THE LUBRICATION OF CANE SUGAR MACHINERY.

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This is a subject which does not at first sight appear to be of major importance in Cane Sugar Factory operation nor possibly of sufficient interest to warrant intensive thought on the part of the Engineer whose duty it is to keep machinery running at all costs. Lubrication is only too often regarded as a necessary evil—a messy, troublesome subject only to be tackled as and when hitches occur in the smooth operation of the plant. This is an old idea, possibly due to the fact that at the beginning of the mechanical era very few suitable products were available as Lubricants. Shifts had to be made with such animal and vegetable fats as were known to satisfy the slow running and low temperature conditions then existent, and a kind of precept was established with their use.

Machinery itself has of late years advanced in design and efficiency to a remarkable degree and indeed is still forging ahead. It will not be denied that such rapid progress owes much to scientific research—in materials—in physical laws and in methods of construction. Each development calls for higher and yet higher speeds, often coupled with temperatures formerly regarded as outside practical working limits. As each link is forged in the rapidly moving chain of mechanical achievement, we are moved at first to a wonder that such things are possible after which we revert to a calm acceptance of facts, which is only disturbed by isolated instances of failure.

How many of us give a passing thought to one feature without which no machinery can operate. I refer to lubrication—and in these times of specialised effort—"Correct Lubrication." Take the ultra high speeds of internal combustion engine parts, coupled with the terrific temperatures of the burning gases in the cylinders. Such units—upon which the whole fabric of civilisation has come so much to depend, could not operate for many moments unless the same human effort in research as has been put into the machine itself—had been devoted to the production of a lubricant capable of withstanding such extreme conditions. Between each rubbing surface of every machine working there must be interposed a suitable lubricating medium before continuous operation can be ensured.

That is all common knowledge, one is inclined to say, but one oil is very much like another and any one good oil will do equally well with any other good oil. A moment's reflection will indicate that vastly different products will be required say for sustaining the terrific load on Mill Bearings and for use in the Crank Chambers of high speed engines. It is just as essential that each lubricant must be exactly suited to its duties as that correct grades of iron or steel are incorporated in the manufacture of the machine itself.

Turning from generalities to the specific subject with which we are dealing—namely—the Lubrication of Sugar Mill Machinery, we must examine the manner in which specialised attention in lubrication can benefit the Sugar Industry.

Let us trace the whole chain of effort in the production of Cane Sugar—right from the cane fields to the finished product, and see the untiring vigilance that is constantly necessary to guard against the immense loss that would ensue upon mechanical failure.

Cane is grown in tropical and sub-tropical countries where an abundant and unfailing "Wet" Season is assured. The year for the Sugar Plantation and Mill is thus split up into seasons dependant upon Nature. A definite portion of each twelve months is necessary for new cane to reach maturity after the last of the old cane is cut. That time is utilised by the mills to put their house in order in readiness for the crushing season to follow.

Once the cane is fully grown and cutting begins, a period of feverish activity commences which is maintained until the last of the cane is cut. Natives do the work armed with sharp knives with which they cut the cane close to the ground and leave it in piles ready for transport. Cane must be crushed soon after cutting otherwise inversion of the sucrose content occurs. It is imperative, therefore, that once cutting is embarked upon, no hitch of any kind shall interrupt the smooth flow of work. To the casual listener this may sound simple, but if one considers the vast amount of machinery which must be kept running continuously during the whole of the crushing season, he will realise that there are a thousand and one details each capable of causing breakdown. Stoppage at this period is inevitably serious and costly.

Section I.

TRANSPORT.

Cane in this country is generally transported direct from the plantation to the mill, where it is weighed. Cane trucks are mainly employed for the purpose and whilst lubrication of these is simple, it must receive regular attention. The duties of cane trucks are continuous and heavy, and axle bearings operate in very adverse conditions. These follow several designs: ball bearings, plain bearings grease-lubricated, and plain bearings oil-lubricated. Because the service is rough, it is a mistake to think that any cheap product will do. Greases offer perhaps more scope for adulteration than any other lubricant, and whilst it is realised that in isolated instances one is apt to be exploited when paying top prices, in the main only goods of a quality commensurate with the price paid are procured. A good grease contains anything up to 88% high quality mineral oil of correct body with sufficient lime or soda soap to thicken it and very little or no water. On the other hand, a poor grease may contain very little mineral oil of doubtful quality, a large quantity of cheap filling such as china clay, gypsum, etc., and considerable water. Some cheap rosin greases sold as suitable for colliery axles may contain as much as 50% adulterant and 25% water. In addition, the ingredients of such greases are often very badly mixed and do not form the homogeneous compound necessary in such a lubricant. It is easy to see the harm that would be done, say to a ball or roller bearing, by employing such a grease. It is no uncommon thing to find that expensive bearings have on occasion to be renewed for no other reason than that an unsuitable grease has been used. The cost in such an instance amounts to many times the entire cost of the lubricant concerned over a very long period. Such grease used on ordinary axle bearings must accelerate the rate of wear and tear over what would be the case if a more efficient lubricant were used.

