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**G.W.R. Mechanics' Institution, Swindon.**

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INTERMEDIATE MEETING. — THURSDAY, NOV. 17TH, 1910.

*Chairman*—Mr. W. A. STANIER M.I.MECH.E.

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**“ THE MECHANICAL ASPECT OF THE CYLINDER  
LUBRICATION PROBLEM, ”**

BY

A. H. NASH (MEMBER.)

WITH DISCUSSION.

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IT is not proposed in this short Paper to attack the problem of cylinder lubrication as applied to internal combustion engines, but to adhere strictly to heat engines in which steam is used. The problem of cylinder lubrication is not by any means new; in fact, engineers have been sorely perplexed since the time of James Watt. Each successive increase in pressure and temperature has brought with it a train of difficulties not anticipated, and the increasing use of high pressure superheated steam has introduced still further lubrication troubles which appear almost insurmountable.

Within reasonable limits, high pressure saturated steam requires but little in the way of lubrication, a dryness fraction of 90 per cent. at exhaust being sufficient to provide moist cylinder walls at all points of the stroke; but with dry steam with from 100° to 150° F. of superheat, cylinder walls and port faces wear very rapidly, increasing considerably the coal consumption.

The selection of the right method of applying the oil has been equally as troublesome as the right lubricant, and it may happen that often a bad method of application has condemned a good lubricant, and a good method has been condemned because of a bad lubricant.

The methods employed for the application of the lubricant to

the cylinder may be divided broadly into two heads :— 1st, those in which the oil is injected into the steam on its way to the cylinder; and 2nd, those in which the oil is fed to the cylinder walls direct, and does not mix with the steam at all. Each of these may be subdivided into hydrostatic and force methods.

Turning to the first method, the oil is delivered into the steam pipe as required drop by drop, and the rush of steam on its way to the cylinder atomises the oil and carries it in suspension to the cylinder walls and port faces. It has not yet been clearly established as to whether the oil fed in this manner is actually pulverised; and as the point is worthy of discussion, a few figures may not be out of place :—

Considering a locomotive with 6' 8½" wheels and 18" x 26" cylinders, travelling at 60 miles per hour, with a cut-off of 20 per cent. : cut-off in one cylinder occurs almost simultaneously with admission in the other cylinder, so that for two-fifths of the stroke steam is flowing in the steam-pipe at a mean velocity of about 160ft. per second, and during the remaining three-fifths is at rest. Is it safe to assume that the velocity of the steam is sufficient to pulverise a drop of oil? And further, would the momentary pause in the velocity of the steam be sufficient to throw down the oil into the steam-pipe?

The oil fed in this way to the cylinder is no doubt serviceable with saturated steam, the initial condensation bringing down the oil with the water, and hence proving an efficient lubricant.

Practice has demonstrated, however, that a pure mineral oil will not adhere to a hot, wet surface. For this reason it is necessary to mix with the oil 5 to 8 per cent. of animal oil or tallow. The addition of this quantity causes a pure hydrocarbon oil (which would otherwise be washed out of the cylinder) to emulsify freely with the water, and make an efficient lubricant.

With superheated steam there is no initial condensation, and a large proportion of the oil is held up in the steam, and as a consequence passes out with the exhaust. Moreover, the oil is subjected to the injurious influence of the high temperature of the superheated steam and, in the case of piston valves, is projected on to the heads, where it sticks, and the steam impinging on it carries away volatile matter, leaving the residue to carbonise.

The second method, *i.e.*, supplying the oil direct, is one favoured

strongly abroad. The oil is fed to the wearing surfaces either by hydrostatic or force feeding, and has many features to commend it. As commonly used, the oil is delivered to the cylinder at or about mid-stroke, where the piston has its greatest velocity. It is the opinion of the Author that the oil is simply being swept away to the covers and so out with the exhaust, and that the best place to introduce the oil would be about one-fourth stroke from each end of the cylinder, for the piston velocity would be relatively low, and the oil would be carried into the centre of the barrel, the very place which needs lubricating most. Oil fed at the ends of the cylinder would not be drawn to the middle at all. The same remark applies to slide or piston valves, which should have a separate feed to each valve face at a point where the velocity of the moving parts is neither a maximum nor zero.

One great feature about this system is that it may be adapted for either superheated or saturated steam, and that the oil is never at, and probably not near, the temperature of the steam, and is therefore not subjected to its injurious effect.

