances which are necessary for certain purposes, then no subsequent amount of refining according to the old methods could succeed in making up for this deficiency.

The oil manufacturers have met the demand for increased lubricating values of the lubricants with enormously improved products by new methods of refining by various processes and addition agents. These results could not have been achieved by the usual old methods of refining, which more or less aimed only at eliminating the impurities.

Although the user is, strictly speaking, not concerned with the means by which these improvements have been attained, but only with the results, he should realize the enormous amount of study and research undertaken by the oil experts before they succeeded in utilizing successfully the *additives* now in use. They include pour-test depressants, viscosity temperature gradient improvers, anti-oxidants, corrosion inhibitors, load-carrying capacity, and oiliness improvers. The lubricating-oil refiner uses these addition agents to improve the mineral oil in the same way that the physical characteristics of the steel are controlled by alloying with small quantities of other metals, such as nickel or chromium, etc.

These additives can do to the mineral oil what super-refining is unable to do; the latter covers the removal of so-called impurities, seeks out the asphaltic and paraffinic constituents, and can show an improvement as regards viscosity temperature gradient and sludging; but it can also remove some of the polar components which give oiliness and the so-called oxidation inhibitors which prevent or retard the formation of oxidation products, which are corrosive in their action.

As previously mentioned, oils, before being selected for practical tests under running conditions, will have to be considered for their physico-chemical properties by the results derived from the conventional laboratory tests using the usual standard equipment.

Oils after running tests are checked in a similar manner.

Viscosity and Viscosity Index.

Least change of viscosity with temperature is desired. This is important for easy starting in cold weather, also, at the other end of the operating conditions, for a good piston-seal and low oil consumption.

As it is important that not too much oil passes between piston and cylinder-wall into the combustion-chamber, a stable oil-film has to be formed as a seal; therefore oil should show least change of viscosity at elevated temperatures.

The thinnest oils should be used that can be held in crankcase without excessive consumption, of such viscosity that will permit the engine to develop its maximum power. However, too light an oil will not provide sufficient film-strength to prevent blow-by, whereas too heavy an oil causes drag. A fact that must not be overlooked is that allowance must be made for wear in engines during service.

Suitable thin oils have all the strength and resistance to break-down which were possessed by the old-fashioned heavy type. They ensure easier starting in all weathers and immediate circulation. Petrol consumption is also improved. Mechanical features, such as the modern oil-control piston-rings, have helped to popularize such low-viscosity oils.

It should be pointed out here that most firms find it necessary to specify separate grades of crankcase oil for summer and winter use, where such are available from the various suppliers.

POUR POINT.

A low pour point is important for circulation of lubricant to bearings and pistons immediately on starting on a cold morning (during the period of danger). Oil must be freely pumpable under the most extreme conditions of cold.

STABILITY.

The oil must not alter in character in use and form undesirable substances (*sludge* and *asphaltic matter*) which choke up filters, oil-pipes, etc., in the system—in short, the oil must have a long life.

The Air Ministry specify a laboratory test for oil stability in which the amount by which the oil alters in quality under this test is taken as an indication of its stability.

To use the oil for a considerable time, it is necessary that it should stand up to temperatures in the sump of over 100° C., and well over 200° C. to keep up a permanent film in cylinder-bore. A summary of the thermal conditions in an engine shows that the lubricating oil used must be working near its critical temperature. At certain parts of the heat-cycle, conditions may exceed this temperature.

It is generally found that the more stable a mineral oil is, the poorer it is in polar groups and less in the position to keep up this permanent oil-film. The opposite condition of these is shown by the *fatty oils* which are necessary for blending to supply the requisite oiliness to protect, for instance, the cylinder-wall from corrosion after the cooling-down period, but the percentage of fatty oils in blending is permissible only to a certain degree, otherwise sticky rings, valves, etc., are the result.

Another point is that if any water from combustion, or through leakage, gets into the sump containing mineral oils blended with fatty oils, the water will *emulsify* with the fatty oils, etc., thereby spoiling the lubricating qualities. The percentage must therefore be kept down to a minimum.

It is well known that the lubricating action of oils depends on the formation of a film of oil adsorbed on the metal surface (through mainly surface reaction). This adhesion is most important.

CARBON RESIDUE.

Only a minute trace of the carbon in the oil is deposited as a residue when the oil is driven off by heat. Similar conditions occur in the combustion-chamber of the engine, and depend on conditions of operating the engine. What carbon does form shall be a minimum, and of a non-crystalline structure (soft in character).

FLASH POINT.

High flash point is necessary to resist oil being burned on cylinder-walls on the explosion stroke. This is important for obtaining a low oil consumption.

When selecting lubricants, consideration must be given to the *corrosion resistance* of bearing metals used in engines. While on the subject of engine-bearings, the author wishes to direct attention to the now-popular thin steel-backed bearings, produced by a well-known firm in this country, and of which the author's firm were probably the first to make use. On account of the excellent structure of the bearing-metal, its much increased resistance to fatigue, and the improved heat conductivity due to the intimate contact between the back of the bearing-shell and its housing, they are a great improvement on the previous conventional thick-wall type.

Besides the well-known anodic treatment of aluminium alloy pistons, there are now a number of chemical and other treatments in use to create various *protective surface finishes* or coatings to encourage the rapid spreading of the lubricant and quick bedding-in of the surfaces during the breaking-in period, by transforming the surfaces to an amorphous-like material.

Parts like piston-rings, for instance, can receive galvanic deposited coatings of metals of low melting point, such as tin, phosphate, or iron manganese phosphate coatings similar to coatings produced by well-known rust-proofing processes or iron oxide films.

Running-in compounds, such as colloidal graphite mixed with suitable oils, also approved *top-cylinder lubricants*, give excellent results when new engines are being run in. Naturally most of such running in has to be left to the client.

One has to guard against engine lubricants which have a tendency to form *hard lacquer* on the sides of the piston-rings, produced by oxidation of the oil at high temperatures in the presence of water and dirt. This may cause trouble through sticking piston-rings, and thereby blow-by.

Sticky carbon deposits are sometimes noticed on valve-stems and under the heads, which interfere with the movement of these parts under working conditions.

Besides correct mechanical features, a *maximum resistance to oxidation* and *gumming* is essential.

Manufacturers must provide for the care of the oil while in service by providing correct *crankcase ventilation* and installing *thermostats* with a view to reducing dilution and removing some of the sludge-forming elements before they have had time to combine, instead of filtering out sludge after it has formed.

OIL FILTERS.

It is generally agreed that crankcase oils do not wear out, but simply become contaminated with various impurities, the removal of which renders the oil suitable for further service. This can be achieved by a good oil-filter.

The primary function of an oil-filter is the removal from the lubricating system of injurious materials, such as abrasives, metal particles, and water.

The majority of filters in use are of the by-pass type, using an *absorbent type* of filtering material, such as cotton fibre, etc.

Another kind of filter is of the *adsorbent type*. Although many doubt it, the fact remains that with some of the filters using adsorbent materials, such as certain clays and earths, not only the impurities are removed, but also some of the essential additives.

As part of the contamination of the lubricants originates from some outside sources, through the breather and air-supply, the use of an efficient *air-cleaner* is advisable. Thus it appears that both an air-cleaner and oil-filter are needed.

It is rather important, from a service point of view, that the various engine-oils recommended by a car manufacturer should mix. Most mineral lubricating oils will do so.

FINAL SELECTION OF THE LUBRICANTS BY THEIR PROPERTIES SHOWN IN PRACTICAL RUNNING TESTS ON BENCH AND ON THE ROAD.

Bench Test.

Engine run on $\frac{3}{4}$ load, 1600–2800/r.p.m. (at intervals of 2 minutes). Actual running time, 100 hours. Temperature of water, 70° C. Oil temperature, 90° C.

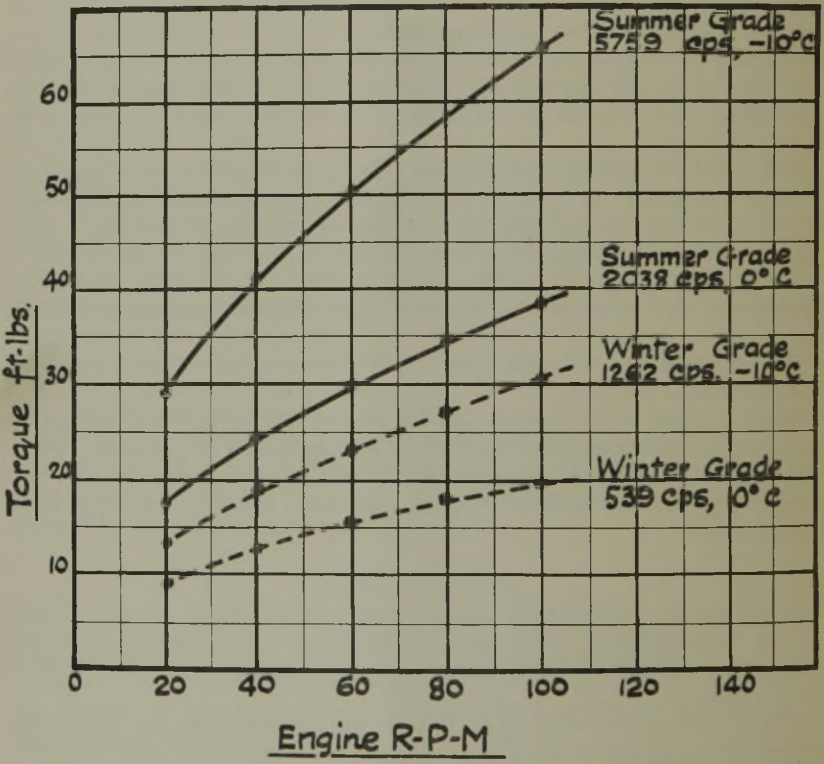

FIG. 1.

GRAPH SHOWING DIFFERENCES IN RESISTANCE TORQUES OF A 6-CYLINDER ENGINE (1710 C.C.) AT LOW TEMPERATURES, USING TWO GRADES OF OIL WITH DIFFERENT VISCOSITIES.

To gauge the effects of the oil on the engine, the latter is inspected after test for: wear, carbon deposits in combustion-chamber, on and under piston-head in ring-grooves, sludge or gum on the relieved portions of the pistons, sludge in crankcase.

The oils are then tested for ash, carbon, asphalt, volatility, emulsibility, pour point, etc.

Crankcase oils are usually found to be fit for further service when the oxidized products insoluble in petroleum ether are below 1 per cent.

Differences, principally in the frictional resistance, when using different oils, can be found by dynamometer tests (using a well-run-in engine), by noting the number of revolutions per minute attained with a fixed carburetter throttle opening, using the same fuel, and other conditions being equal, for each comparative test.

Cold-room tests are carried out with a view to comparing the engine-cranking speeds, engine-resistance torques, and starting performances with the different oils.

Road tests are carried out to find the values on performance, consumption of oils and fuels, and to show the effects of the oils on the engine, etc. Inspection is continued on similar lines as mentioned under "Bench Tests." A distance of about 10,000 miles is usually covered by these road tests. It should be mentioned that these tests are partly carried out with intermittent stops at short intervals, in order to cool the engine.

TABLE I.

Showing Properties of some Well-known Crankcase Oils Used by the Author's Firm.

	Summer-Grade Engine Oils.		Oils that can be Used Summer and Winter.			Winter Grades Only.	
Specific gravity	0·886	0·895	0·882	0·879	0·878	0·874	0·870
Flash point :							
Closed	440	425	424	430	425	415	—
Open	480	450	439	445	445	450	420
Viscosity (Redwood No. 1) :							
70° F.	1724	2025	1485	1347	1290	680	610
100° F.	625	680	526	480	470	278	257
140° F.	223	220	185	171	170	114	108
200° F.	78	75	67	65	66	54	54
Viscosity index	108	95	100	100	103	117	120
Pour point, °F.	0	10	0	5	0	0	5
Carbon residue (Conradson)	0·54	0·45	0·48	0·18	0·38	0·06	—
Emulsibility	Slight	Slight	Slight	Slight	Slight	—	—
Asphaltene content	Trace	Trace	Trace	Trace	Trace	—	—

LUBRICATION OF GEAR-BOXES.

Experience has taught the car-producer that a lubricant, to be satisfactory for the above, must have certain characteristics. It must have a high enough viscosity to ensure low tooth-friction, which is necessary for the reduction of wear and noise to a minimum; but the viscosity must not be sufficiently high to create excessive heat and power loss due to the churning action of the gears, nor must it offer undue resistance to gear-change. It should have the capacity to carry off the maximum amount of heat and give maximum resistance to oxidation and sludging, and should have sufficient body to prevent leakage under operating conditions.

All these conditions are fulfilled by good engine-oils, and at the author's works the adopted summer-grade engine-oils are used satisfactorily for the lubrication of their synchromesh gear-boxes. In addition, the number of different lubricants to be kept in stock is reduced.

REAR-AXLE-GEAR LUBRICANTS.

In recent years, with the advent of the hypoid-gear rear axle, special lubricants, possessing a high film-rupture strength—the so-called " Extreme Pressure " lubricants—have been developed to meet the special demands in the lubrication of these gears. They are known as " Powerful Extreme Pressure " lubricants. E.P. lubricants, but with milder E.P. properties, are also used on many axles fitted with ordinary spiral bevel-gears, the tooth-loads of which are too high for ordinary mineral gear-oils, although, if properly made, a powerful E.P. lubricant may be used with gears requiring only mild E.P. lubricants, or even straight mineral oils. Without these E.P. lubricants, where they are necessary, the size of the gears and axle-case would have to be increased, and thereby the unsprung weight of the axle raised, which is undesirable. The film-strength of these lubricants is generally associated with a chemical reaction between the lubricant and the contacting metals.

With regard to the selection and supply of these lubricants for the various rear axles, there are so many variables outside the oil-refiners' control that a very close co-operation is necessary between the car-producer and the oil-firms. So much depends on tooth-loads and deflection, metallurgical conditions of gears, oil-capacity of axle gear-case, and possible maximum oil temperature that can be attained, etc.

Sometimes E.P. lubricants have to be used in axles with a small reservoir capacity, where a conventional high-quality lubricant could be best used otherwise.

An E.P. lubricant suitable for rear axles with gears that are stressed with high tooth-loads must have chiefly: sufficient load-carrying capacity; stability both in service and in storage; absence of abrasive and corrosion action; fluidity under all service conditions, and freedom from foaming.

The teeth of the spiral bevel-gears in the various car rear axles produced at the author's firm are stressed with *maximum tooth-loads* varying from about 2600 to 3250 lb. per inch face-length, calculated from loads due to torque to slip rear wheels with a friction coefficient of 0·65. As the stress is transmitted through line contact, very high stresses in the gear-tooth surfaces have to be expected.