The types of grease with which we are mainly concerned are soap thickened greases. These are mixtures of soaps and mineral oils out of which ingredients it is possible to manufacture a variety of products.

The soaps employed may be Sodium, Calcium, Aluminium, or Lead and are produced by the chemical reaction of either an animal or a vegetable fat with the metallic base.

Sodium or caustic soda greases form high melting point products with a fibre like texture and certain grades are very useful for high temperature duties in steel mills. They are also used for locomotive journals and side rods, tunnel bearings and in lighter form for gears, etc.

Calcium or lime soap greases are used for ball and roller bearings, for water pumps and in situations where insolubility in water is an advantage. They are not suitable for temperratures above 212° F. as a separation of soap and oil is liable to result beyond that point. A grease of this nature having a melting point of 190 to 200° F. serves excellently for ordinary plain journals.

Aluminium soap greases are somewhat more complex in character and vary according to the aluminium soap base used in the manufacture. Aluminium soap of stearic acid with a light mineral oil produces a grease of low cohesive character, whilst an aluminium soap of oleic acid with the same oil produces a highly cohesive grease of rubbery texture.

Lead soap greases are useful as extreme pressure lubricants and such greases have the quality of ready adhesion to metals.

Journal Boxes for oil lubrication need a heavy dark lubricating oil as the lubricant and ensure a constant and ample feed through a felt pad or by a special packing of wool waste. In the latter the wool used is initially saturated with oil and a firm pad is twisted up and pushed to the back of the box. A centre pad, not so tightly made, is inserted so as to maintain contact with the journal up to its centre. An end plug is then put in, this also being tightly made up, its purpose being to keep the centre plug in position. Care must be used in packing these boxes to ensure firm contact between the waste and journal. A definite level of oil is maintained in the box and ample lubrication is effected by the capilliary action of the felt pad or wool.

Where motor transport is employed, one is usually familiar with the disastrous results of the false economy of purchasing cheap lubricants. Defects in motor vehicles quickly manifest themselves in no uncertain fashion, and vehicles laid up for repairs, often when they can least be spared, are often a visible proof of this. Whilst it is not intended to indicate that the use of quality lubricants will prevent all ills to which mobile transport is heir, the employment of such will definitely remove a doubtful factor in operation and will definitely prolong the useful life of the machine.

Diesel Engined Locomotives are becoming widely used on account of the general convenience of such units. This saving is only realised whilst maintenance costs show no material increase. Maintenance of a Diesel engine depends positively more upon correct lubrication than upon any other factor. Compression pressures reach very high figures, the corresponding temperatures being of the order of 1,000° F. The burning temperatures of the incandescent gases are several times that figure and altogether the oil film sealing the piston in this type of engine has to operate against more rigorous conditions than in any other type of engine. Bearing pressures, too, in the Diesel engine are of a very high order and one characteristic of the oil employed must be its ability to maintain maximum viscosity at high temperatures. The fluctuating load on the bearings makes it essential that ample cushioning is present between journals and bearings, and as clearances are of necessity small the oil must at one and the same time possess fluidity to allow it to circulate in these fine clearances, and film strength enough to resist rupture under the heavy pressures. A lubricating oil having exceptional qualities is called for and no other should ever be used in a Diesel engine.

AT THE MILL.

After weighing, the cane is fed on to a mechanical conveyor feeding into the crusher and grinding rolls. Before reaching the rolls the cane is passed through revolving cane knives which cut the cane into short pieces and thus facilitate extraction. The cane knives require considerable power to drive them, various methods being used.

STEAM ENGINE DRIVE.

A vertical enclosed high speed steam engine is usually coupled direct to the shaft carrying the knives. In the cylinders of such an engine a pure mineral and not a compounded oil should be used, as a large amount of condensation is usually present, and water finding its way via the rods into the crank chamber carries oil with it. If a compounded oil were used, contamination of the crank chamber oil would ensue, rendering the latter liable to emulsification.

A medium bodied pure mineral is essential in the crank chamber in order that separation from the water present may readily take place. The same oil is quite suitable for the bearings carrying the knives, which are usually of the ring oiled type.

ELECTRIC MOTOR DRIVE.

If equipped with ball bearings, the motor should only be lubricated with a special ball bearing grease for reasons mentioned earlier in the paper. Motor bearings run for so long with practically no attention that correct treatment costs practically nothing. Where fitted with ring oiled bearings a high grade light mineral oil should be used. A poor quality mineral oil of light body such as is employed in these bearings will deteriorate in service by thickening up. This is caused by temperature variation and the absorption of oxygen during that process assists in deposits being precipitated. These deposits together with such foreign matter as finds ingress into ring oiled bearings are apt to accumulate at the bottom of the oil container and contact with the rings will impede or prevent their working. All bearings should be cleaned out and replenished prior to each crushing season.