The system has one great drawback when used in conjunction with a hydrostatic lubricator, as there is not sufficient force behind the oil to prevent oil holes in wearing surfaces from choking. These remarks would not apply, of course, to the system when used in conjunction with force feed apparatus.

Force feeding has many applications in marine and stationary engine work, but its use is not extensive in British locomotive practice. On the Continent it is in great favour, owing to the large number of compound locomotives in use, as on account of the difference in pressures in the high and low pressure cylinders, the hydrostatic system is not readily applicable.

The first consideration in the choice of an oil should be its friction-reducing quality. The tests, commonly recognised as differentiating a good cylinder oil from a bad one, fail totally in determining the friction-reducing quality of an oil.

There is a limit in the flash point above which it is too costly to manufacture. The higher the required flash point on a specification, the greater the tendency to tar or coke, even when using superheated steam in the refining process, and this may be the effect when in service. Obviously, the temperature to which an oil will be subjected in service

should not be so great as the temperature at which it was refined, and as the expense varies with the refining temperature, it should be imperative to state when ordering an oil at what temperature it is to be used.

The oil wanted, then, is the one with the best friction-reducing quality, consistent with non-volatilisation at the service temperature, and neither viscosity nor flash point nor any other recognised test will show this quality. As to the values of viscosity and flashing point, the Author pointed out in a previous Paper (Feb., 1905) "that too much importance had in the past been attached to these qualities in selecting the best cylinder oil. The thickest was usually considered the best, but whether the viscosities of oils as measured at the ordinary temperatures were high or low, they all had the same viscosity at the temperature of superheated steam, and lubricating drops were independent of viscosity." The pressure under service conditions also considerably affects the flash point, and the vapour tension as measured in the open air at atmospheric pressure obviously cannot be the same as the vapour tension under pressure. Further, no relation has yet been established between viscosity and flash point.

The difficulty at present would appear to be not so much to find a good oil as to find a satisfactory test to indicate the behaviour of a cylinder oil when in use, and its proper friction-reducing qualities. Until such a test had been arranged, the Author is afraid he will have to repeat an observation he made during the discussion on his Paper on "Lubricants," in which he stated that there were no oils upon the market, suitable for the temperatures and pressures such as were in use at that time, and he can only add to this that the solution seemed just as far off now as then.

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## DISCUSSION.

The CHAIRMAN remarked that Mr. Nash had put before them the two systems of cylinder lubrication, but had said nothing about getting the oil to spread. This was one of the principal troubles on the Continent. The oil lubricated the point or surface where it was injected, but the difficulty was to apply it so as to get the lubrication to spread over the whole surface. With engines using saturated steam, the oil injected into the steam-pipe became emulsified, and (as had been remarked at a

former discussion) most of the oil went up the blast pipe. On the other hand, the oil was spread sufficiently to cover the whole of the surface to be lubricated.

There was a suggestion, that with the force feed lubrication it would be possible to have the piston rod and piston valve rod drilled and radial holes drilled in the heads between the rings, and a flexible connection between the lubricating pipe, piston rod and piston valve rod. This arrangement would be attended with difficulties and trouble.

Mr. C. T. Cuss drew attention to the fact that motor cars had been responsible for developing many things applicable to railway work, and aeroplane motors had been responsible again for further improvement and progress. The lubrication problem in the latter was a difficult one, and he noticed some time ago that castor oil mixed with a large percentage of petrol had been used, the oil, of course, acting as the lubricant, and the petrol as the distributing medium. He would be glad to hear Mr. Nash's views as to some similar means of thinning and distributing the lubricant for locomotive work.

The AUTHOR said, with regard to the spreading, he thought if the oil were fed at a quarter and three-quarters of the stroke of the piston, where the piston velocity was not very great, a thin lubricant (with a reasonably high flash point), as suggested by Mr. Cuss, would do very well. He had, however, never seen such a scheme put forward.

Mr. E. R. JONES contended that the feeding of oil to the point where the velocity of the piston was greatest would be more beneficial.