It should be mentioned here that the film-strength of the lubricant must be higher than that necessary for ordinary driving conditions, to prevent *scoring on the " coast " side* of the gear-teeth that may be caused by the shock-load conditions when suddenly letting in the clutch while coasting at high speeds, or by quick down-gear changes at such speeds, which is made possible with the modern synchromesh gears. These loads can be considerably higher than those of the low gear-drive, besides being shock-loads. The use of trailers can be another source of high tooth-loads.

The most important single property of an E.P. lubricant is *load-carrying* *capacity.* The laboratory testing-machine at the author's firm is the Timken machine. He would like to have had the use of the latest S.A.E. machine for comparison, but none was so far available for his firm.

None of the powerful E.P. lubricants was required by the author's firm, although those finally chosen could not be called particularly mild.

There is still a definite need for a standard procedure of testing to enable the proper selection of E.P. lubricants.

As the load-carrying tests of the various lubricants submitted did not always correlate with tests under road conditions, the author constructed, several years ago, a special "*Torsion-loaded axle-gear-testing fixture*" on the four-square principle. With this, any road-test condition could be obtained, with the exception of the "coasting" conditions mentioned previously. By finding the number of "cycles" (from time-load factor) necessary, to correlate with the findings from numerous road-tests under the above conditions, data were obtained that could be used as a basis to estimate the possible life of the gears and bearings. This gave with maximum engine torque at a pinion speed of 3500 r.p.m approximately 100 hours running time.

TABLE II.

Results of Tests of Various Gear Oils on Timken Machine and "Torsion-Loaded Axle-Testing Fixture."

(See photo and sectional drawing of fixture, Figs. 2 and 3.)

Tests carried out on No. 1 assembly. Load on pinion shaft 67 ft. lb. Speed of pinion shaft, 3500 r.p.m. Oil temperature maintained at 75° C.

	Straight Mineral Oils.		Extreme Pressure Lubricants.						
	A.	B.	D.	E.	G.	J.	L.	F.	A.*
Gear test No.	G.6	G.11	G.10	G.14	G.22	G.27	G.30	G.29	G.18
Timken machine, lb.	16	14	60	28	65	67	60	80	16
Serial No. of gears	618	124	125	249	235	950	515	511	888
Clinging properties of oil	Poor	Poor	Fair	Good	Good	Good	Good	Good	Poor
Test in hours	1¼	¼	14	100	100	100	100	200†	13
Condition of gears	Scored	Scored	Scored	Good	Good	Good	Good	Good	Scored
Condition of bearings	Good	Good	Pitted	Good	Good	Good	Good	Good	Good

* Gears used in this test were previously run-in with E.P. Oil F, then tested on fixture with "A" Lubricant. Time run before picking-up occurred, compared with Gear Test No. G.6, shows the advantage of running-in with E.P. Oil.

† After 100 hrs. oil was changed and load increased to 77 ft. lb. and test extended to 200 hours.

A and B are straight mineral oils (at 70° F. viscosity approximately 9500 seconds No. 1 Redwood) that were used satisfactorily in rear axles, which had to carry smaller loads than the present ones.

STABILITY OF E.P. PROPERTIES.

These lubricants all tend to lose some of their E.P. properties during use or under heating (depletion of chemical ingredients). On the extent

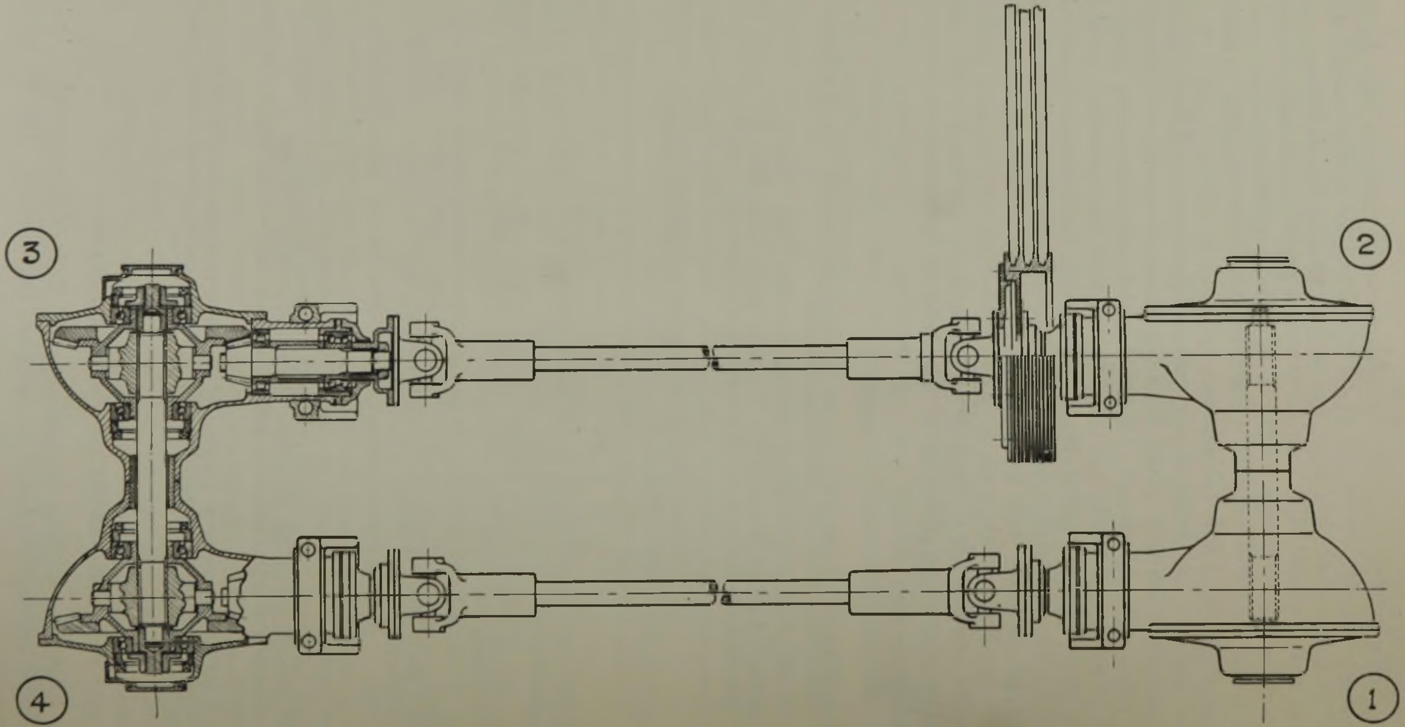

FIG. 3.

PLAN VIEW OF TORSION-LOADED AXLE GEAR-TESTING FIXTURE. PART SECTION.

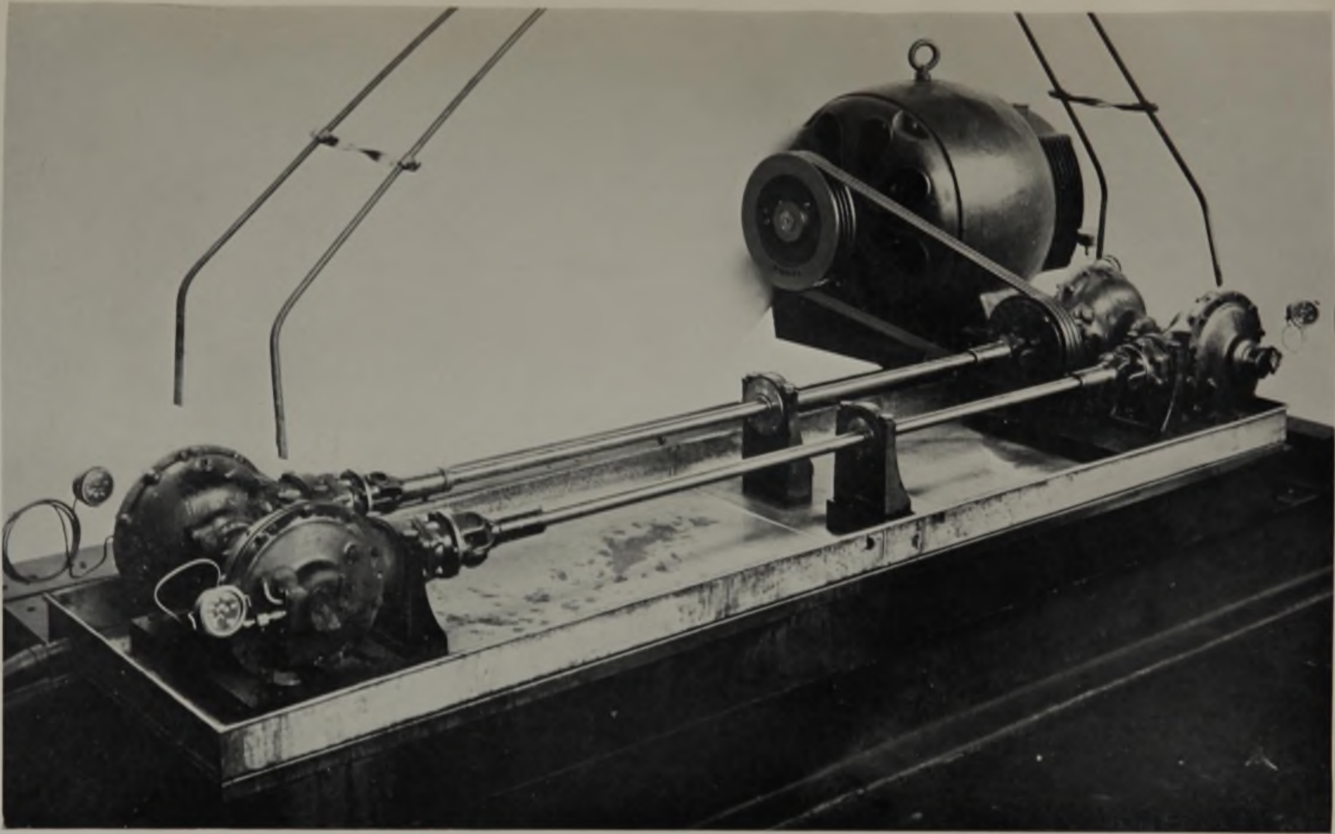

Fig. 2.

TORSION-LOADED AXLE GEAR-TESTING FIXTURE.

[To face p. 638

of the retention of their E.P. properties depends the suitability of the various E.P. lubricants.

No separation in storage must occur. Care must be taken to keep out moisture, on account of possible separation in an otherwise stable product. The author experienced considerable trouble in the early days of the lead-loaded rear-axle lubricants due to the separation of the lead products.

ABSENCE OF ABRASIVE ACTION.

Correct E.P. lubricants should cause no greater wear of the various parts of the rear axle assembly than ordinary mineral gear-oils. Wear does, however, occur when abrasives are present, either in the original base-oil or derived during manufacture. Another cause of wear may be due to lack of sufficient load-carrying capacity.

Instead of employing a testing machine, such as the Timken, for wear measurements, the author uses the previously mentioned torsion-loaded axle-gear testing fixture, particularly for wear on ball and roller bearings, and instead of looking for loss in weight, the differences in the diametral clearances and the condition of the wearing surfaces before and after tests are taken into consideration; the oil temperature is kept at 75–80° C. and, so that tests are carried out under practical service conditions, no steps being taken to eliminate moisture.

CORROSION.

Corrosive tendencies should be negligible. In the presence of moisture in the axle-case—which cannot be avoided, being due to condensation—the author found, on tests, that, with certain lead-containing lubricants, the sulphur-films showed practically no tendency to react with the moisture.

The addition of lead-soap apparently eliminates corrosive action on steel, as was shown by the above tests, and also by laboratory tests carried out with various E.P. lubricants containing 1 per cent. of water, at 95° C. for 50 hours.

FLUIDITY UNDER ALL SERVICE CONDITIONS AND FREEDOM FROM FOAMING.

Channelling at low temperatures is serious, as it might easily result in gear failures. The lubricant must therefore flow freely at low temperatures.

The author does not know of any definite method for measuring either of the above properties.

Foaming can become a source of trouble, as, due to the volume increase, which might be considerable, according to the rate of agitation, a leakage of the gear-lubricant from the axle-case to the brakes is likely to happen.

It is important to bear always in mind that mixing of various E.P. lubricants must be avoided, as dissimilar chemicals will not mix, or the proper balance might be disturbed.

Use has been made of the opportunity of checking the used oils in axles from certain cars in service, with the exact mileages and conditions known, with a view to ascertain the chemical and physical changes in the compounds. These were usually found to be reasonably small. In some instances it was noticed that mixing of different E.P. lubricants had occurred, with detrimental results to gears and bearings.

Ball and roller bearings were also checked for wear, etc.

The author adopted for the conventional hour-glass and cam-type steering-boxes, as used at his firm, the same E.P. lubricants as for their rear axles.

TABLE III.

Typical Examples of Approved E.P. Rear-Axle Lubricants.

Oil Designation.	E.	G.	J.	L.	F.
Specific gravity	0·942	0·906	0·948	0·938	0·975
Pour point, °F.	20	10	25	15	20
Viscosity (Redwood No. 1) :					
70° F.	5800	5000	9250	8100	9800
100° F.	1675	1520	2580	2380	2700
140° F.	460	470	678	670	730
200° F.	120	135	165	172	182
E.P. addition agents	Vary according to type of E.P. lubricant, and are oil supplier's property.				

WORM-GEAR LUBRICANT.

For conventional worm-gears in axles, as used by the author's firm (steel-worm, bronze-wheel), where tooth-loading is not severe, certain well-refined mineral oils were found to be extremely satisfactory.

In selecting them one has to look for characteristics on similar lines to those in lubricants for rear axles with highly stressed spiral bevel-gears, with the exception of the load-carrying capacity, which in this case need not be so high.

Since all the physical properties of bronze change with temperature, one has to expect that continuous running at high lubricant temperatures will hasten metallurgical failure.

TABLE IV.

A Typical Example of Approved Worm Gear Lubricant.

Type of lubricant	Straight mineral.
Specific gravity	0·910
Pour point	0·30
Viscosity (Redwood No. 1) :	
70° F.	9500
100° F.	2750
140° F.	750
200° F.	196

CHASSIS LUBRICATION BY SEMI-SOLID LUBRICANTS.

Many chassis parts are lubricated with greases, often where leakage is to be avoided; but by careful design it is possible to use oil instead of grease with advantage. That this has been realized is shown by the fact that an increasing amount of oil is now being used for this purpose.