If driving through enclosed helical or spur gears, an extra heavy mineral oil is required for the gears. This should be removed, the gear-case cleaned out, and the oil filtered and replaced each year.

CRUSHER AND GRINDING ROLLS.

After leaving the cane knives the cane passes along on a conveyor and is fed to the crusher rolls. The purpose of these rolls is to thoroughly break up the cane and prepare it for easy handling by the grinding rolls. The grinding rollers subject the cane to an intense pressure and extrude most of the juice in the first two mills, whilst the remainder is extracted in the back mills with the aid of dilution water. Some installations consist of one or two crushers in tandem followed by a series of mills, as many as 15 to 18 rollers being employed.

It is apparent that the terrific pressure required between the rollers must be applied mechanically, and in most modern plant this is done by hydraulic means. The equipment used is the usual pump and accumulator operating on hydraulic bearing caps on the top roller bearings of the mills. The fluid medium employed may be any light or medium bodied oil which is in use elsewhere on the plant, such as light crank chamber oil or air compressor oil. Where conditions are wasteful, a soluble oil mixed with water may be employed with success.

When tackling the lubrication of the crushing and grinding mill roller journals themselves, we are up against some of the most severe conditions known to the lubrication specialists. Ultra high pressures and extreme slow speeds—two of the most deadly opponents of good lubrication—have to be catered for. This particular problem may be described as affecting the "Heart" of the factory itself, a shut-down here due to defective lubrication or excessive wear will cause stoppage all along the line and congestion in the preceding departments. The only methods of ensuring against such a contingency are minute attention to adjustment during the annual overhaul, by making certain that the lubrication system is positive and foolproof and that the correct lubricant for the purpose is exclusively used.

As in most lines, a variety of ways of achieving the same purpose is made use of for the lubrication of mill roller bearings. A grinding mill consists of three rollers, the top roller which is loaded mechanically or hydraulically, the feed roller which deals with the incoming cane, and the discharge roller which takes the crushed cane over a stationary plate from the feed roller and discharges it to the bagasse conveyor. The pressure on the top roller bearings is almost vertically downwards, that on the feed and discharge rollers upwards along lines connecting the centre of the top roller to the centre of the roller concerned. It is clear from this where the position of highest pressure on each bearing will be, taking into account the direction of rotation of the mill. Mill bearings are grooved to facilitate the introduction, and even distribution, of the lubricant. Unless correct grooving is cut, satisfactory running of these heavily loaded bearings will be impossible. The area of maximum pressure should be left plain and undisturbed in any way whatsoever, whereas it is occasionally found that small channels are cut for the purpose of conducting oil to that area. A moment's reflection will serve to show that such grooves provide a ready outlet from the point of highest pressure, and that the oil makes its escape by that route. The correct method of grooving heavy duty bearings is to provide a shallow groove along the full length of the bearing except for an inch or so at each end for retaining the oil. This groove must be placed in the position of least pressure and in advance of the pressure area considering the rotation of the journal. The edges of the groove must be gradually chamfered into the face of the bearing so that no scraping edge exists whatsoever. The oil should be fed into this groove, the wedge shaped leading edge of which will facilitate the formation and introduction of a supporting film into the pressure area.

In considering suitable lubricants for mill bearings, it is evident that only heavy adhesive products will give the service required. There is a danger that such heavy lubricants will not feed evenly at low temperatures, but the use of mechanical force feed lubricators allows the use of a high-grade oil with economy. A feature of such oils is their fluidity at comparatively low temperatures and the property of retaining relatively high viscosity at high temperatures. In other words, the viscosity curve does not fall so steeply as that of a low grade oil, and moreover, feeding is possible over a range of temperatures. A high grade compounded steam cylinder oil is the most satisfactory lubricant to use for mill bearings. Such an oil will form a tenacious oil film capable of withstanding the extreme bearing pressures realised, and will lubricate satisfactorily even when juice finds its way into the bearings. Modern journal testing machines demonstrate that mixtures of mineral and fatty oils provide an oilier and more adhesive film than a pure mineral oil, and in consequence minimise friction.

Nowadays manufacturers of sugar milling machinery equip heavy duty bearings such as those carrying mill rollers, with mechanical force feed lubricators. In cases where other and less certain means are employed, considerable economy and improvement in runnning conditions can be secured by a comparatively small expenditure on these devices. A good arrangement is to supply a number of separate lubricators say with either three or six feeds. These can be fixed adjacent to the bearings to be supplied, and a short separate lead can be taken to each. A chain and sprocket drive from one of the rollers is perhaps the simplest means of operating the lubricator.