Mr. T. C. DAVISON referred to the fact that the Author had raised an interesting point in connection with the spraying of the lubricating oil, as he suggested that in the ordinary steam engine using saturated steam the oil was carried to the surface of the cylinder by the droplets of water. If that theory was correct, and was the main factor in ensuring satisfactory lubrication in the saturated steam cylinder, the conditions would be altogether different in the cylinder in which superheated steam was being used. He did not think it was necessary to make such an assumption if it was borne in mind that the lubricant was a liquid in either case. The oil was not vaporised—he thought they could be quite certain of that—at the pressure to which the oil was subjected. At that particular temperature it may be vapour at atmospheric pressure, but the great pressure to which it was subjected kept it in the form of a

liquid, and therefore the droplets—seeing that the steam had pulverised the oil—were uniformly distributed throughout the steam, and as the steam must be in a state of tremendous agitation in the cylinder, the droplets of oil were carried against all the surfaces, including those which require lubrication. He did not know whether it was a fact, but he should imagine that the factors which governed lubrication as applied to the cylinder in which saturated steam was being used applied equally to the cylinder using superheated steam. Mr. Nash had suggested that the determination of viscosity and flash point was no indication of the suitability of an oil for cylinder lubrication. Of course the determination of these points did not give any figure which applied to the oil under the conditions in which it was being used in the cylinder. The determination of viscosity at 180° F. did not give them any measure of the viscosity at the cylinder temperature. It was a fact that the viscosity of all lubricants—liquids and solids—was practically the same at the cylinder temperature, but there was a relationship between the viscosity of an oil at temperatures of say 140° F. and 180° F. and the way it behaved in the cylinder. If it were proved by experiment that of two oils one oil was a very much better lubricant than another, then the determination of viscosity helped them to recognise the good oil in future. With regard to the flash point, that was of importance, because it enabled them to determine whether the oil in question contained light fractions. He would explain at the next meeting that the hydrocarbon oils were very complex, and were built up of a number of constituents. Some oils might be built up of relatively light fractions and relatively heavy ones ; and in the cylinder a light oil would be easily volatilised. The flash point was useful for distinguishing between a uniform oil and one made up of “ tops and bottoms ” (or relatively light and heavy hydrocarbons). He agreed that it gave no indication as to how the oil would behave as a lubricant.

The AUTHOR replied, in regard to spreading the droplets, that he rather thought the condensation would bring down the oil out of suspension. If there were no initial condensation the oil would not be brought down unless at the far end of the cylinder when the pressure was dropped.

Mr. DAVISON observed that a hydrocarbon oil remained a liquid and was pulverised, *i.e.*, broken up into droplets, and these must be distrib-

uted in the volume of steam at once, and there was no bringing the oil down. He was very doubtful as to whether condensation was a factor in the lubrication of the surface, as it was only tacking on a little oil to a little water, and he did not think the presence of water helped a pure mineral oil to adhere to the metallic surfaces. It was the fatty matter which helped the oil to stick to the metallic surfaces quite independently of the presence of the water.

The AUTHOR was of the opinion that if a pure hydrocarbon mineral oil were used with saturated steam good lubrication would not be obtained, as all the oil would be washed out. There must be an emulsion.

Mr. Cuss remarked that, as Mr. Nash had omitted to touch on the question of the removal of the carbon deposit, it looked as though he was confident of being able, by having two holes in the cylinder, to avoid it altogether, but since carbon deposits occur and have to be got rid of, he thought the two practical features which should be discussed were how to get rid of the carbon and finding a way of avoiding it altogether.

The AUTHOR replied that he was inclined to blame the system of spraying oil into the steam for the deposit of carbon, and made a sketch illustrating his point. He said the impinging of hot steam took away the volatile constituents from the oil, leaving a residue. With the other system a proper feed of oil on the actual surface should provide efficient lubrication, and there should be no carbonising on the piston head.

The CHAIRMAN said Mr. Nash had drawn attention on several occasions to the advantage of putting in the oil at one fourth from each end of the cylinder, and he (Mr. Nash) thought it would spread sufficiently to lubricate the cylinders properly. He had not determined the point at which to put the oil in for the piston valves. The carbon deposit on the piston valves was much greater than on the piston and cylinder. It seemed to him (Mr. Stanier) that some of the carbon deposit was due to the fact that the oil was put into the steam-pipe sufficiently far from the valve for the superheated steam to char it before it could be carried to the cylinder for lubrication purposes, and it occurred to him that one of the solutions of the difficulty was to put the oil in with a saturated steam jet near the steam chest, so that it would be an emulsion while lubricating the piston valve heads and also

when it reached the cylinder. This seemed to him, irrespective of the quality of the oil, one of the points which might be considered for more efficient lubrication, saving of piston rings, and also decrease of carbon deposit.