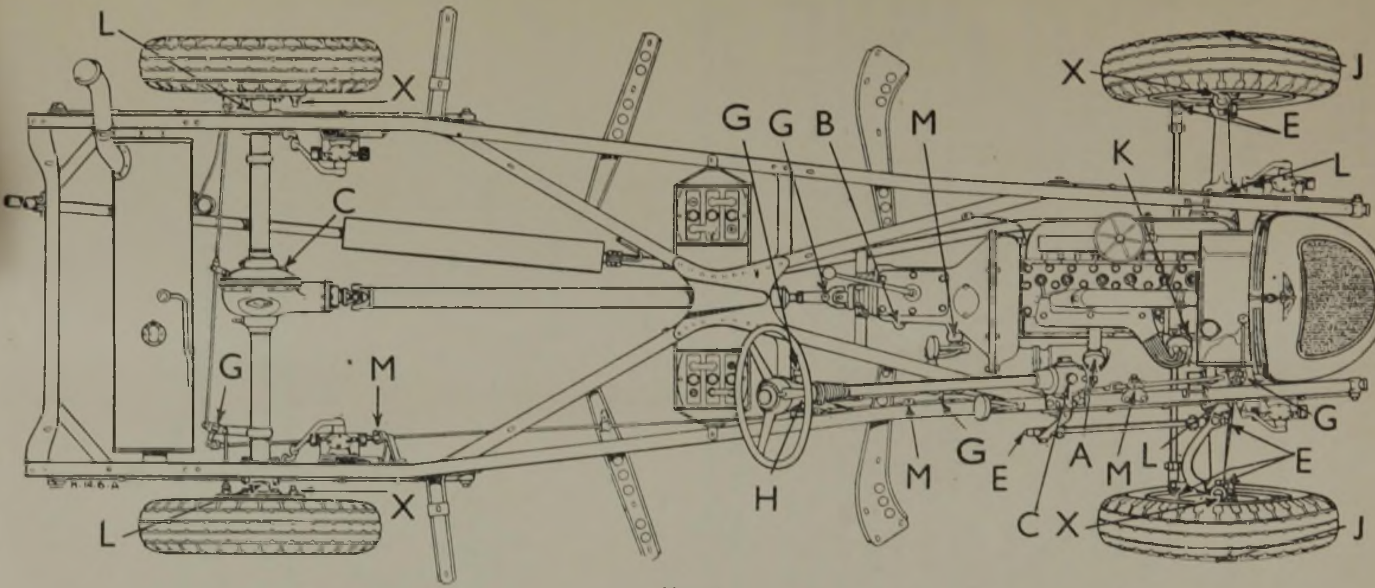

Fig. 4.

CHART SHOWING THE VARIOUS POINTS WHICH HAVE TO BE GIVEN PERIODIC ATTENTION USING EITHER OIL OR GREASE AS RECOMMENDED BY THE MAKERS.

Of the two types of greases chiefly in use, the *lime-base* grease is more generally applied. It is moisture-resistant, but not good for high temperatures. Where usually used, the parts work under normal conditions, often only slightly in excess of atmosphere.

Care must be taken in choosing grease where grease-guns are used. High pressure tends to separate greases, releasing the mineral oil and leaving behind the soap.

Soda-base greases are water-soluble, and suitable at higher temperatures than the lime-base greases. Oil does not separate so readily from soda base; they are fibrous, and this stringy structure seems to act as a sort of sponge for the retention of the mineral oil. The high-speed type of soda-base grease which resists centrifugal force is used as lubricant for parts revolving at high speeds, such as certain types of universal joints on motor-car propeller-shafts.

By incorporating into the grease a percentage of a colloidal material, greases are now produced (reversibility greases) in which there is practically no separation of the oil from the base material on heating and cooling.

Some of the approved greases are of the *metallic compound filled type*, others are *graphite greases* (Gredag, mixture of colloidal graphite and grease).

Greases can be selected by analysis, which might present certain difficulties in regard to some of the ingredients, and by several physical tests which are more or less arbitrary. Stability in storage and use must also be considered.

The simplest way of testing greases for selection, as far as the car manufacturer is concerned, is to check their performance under service conditions.

TABLE V.

Particulars of Approved Greases.

	Wheel Hubs and Grease Gun.	Water Pump Grease.	High Speed Grease.
Melting point (Pohl's), °F.	216	210	325
Ash, %	2·80	4·40	4·10
Nature of ash	Lime	Lime	Soda
Water, %	1·00	2·50	0·12
Free acidity, %	0·17	0·22	Neutral
Total saponifiable, % fat	26·28	47·70	28·50
Unsaponifiable, % oil	69·92	45·40	67·28

There are other special lubricants, such as oils used for certain hydraulic equipments in the car—*e.g.*, shock-absorbers, hydraulic-brakes, etc.

The author wishes particularly to thank Lord Austin for his interest in the presentation of this paper.

Afternoon Session—Tuesday, May 23rd.

DISCUSSION.

Mr. A. Beale said that as a manufacturer of oil filters he had naturally been pleased by the amount of attention given to that subject, but he was avoiding the temptation to make capital out of it. He merely asked permission to put before the meeting some facts which had come within his experience and which had some bearing on the papers.

Eighteen months ago he had fitted to a new 14-h.p. car a very efficient by-pass filter which automatically cleaned its filtering surface and collected the solid impurities in the filter sump. He left in position a cloth filter of conventional design.

In 19,000 miles driving under arduous conditions, mostly in London traffic, he had not drained the sump of the car or of the filter until the previous week, when he did so for the sake of the information then presented. In the oil he found less than 0·1 per cent. of " carbon " (as defined by Mr. Wilford)—*i.e.*, less than 10 gm. The engine sump and oil-ways were perfectly clean. The cloth filter contained 11 gm. of " carbon " and the finer filter 28 gm.

Thus altogether in 19,000 miles only 49 gm. of " carbon " (less than 0·5 per cent.) had been formed in the oil, and most of it had of course been prevented from circulating round the engine.

It had not surprised him, as the maker, that the fine filter had kept the oil in circulation so clean; but he confessed that he was surprised at the extremely small amount of " carbon " formed altogether. It seemed that keeping the oil in circulation clean diminished the actual amount of impurity formed, and as a layman in that gathering of specialists he would be very glad if somebody could tell him why.

Mr. J. Romney said that there were a number of points in the very interesting papers which had been presented on which he would like to comment, and others on which he would like information.

Mr. Brozyna considered used oils satisfactory for further service if they did not contain more than 1 per cent. of oxidized products. If his oxidized products included the so-called " carbon," his decision would mean the rejection of a very large number of crankcase oils which were behaving very satisfactorily and which would be especially useful for continued use if filtered. If, however, Mr. Brozyna referred to, as oxidized products, asphaltic matter, or that proportion of the solid matter which was benzole soluble, he would agree with him that the oil was in a bad state.

In Table I of his paper, Mr. Brozyna gave figures for crankcase oils used by his firm, and apparently these contained traces of asphaltenes. He (Mr. Romney) was very surprised that a positive result should be returned on any reasonably refined new oil, and would be interested to have details of the test, which might be a special one.

Mr. Brozyna mentioned that he did not know of any standard foaming test. Mr. Romney did not think that there was one officially approved, but Mr. Brozyna might be interested to know that Standard Motors of U.S.A. included a foaming test in their specifications for Hypoid gear oils. Further, the Institution of Automobile Engineers, Research Department, published a report, some time ago, on the foaming of oils, in which a rather interesting foaming test was described, the degree of foaming being determined by weighing a fixed volume of foam prepared under controlled conditions.

The comments on filters in Mr. Brozyna's paper evidently referred to units attached to engines, but the whole subject of reclamation of used oil was of great importance. Many of the standard filters and reclamation plant were extremely useful, but he wished users would recognize their limitations. He often had to deal with complaints such as " The oil had gone like water, and even filtering it made it no better." The reference was, of course, to fuel dilution, and it was difficult to get users to realize that reclamation plant could have little effect on dilution unless it was of the type in which some form of distillation was attempted.

Mr. Wilford's paper was especially interesting. As the chief chemist of a very large transport undertaking, Mr. Wilford was in the fortunate position of being able to carry out extensive practical tests, and had found that high-grade oils had shown a definite economy, in spite of the relatively high initial cost. He had come to this conclusion as the result of practical tests, but it was interesting to note that he had been prompted to work extensively with high-grade oils on his compression-ignition engines in the first place because he felt that it gave him a margin of safety. It was essential that users, and particularly small users, should realize the importance of this safety factor, rather than look for the cheapest oil that did not cause obvious and immediate trouble. It should be remembered that the cost of lubrication represented a comparatively small proportion of the total running costs, and it was just because the small user was not in a position to find out for himself with any degree of certainty the relative long range merits of high-grade and inferior oils that he should play safe.

On page 610 Mr. Wilford gave a table of characteristics of oils tested. He (Mr. Romney) was very surprised at the figure given for asphalt after oxidization on Oil B. Having regard to the viscosity and the very low specific gravity, the asphalt figure was remarkably high, even for the London Passenger Transport Board method of asphalt determination. He would also like to be quite clear about Mr. Wilford's determination of hard asphalt in used oils. He presumed that it involved separation of the benzol solubles and insolubles in the solid matter.

Mr. Whitehouse made an appeal for viscosity gradings. There was a B.S.I. classification in existence, but this was framed so long ago that it would be a good thing if the Institute of Petroleum would produce a new system. The S.A.E. grading was too wide, and there was also too much dependence on viscosity temperature curve when translated into their conventional manner of recording viscosity. Oils of the same Redwood viscosities at 140° F. might have different S.A.E. numbers. In fact it was possible for an oil, more viscous than another at 140° F., to have a lower S.A.E. rating.

Many people were interested in viscosity index, and the American system was to some extent used in England. If this or some other system were adopted officially in that country, it might be possible to link it up with the viscosity classification. For instance, their viscosity ranges might be indicated by *A*, *B*, *C*, etc. Assuming viscosity indices ranging from, say, 0 to 130, they would work to the nearest 10, or to the nearest lower multiple of 10, and an oil would be fairly clearly defined by some such symbol as *C*90. It should not be impossible to go even further and bring in stability if a standard oxidation test could be agreed on. There were many oxidation tests, and it was impossible to be dogmatic on the question of which was most informative, but it was better to adopt a fairly well accepted one than none at all. He would favour the Air Ministry test, which Mr. Wilford used, but with measurement of asphalt which he adopted but which the standard test ignored. If it was argued that a specification which included such a test would eliminate a few oils claimed to have been found satisfactory, it would at least have the more important effect of cutting out many oils which were of very poor quality.

Mr. Whitehouse had made quite an impassioned speech for the small transport operator. It was evident that education was required, and Mr. Whitehouse and his friends in engine-manufacturing industry were the men to do the teaching. Apparently, whenever Mr. Whitehouse lectured to operators on the importance of oil filters, he caused a rush on the local dealers next day. In other words, he scared the operators, and that was what the manufacturers should do in an official manner. They should state right at the start that their engines could only be expected to work satisfactorily on high-grade lubricants. Of course, that would mean definition of the high-grade oils, and that was where an Institute of Petroleum decision on a classification would be necessary.

DR. E. R. REDGROVE congratulated Mr. F. C. Whitehouse on his frank exposition of the difficulties experienced with very small fleets and isolated vehicles.

Generally these difficulties were due to failure to appreciate that the splendid engineering job which comprised the modern commercial vehicle, needed intelligent handling and regular attention.

On the question of oil filters, he thought these could become a source of real danger if persistently neglected, and would go so far as to suggest that when the by-pass valve came into operation, the fuel supply was automatically cut off; then a clean filtering element would have to be introduced.

MR. J. ERIC HASLAM said that Mr. Whitehouse's paper was one which particularly emphasized the President's remarks concerning the value of collaboration between engineering in general and the petroleum industry.

Just as Mr. Whitehouse tried to pass the responsibility of sludging on to the petroleum industry, so they in their turn invariably passed it on to the designers.

When it was realized that at least 90 per cent. of the sludges which were found in ordinary commercial vehicles, particularly those on short-journey work—which were the type to which Mr. Whitehouse was largely referring—were due to the contaminations of the oil with materials wholly from the outside, it was somewhat difficult to see how one could blame the oil for it. He referred, of course, to the products of blow-by—namely, carbon, and in particular water, which latter condensed in a cold sump and made emulsions with the suspended carbon. These were the typical sludges.

One was faced with the alternative, therefore, of either keeping these materials in complete suspension or of preventing their occurrence, which latter, of course, was the more sound practice and was the engineer's job. The former could only be regarded as unsatisfactory since prevention was always better than palliatives, especially in view of the fact that it had been proved that high quantities of suspended matter were a cause of high cylinder wear.

For some time he had advocated that there should be some means of keeping the sump temperatures relatively high in those areas where the gases were in contact with the oil. This could be done by lagging the sump; whereupon the heat dissipation would have to be effected by an efficient oil-cooler fitted elsewhere. This at least would take care of the difficulty of condensed water and prevent the separation of sludges in the form to which Mr. Whitehouse referred. Although certain costs might be involved, this seemed to be the only solution other than the semi-satisfactory methods of sump ventilation which were of decreasing efficiency as the engine wear increased and blow-by became heavier.

Mr. J. C. Jennings said that it was a commonplace for the engineer to make more and more demands on the oil chemists, and Mr. Whitehouse's plea for still better oils fell into line with many others. He thought it would be admitted that on the whole the chemist had kept up with those demands by producing oils of constantly higher quality and stability to meet the more and more exacting requirements of the modern internal-combustion engine. In particular there had been considerable improvement in the stability to oxidation of lubricating oils, and progress would continue, but there was scope for the co-operation of the metallurgist in this aspect of the matter. The effect of metals as catalysts in oxidation was well known, as was the difference in catalytic effect of different metals. The well-known work of Baaden showed clearly how the sensitivity of oils to various metals differed. Certain metals, such as copper, were characteristically effective as catalysts, while others, such as nickel, were relatively inert. From the oil chemist's point of view the popularity of active metals such as lead–bronze for bearing material was rather unfortunate. He was not suggesting for one moment that such metals should be abandoned just because of their effect on oil, but he did feel that where other properties were equal or nearly equal, selection should be made of the least active metals. The same applied to piston and cylinder metal, and even the material of which the crankcase was made. Research might be directed to providing the least possible activity of metals with which oil came into contact either by variations in the constitution of these metals, or by the preparation, chemically or otherwise, of inert surfaces. This might be a wider problem for the metallurgists than the one they had given them, but he would assure them that they would be pleased to co-operate.

Dr. E. R. Redgrove said he always felt that the Air Ministry oxidation test, without a determination of the amount of asphalt formed during oxidation, revealed only a portion of the changes that had taken place in the oil. His paper published in 1935 (*J. Instn Petrol. Tech.*, 1935, **21**, 612), directed attention to this fact, and the results given by Mr. Wilford for oils *C* and *E* in Table I and Fig. 1 showed the desirability of including the asphalt determination in the examination.