Owing to dust and foreign matter finding its way into bearings, oil grooves are liable to become clogged up. Means for flushing the bearings with hot water are sometimes provided as it is out of the question to dismantle the mills for clearing oil grooves during the crushing season. A tell-tale on the oil supply is fitted so that a building up of oil pressure in the oil grooves is readily noticed.

A common arrangement for lubricating certain lower mill roller bearings is from a trough on the bearing made to hold a semi-solid lubricant in contact with the journal. One of the most satisfactory lubricants for such a purpose is a medium heavy black compound such as is used for dressing exposed gear teeth.

Crown gear teeth are subjected to very heavy pressures and they require treatment with a heavy black adhesive compound of the same nature as that mentioned above.

MILL DRIVES.

The two forms of drive most suited to Sugar Mills are steam engine and electric motor through gearing.

STEAM ENGINE DRIVE.

Horizontal steam engines are employed using saturated steam at about 100 lbs. per square inch pressure. These drive the mills through large open double reduction gears. The exhaust steam from the engine is passed to a common exhaust range, the contained heat being efficiently utilised in production.

In tackling steam cylinder lubrication, the necessity of keeping oil out of the exhaust steam must be appreciated. Excessive or irregular feeds or inefficient separation may cause coating of the heating surfaces of the evaporators with oil and thus impair the conductivity of the tubes. This will lead to an increase in back pressure on the engine with a corresponding reduction in efficiency throughout. There is a risk also of oil finding its way back to the boilers via the condensate from the heating apparatus.

In order to guard against the above troubles, cylinder oil should be correctly and efficiently fed to the engine so that perfect lubrication is obtained on a minimum quantity of oil. By feeding into the main steam pipe through an atomiser, the oil is divided up into a fine spray and is carried along with the steam on to every internal working surface of the engine. Feeds can be made positive and regular by the employment of a mechanical force feed lubricator, which instrument is capable of extremely fine adjustment. The steam separator should receive regular attention in draining and should be amply large enough for the job.

Steam in Sugar Mills is usually on the wet side and for these conditions a slightly compounded oil of medium body is advisable.

Engine bearings are lubricated in a variety of ways of which the gravity circulation system is perhaps the best and most economical. A good mineral heavy engine oil will cover most requirements, but a highly compounded bearing oil may perhaps be regarded as an added insurance to good lubrication seeing that these heavy duty bearings are called upon to operate for long periods at a time without opportunity for adjustment. The same oil also suits the bearings of the double reduction gears, but the gear teeth themselves can either be coated with a heavy black compound, or if bath lubricated can utilise reclaimed cylinder oils.

ELECTRIC DRIVE.

Large motors operating through enclosed high speed reduction gears and then through slow speed gears take the place of the steam engine in the preceding paragraph. Lubrication of the two sets of gears is often dealt with by one circulation system for the whole, when one oil has to serve for both high speeds—light pressures and low speeds—heavy pressures. This was the arrangement in one of the large local mills until the engineer set himself seriously to overcome certain defects which manifested themselves. He split up the one lubrication system into two, preserving the original arrangement of pressure circulation for the high speed side and sealing it to prevent egress of the oil in circut to the low speed side. He then converted the low speed reduction into a bath lubricated system and introduced a heavy "Extreme Pressure Lubricant" to serve the slow speeds and high tooth pressures of that section. Each condition was thus correctly provided for—high speeds and light pressures employing a medium bodied oil—low speeds and heavy pressures employing a special heavy oil manufactured to meet conditions of extreme pressure. Results have amply justified the thought expended on the problem and the ingenious method of carrying it out—for it is no simple matter to incorporate structural alterations in such equipment.

External to these gears is a double reduction spur gear train as is used for reducing the speed of the steam engine to that of the rollers, and the lubrication of these is dealt with in a similar manner.

VACUUM PUMPS.

The duty of these important units is to remove air and other non-condensible gases from the condenser system. The boiling point of the juice is controlled by the pressure in the system and more rapid evaporation is ensured the higher the vacuum. Vacuum pumps are mostly of the horizontal reciprocating type either in tandem with a steam engine or worked by belt or other external means. The air cylinders require a very sparing feed of a medium-bodied high-grade mineral oil and the same grade will also do for the external bearings. Reliability is essential here as a fault in the condenser system may hold up production for some considerable time.

CENTRIFUGALS.

Whilst each department carries its own load of responsibility, without doubt the centrifugals are of maximum importance in a Sugar Mill and must be maintained in constant operation if production to schedule is to be obtained.

Centrifugals operate on ball bearings either oil or grease lubricated. In no other mechanical appliance does lubrication so seriously affect the useful working life of the article. The lubricant must serve as a preservative for the surfaces of the steel balls and races as the slightest suggestion of corrosion will commence destruction of the bearing. If a grease is used the remarks on greases at the beginning of the paper apply, if an oil, then only a pure high-grade mineral oil of suitable body should be used.

CRYSTALLISERS.