Mr. C. B. COLLETT : In Austria a very thin oil had been tried with the superheated steam engine. The oil was a mixture of a black oil with paraffin, and the effect of this very thin lubricant was good, the latter volatilising, leaving a thin film of black oil behind ; but if the driver fed too much oil "groaning" ensued, as the lubricant got too thin. This practice seemed to have been dropped, although it was used to a considerable extent when first superheaters came into general use. With regard to the spraying of the oil, Mr. Nash seemed to doubt whether a drop of oil was split up by the velocity of the steam. He could mention an experiment in which the oil was put into the steam-pipe by means of small "cups." On setting the engine going, with the brake on, it was found that the steam carried a very thin spray of oil, a spray so fine that it could hardly be distinguished. He thought there was no doubt about it being sprayed at 60 miles per hour.

With regard to the carbon deposit, it was a strange thing that the piston valve in moving up and down the valve chamber gathered particles of carbon and they were not blown off by the steam passing the valve. A valve taken out of a superheated engine would be found to have the edge of the port and the edge of the valve covered with carbon. This was very difficult to explain. As to the method of putting the oil directly into the cylinder, he had tried it in the case of piston valves. Putting it in through one hole was not found satisfactory, as it was very difficult to get it right round the valve, and he did not like to make the hole too big because it got filled up with carbon. Another trouble was the variation of steam pressure in the cylinder, for this made a large fluctuation in the oil feed. The locomotive was a most difficult machine to lubricate as there were so many things to contend with, as travelling under such varying conditions no form of gravitation arrangement could be employed. One would think the spray device would be the least effective, whereas in practice it was the most, and less oil was used.

The AUTHOR said he was glad to hear of the experiment in support of the spraying theory. He could not find that it had been established at all.



Mr. STANIER in concluding the meeting said that the wear on the piston rings made it pretty evident that there was not efficient lubrication. Probably the absence of water in the steam on account of superheating had destroyed efficient cylinder lubrication. The carbon deposit on the valves was probably due to the oil being burnt up on the valves before it got to the cylinders.

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[No. 101—SECOND PART]

INTERMEDIATE MEETING.—THURSDAY, NOVEMBER 24TH, 1910.

*Chairman*—Mr. W. A. STANIER, M.I.Mech.E.

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## “ THE CYLINDER LUBRICATION PROBLEM ”

(PHYSICAL AND CHEMICAL PROPERTIES OF LUBRICANTS),

BY

T. C. DAVISON, F.C.S., WH.Ex. (MEMBER.)

WITH DISCUSSION.

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The solution of the problem how to efficiently lubricate the frictional surfaces of steam cylinders using high pressure superheated steam, and of internal combustion engines, in its present stage, is to be found rather in the discovery of a better lubricant than improvement in the method of lubrication. Close co-operation between chemist and engineer is therefore to be desired, and will probably lead to advances in the desired direction with the least expenditure of effort. It is largely a chemical problem, and engineers struggling with it will profit by having a good general knowledge of the chemical composition and properties of the available lubricants.

It will only be possible in this Paper to give a general survey of the composition and properties of lubricants treated in groups, and to

discuss the more important matters affecting the problem of cylinder lubrication.

Lubricants, excepting a few solids of a special nature, may be divided into two classes—Mineral (or Hydrocarbon) Oils, and Fixed Oils.

MINERAL OILS, as the name suggests, are of mineral origin, occurring in the earth in a great many localities. By far the greatest accumulations are found in the oil fields of the United States, and the latter are the chief source of supply. Large, and perhaps increasing, quantities are also obtained from an extensive oil-producing district in South East European Russia. A third source for British consumption is a shale formation in Scotland. These are the only sources which produce oils in sufficient quantities to be of commercial importance. The three products differ more or less from each other in composition and properties, and are known commercially as American, Russian, and Scotch Shale oil.

Mineral oils, whatever their source, are composed almost entirely of hydrocarbon compounds, *i.e.*, compounds composed of the elements hydrogen and carbon only. Compounds containing other elements—oxygen, sulphur and nitrogen—are also present, but in such very small quantities in the oils as placed on the market that they may be ignored for the present purpose.

Compounds of carbon and hydrogen are very numerous, but they may be classified into series, the individual members of which bear a general relationship to each other in chemical constitution and properties.

Mineral oils are never simple hydrocarbon compounds, but are built up of several members of at least two or three of these series of compounds.