Some authorities maintained that importance attached to the amount of acidity developed, but he considered that this determination could be omitted, because the non-volatile acids formed by the oxidation of lubricating oils were not corrosive to the metals normally found in engines and their bearings.

Mr. J. Romney said he would like to add to his previous remarks by commenting on two points which had arisen in the discussion. A speaker had referred to the fact that the importance of asphaltic development in an oxidation test was not sufficiently recognized and that he had been pressing for this recognition for some time. It might interest him to know that in the laboratory with which he (Mr. Romney) was associated, Air Ministry oxidation tests had been carried out for at least eight years on a large variety of oils, quite apart from Aero oils, and the determination of asphalt after the test had been carried out as a matter of course over the whole period.

It had been suggested that it might be a mistake to associate oil consumption in an engine with viscosity, and that it might be some other property—*e.g.*, surface tension—which controlled consumption. This might be true, but the fact remained that practical tests had been carried out time and time again under controlled conditions, and the general conclusion had nearly always been arrived at that, other things being equal, consumption fell with increased viscosity. That meant that whatever other property was really relevant, it was sufficiently closely reflected by viscosity, and it was quite fair for all practical purposes to establish a relationship between viscosity and consumption.

Mr. C. H. Barton said that Mr. Wilford's observations had shown that he obtained the best economy and performance, so far as the lubricant was concerned, by using solvent extracted oils in compression-ignition bus engines. Since many engine-makers and operators, both in America and Europe, had found that ring-sticking in high-speed diesel engines working under severe conditions of load and temperature took place more rapidly with solvent-extracted and " highly-stable " oils than with most other types of lubricants, it was evident that Mr. Wilford's engines did not work under conditions in which ring-sticking was an important consideration.

It was rather remarkable that the use of a flushing oil should be so ineffective in keeping down the " carbon " content of the crankcase oil in Mr. Wilford's experiments. Possibly the sludge deposits had become " bedded down " to such an extent that they were not removed by the flushing oil, although they tended to break up again under normal working conditions after the addition of fresh engine oil.

Mr. H. J. Young said that he had listened to the discussion of the papers by Messrs. Whitehouse and Wilford with interest because it appeared to him that the vital point had been overlooked. Mr. Wilford, on the one hand, was giving help to petroleum technologists, while Mr. Whitehouse was seeking it from them. The former was dealing with, say, 10,000 vehicles and one operator, the latter with 10,000 operators and one vehicle. Quite clearly if 1 or 10,000 operators were of the calibre described by Mr. Whitehouse, the only help he could possibly obtain would be from an institution of different nature from that of the Institute of Petroleum. Again, it reflected great credit on his vehicles that they did so well in such circumstances, whilst reflecting no discredit on the lubricants which these operators either did not use or, if they did, misused.

Dr. E. R. Redgrove said he would like to know how Mr. Brozyna justified the statement in his paper to the effect that low flash-point was the cause of high consumption. Also the statement (see page 632) that high flash-point resisted the oil being burnt on cylinder walls on the explosion stroke, important for obtaining a low oil consumption. Surely oil consumption was determined almost solely by the viscosity of the oil, the wear of the bore and the freedom and fit of the rings in their grooves.

Did Mr. Brozyna recommend the use of colloidal graphite for normal use after the running-in period, because many advantages would appear to favour such a course ?

Mr. E. A. Evans said that it was hardly fair to the oil companies to say that they were averse to the specifications. They had done a good deal in the past to assist organizations to formulate specifications, whether it had been Government Departments, railways, or any other large undertaking. The oil suppliers were willing to give of their best. This did not mean that they were willing to make specifications merely for the asking, quite irrespective of the source of the request. The chief interest to the oil companies was to ensure that the best lubricants were available for any particular purpose, and that the users would be protected.

Obviously it was not in the interests of every user to have a very broad specification, which would be essential if British Standard Specifications were introduced. There might be opportunities for producing specifications for a highly specialized piece of mechanism, but who was going to legislate for all types of internal-combustion-engine lubrication? There were many types, and there were many conditions of engines in those types. A new engine often required a different type of oil from an older and more worn one. One purchaser might be able to afford a good-class oil, whereas another might be compelled by force of circumstances to buy a cheaper lubricant.

Wilford made this point very clear. He stated that the first thing to do was to carry out service tests on as large a scale as possible. After this had been done, and not before, was it possible to formulate a purchasing specification. That being so, how were the thousand and one users going to make tests on engines, and then, having decided on the types of oil, formulate the specifications for their particular needs? A large undertaking such as a transport company could make preliminary selections and then base a specification upon the successful lubricant, because they could drain the oil at regular periods, make adjustments to their engines, and generally maintain the fleet in an economic and engineering way.

Brozyna, speaking for the car manufacturers, stated that experience had taught the manufacturer that laboratory tests alone, however carefully carried out, did not give sufficient data to enable a decision to be reached. What was a specification based on except laboratory tests? Whitehouse stated that " By this is not meant that all oils should have the same constituents, as obviously that would put an end to all research and progress." Did not a specification lead to standardization of the constituents? If so, according to Whitehouse, specifications were going to stifle progress.

Classification was closely allied to specifications. A classification was obviously extremely broad. The animal kingdom, for example, was classified into types. It must be so. It was not necessary to give a specification for a lion to know what type of animal was being spoken about. Surely they would have gone a long way ahead if they could induce people to think harmoniously about a medium or a heavy oil. Let them first of all persuade people that they must describe the oil which they required in some general term which could be numerically defined. The proposed British Standard Classification did that. It gave the viscosity limits which were allowed for a medium, a heavy, or a super-heavy oil. It left the field open for the users to consult the oil industry, which had the experience.

It would be absurd at that stage to include a viscosity index, a gravity, or a stability test. If a viscosity index were included, the oil industry would be tempted to recommend oils of a certain viscosity index which would give them the biggest profit, irrespective of whether they were the best for the customer or not. Stability had not yet been defined, so why attempt to include something which had almost a nebulous character?

The proposed classification had certainly been troubling the minds of some of the best brains in the industry for about three years, sorting and sifting. He thought it was time that heed should be given to their opinions. These people had been assisted by men well known in other industries. The petroleum industry itself supported the classification, and he sincerely hoped that it would be published. Critics there would always be. Definite suggestions from anybody would be welcomed, but let them provide for the thousands of users of lubricants.

MR. WILFORD, in a written reply to the Discussion on his paper, stated that the degree of contamination of the lubricating oil concerned in Mr. Beale's test was certainly low, although he did not regard the figure quoted as an exceptional one. Thus the average " carbon " content of used oils from petrol engines fitted to London buses was about 0·75 per cent. after 12,000 miles, and it was evident from this that in individual engines oil as lightly contaminated as that found by Mr. Beale might be encountered. The suggestion that if the oil in circulation were kept clean there would be a diminution in the amount of impurities which would otherwise have been formed, did not seem unreasonable, although he had no evidence one way or the other—except that if the contamination was due to incomplete combustion of the fuel, and this was the source of the greater portion of the " carbon " found in used oils from C.I. engines, then, of course, the continuous removal of this material would not prevent its being continuously produced. In this connection it was of interest to observe that with certain C.I. engines of the direct-injection type, the amount of " carbon " in the used oil after 12,000 miles was less than that found in used oil from petrol engines.

Both Mr. Romney and Dr. Redgrove had referred to the value of the estimation of asphalt after oxidation, and it was interesting to know that in the laboratory with which Mr. Romney was associated this test had been applied from a rather earlier date than it had been in the London General Omnibus Co.'s laboratory. In view of these comments it was perhaps somewhat surprising that the test had not up to now appeared in specifications, apart from those of the London Passenger Transport Board.

Mr. Romney had asked for information as to the method employed for estimating hard asphalt in used oils. This involved first an extraction of the used oil with pure benzene. A suitable portion of the extract was taken and the benzene removed by vacuum distillation, the usual precautions being observed for getting rid of last traces of benzene vapour from the distillation flasks. Hard asphalt was then determined in this recovered oil, using the method described on page 621.

Mr. Barton had referred to trouble experienced both in America and Europe with ring-sticking in high-speed diesel engines and attributable to the use of solvent-extracted oils. It was true that at the time the paper was compiled the London Passenger Transport Board had encountered but little trouble of this character. More recently, however, a certain amount of ring-sticking had been observed in engines dismantled for overhaul. It was difficult to say, however, whether this was due to the use of solvent-extracted oil or whether it was a consequence of the fact that the engines were giving a longer life than they used to do, and that as this occurred troubles which had not previously had time to develop became apparent. The matter was under investigation, but some time was likely to elapse before any further data were available.

Mr. Barton also referred to the experiments with a flushing oil. It was probable that had the flushing treatment been repeated a sufficient number of times, discarding the dirtied oil, if necessary, a reasonable degree of cleansing would have been obtained. It seemed evident, however, that such a procedure would have been at least as lengthy and as expensive as dropping the engine bases, which it was desired to avoid.

Mr. Brozyna in reply to the discussion on his paper wrote that the last sentence of Mr. J. Romney's first query was quite correct. His (Mr. Brozyna's) reference to oxidized products was to asphaltic matter, which should be below 1 per cent. (about 0·7 per cent.). Carbon could not be included, as this was actually a residue, due to burning, oxidation, and general destruction of the carbon hydrogen molecule. The carbon would be removed by an efficient filter.

In mentioning asphaltenes, as for example in Table I, he thought Mr. Romney would agree with him that from an engineer's point of view, and for all practical purposes, if only a stain could be observed, it was preferable to describe it as a trace (or sometimes negligible) rather than nil, as a trace in any form of matter was indeterminable, which rendered the term very ambiguous in most cases.

No special method of test was applied.

In answer to Dr. E. R. Redgrove, he was aware that the flash point was considered unimportant by many. He agreed with him that the wear of the bore and the freedom of fit of the rings in their grooves were two important points pertaining to low oil consumption, but surely of two oils, one with a high, the other with a low flash point both having a high viscosity index, and the mechanical conditions as mentioned above being equal, the one with the high flash point should be preferred, as such an oil should better resist the burning of the fine oil film on the cylinder wall during the explosion stroke.

The point raised concerning low flash point being the "cause of high consumption" has now been eliminated.

Referring to the query of recommending the use of colloidal graphite after the running in period, no doubt excellent results would be achieved if it was applied in an intelligent manner; on the other hand, if used with an unsuitable oil or in the presence of water, as might be caused by condensation or leakage through the cylinder gasket, the effects could be very serious, separation of the graphite taking place, forming an exceptionally voluminous sludge, which, although small in weight, was very large in bulk and might cause obstruction.

ABSTRACTS.

AUTHOR INDEX.

The numbers refer to the Abstract Number.

Geology.

994. Travis Peak Formation of Central Texas. R. H. Cuyler. *Bull. Amer. Ass. Petrol. Geol.*, 1939, **23**, 625–642.—The Travis Peak is the lowest formation in the Trinity Group in Central Texas. At the type locality in Travis Co., it consists of three members: the lower (Sycamore) consisting essentially of conglomerates and sands, the middle (Cow Creek) of limestones, and the upper (Hensell) of sands and marls. The formation has a total thickness of 263 ft., although this varies according to the locality. The general character, however, of the various phases in the different localities is the same, and their relationship is shown in a vertical section and table.

The Cow Creek beds are distinguishable from those in other parts of the formation by their lithologic characters and abundant fossils, the fauna of the Travis Peak, in fact, being mainly restricted to the Cow Creek.

Reference is made to the Glen Rose–Travis Peak contact, which, owing to similarity in lithologic character, causes much difficulty in differentiating the formations. It has been defined by R. T. Hill that the " lowest appearance of the peculiar fossils

Monopleura and *Requienia* indicates the beginning of the Glen Rose formation." Collections made by the author from various outcrops of the Travis Peak formation show that in many places this definition is reliable. G. S. S.

995. Sub-surface Study of Greenwich Pool, Sedgwick County, Kansas. A. S. Bunte. *Bull. Amer. Ass. Petrol. Geol.*, 1939, **23**, 643–662.—The Greenwich Pool, comprising parts of Sections 10, 11, 14, 15, and 22 of T. 26 S., R.2 E., Sedgwick Co., Kansas, is located on an anticlinal ridge parallel with the Nemaha buried mountains. The structure was discovered by the Shell Petroleum Corporation in 1925 by core-drill exploration.

Although the Permian and Pennsylvanian systems are present, they have no economic bearing and are not discussed. It is from the Mississippian and the upper part of the Ordovician that the producing zones of the field occur. Late in Mississippian times the area was uplifted and folding took place, followed by a cycle of erosion. Thus, the Mississippian and older formations unconformably underlie the Pennsylvanian.

The Mississippian Limestone, varying in thickness from 208 to 266 ft., is characterized in the uppermost 150 ft. by the presence of large amounts of chert associated with limestone. Within this cherty portion porous zones occur, forming good reservoirs for oil and water. This formation is followed by the Kinderhook Shale.

Underlying the Kinderhook unconformably is the Viola Limestone (Ordovician) This has an average thickness of about 40 ft. and in its uppermost part is very porous, constituting an excellent reservoir for oil.

The Simpson formation, about 125 ft. thick and underlying unconformably the Viola Limestone, consists of sand with small amounts of green shale. Near the base a petroliferous zone occurs.

Production.—The Viola Limestone is at present the main producing zone. It has yielded a total of about 6,504,319 brls., an average per acre of 15,125 brls., and an average per well of 144,540 brls.

Eight wells have been located and completed in the Simpson formation, and to date have produced a total of 316,646 brls. of oil, an average recovery per well of 39,580 brls. G. S. S.

996. Wildcat Drilling in 1938. F. H. Lahee. *Bull. Amer. Ass. Petrol. Geol.*, 1939, **23**, 789–794.—In this paper a review is given of wildcat drilling for the year 1938. Figures are supplied for the Gulf Coastal Plain States and for the whole United States with the exception of Ohio and more eastern States from which information has not been received.

A steady increase is revealed both in number of wildcat wells drilled and in the average depth of hole. Questions are raised on the control and effects of further discovery of new pools in the future. G. S. S.

997. Wildcat Activity in Kansas, 1938. E. A. Koester. *Bull. Amer. Ass. Petrol. Geol.*, 1939, **23**, 795–796.—This is a very brief account of wildcat activity in Kansas during 1938. A table is given classifying all wildcat wells according to method of location. Economic conditions have tended to diminish wildcatting in recent years. G. S. S.

998. Developments in Kansas, 1938. R. G. Moss. *Bull. Amer. Ass. Petrol. Geol.*, 1939, **23**, 797–806.—A brief summary is given of oil and gas developments in Kansas during 1938, reference being made to the leasing activity and geological work completed.