The driving worm usually dips in a trough in which case a heavy black lubricating oil or steam cylined oil is most satisfactory for maintaining the level in the trough. Where such an arrangement is impracticable, a heavy black adhesive compound—hand applied—is possibly the most suitable means of serving this item.

POWER PLANT.

In electrically driven mills power is often generated in the Power House of the mill itself. Lubrication in this department is of major importance and every effort is needed to maintain a high standard of efficiency.

STEAM TURBINE PLANT.

Whatever the design of the steam turbine, whether geared or direct coupled to the generator, the same system of lubrication is usually employed, viz., pressure circulation by which means all bearings are pressure fed, the oil afterwards being returned to a common sump. The duties of an oil in a steam turbine are to provide a constant film, to rapidly conduct away heat, to resist oxidation and sludging to the utmost degree, and to readily separate from water. To obtain these characteristics it is necessary to turn to oils refined from a certain class of crude, those from the Pennsylvania fields being acknowledged as having the qualities required.

DIESEL ENGINE PLANT.

In Diesel engine lubrication, piston sealing has to be secured against very high pressures and extremely high temperatures. With faulty lubrication a high rate of wear and tear is inevitable and oils which readily break down are entirely unsuitable. Here again the crude must be selected with a knowledge of the requirements of the finished product, and the lubricant must be manufactured with all the care devoted to the production of any other high class article. By-product oils such as those evolved by the cracking process in producing petrol are particularly unsuitable and should never be considered. A good oil possesses fluidity at low temperatures and yet maintains good viscosity at high temperatures. For Diesel engines an oil which will produce a soft carbon rather than a hard carbon is preferable and will give the most satisfactory results.

A feature inseparable from internal combustion engine performance is "Dilution" of the lubricating oil by fuel oil. High pressures on the upper side of the piston, defective combustion and the spreading and scraping action of the rapidly moving piston cause fuel oil to pass down the cylinder walls and dilute the crank chamber oil. Needless to say, careful use of good lubricants is somewhat nullified by this happening and it is up to the operator to take all possible precautions to cut out dilution. In the first instance careful selection of the lubricating oil will minimise piston and cylinder wear and help to keep the cylinders gas tight. Complete combustion of the charge will dispose of the possibility of surplus fuel oil working down the cylinder walls, and to this end accurate setting of the fuel pump is essential.

Low temperatures such as accompany delayed warming up result in a marked increase in cylinder wear, and therefore of dilution. This has been found to be related to corrosion attributable to condensation on the cylinder walls of water from the products of combustion and acids formed during combustion. Tests in which hydrogen was used as a fuel in order to eliminate the formation of certain of the acids showed a large reduction in cylinder wear. This has been further borne out by the use of corrosion resisting metals for piston and cylinder liners. A large number of tests under steady running conditions showed a rapid increase in cylinder wear below a water circulation temperature of 190° F.

Sludging of the lubrication oil is closely tied up with dilution as the presence of fuel oil carrying impurities down with it together with metallic particles and moisture causes oxidation and deterioraof the oil in the crank chamber and allows sluding to take place more readily than would otherwise be the case. Therefore, dilution is a thing to be watched and counteracted as far as possible.

STEAM ENGINE PLANT.

Steam engines for power generation are usually of the vertical totally enclosed type, the cylinders being lubricated by some form of mechanical or hydrostatic lubricator, whilst the external parts are lubricated on the pressure circulation system. This type of engine was discussed earlier in the paper and nothing further need be added here, except to say that a guide to the grade of oil most suitable for crank chamber use is the size of the engine and gauge pressure on the oiling system.

Section 2.
THEORY OF LUBRICATION AND LUBRICANTS.

In Section I a resumé has been made of the main requirements from a lubrication standpoint, of the grades of oils and grease best suited to sugar milling machinery. Whatever the lubricant in use, the theory underlying correct lubrication remains the same and this paper would scarcely be complete without a brief reference to the basic principles.

Any plain surface, however accurately ground or finished, on examination under the microscope discloses a series of indentations and irregularities over the whole area. When two such surfaces are rubbed together under load these prominences engage one with the other and energy is required to produce motion. This energy is manifested in the form of heat and in accordance with the speed of rubbing and the load, so heat is generated. With dry surfaces this heat is apt to increase rapidly to a pitch at which fusion of the two surfaces occurs and seizure is said to take place.

Lubrication consists of interposing some medium between the two surfaces which will fill in the irregularities and separate the solids by a film capable of standing up to rapid shearing action under motion without the generation of uncontrollable heat.

A number of materials have been found suitable to act as a lubricating medium—to mention a few—graphite, soapstone, mica (solid lubricants); animal fats, vegetable oils, mineral oils, water and indeed a vast number of liquids (fluid lubricants).

Common practice has limited the choice to a few well known substances—graphite is perhaps the best known and most satisfactory in the solid series, whilst animal fats, vegetable oils and mineral oils, both separately and in a variety of combinations, are used as fluid lubricants.