The members of a series of hydrocarbons can be represented by the same generic formula ; for instance, the methane series, or paraffins, which predominate in American petroleum, can be represented by the formula  $C_n H_{2n + 2}$  (which means that in the molecule there are two more than twice as many atoms of hydrogen than there are carbon atoms). The simplest member of this series is marsh gas, represented by the formula  $CH_4$  (one atom of carbon combined with four atoms of hydrogen, or 12 parts by weight of carbon combined with 4 parts by weight of hydrogen), and the most complex has probably a higher value for  $n$  than is represented in the formula  $C_{60}H_{122}$ .

The principal series are the paraffins,  $C_n H_{2n + 2}$  ; the olefins,  $C_n H_{2n}$  ;

the acetylenes,  $C_n H_{2n-2}$ ; and the naphthenes, which are represented by the same generic formula,  $C_n H_{2n}$ , as the olefins, but have a different molecular arrangement.

As the value of  $n$  increases in the different hydrocarbon series, so the density or relative weight of the compound increases. The lowest members of the methane series, from  $CH_4$  to  $C_4 H_{10}$  are gases at the ordinary temperature.  $C_5 H_{12}$  is a very light limpid liquid, and succeeding members are liquids of gradually increasing density and consistency, which pass gradually into solids in the highest members.

Hydrocarbons as a class are very stable bodies, and the liquids and solids can be distilled unchanged like water. Like water they have a definite boiling point, and the latter rises progressively with increase of density and complexity of the molecule. As an example, the boiling points are given below of some members of the methane series at about atmospheric pressure :—

Formula.		Boiling Points.
$C_5 H_{12}$	...	$38^\circ C = 100^\circ F$
$C_6 H_{14}$	...	$71^\circ C = 160^\circ F$
$C_8 H_{18}$	...	$125.5^\circ C = 258^\circ F$
$C_{10} H_{22}$	...	$173^\circ C = 343^\circ F$
$C_{12} H_{26}$	...	$214^\circ C = 417^\circ F$
$C_{14} H_{30}$	...	$252^\circ C = 486^\circ F$
$C_{16} H_{34}$	...	$287.5^\circ C = 550^\circ F$
$C_{18} H_{38}$	...	$317^\circ C = 603^\circ F$

With increase of pressure the boiling points are of course raised, as in the case of water. At atmospheric pressure the latter boils at  $100^\circ C$  ( $212^\circ F$ ), but under a pressure of 200lbs. per sq. inch the boiling point is raised to  $200^\circ C$  ( $392^\circ F$ ). Corresponding data for the hydrocarbons are not available, but the assumption is probably correct that their boiling points are influenced by pressure in a closely corresponding ratio. It follows, therefore, that hydrocarbons which would be easily vaporised at cylinder temperatures under atmospheric pressure would remain liquid under steam pressure.

The crude oil, as obtained from the oil wells and from Scotch Shale, consists of numerous members of several series of hydrocarbons of differing boiling points, the extremes varying considerably in different oils. The gaseous hydrocarbons separate at the oil fields, and are used

at places near the site for lighting and other purposes for which gaseous fuel may be used. The crude liquid is separated into fractions by the simple process of distillation, each succeeding fraction having a higher boiling point range, and being made up of denser and more viscous hydrocarbons. The components of lowest boiling point come off first and form the naphtha, petroleum spirit, and petrol of commerce. Then follows ordinary burning petroleum, succeeded by cleaning oil, then the thinnest spindle lubricating oils, and these in turn by lubricating oils of gradually increasing viscosity and density the last portions being generally semi-solid. There remains in the retort a black residue more or less approximating to pitch.

The lubricating oils, prepared as just described, are refined by agitation with sulphuric acid, which decomposes and removes tarry and other foreign matters, followed, after removal of the acid by settling and washing, by a similar agitation with soda solution, which neutralises the last traces of acid, and dissolves other objectionable matters. The oil is finally well washed with water and dried. Frequently the oil is further decolourised by filtration through carbon.

Lubricating oils are also prepared from suitable crude oils by simply distilling off the lighter portions until the residue is of a suitable consistency and boiling point. This is then refined by treatment with sulphuric acid and soda, frequently followed by filtration through carbon. Oils prepared in this way are known as "reduced" oils. They are very dark coloured and opaque. Generally speaking they are superior in lubricating properties to the distilled oils.

Now, whilst the general effect of heat on the hydrocarbons is to cause them to boil and distil unchanged, it also has a tendency to cause them to decompose into simpler products. This tendency usually becomes more marked with increasing density and complexity of the hydrocarbon molecules. The products are much lighter hydrocarbons, partly gaseous, carbon and hydrocarbons very rich in and closely approximating to carbon.