Drilling activity fell about 41% (1100 wells) below that of the previous year although, despite this, a number of new pools were discovered and two new counties were added to the producing list. The Morel Pool (Graham Co.) was probably the most important discovery, and this extended the general producing area of western Kansas nearly 15 miles north-west.

Of extensions to old pools, the most active development took place in the Zenith Pool. This had nearly 100 wells drilled in it and the area extended a mile north and 1½ miles east. The December runs were 74,168 brls., and on 1st January, 1939, the pool potential was 208,238 brls.

Towards the close of the year a very active leasing campaign was going forward in North-east Kansas and adjoining parts of Missouri and Nebraska (Forest City basin). G. S. S.

999. Recent Development in Illinois, with Discussion of Producing Formations below McClosky "Sand." A. H. Bell and G. V. Cohee. *Bull. Amer. Ass. Petrol. Geol.*, 1939, **23**, 807–822.—From March 1938 to March 1939 the rate of oil production in Illinois has increased rapidly from a daily average of 43,000 brls. to 160,000. This increase has arisen almost wholly owing to development on the western side of the Illinois basin, production originating from sandstones in the lower part of the Chester series (Upper Mississippian). A recent discovery of oil in Devonian limestone in the old Sandoval field (Marion Co.) may have an important bearing on future development.

A discussion of developments during the twelve-month period is included in the paper, together with a review of the known occurrences of oil in Illinois below the McClosky formation. Tables are given of the producing formations in Illinois and approximate depths to principal producing horizons in the oil-fields. G. S. S.

1000. Developments in Oklahoma during 1938. E. F. Shea. *Bull. Amer. Ass. Petrol. Geol.*, 1939, **23**, 823–835.—Activity in all branches of the oil industry in Oklahoma showed a marked decrease during 1938. Total oil production was approximately 170,000,000 brls., representing a decrease of 50,000,000 brls., or more than 23% from the total of 1937. The Oklahoma City and Fitts Pools continued to lead the State output with an annual production of 38,796,000 and 16,655,000 brls., respectively.

Seismograph work was again the chief exploratory means used in the quest for new structures, although a reduction of 20% was shown in the average number of crews as compared with 1937.

Very slight decrease occurred in wildcat drilling. Of the 2000 well completions, 220 (11%) might be classed as exploratory wells, and the great majority of these were situated close to producing pools in the central part of the State. Resulting from the drilling of the 220 wells, forty-two new producing areas or extensions to old producing areas were discovered, and of these sixteen might be considered as extensions to known pools and twenty-six as new pools. Thirty-nine of the discovered wells produced oil and three produced gas. Pennsylvanian sediments accounted for production in nineteen discovery areas, Ordovician in nineteen wells, and Siluro-Devonian in four wells.

In his conclusions the author states that much untested territory still remains within the State in which new pools undoubtedly await discovery.

Tables of discoveries in Oklahoma during 1938 and a map showing location of new pools and the more interesting wildcat wells accompany the paper. G. S. S.

1001. Developments in West Texas and South-eastern New Mexico during 1938. H. P. Bybee, B. R. Haigh, and S. J. Taylor. *Bull. Amer. Ass. Petrol. Geol.*, 1939, **23**, 836–843.—Drilling operations in South-eastern New Mexico and West Texas during 1938 were 21·2% less than in 1937. South-eastern New Mexico had 16·2% less operations of all classes, but had 53·3% more wildcats and outposts, which were responsible for many extensions of existing fields, although they included only two new discoveries. West Texas had 22·5% less operations, but had 15·7% more wildcats, with results almost identical with conditions in New Mexico. Of sixty-six wildcats in New Mexico, twenty-four were completed as oil wells and one as a gas well; whilst of 192 wildcats in West Texas, forty-six produced oil wells and three gas wells.

Much geophysical prospecting and core drilling were done, particularly in New Mexico, where the work was more extensive during 1938 than in any previous year. Twenty-seven core tests were recorded.

Drilling and production figures for the two areas are tabulated. G. S. S.

1002. Developments in North-Central and West-Central Texas, 1938. J. J. Maucini. *Bull. Amer. Ass. Petrol. Geol.*, 1939, **23**, 844–859.—Developments and discoveries in

1938, which showed a considerable advance in these areas, have greatly increased the importance of the Strawn formations as a major producer. Similarly, the Bend, Canyon, and Cisco series have contributed very largely towards the activities of the region.

Bend Formation.—Although practically all wells drilled sufficiently deep to test beds have yielded showings of oil, no production of economic importance has so far been developed in this series north of Young County.

Strawn Formation.—The chief discovery in this series was the Hull-Silk Pool in North Archer County. Of much importance, also, was the completion of the Adams Oil Co. Moer No. 1 well. This was completed from the Finley Sand (13 miles south-east of the Hull-Silk pool) and gauged 86 brls. in 18 hours.

Canyon Formation.—Important discoveries were made in Wichita and Archer Counties in the Holliday Pool, near Holliday, and in the King-Castlebury Pool, Wilbarger County. In the west-central district the most important new developments in the Canyon were in the Griffin Pool in Jones County, and in the McMillan Pool, Haskell County. The latter production area is expected to be confined to about 40 acres with a recovery of 2000 brls. per acre.

Cisco Formation.—A large number of pools were brought in from these beds during 1938. The most significant probably was the discovery of production in several new pools in Jones County from the Swastika Sand, notably the Chittenden, Irvin, and Noodle Creek Pools.

Extensions of much consequence were made east and west of the K.M.A. field. Prior to 1938, eighty-nine wells had been completed in the field of approximately 10,000 acres. At the close of 1938, 890 wells had been completed and the field extended east, west, and south to include approximately 32,000 acres.

Despite larger new production in 1938, the total production was slightly less than that in 1937—viz. 309,599 brls. This result was attributed to the drastic proration conditions which ruled during 1938. G. S. S.

1003. Developments in South Texas, 1938–1939. G. Kidd. *Bull. Amer. Ass. Petrol. Geol.*, 1939, **23**, 860–870.—During the year forty fields were discovered in South Texas, and their geographic positions are shown on a map. In addition, fifty-eight new sands were proved for production. This record is surpassed only by the year 1937–1938, and exceeds the records of other years both in number of discoveries and in probable additions to reserves.

Of outstanding importance was the development of large production from the Frio-Vicksburg. From this sand group were proved the major oil-producing zones in the district, and of the discoveries eight fields and twenty-seven sands were from this zone. The new fields are Alice, East Alice, La Gloria, Blucher, Kelsey, La Reforma, Sun, and McAllen.

In the coastal area the new Frio fields are : Cordele and Francitas (Jackson Co.), Bonnieview, La Rosa and Melon Creek (Refugio Co.), and Riverside (Nueces Co.). As a group these fields constitute probably the year's greatest contribution to South Texas reserves. G. S. S.

1004. Development in East Texas during 1938. E. A. Wendlandt and G. W. Pirtle. *Bull. Amer. Ass. Petrol. Geol.*, 1939, **23**, 889–895.—The East Texas district, as here discussed, comprises forty-four counties in the north-east of the State, and covers an area of about 37,000 sq. miles.

Discoveries included two oil-producing areas, two gas and distillate areas, and oil production in two old gas-fields. A total of 2213 wells were drilled during the year.

Although a number of completions were made in the district, these decreased by about 35 — during 1938 as compared with the preceding year.

Considerable exploratory drilling was directed to the Paluxy, lower Glen Rose, and Travis Peak series (Lower Cretaceous). G. S. S.

1005. Progress of "D'Arcy Exploration's" British Oil Search. Anon. *Petrol. Times*, 15.7.39, **42**, 76.—Eakring No. 1 well found good-quality crude in June at a depth of 1914 ft., and during the first week gave 107 tons by bailing. The well was deepened to 1978 ft. to determine the full extent of the sand. At Formby, Lancashire, seven of the shallow geological bores are capable of producing oil from depths of 100–150 ft. The oil is of good quality and three of the wells have given some 70 tons of oil. This is seepage oil, and geophysical work will be undertaken before deciding on further drilling.

The Hardstoft well is giving two tons of oil/day after cleaning and acid treatment. Some 300 tons of oil have been recovered in nine months as compared with 29 tons in 1937. Cousland No. 2 was completed at 2432 ft. on encountering water, and will be used as an observation well. Eskdale No. 2 found a considerable gas yield at 4212 ft., and has entered salt and anhydrite which probably caps the Permian.

G. D. H.

1006. Earthquakes and Petroleum Deposits. E. Fossa-Mancini. *Bol. Inform. Petroleras*, April 1939, **16** (176), 23–50.—Examination of the effects that may be looked for in petroleum deposits, due to seismic disturbances in neighbouring regions. One of the conclusions arrived at is that owing to the contraction and expansion of the rock the globules of oil tend to collect and to become separated from the water, so that in this respect the seismic action may be beneficial, whilst, on the other hand, damage may be suffered by displacements in wells, fracture of pipe-lines, and disturbance of plant erected at the surface. A very complete bibliography is attached.

H. I. L.

1007. Petroleum in Peru. Jochamowits. *Bol. Inform. Petrolas*, May 1939, **16** (177), 71–76.—This is a consideration from the geological point of view of the extensive possibilities existing in Peru for obtaining petroleum, many of which have not as yet been touched, whilst others have been only superficially explored. H. I. L.

1008. Geological Structure of the Styria Basin and the Question of its Oil Prospects. A. W. Hermaden. *Petrol. Z.*, 1939, **35**, 389–397.—A detailed description of the geological structure of the territory concerned is given. The prospects of finding oil are considered to be doubtful, although it is possible that oil deposits may exist in the southern part of the basin. No drilling has been started up till now. E. W. S.

Geophysics.

1009. Developments and Trends in Geophysical Petroleum Prospecting. Anon. *Petrol. Engr*, Midyear 1939, **10** (10), 72, 74, 76.—There has been a definite shift in the past year in reconnaissance work from the reflection seismograph and torsion balance to the use of the gravimeter, and soil and soil-gas analysis. The use of the refraction seismograph has been virtually discontinued.

The Eola type of structure, with its small amount of reversal and prevalence of faults, has made correlation methods indispensable, and this has led to improvements in reflection instruments. These have permitted the working of the Sparta–Wilcox trend area, which was hitherto thought too difficult for the reflection method.

The number of operating seismograph crews has decreased, whilst the gravimeter parties have increased from 24 to about 60. G. D. H.

1010. Progress and Trends in Geochemical Methods of Prospecting. J. B. Eby. *Petrol. Engr*, Midyear 1939, **10** (10), 78, 80, 82.—The geochemical exploration process is designed primarily to find oil or gas in place. A shallow surface specimen of soil is taken for wax analysis and a deeper specimen from a depth of about 8 ft. for ethane determination. After the wax and gas analyses, the data are plotted on maps. At West Saxet the data indicated two oil horizons, and this indication was later confirmed.

Soil surveys are being made in various parts of U.S.A., in Venezuela, and in Russia. It is believed that soil analysis has excellent possibilities of becoming a successful and recognized method of exploration, but it is as yet impossible to state just what the future holds for it. G. D. H.

Aerial Survey.

1011. Recent Developments in Technique of Aerial Photography. H. T. Bruce. *Petrol. Engr*, May 1939, **10** (8), 31–32; June 1939, **10** (9), 141–142.—To-day aerial cameras are available with lenses capable of producing reconnaissance and survey maps with contour intervals as close as 5 ft. Multi-lens cameras have now become standard for most types of vertical photographic work, and to fill in the blanks of the Maltese Cross print so produced, two five-lens cameras have been mounted side by side with one turned through 45° about a vertical axis. They are operated together.

Planes of special types are required. The average working altitude is 15,000–25,000 ft. The solar navigator has greatly facilitated work in territory for which no maps exist. It automatically solves the problem of varying winds and drifts, and a predetermined course can be followed with an accuracy of 0·25°. This triangulation flight lines can be made.

The details of an aerial survey are briefly described.

By means of the stereoplanigraph, precise contour maps can be drawn. The map scales have ranged 2 ft./in. to 2 ml./in. Under most conditions contour maps can be made by this method more economically than by conventional ground survey, and to the same or even to a greater degree of accuracy.

Costs depend on individual conditions; the type of plane, weather, scale. Some government maps have cost as little as $4/sq. ml. at 2 in./ml. In many instances aerial survey costs have been lower than those of ground surveys. G. D. H.

Drilling.

1012. Use of Water with High Salt Content for the Preparation of Cement Slurry. I. V. Visotski. *Neft. Khoz.*, April–May, 1939, **20** (4–5), 53–55.—At many points of the Russian steppes, owing to lack of ordinary water for the preparation of cement slurry, salt water has been used. This has been the case especially in the Ural–Emba region, where since 1930 for cementing, water with 18–19° Bé salt content, and later even more salty water (up to 25° Bé), were employed.

The properties of cement slurry prepared with water of varying salt contents were examined, and the effect of the addition of varying proportions of calcium chloride has been studied.

Results of tests were satisfactory. Minimum setting and hardening times were obtained with water which had been diluted to a 10° Bé salt content. Such salt water accelerates setting, and may therefore replace fresh water containing accelerators. Addition of $CaCl_2$ to this 10° Bé water still further improves the quality of the cement, so that it approaches the standard for plugging-back operations. L. R.

1013. Skidding Derricks by Means of the Draw-Works and the Electric Motor of the Drilling Rig. G. V. Drogalin. *Neft. Khoz.*, March 1939, **20** (3), 13–16.—In Sula–Tepe sixteen wells had to be drilled by means of three derricks within half a year. The distance between locations being 100 m., pumping aggregates could be placed between two wells, serving both without moving. The derricks had to be skidded over special wooden substructures, owing to the mountainous ground, and the pulling power was supplied by the motor of the drilling rig. Details of skidding procedure and organization of work are given.

It is concluded that the method of skidding derricks employed has the following advantages:

> It eliminates dismantling and assembling the equipment; it sets tractors free and eliminates waiting time for tractors;
>
> The movement of the derrick is smoother and more uniform than with tractors;
>
> There is a considerable economy in time and better use is made of derricks and drilling equipment;
>
> Cost of rigging-up well equipment is considerably reduced. L. R.

1014. Diesel Engine as used for Drilling. A. D. Luco. *Bol. Inform. Petrolas*, April 1939, **16** (176), 17–21.—Describes the advantages of diesel engines over steam for operating rotary drills and the auxiliary mechanisms which are necessary in order to overcome the inherent lack of flexibility which characterizes any diesel or I.C. engine as compared with the simplicity, robustness, flexibility, and ease of handling provided by steam plant. H. I. L.

1015. " Directed " Borings. J. Opes. *Bol. Inform. Petrolas*, April 1939, **16** (176), 56–66.—Description of methods adopted and tools used for deviating the boring from the line it would follow by ordinary methods of vertical drilling. Particulars given are taken from operations which were carried out with success at Comodoro Rivadavia. H. I. L.