Graphite may be used dry or mixed with grease, oil or water and is mostly employed in special process machinery where traces of oil would be extremely detrimental or where heat makes the employment of oil impracticable.

Our concern is mainly with the use of fluid lubricants and the guiding factors in their selection for their various duties. One of the main features commending an oil to our notice is that elusive property known as "oiliness." This quality is not by any means bound up with viscosity or body, but may be augmented by combination with certain substances, the amount by which this is possible being determined by certain physical limitations and by the use to which the lubricant is to be put.

It is common knowledge that a dry metallic surface can be wetted by an oil, the term describing this condition being "adsorption" of the film by the metal. The amount of adsorption varies with the kind of oil in use, but it will be apparent that once adsorption has taken place some lubrication is always present. A further quality possessed by an oil is that of surface tension—a condition between the molecules tending to contract or hold the film together.

How does this affect lubrication? By way of illustration let us first take the case of the plain bearing. In order to run under practical conditions a journal must be smaller in diameter than the bearing in which it runs. The difference may be only a matter of thousandths, but it nevertheless exists. Oil is introduced into the clearance, and the journal can be visualised as resting on the bottom of the bearing with the clearance space entirely filled.

Whilst at rest, metal to metal contact (except for the adsorbed film) exists at the bottom and a film of oil slightly wedge-shaped extends to the top of the bearing. As the journal commences to rotate, it first rolls infinitesimally and entraps part of the oil film filling the clearance space. Further rotation causes oil to be carried beneath the journal, the adhesion to the surface and the film strength assisting in this operation, with the result that the journal is slightly raised on the film of oil. The load on the shaft, speed and direction of rotation locate the journal in a definite position in the bearing and slightly eccentric to it. The journal is thus supported on a wedge-shaped film of oil and is maintained so by the operating conditions.

The oil wedge is therefore essential to good lubrication and the effective formation the wedge is dependent upon the adhesion of the oil, its film strength and the loading and construction of the bearing. This principle has been effectively proved in practice in the "Mitchell" thrust block, the pivotted bearing surfaces of which align themselves at a slight angle or wedge to the collar.

OIL CHARACTERISTICS.

Refining:

Mineral oils are refined by various processes from crudes obtained at varying depths below the earth's surface. They consist of chemical combinations of hydrogen and carbon—sometimes with a small percentage of other elements and in the raw state are often contaminated with extraneous matter.

Methods used in refining are steam distillation, vacuum distillation, a combination of steam and vacuum distillation, the new solvent process and the cracking or pressure—temperature method. The refiner who specialises in quality lubricating oils confines himself to the three first mentioned methods, whilst for maximum output in petrol and fuel oils, the latter method commends itself.

The lubricating oils specialist must first secure crudes suited to the requirements of the machinery to be lubricated, only certain select crudes being of this nature. For instance, Pennsylvanian crudes are known to produce lubricants having qualities of rapid demulsibility, to be free from sulphur and asphalt, and to maintain a good viscosity curve. North Illinois crudes contain sulphur which is difficult to eliminate, Gulf Coast are mainly naphthene base containing asphalt and sulphur; California are naphthene base; Russian crudes have a low carbon content, low cold test and good viscosity curve, though not the equal of Pennsylvanian in this respect. Burma and Sumatra crudes are high in asphalt, possess poor demulsibility and have poor viscosity curves. Persian crudes are similar to Burma; Mid-Continent make poor lubricants; Texan being very similar in that respect. The new solvent method of refining enables better lubricants to be manufactured from poorer crudes than would otherwise be the case.

The system in vogue employs selective solvents of different natures for separating the high and low grade constituents known to exist in all lubricating oils. These are used at a certain temperature—according to the solvent in use—at which temperature the solvent is miscible with the crude at the maximum efficiency. For example Nitrobenzene is employed at 32° F., Phenol at 131° F., Methyl Acetate at 104° F., Chlorex at 30 to 80° F. and so on. According to the quantity of solvent used, so oils of varying viscosity index can be produced to working limits depending upon the raw material employed. The solvent on mixing with the crude forms layers which are then separated, the solvent being afterwards evaporated off, leaving a product of pre-determined quality. Much experimental work has been done up to date to provide the data used for refining on these lines, and the results achieved definitely indicate advantages with the poorer range of crudes. It is possible to extract better quality lubricating oils from these crudes by the solvent process than by temperature distillation, but generally speaking, a good crude must be used for the manufacture of a quality lubricating oil.

In steam distillation the process is accelerated by the introduction of the vapour of some liquid, usually water. Petroleum hydrocarbons decompose under the action of heat and the use of steam has the effect of lowering the temperature of distillation and thus preserving the heavier lubricating molecules in their original form. The same object is achieved by employing a partial vacuum, whilst a combination of the two methods possesses advantages over either one.