It does not always follow that the heavier the oil and the higher the flash point the greater will this decomposition be, because molecules of corresponding complexity and boiling point in different series have different degrees of stability

Speaking generally, an oil composed entirely of the middle members

of the hydrocarbon series should be relatively free from this tendency to decomposition.

The formation of carbon deposits in engine cylinders lubricated with hydrocarbon oils is the result of this decomposition, and is not due to the deposition of tarry or pitch-like matters which are often supposed to be present in the oils. The proportion of such matters in all ordinary lubricating oils is very small indeed and quite negligible.

FIXED OILS AND FATS are so called because, unlike the hydrocarbon or mineral oils, they cannot be distilled. When heated alone they darken and evolve acrid vapours. Further heating to about  $315^{\circ}\text{C}$  ( $600^{\circ}\text{F}$ ) leads to the evolution of carbonic acid gas, together with a very pungent acrid compound, acrolein,  $\text{C}_3\text{H}_4\text{O}$ , and volatile organic acids. Gaseous liquid and solid hydrocarbons are also formed.

The fixed oils and fats are derived from animal and vegetable tissues. The difference between an oil and a fat is merely a matter of temperature. By a sufficient lowering of temperature oils become congealed to fats, and fats on heating melt into oils.

Fixed oils and fats are compounds of carbon, hydrogen and oxygen. In constitution they are organic salts, termed ethereal salts, formed by the combination between an organic base and a fatty acid.

As sodium chloride, or common salt, is formed by the combination of soda and hydrochloric acid, with the elimination of water, represented by the equation  $\text{Na}_2\text{O} + 2\text{HCl} = 2\text{NaCl} + \text{H}_2\text{O}$ . So a neutral oil or fat is formed by the combination between a compound organic base and a fatty acid, with the elimination of water.

A soap is formed from an oil or fat by the replacement of the organic base by a metallic oxide. For example, ordinary soap is a combination between soda and fatty acid, the soda simply displacing the organic base.

The base constituent of oils and fats is a member of a series of bodies called alcohols, and the majority contain the same alcohol, called glycerol, which is represented by the formula  $\text{C}_3\text{H}_5(\text{OH})_3$ . It is a tri-acid base, and combines with three molecules of a monobasic acid.

The acid constituents are made up of members of a series of bodies termed fatty acids, as already stated. The particular fatty acids which predominate in fats and oils used for lubrication are three in number, and are called Stearic, Palmitic, and Oleic acids.

Stearic and Palmitic acids are consecutive members of the same series. The series are derivatives of the paraffins, and are represented by the generic formula  $C_n H_{2n+1}.COOH$ , or, more simply,  $C_n H_{2n} O_2$ . They are solids at the ordinary temperature.

Oleic acid is a member of a series derived from the Olefins,  $C_n H_{2n-1}$ , represented by the generic formula  $C_n H_{2n-1}.COOH$  or  $C_n H_{2n-2} O_2$ . It is a liquid at the ordinary temperature.

In the natural oils and fats they are combined as glycerides, forming neutral ethereal salts, which are called Stearin, Palmitin and Olein respectively. Stearin and Palmitin predominate in the fats solid at the ordinary temperature, and Olein in the fluid oils.

Rape, Olive, Castor, Animal, Neatsfoot and Lard Oils, together with Tallow and Palm Oil, are glycerides, but Sperm oil and wool grease (grease obtained in the scouring of sheeps' wool) are composed of fatty acids combined with higher alcohols, more complex than glycerol, which are solids at the ordinary temperature.

When subjected to steam under pressure, or slightly superheated steam at atmospheric pressure, these oils and fats decompose into free fatty acids and glycerine, or free fatty acids and solid alcohol, as the case may be. Some are much more susceptible to this decomposition than others.