Transport and Storage.

1016. Launching Submarine Pipe-line at Caleta Cordova, for Loading Tankers. L. Aguirre. *Bol. Inform. Petrolas*, May 1939, **16** (177), 14–32.—Describes construction and laying of two pipe-lines, 1–12 in. and 1–8 in. from the pumping-section near the shore to a dolphin placed adjacent to the anchorage for the tankers, the latter being connected by means of flexible pipes coupled to the fixed pipes terminating at the dolphin. The construction is fully illustrated. H. I. L.

Crude Petroleum.

1017. Patent on Crude Oil. W. W. Ledbetter. U.S.P. 2,162,281, 13.6.39. Appl. 8.7.36. Method of separating oil from water by introducing the oil at the base of a confined column of salt water and allowing it to rise while stirring. The accumulated oil above the column is then withdrawn. W. S. E. C.

Cracking.

1018. Patents on Cracking. E. J. Houdry. U.S.P. 2,161,676, 6.6.39. Appl. 8.11.35. Process for the catalytic conversion of hydrocarbons boiling above the gasoline range into high anti-knock fuels, including gasoline. The hydrocarbons are treated with adsorptive silicious contact materials or catalysts in recurring cycles.

J. C. Bolinger, W. A. Howard, and P. Woolley. U.S.P. 2,162,933, 20.6.39. Appl. 23.8.37. Protection of condenser tubes in cracking tube-stills against corrosion or salt deposition by injecting ammonia into the oil-distillation system. The salts are removed by introducing liquid water in the vapour line just ahead of the heat exchanger or condenser into which it discharges.

S. A. Guerrieri. U.S.P. 2,163,170, 20.6.39. Appl. 21.12.35. Vapour-phase cracking of hydrocarbon gases and vapours in the presence of molten metal. W. S. E. C.

Polymerization.

1019. Patents on Polymerization. D. R. Stevens and W. A. Gruse. U.S.P. 2,161,392, 6.6.39. Appl. 3.11.36. Polymerization of normally gaseous olefines by subjecting them to the action of a mixture of 3% concentrated sulphuric acid and 97% of *ortho*-phosphoric acid at 100–250° C.

B. J. Flock and E. F. Nelson. U.S.P. 2,163,275, 20.6.39. Appl. 14.8.36. Stabilizing cracked hydrocarbon distillates to remove normally gaseous hydrocarbons by partly liquefying the gases under pressure to produce a liquid phase of relatively high olefine content and a gaseous phase of lower olefine content. The liquid-phase material is then supplied without lowering the pressure to a zone where it is polymerized, using a catalyst in the absence of the gas phase. The gaseous phase is supplied to a second polymerizing zone, which is maintained under a lower pressure than that of the first zone, and is polymerized in the vapour phase.

W. E. Kuhn. U.S.P. 2,164,293, 27.6.39. Appl. 13.3.37. Conversion of hydrocarbon oils and gases into gasoline by a combination gas polymerization and oil-cracking process. W. S. E. C.

Synthetic Products.

1020. Production of Gases for Synthesis. W. Held. *Petrol. Z.*, 1939, **35**, 435–437.—The author gives a short critical account of the methods used to-day for the production of hydrogen in Germany from lignite, lignite briquettes, and different forms of coal. In U.S.A. part of the hydrogen is made from hydrocarbon gases, a method which may be of some interest for Germany in connection with the by-products of the synthesis itself. All the big manufacturers in Germany, like Krupp, Bamag- Meguin, Pintsch, and others, have now developed plants for the production of mixtures of nitrogen and hydrogen or hydrogen and carbon monoxide in the right proportion ready to use for synthesis. E. W. S.

1021. Production of Hydrocarbons. W. Held. *Petrol. Z.*, 1939, **35**, 493–495.—Figures are given regarding the requirements of German plants for the production of synthetic hydrocarbons and methanol. Data concerning quantities of hydrogen and metals for furnaces and containers are also given. E. W. S.

Refining and Refinery Plant.

1022. Cresol as Lubricating Oil-Refining Solvent and its Use in S.N.P. Process. H. Suida and H. Poell. *IIme Congrès Mond. Pétrole*, **2** (Sect. 2), 807–821.—Nomenclature of solvent extraction is critically examined and the terms " solvent raffinate " and " solvent extract " are adopted.

The use of anhydrous cresol as a solvent is discussed and its selectivity compared with those of nitrobenzene and phenol. It is shown that cresol is superior to all other solvents except nitrobenzene. A two-stage extraction process is described in which the oil is extracted in the first stage with anhydrous cresol, and in the second stage the solvent extract is saturated with water yielding a raffinate of inferior quality to that of the raffinate from the first stage. The process is further improved by the addition of 15–35% of nitrobenzene to the cresol in the first stage. The lay-out and operation of a technical S.N.P. plant at Hamburg are described. W. P.

1023. Solvent Extraction of Lubricating Oils with Phenol. R. Navarre. *IIme Congrès Mond. Pétrole*, **2** (Sect. 2), 823–835.—The use of phenol as a solvent is discussed in relation to current practice. Operating temperatures have been reduced and the settling difficulties thereby introduced have been largely overcome by re-cycling and by the introduction of suitable temperature gradients throughout the process. Nevertheless, in spite of improvements in contacting and in separating, practical results remain considerably inferior to theoretical expectations.

The use of wet phenol has permitted extension of the process to the production of less highly refined oils and to the further fractionation of the solvent extract. W. P.

1024. Solvent Extraction of Columbian Distillates with Phenol. S. Hemmer and R. Gay. *IIme Congrès Mond. Pétrole*, **2** (Sect 2), 837–854.—Refining by solvent extraction depends on the coexistence of two liquid phases and the variations in the critical temperatures. The range of coexistence is found to be greater the more paraffinic is the oil and the higher its molecular weight. Miscibility curves are given for various oils in contact with anhydrous and with dry phenol. The author uses triangular diagrams showing equilibria between phenol-paraffinic hydrocarbons—naphthenic hydrocarbons—to explore the possibilities of phenol extraction for a given oil.

W. P.

1025. New Methods of Oil Refining ; Solvent Extraction with Phenol. F. Schick. *IIme Congrès Mond. Pétrole*, **2** (Sect 2), 855–862.—A solvent refining plant is described and analyses are given of the products derived from it. Phenol is used as the solvent, and the plant provides for continuous extraction and solvent recovery. W. P.

1026. Solvent Extraction. A. Klinkenberg. *IIme Congrès Mond. Pétrole*, **2** (Sect. 2), 863–869.—The author analyses the various extraction processes into their simplest forms. The extraction factor, E (the ratio of quantities of substance dissolved in the extract phase and the residual phase) is calculated for a variety of processes.
W. P.

1027. Fractionation of Heavy Oils by Solutions of Gases at Ordinary Temperature. M. M. Godlewitz and S. Pilat. *IIme Congrès Mond. Pétrole*, **2** (Sect 2), 883–886.—The complete fractionation of high-boiling, viscous lubricants can be effected at ordinary temperatures by the treatment of a solution of mineral oil in light hydrocarbons with gases under pressure (methane, natural gas, carbon dioxide, etc.). The introduction of the gas under pressure causes the separation of the heavier hydrocarbons as a second liquid phase. Those hydrocarbons will be separated which are themselves bad solvents for the gas employed. Methane is dissolved most in light hydrocarbons and least in high molecular paraffins and in aromatics. These latter will therefore separate out. Examples of the process are given. W. P.

1028. Government Distillery at San Lorenzo. T. Tabanera. *Bol. Inform. Petroleras*, May 1939, **16** (177), 33–46.—Complete description of the lay-out, including power plant, tanks, pumps, stills, and electrical gear at the above refinery. H. I. L.

1029. Recovery of Sulphur from Flue Gases. A. R. Powell. *Industr. Engng Chem.*, 1939, **31** (7), 789.—A description of the various commercial units at present in operation for the recovery of sulphur from flue gas. H. E. T.

1030. Patents on Refining. M. T. Kendall. U.S.P. 2,161,580, 6.6.39. Appl. 16.10.36. Continuous process of neutralizing acid-treated hydrocarbon distillate by quickly suspending finely divided quick-lime in 200–400 parts by weight of water, and then immediately contacting the acid-treated cracked distillate with the suspension.
W. S. E. C.

Chemistry and Physics of Petroleum.

1031. Hydrogenation of Ethane on Cobalt Catalysts. E. H. Taylor and H. S. Taylor. *J. Amer. chem. Soc.*, 1939, **61**, 503–509.—The rate of the hydrogenation decomposition of ethane has been studied on a cobalt/thoria/copper/kieselguhr catalyst and on four cobalt/magnesia catalysts containing varying proportions of the components. The results indicate that for this reaction cobalt is less active than nickel, but much more active than copper. The cobalt/magnesia catalysts are much more active than the cobalt/thoria/copper catalysts, and over the range of compositions studied the activity of the catalysts of the cobalt/magnesia type increased with increasing cobalt content.

The results show that by the substitution of magnesia for thoria, the availability of cobalt for ethane hydrogenation is enhanced, so that the rate of reaction per gramme of cobalt is much greater with the cobalt/magnesia catalyst. On the other hand, this type of catalyst does not give such high yields of liquid product as the cobalt/thoria catalysts. It is concluded, therefore, that the thoria in the Fischer catalyst exerts a promoter action for catalyzing the polymerization of the hydrocarbon radicals to the desired products. W. E. J. B.

1032. Polymethylbenzenes. XXIII. Preparation and Physical Properties of 3- and 5-Ethyl*pseudo*cumenes and of Ethylmesitylene. L. I. Smith and M. A. Kiess. *J. Amer. chem. Soc.*, 1939, **61**, 284–288.—The authors have prepared 3- and 5-ethyl*pseudo*cumene and ethylmesitylene. The latter was prepared by conversion of bromomesitylene into the Grignard reagent and ethylation of the latter to yield the hydrocarbon in about 40% yield. It was also prepared by the conversion of mesitylene into acetomesitylene, followed by reduction of the ketone.

5-Ethyl*pseudo*cumene was prepared in a manner similar to that of ethylmesitylene. 3-Ethyl*pseudo*cumene, a new hydrocarbon, was prepared by converting 3-bromo-

*pseudo*cumene into the Grignard reagent, which was then ethylated. The structure of the latter has been proved and various derivatives have been described.

Physical properties of these hydrocarbons are noted below.

	Ethylmesitylene.	5-Ethyl*pseudo*-cumene.	3-Ethyl*pseudo*-cumene.
Boiling point, °C. . .	210 (725 mm.)	210 (725 mm.)	214 (725 mm.)
Freezing ,, °C. . .	− 15·56	− 13·58	Liq. at − 50
n_D^{20}	1·5074	1·5075	1·5133
d_{20}^{20}	0·894	0·889	0·900

W. E. J. B.

1033. Vapour Phase Catalytic Conversion of Tertiary Butymethyl Carbinol and Tertiary Butylethylene. P. L. Cramer and A. L. Glasebrook. *J. Amer. chem. Soc.*, 1939, **61**, 230–232.—A study has been made of the vapour-phase catalytic conversion of *t.*-butylmethylcarbinol and *t.*-butylethylene over activated alumina and anhydrous aluminium sulphate to yield the three isomeric hexenes, *t.*-butylethylene, *unsym.*-methyl*iso*propylethylene, and tetramethylethylene.

The experiments were carried out over the temperature range 275–390° C. in a Pyrex tube heated in the conventional type of electric furnace.

In contrast to results obtained by liquid phase reactions with acid catalysts, the dehydration of *t.*-butylmethyl carbinol over activated alumina yields *t.*-butylethylene rather than tetramethylethylene as the principal olefin. This reaction is largely independent of the reaction temperature.

In accord with results obtained in liquid-phase reactions with acid catalysts, tetramethylethylene is the principal olefin formed by the vapour-phase dehydration of *t.*-butylmethylcarbinol over anhydrous aluminium sulphate.

t.-Butylethylene was passed unchanged over alumina, whereas over aluminium sulphate the olefin is rearranged to give the same mixture of hexenes as obtained from *t.*-butylmethyl carbinol over the same catalyst. W. E. J. B.

Analysis and Testing.

1034. Modified Ostwald Viscometer for Routine Control Tests. Anon. *Nat. Petrol. News*, 14.6.39, **31** (24), R. 262.—The Zeitfuchs modification of the Ostwald viscometer has been further modified by the addition of a third tube in series with the tube bearing the capillary. The third tube joins the existing tube at a point at the bottom of the upper bulb and is connected, through a stop-cock, semi-permanently to a vacuum supply. The third tube is used for filling and cleaning operations, and is operated by closing the existing limb with the forefinger and opening the vacuum supply-line cock.

H. G.

1035. The Critical Solution Temperature of Mineral Oils in Acetone. E. Vellinger. *IIme Congrès Mond. Pétrole*, **2** (Sect. 2), 871–878.—The author discusses the use of Critical Solution Temperatures (C.S.T.), and describes his method of determination and his investigations with various solvents. Acetone was selected as the most serviceable solvent.

The origin of the crude has a negligible effect on the C.S.T. in comparison with that of method and degree of refining. Refining either with H_2SO_4 or earth elevates the C.S.T.; ageing, either artificially (oxygen at 110° C.) or in service (whether below or above 150° C.), has little effect on the C.S.T. in the case of normally refined oils, but causes an appreciable lowering of C.S.T. in the case of over-refined oils. This is attributed to the greater oxygen absorption of these latter. W. P.

1036. Analysis of Phases in an Extraction Process. A. Schaafsma. *IIme Congrès Mond. Pétrole*, **2** (Sect. 2), 789–881.—The methods devised for the analysis of the phases in a counter-current extraction process are described.

Various methods of determining the solvent (furfural) and oil contents of the phase were investigated : (1) washing out solvent with alcohol ; (2) evaporation of solvent at 195° C. ; (3) measurement of dielectric constant. Method 3 was selected as most suitable for rapid analysis provided an analysis of the oil is not required.

The refractive indices of the solvent-free products were also determined in the case of Method 2. Raffinate yield can be calculated from a knowledge of the refractive indices of the base material, the raffinate, and the extract. Also, for a given base the refractive index of the raffinate is a measure of its quality. W. P.

Motor Fuels.

1037. Gum Formation in Alcohol-Gasoline Blends. D. A. Ilyin. *Neft. Khoz.*, March 1939, **20** (3), 50–52.—Cracked gasoline containing various percentages of absolute alcohol has been exposed for varying periods to 40° C. in the presence of steel, brass, and aluminium strips.

It has been found that the addition of alcohol definitely reduces gum formation in cracked gasoline. Gum formation is, however, accelerated by certain organic admixtures to alcohol, such as acetic acid and ethers, and by catalytic action of certain metals, especially brass. Addition of straight-run gasoline has a retarding effect.