Cracking distillation produces a much greater yield of petrol and paraffin from the crudes and at the same time a poorer quality of lubricating oil. The combined action of pressure and heat serves to split up the larger molecules of which lubricants are chiefly composed into smaller and simpler molecules and the lubricating oils obtained by this process are not so suitable for exacting conditions as those obtained by the first mentioned methods.

In classifying crudes, three main headings cover the range—paraffin base, naphthene base and mixed base. From the former, the bulk of high-grade lubricants are obtained. Very little asphalt is contained in them, but they are rich in paraffin wax and petrol. Naphthene base crudes contain considerable quantities of pitch or asphalt, whilst mixed crudes contain all the above compounds. Paraffin base crudes are usually distilled by the combined steam and vacuum process in order to preserve the lubricating qualities of the products. Cracking is resorted to with Naphthene base oils in order to derive the greatest quantity of light products. Mixed base crudes are refined by a combination of both processes.

The crude is heated in stills in accordance with whichever method of refining is decided upon and vapours are driven off at the varying temperatures reached. These vapours are taken through condensing coils from whence the liquid runs through sight boxes to storage tanks, a separate tank being reserved for each "cut." In order of gravity the following cuts are obtained:—

Petrol
Paraffin
Power Paraffin
Fuel Oil
Wax Distillate
Residual Cylinder Stock.

Lubricating oils are produced from the wax distillate, the wax being in an amorphous or soft form. This distillate is again distilled, very little steam being used and is slightly "cracked" in the process. The amorphous wax (petroleum jelly) in the distillate is thus changed to a crystalline form in which state it is easily extracted by pressing in filter presses at a temperature which fixes the pour test of the extracted oil. This extract is now steam distilled again for the production of lubricating oils, which after blending and compounding, form the various grades of motor, shafting, compressor and bearing oils ordinarily met with.

Bright cylinder stocks are produced from residual cylinder stocks by a process of filteration. The bright stocks contain amorphous wax (petroleum jelly) in varying quantities and the cold test is objectionably high. To reduce this a process known as cold settling is resorted to. The stocks are filled in to a vertical cylindrical tank containing refrigerating coils at the top. Means for extracting samples are provided at various stages down the tank so that the division between the amorphous wax and the settled stocks may be located. The finished bright stock is then drawn off from different levels, the cold test being settled by the temperature of refrigeration. After removal of the naphtha from each fraction, the bright cylinder stock is ready for compounding into cylinder and motor oils and the amorphous wax, after further treatment, is available as a commercial petroleum jelly, and after further treatment for pharmaceutical purposes.

Compounding:

The addition of certain animal or vegetable oils in predetermined quantities augments the lubricating qualities or oiliness of a mineral oil under certain conditions. For instance, a steam cylinder oil compounded with a certain amount of tallow possesses greater adhesion to metal, especially in the presence of water. When an oil is required to emulsify freely as is the case with a marine engine oil where sea water may be flushed on to a bearing at any moment, blown rape oil is the compounding used. Similarly, for other purposes Lard Oil, Castor Oil, Cocoanut Oil, Linseed Oil and a variety of other products may be used for compounding.

Blending:

Judicious blending is resorted to in order to produce lubricants of certain qualities which are difficult to obtain in the straight run oil. Correct blending calls for a certain amount of special knowledge and skill in order that a standard quality may be ensured.

SPECIFICATIONS.

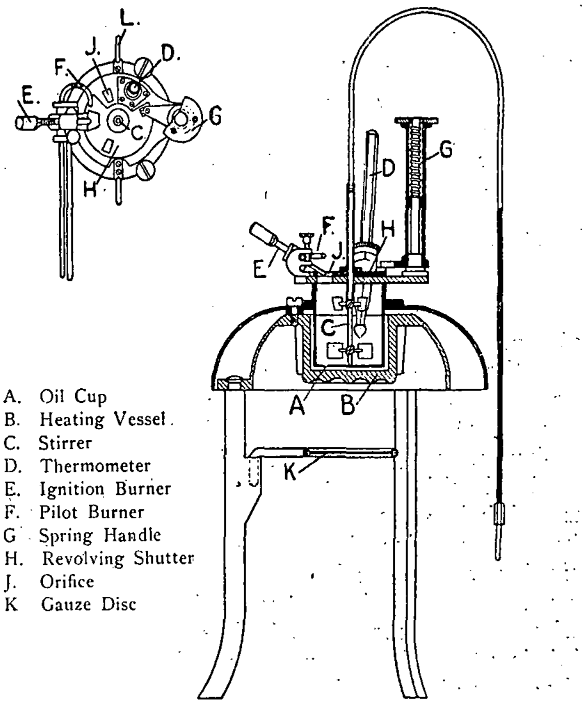
The average user of lubricating oils is apt, and is indeed encouraged, to judge oils by their physical specifications. Whilst these figures are necessary in order that an oil more or less correct for the purpose for which it is intended is selected, they are in themselves very little guide as to the actual quality of the lubricant. Generally speaking, the only indication given by viscosity figures is manifested in the fact that a high-class oil is more fluid at low temperatures and maintains a higher viscosity at high temperatures than a low grade oil.