An experiment to test various oils in this respect, by heating them in a steam boiler at 250lbs. pressure for  $7\frac{1}{2}$  hours, gave the following results :—

	FREE FATTY ACIDS.		DIFFERENCE.	NEUTRAL OIL DECOMPOSED.
	Before Exp.	After Exp.		
	Per cent.	Per cent.	Per cent.	Per cent.
Tallow .. ..	1·2	40·0	38·8	41·2
Lard Oil .. ..	6·5	33·3	26·8	30·1
Castor Oil .. ..	1·5	28·0	26·5	28·2
Rape Oil .. ..	2·0	24·3	22·3	23·9
Wool Grease .. ..	19·7	21·4	1·7	3·7

The neutral oils are without action on metals, but the free fatty acids formed by their decomposition, like the stronger mineral acids, are capable of attacking and corroding metals, and the reaction is acceler-

ated by elevation of temperature and pressure. The use of a lubricant entirely or largely composed of a fatty oil therefore results in the eating away of the internal surfaces of the cylinders, etc., which are exposed to its action, and it is only a matter of time to effect such a weakening of the parts as to render them unsafe. This result is especially marked in the case of tallow.

The products of the corrosion are metallic soaps, with oxides of iron and copper, etc., as bases. They are all solids, of a leathery, gummy character, which will mix with other solid matters and bind them into a hard and more or less sticky mass. The latter accumulates on the edges of the ports, ends of the cylinder, the faces and rings of the piston, and the mouth of the blast pipe, forming a hard deposit, which becomes an obstruction and is difficult to remove.

The fatty oils possess the quality of oiliness in a much higher degree than the hydrocarbon oils. The difference is quite apparent when an oil selected from each class is rubbed between the finger and thumb. The hydrocarbon oil forms so thin a film that it fails to bridge over the inequalities of the rubbing surfaces, which in consequence tend to interlock, and cause the harsh feeling experienced. The fatty oils, on the other hand, form a film between the rubbing surfaces which remains thick enough to keep the inequalities apart, and the friction between the moving surfaces is practically that resulting from movement in the oil itself, or fluid friction. It is not easy to define oiliness, or to determine altogether what makes it vary in the two classes of oils. One factor is surface tension, which is much smaller in the fatty oils than it is in the hydrocarbon oils. The fatty oils, in consequence, spread over and cling to metallic surfaces more readily than hydrocarbon oils.

Pure hydrocarbon oils have not been found to be good lubricants for cylinders of engines using saturated steam. The reason for this appears to be that the isolated droplets of the atomised oil have a surface tension so relatively high that they do not adhere to the frictional surfaces already moist with water, but run off and pass out of the cylinder practically ineffective. By adding a small proportion, say five per cent., of a fatty oil to the hydrocarbon oil, the whole appears to be emulsified with the water held by the steam, and in this condition it readily adheres to the surfaces to be lubricated.

When working with superheated steam, the conditions in the cylinder

are altered, because water, with which the oil could emulsify, is now absent. The use of a small proportion of fatty oil will, however, in all probability still greatly assist the hydrocarbon oil in adhering to the frictional surface, because of its lower surface tension. The effect of the fatty oil in this direction would be greater after decomposition, with formation of free fatty acids.

It is questionable whether the addition of a small quantity of fatty oil to the cylinder lubricant causes appreciable corrosion of the metals, but it will be reduced to a minimum by the use of wool grease, which resists decomposition better than any other commercial oil or fat. Rape oil is, probably, much better for the actual lubrication.

The Author is of the opinion that satisfactory lubrication would be effected, and the formation of carbon deposits much reduced, by the use of a carefully selected distilled hydrocarbon oil of a moderate viscosity, such as is used for axle lubrication, with a small proportion, say 10 per cent., of rape oil.

The thinner oil would lubricate as well as the heavy oil commonly used for steam cylinder lubrication, because all oils and fats, whatever their viscosity at ordinary temperature, have practically the same viscosity at the cylinder temperature, but it would volatilise more rapidly during the exhaust stroke.

The selected oil should be as free as possible from the heaviest hydrocarbons present in the thick oils, which have the greatest tendency to crack with the deposition of carbon, but it should have a moderately high flash point, to reduce the volatility as much as possible.

Oils complying with these conditions, but obtained from different sources, will probably possess different degrees of stability under cylinder conditions. American oils are largely composed of paraffins, whilst Russian oils are almost free from this series, and consist largely of naphthenes. Oils from these two sources, of the same volatility, would probably differ very appreciably in their tendencies to form carbon deposits.

Unfortunately, no laboratory test has yet been devised which will imitate cylinder conditions; but tests could be arranged which would enable suitable oils to be picked out for practical tests.



## DISCUSSION.

The CHAIRMAN remarked that the Author had gone fully into the composition of oils and the effect of temperature. One constantly heard it said that the lubricating value of oils was not nearly so uniform as could be obtained. No doubt this was due to the demand for petrol, as the oil refiners had some process by which they obtained more petrol by sacrificing the lubricating oils.