Inhibiting agents which are normally used to stabilize cracked gasolines are not always effective with alcohol–gasoline blends. Optimum induction periods are obtained by addition of amino- and oxy-compounds. The stabilizing action of an inhibitor concentration of 0·01% lasts for considerable periods up to ½ year. The most effective inhibitor action is obtained with fresh gasolines. L. R.

1038. Ethyl Fluid Blending Chart for Motor-Method Octane Numbers. L. E. Hebl, T. B. Rendel, and F. L. Garton. *Industr. Engng chem.*, 1939, **31** (7), 862.—This chart is so constructed that when the octane number of a leaded gasoline is plotted against the amount of tetraethyl lead added, a straight line results. The effectiveness of tetraethyl lead in different fuels can thereby be readily compared in terms of the slope of the line obtained.

The method of construction employed in the chart illustrated generally follows that described by the authors in a previous paper on the subject with certain adjustments embodied which were made as a result of additional data since accumulated.

The factors influencing the octane number of a leaded gasoline and which are incorporated in the chart are recapitulated as follows :—

1. The effectiveness of *iso*-octane at different concentrations.
2. The effectiveness of tetraethyl lead at different concentrations.
3. The octane number of the base gasoline.
4. The lead susceptibility of the gasoline.
5. The concentration of tetraethyl lead added.

Following an outline of the method adopted in determining values used in constructing the chart the scales of which were based on the average of a large amount of data obtained co-operatively on groups of from 17 to 20 C.F.R. engines, the authors discuss the accuracy of the chart in relation to the different lead responses of certain engines. It is pointed out that data from abnormal engines will necessarily produce a deviation in the slope or a curvature of the line, but with an average engine an accuracy of ± 0·1 octane number can be obtained from the chart.

The usefulness of the chart is next shown when the lead susceptibilities of various blends of di*iso*propyl ether, *iso*octane and straight-run aviation gasoline, also of *iso*-octane with vapour-phase-cracked gasoline are shown graphically, and it is illustrated how widely the lead susceptibilities of certain materials may vary.

In conclusion a short description is given of a simpler graphical derivation of an ethyl blending chart. E. F. C.

1039. Factors in Knock Rating and Lead Susceptibility of Gasoline. F. G. Graves. *Industr. Engng Chem.*, 1939, **31** (7), 850.—This article presents a definite relation between octane number loss for cracked gasolines and their initial knock rating the latter being dependent on the cracking stock origin. Composition and sulphur content of gasolines have been recognized as influencing the lead susceptibility. Employing a numerical expression for lead susceptibility developed by other investigators, relations between this characteristic and sulphur content are developed for straight-run and cracked gasolines as well as for aromatic stocks. This relation should be of some value in estimating the lead susceptibilities of various gasolines. Paraffin and naphthene hydrocarbons have the highest susceptibility. Although pure aromatics have a higher susceptibility than olefines, they are more sensitive to the effect of sulphur compounds. H. E. T.

1040. Patent on Motor Spirit. W. A. Schultze. U.S.P. 2,162,319, 13.6.39. Appl. 6.10.36. Refining cracked gasoline to reduce the sulphur content by treatment in the vapour-phase with bauxite at 500–750° F. W. S. E. C.

Lubricants.

1041. Patents on Lubricating Oil. J. M. Whiteley and H. C. Vesterdal. U.S.P. 2,160,930, 6.6.39. Appl. 23.3.35. Separation of wax from petrolatum by means of propane.

O. S. Pokorny. U.S.P. 2,160,985, 6.6.39. Appl. 3.2.37. Dewaxing hydrocarbon oil using a mixture of equal parts of methyl normal propyl ketone and methyl normal butyl ketone.

W. P. Gee and M. Neuhaus. U.S.P. 2,161,567, 6.6.39. Appl. 27.3.37. Solvent extraction of lubricating oil using furfural.

H. H. Gross. U.S.P. 2,161,569, 6.6.39. Appl. 19.2.38. Solvent dewaxing of lubricating oil using a mixture of methyl ethyl ketone and benzol.

W. B. Hendrey. U.S.P. 2,161,572, 6.6.39. Appl. 1.5.37. Solvent refining of hydrocarbon oil using a mixture of *ortho-* and *para*-chlorphenol containing 50–75% of the *para*-isomer together with a subsidiary solvent, *e.g.*, chloroform.

E. C. Knowles. U.S.P. 2,161,581, 6.6.39. Appl. 27.1.38. Dewaxing hydrocarbon oil by means of a small proportion of montan wax and cellulose stearate.

H. S. Holt. U.S.P. 2,161,625, 6.6.39. Appl. 14.1.38. Solvent extraction of lubricating oils using methyl ethyl ethynyl carbinol.

E. Terres, J, Moos, and E. Saegebarth. U.S.P. 2,161,753, 6.6.39. Appl. 22.3.35. Solvent extraction of hydrocarbon oils using tribromhydrins in admixture with an auxiliary solvent.

T. A. La Brecque. U.S.P. 2,161,964, 13.6.39. Appl. 10.7.34. Apparatus for use in reclaiming used lubricating oil.

B. S. Greenfelder and M. E. Spaght. U.S.P. 2,162,195, 13.6.39. Appl. 6.2.35. Refining of lubricating oil by contacting it with a gas containing free oxygen at 120–500° F. in the presence of hydrogen oxide for a sufficient time to convert a substantial portion of oil of relatively low viscosity index into oxidation products which are preferentially soluble in liquid solvents such as benzaldehyde, nitrobenzene, cresylic acid, phenol, etc.

E. Terres, J. Moos, and H. Ramser. U.S.P. 2,162,682, 13.6.39. Appl. 25.10.37. Solvent extraction and dewaxing of mineral oils by means of fluorinate aliphatic hydrocarbon compounds.

K. C. Lauglkin. U.S.P. 2,163,245, 20.6.39. Appl. 15.6.37. Solvent extraction of hydrocarbon oils by means of phenol and 5–20% by weight of free sulphur is digested with the oil at 250–400° F. for 2–6 hrs.

W. Schrauth. U.S.P. 2,163,563, 20.6.39. Appl. 15.2.36. Method of reclaiming lubricating oil. W. S. E. C.

Asphalt and Bitumen.

1042. Methods of Classification and Analysis of Asphalts. H. Suida and F. Motz. *Petrol. Z.*, 1939, **35**, 511–517.—The methods used in Germany to-day for the analysis of petroleum asphalts are all subject to objection. At the present time the methods of Maass and Poll, working with different solvents, fuller's earth, and coagulent agents, are the most widely used. The results are, however, not strictly reproducible, because the temperatures of solution and adsorption are not standardized and the solvents like standard gasoline, etc., are not absolutely identical in every case. In a new combined plant, the treatment with fuller's earth in a nitrogen atmosphere and the extraction with chloroform and pyridine are effected nearly automatically. The temperatures of adsorption and of extraction are low and kept within very narrow limits, the asphalt being decomposed into a petroleum portion, asphaltic resin, petroleum resin, and hard asphalt. The resulting hard asphalt contents, in spite of low temperatures in the pyridine extraction, are far lower than those stated in the analysis of the same asphalts with earlier methods. E. W. S.

Special Products.

1043. Qualities of Naturally Condensed Waxes from Crude Petroleum. E. Casimir and C. Creanga. *Petrol. Z.*, 1939, **35**, 511–517.—Waxes accumulating on the walls of pipe-lines, tanks, etc., containing Roumanian paraffin base crudes chiefly consist of hydrocarbons (77–96%), the remainder being resins, asphaltic matter, and contaminations. 21–48% of the hydrocarbons are higher hydrocarbons with a melting point of up to 91–92° C. They are scarcely soluble in gasoline, ether, and other organic solvents, readily dissolved in chloroform, and precipitated from the chloroform solution by rectified spirit at 20° C. These hydrocarbons form the hard ceresin. In addition, the waxes contain some 6–13% of other solid hydrocarbon of 57–60° C. melting point. This is the so-called soft ceresin, the rest being oils. As the hard ceresins contained in the waxes are very similar to those produced from ozokerite as far as gravity, microstructure, appearance, etc., are concerned, the waxes may be used as a raw material equivalent to ozokerite. E. W. S.

1044. Alkylation of Phenols. V. I. Isagulyants and P. P. Bagryantseva. *Neft. Khoz.*, February 1939, **20** (2), 36–41.—The following methods of synthesis of *para*-tertiary butylphenol under atmospheric pressure have been examined systematically : (*a*) The reaction of *iso*butyl alcohol with phenol in presence of anhydrous zinc chloride. (*b*) The reaction of *iso*butylene with phenol in the presence of zinc chloride and aluminium chloride. (*c*) The effect of tertiary butyl chloride and hydrochloric acid on the acceleration of the alkylating reaction.

Optimum conditions for the alkylating reaction have been established, and also the quantities of catalyst necessary.

A profitable procedure of obtaining *para*-tertiary butylphenol has been evolved in which the alkylation of phenol is carried out with *iso*butylene in the presence of a small quantity of anhydrous aluminium chloride under low pressure, giving a yield of 78% of theoretic. This yield can be slightly increased by reactivating the portion of phenol that has not taken part in the reaction. L. R.

Detonation and Engines.

1045. What About the Engine. A. Taub. *J. Soc. aut. Engrs*, 1939, **44**, 201–209.—The author contends that tank mileage depends on the ability to utilize lean mixtures, and thinks that American automobile engine designers will shortly be forced to give more attention to this problem, due to the imminence of increased fuel taxation. During the past year or two in England the author has been engaged on intensive research on this problem at Vauxhall Motors, and maintains that the shape of the combustion chamber as such does not effect the problem, except in so far as it tends to create " hot-spots," exhaust poisoned pockets, or too high a surface-to-volume ratio during the first two-thirds of the burning period. The effect of trapped exhaust products, the use of wide-gap plugs and improved coils, corrected distribution from the carburettor proper, vacuum control of spark advance, and long reach plugs are discussed.

The method of forecasting engine roughness by the plaster-cast method is being used by Vauxhall Motors, and data are given of analyses of several types of cylinder head by this method. The Cossor Dodds Cathode-Ray Indicator has proved very useful in studying combustion, and photographic reproductions of oscillograms showing pressure-time, and " rate of charge " of pressure during combustion are given, which make it possible to determine the actual pressure at the instant of maximum rate of pressure rise or the pressures in terms of percentage of peak pressure at any point during the combustion period. C. H. S.

1046. Fuel-Economy Possibilities of Otto-Cycle Aircraft Engines. D. S. Hersey. *J. Soc. aut. Engrs*, 1939, **44**, 235–251.—Calculations based on tests with single-cylinder units operating at compression ratios between 6·5–1 and 8·2–1 show that under ideal conditions with a 10–1 compression ratio, and operating at optimum spark setting on non-detonating fuel, best economy indicated specific fuel consumption of 0·307 lb. per 1 H.P./Hr. could probably be expected, which at the peak full-throttle mechanical efficiency of 92·5% should give a brake specific fuel consumption of 0·332 lb. per B.H.P./hr.; an improvement of approximately 22% on the consumption now being obtained on engines of about 6·5–1 compression ratio operating at reduced spark advance settings.

The limiting factor is detonation and consideration of the factors affecting detonation shows that compression ratio, spark advance, mean effective pressure, intake charge temperature, cylinder operating temperature, and fuel-air ratio must be jointly considered to obtain the best compromise. The effect of these variables under high output and economy conditions are dealt with at length, together with the means adopted to eliminate detonation.

The author is of the opinion that fuel-economy improvements can probably be obtained in current engines with only relatively minor changes in construction or equipment, and without any corresponding reduction in take-off output. Such changes might include automatic spark advance control, lowering of mixture temperatures by intercooling or reducing as much as possible the tip speed of the supercharger impeller, and operation at lowest engine speed which will give the desired cruising power at full throttle or at the limiting mean effective pressure. It is suggested that full throttle at all cruising powers should be aimed at, the cruising output being controlled by varying engine speed. C. H. S.

1047. C.F.R. Research Methods of Test for Knock Characteristics of Motor Fuels. Anon. *J. Soc. aut. Engrs*, 1939, **44**, 277–280.—The original research method for motor-fuel testing in the C.F.R. engine was developed by the Co-operative Fuel Research Committee in 1932. Some of the details of test conditions were never clearly laid down, and when the motor method came into general use the old research method was used to a small extent only, except in Germany, where the newer method was never generally adopted.

In recent years it has become evident that a less severe method of test in addition to the motor method gives at least some indication of the probable behaviour of the more temperature sensitive fuels under road conditions in comparison with other fuels relative to the A.S.T.M. ratings.

For research purposes only the original research method has now been clearly defined and approved by the Committee.

The variations from the motor method are as follows :—

Speed.—600 r.p.m. ± 6 r.p.m.

Spark Advance.—Fixed at 13 degrees B.T.C. for all compression ratios.

Intake Air Temperature.—125° F. ± 2° F.

Standard knock intensity is that obtained with a blend by volume of 70% *iso*-octane 30% normal pentane under standard operating conditions at a compression ratio of 5·75–1 and a barometric pressure of 760 mm. Hg.

Compression Pressure.—At a compression ratio of 5·75–1 corrected for barometric pressure of 760 mm. Hg. the compression pressure shall be 130 lb. per sq. in. gauge, and at a corrected compression ratio of 6·7–1 it shall be 160 lb. per sq. in. gauge. C. H. S.

1048. Filtering Fallacies. A. M. Wolf. *J. Soc. aut. Engrs*, 1939, **44**, 259–270.—This paper, although it does not seek to belittle the usefulness of oil filters or to discourage their use, nevertheless points out that users who imagine that the use of such equipment as fitted to present-day engines solves their lubrication problems are liable to get a rude shock. The author is of the opinion that very much more care should be exercised when locating the filter, which should be built in rather than tacked on to the engine, which practice in many cases leads to trouble. A high mounting is desirable, to ensure draining of the return line after the engine has stopped and to minimize the amount of chilled oil left in the filter. Shortcomings of filters are enumerated to form a basis of a true analysis of their intrinsic worth. Operating conditions which may vary from "stop and start" work in low temperatures to continuous high-temperature operation may in the first case cause the filter to become inoperative, due to lack of heat, and the other extreme may produce oxidation product sufficient to arrest its functioning.

Many other aspects of the problem are dealt with, including types of filtering media, frequency of cleaning and replacing elements, moisture accumulation, and the merits of mechanical versus chemical filters. Data are presented on examination of crankcase oils from a large number of cars and trucks, some fitted with and some without filters, and the oil-flow characteristics of several filters as affected by grade of oil and operating temperature and pressures. The paper also touches upon the question of the removal of additives by filters and experiences with oil filters in aircraft practice. C. H. S.

1049. Comparison of Diesel and I.C. Engines. A. D. Luco. *Bol. Inform. Petrolas*, April 1939, **16** (176), 9–16.—Full technical exposition of the higher efficiency of the diesel engine, with particulars of tests and a list of applications in order of merit. H. I. L.

1050. Diesel Motor Coaches on the State Railways (Argentine). Anon. *Bol. Inform. Petrolas*, April 1939, **16** (176), 3.—The great increase in speed of which the diesel-driven trains are capable has resulted in an average time saving of 50% and the elimination of sleepers on many trains. Both fuel and lubricants are indigenous products. H. I. L.

Economics and Statistics.

1051. Relation between Crude Oil and Product Prices. S. A. Swensrud. *Bull. Amer. Ass. Petrol. Geol.*, 1939, **23**, 765–788.—The relation between crude oil and refined product prices has long been a source of discussion within the petroleum industry, and particularly since the inauguration of proration.

Two main questions arise : (1) the fact as to the relationship existing periodically between the price of crude oil and the value of refined products they produce, (2) the sequence in crude oil and product price movements.

A study has been made during the years 1920–1939 and data are now presented in tabular form showing how the value of products, price of crude, and the refiner's margin have varied periodically during this time.

The market value of the refined products is shown to have declined considerably more than the raw material itself. Since the beginning of 1927 the wholesale value of the refined products from a barrel of crude declined by an average of $1·26 a barrel as compared with the years between 1920 and 1927. Similarly, the price of crude declined by an average of 92 cents a barrel. Thus it is clear that a considerable change has taken place during the period of study in the price relationship between crude oil and refined products. Since 1927, for example, the products of a barrel of crude have decreased by 34 cents a barrel more than has the posted price of the raw material from which they are obtained. It should be remembered, however, that with the increased yield and quality of gasoline the products of a barrel of crude are now relatively a more valuable combination needing additional refining operations than the combination of products made in the early years of the study period.

The industry has in recent years maintained greater stability in the general range of crude oil prices, although it would appear the lag of downward movements acts to the detriment of the refining industry. Moreover, since State proration became customary about 1930, this lag has been more pronounced. It would seem to be better to have crude prices rely more directly upon product prices.

An appendix to the paper contains a full compilation of price data from 1920–1938 inclusive. G. S. S.

1052. Production and Export of Petroleum for Ecuador—1938.—Director General of Mining and Petroleum Production Ecuador. *Bol. Inform. Petroleras*, April 1939, **16** (176), 82–83.—Complete statistics are given, showing a nett production of petroleum of 358 cu. m. and of gasoline from natural gas of 6245 cu. m. Practically all the petroleum was exported and of the gasoline nearly one third went to Great Britain. H. I. L.

1053. Completion of the New Petroleum Laws in Brazil. J. A. Celiz. *Bol. Inform. Petroleras*, May 1939, **16** (177), 68–70.—Commentary on the new laws introduced in Brazil for protection of the petroleum industry. H. I. L.

1054. Convention between Bolivia and Paraguay Concerning the Supply of Petroleum. Anon. *Bol. Inform. Petroleras*, May 1939, **16** (177), 64–67.—Text of an agreement between Bolivia and Paraguay for the establishment of a pipe-line in El Chaco together with distilleries on the River Paraguay. Agreement dated 21st April, 1939. This agreement gives the Y.P.F.B. the exclusive right for 30 years, to distil crude oils produced in Bolivia, Paraguay, or elsewhere, on behalf of the Government of Paraguay. At the end of this period the whole installation shall be handed over to the Government of Paraguay at a valuation to be made at the time of handing over. H. I. L.

1055. World Legislation with Respect to Petroleum. (Cont.) Y. P. F. Librarian. *Bol. Inform. Petroleras*, April, 1939, **16** (176), 67–78; May 1939, **16** (177), 59–63.—These useful extracts of mining laws and bibliography are continued from *Bol. Inform. Petroleras*, No. 174. H. I. L.

BOOKS AND PUBLICATIONS RECEIVED

Automobile Facts and Figures. Twenty-First Edition. Pp. 96. Automobile Manufacturers Association, Inc. New York.

This is the twenty-first consecutive issue of the annual statistical review of the automobile industry, comprising numerous statistics relating to every aspect of the trade. Although production and sales of motor vehicles declined in 1938, the use of highway transport facilities continued near the 1937 peak.

Report on the Geology of the Superficial and Coastal Deposits of British Guiana. By D. R. Grantham and R. F. Noel-Paton. Pp. 122. 9 maps in folder. Geological Survey of British Guiana. The Argosy Co., Ltd., Georgetown, Demerara. 1938. Price $1.

A critical examination is given of a series of well samples and records resulting from the drilling of some eighty water-wells along the coastal belt of British Guiana and the bearing of the investigation on the possibility of the occurrence of petroleum is discussed. The evidence of the wells appears to provide no direct indication of the presence of petroleum. Reference, however, is made to the possibility of a rock floor 3000 ft. and upwards below the surface in the area between New Amsterdam and the Courantyne River. In this case the presence of Tertiary beds older than Pliocene in age may be inferred with the concomitant possibility of the presence of petroleum.

It is considered that the next step should be the establishment, by geophysical methods, of the depth of the rock floor in the Berbice–Courantyne district, to determine whether there is room for the inferred older Tertiaries.

The Birth of the Oil Industry. By Paul H. Giddens. Pp. 216. Macmillan Company, London. Price 14*s*.

This book represents a comprehensive narrative of the origin and development of the petroleum industry in Western Pennsylvania up to 1870. Based on fresh sources of information (many of which may be found in the collection at the Museum of the Drake Well Memorial Park near Titusville), it represents a vivid and concise account of the early years of speculation and struggle. Individual chapters deal with the great flowing wells of 1861–1864; methods of transporting the oil to market; development of markets; establishment of refineries; federal taxation; the rise and decline of oil towns; the battles between teamsters and oil men following the laying of the first pipe-lines; the depression years of 1867 and 1868; the formation of oil rings and exchanges. The book is written in an interesting, flowing style, and is a blend of drama and accurate documentation.

INSTITUTE NOTES.

SEPTEMBER, 1939.

WARTIME ARRANGEMENTS.

Correspondence for the Institute should continue to be addressed to the Adelphi, London, W.C.2. Enquiries, however, can only be dealt with by post, and the Institute's Library is temporarily closed.

Meetings of the Institute in London are suspended until further notice.

The Journal will continue to be published monthly, although for reasons of economy, it may be necessary to reduce the number of pages in each issue. Owing to numerous changes in the addresses of members, some delay may occur in the receipt of the Journal.

Central Register. Over 400 members of the Institute in Great Britain have completed the forms for the Central Register compiled by the Ministry of National Service and Labour. These forms have all been forwarded to the central organisation at Montagu House, Whitehall, London, S.W.1. The Institute, as such, does not administer the Central Register or any part of it, for the making of appointments or recommending candidates to employers. This function is being carried out entirely by the Ministry of National Service and Labour.

ARTHUR W. EASTLAKE,
Honorary Secretary.

No. 1666.

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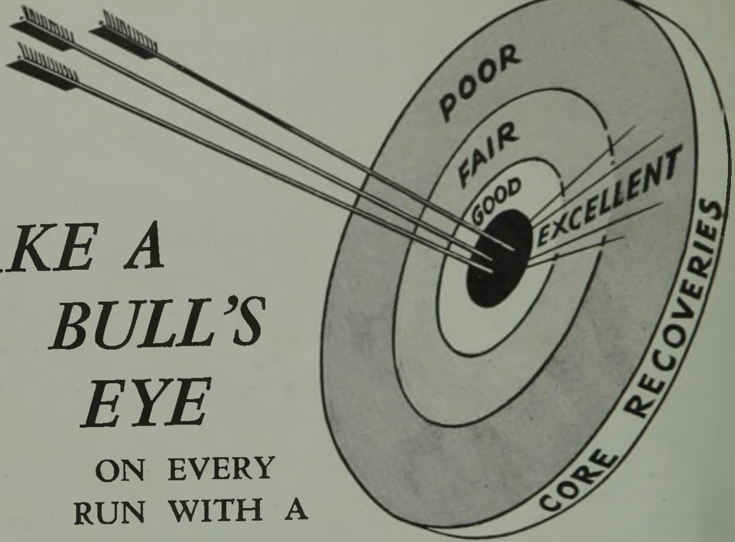

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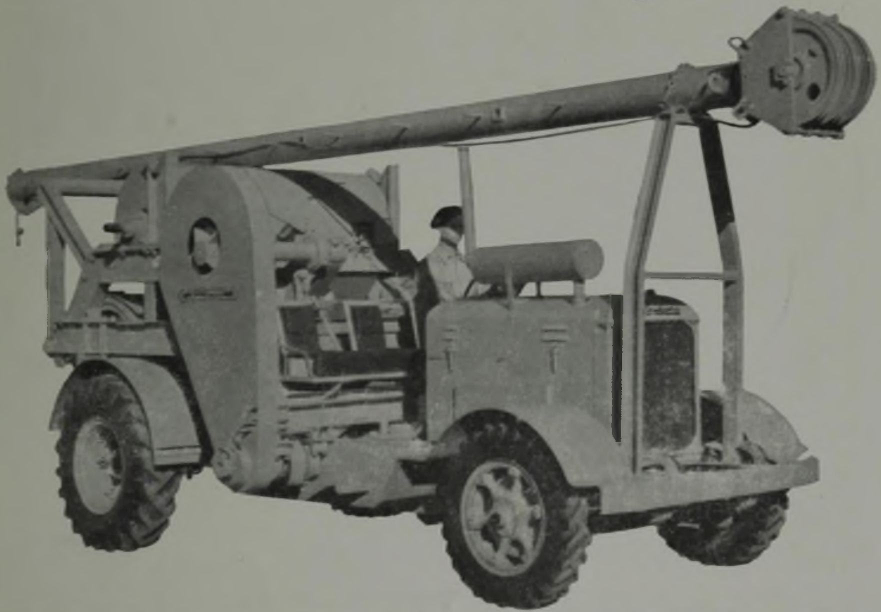

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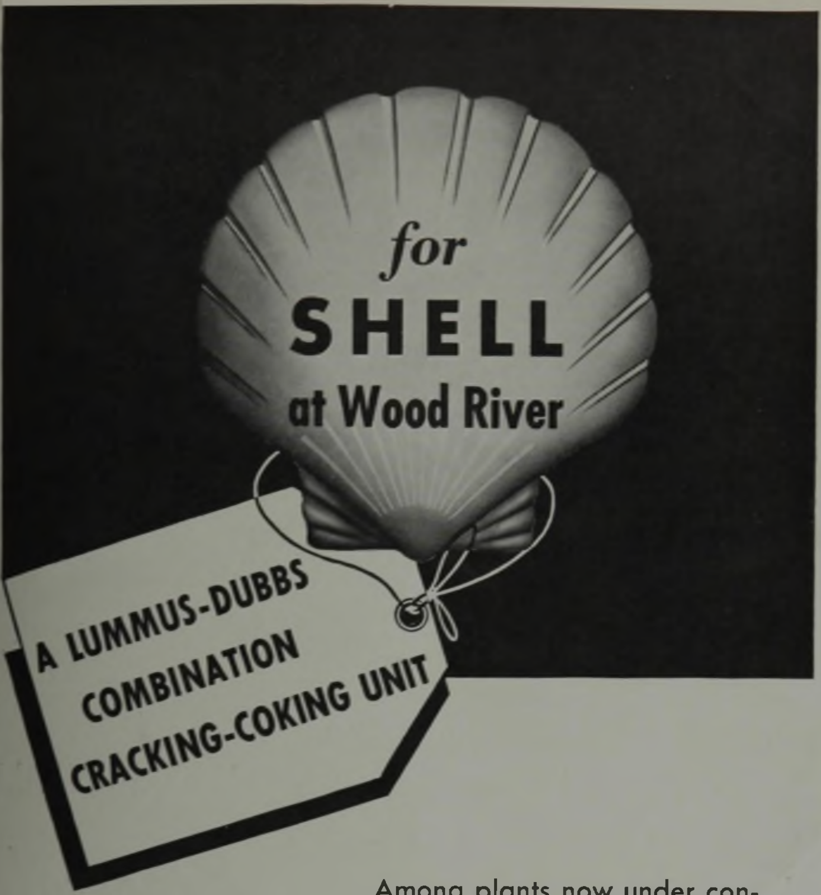
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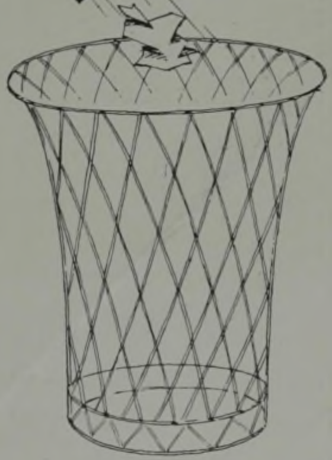

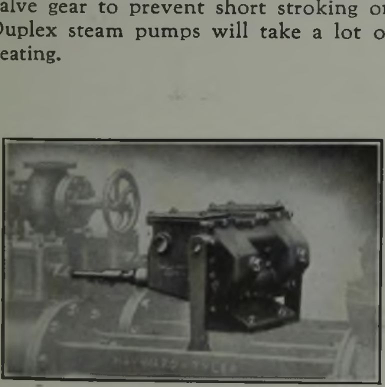

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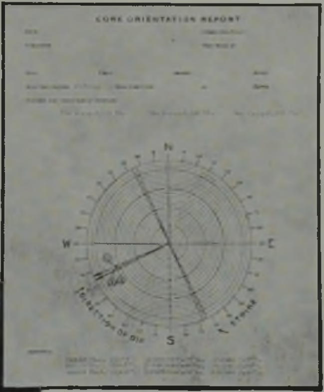

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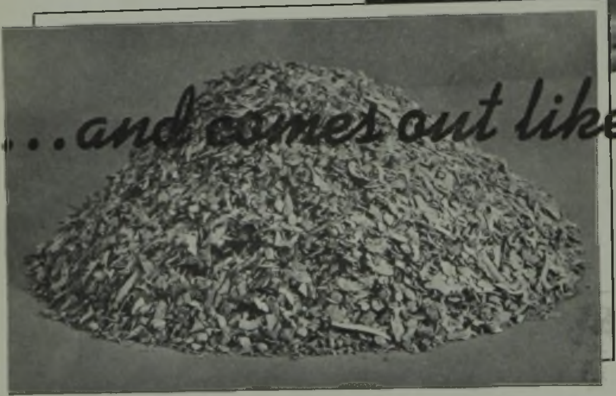

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