With regard to wool grease, he asked whether an addition of five per cent. of wool grease to cylinder oil would raise the decomposition point. He believed it was possible by mixing animal oil with mineral oil to obtain a much higher flash point than was the case with either mineral or vegetable oils by themselves.

The AUTHOR : The admixture of a fatty oil with the hydrocarbon oil would not raise the flash point very materially unless the fatty oil was in very large proportion, and the oil to which it was added had a comparatively low flash point. All the fatty oils have a flash point between about 450° F. and 480° F., and the oils which were used for cylinder lubrication generally approached these figures.

It was quite true that at the present time the greatest demand was for petrol and burning petroleum. To meet this demand, the crude oils were distilled in such a way that a good deal of cracking was brought about. It was done by distilling the oil in a still which was sufficiently capacious to allow a large part of the oil which had been distilled to condense in the roof and drop back on the hot oil. The effect of this was to cause it to split up into simpler molecules, and these simpler molecules formed petrol and burning petroleum. Instead of getting a normal distillation of perhaps five to ten per cent. of these light hydrocarbons, as when the process was carried out by the use of superheated steam, the yield of petrol and burning petroleum was probably increased to 50 per cent., and it was quite true that the effect of that treatment was to seriously reduce the lubricating qualities of the oil which was finally obtained from the residue. Cylinder oils may be considered to be the residue from which burning petroleum has already been produced.

Mr. C. T. Cuss enquired whether it would be possible to extract lubricating oil from the hydrocarbon which came down under pressure

on making oil gas, because the original oil would be a Scotch shale heated from 800° to 1000°, and tar and hydrocarbon were given off after compression.

Mr. A. H. NASH asked, with regard to carbon deposits, whether any research had been made to find out the chemical constitution of the deposit: Was it carbon, or some complex hydrocarbon?

A cylinder oil should have been prepared at a temperature considerably above that at which it was going to be used. Hydrocarbon oil for use at 500 degrees should be oil prepared at 100 degrees above that, and then there would be no trouble from the oil cracking.

The AUTHOR, replying to Mr. Cuss, said that oil gas tar consisted of the products of cracking the oil, and largely corresponded to the deposits which were formed in the cylinder. Hydrocarbon tar from oil gas works was really a mixture of the products of cracking, very dense, tar-like bodies, and very light hydrocarbon oil, *i.e.*, two ends of the series, the lubricating members being absent.

Experiments had been made to determine the character of the deposit in cylinders, and it was found to consist partly of hydrocarbons, which could be extracted by solvents, such as ether, hydrocarbons insoluble in solvents, elemental carbons and mineral matter.

With regard to Mr. Nash's suggestion that the oil used in the cylinder should be prepared with a boiling point well above the cylinder temperature, he was afraid that if any such stipulation were enforced, the use of hydrocarbon oils for cylinder lubrication would have to be abandoned altogether. It should be borne in mind that the boiling point depended upon the pressure to which the oil was subjected, and in the steam cylinder, with a pressure of 200lbs. per square inch, the boiling point was so raised that quite a light oil would remain in the liquid condition. The trouble was that on the exhaust side the temperature remained practically the same, but the pressure dropped, and the oil became volatilised and escaped with the exhaust.

The CHAIRMAN remarked that the problem of clearing the carbon deposit was a very pressing one to the Running Department. The only effectual method was to scrape it off.

Before superheaters were in general use it was customary to take out piston valves and clean them with paraffin. The deposit on the rings before was not nearly so hard as it is now. If, as the result of Mr.

Davison's experiments and testing of the mixtures, they could arrive at an oil which would give softer deposits, it would be a great benefit to the engines and those who had to handle them.

Nothing had been said about the salts carried over with the steam. No doubt with hard water there was a certain tendency for lime to be deposited with the carbon. He did not know whether Mr. Davison had tested any deposit to see if there was lime in it, or had tested only for carbon. Perhaps in his concluding remarks he would tell them.

The AUTHOR replied that complete analyses had been made of cylinder deposits. They usually contained salts derived from the water in the boiler, due to priming, and also smokebox ashes, and these together sometimes accounted for more than 50 per cent. of the total deposit.

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On account of the importance of the subject, and the absence of any definite conclusions, it is proposed to re-open the discussion on the "Cylinder Lubricating Problem" during the next Winter Session.