Specific Gravity:

Oils from different sources vary as to specific gravity and it is more or less possible to locate the origin of an oil from that figure. For different crudes specific gravity figures as low as 0.730 and as high as 1.06 have been recorded, but the general run gives figures of from 0.860/0.895 for Pennsylvanian, 0.900/0.930 for Mid-Continent, up to 0.960 for Burma, Texas and so on. Specific gravities of oils are determined at a temperature of 60° F, and for ordinary purposes specially constructed hydrometers are used.

Flash Point:

This is the temperature at which vapours driven off by slowly applied heat, produce a flash in the presence of a flame, but do not ignite. Two methods are commonly used, the open flash and the closed flash tests, the former giving a reading



A. Oil Cup
B. Heating Vessel.
C. Stirrer
D. Thermometer
E. Ignition Burner
F. Pilot Burner
G. Spring Handle
H. Revolving Shutter
J. Orifice
K Gauze Disc

Fig. 1. Pensky-Martens Apparatus.

25-35° F. above that from the latter. The apparatus commonly used for the determination of the closed flash point is the Pensky-Martens instrument illus-

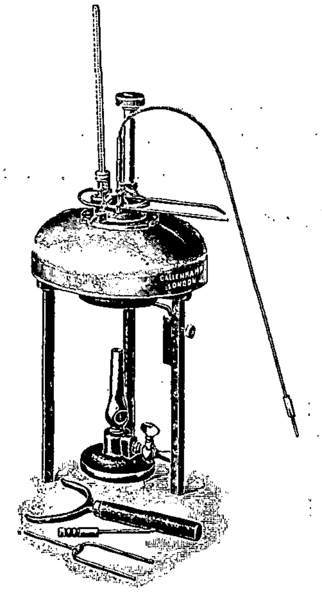


Fig. 2. Pensky-Martens Flash Point.

trated in Figs. 1 and 2. The same instrument is used for the open flash point except that the cover of the cup is replaced by a clip to carry the ther-

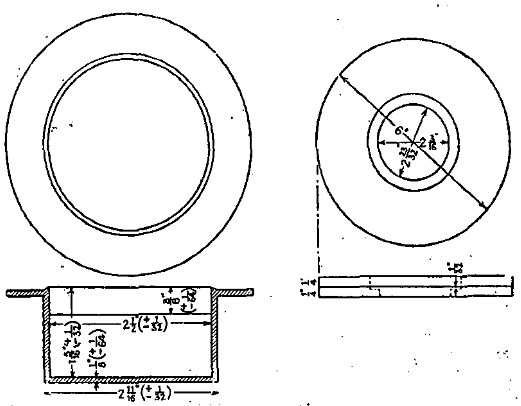


Fig. 3. Cleveland Open Flash Point.

mometer and test flame. In the U.S.A. the Cleveland Open Cup is used for flash point tests. This is shown in Fig. 3.

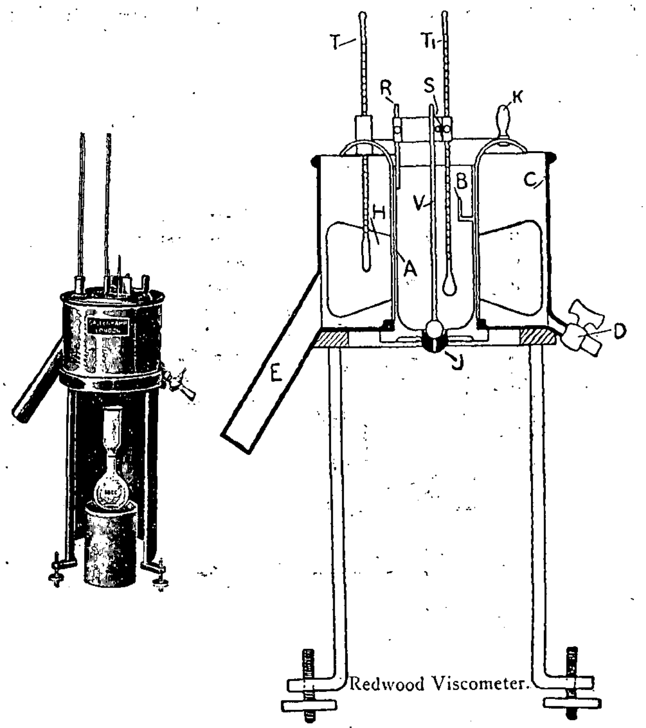
Fire Point:

If heat is applied beyond the flash point, the temperature at which sufficient vapours are given off to maintain a flame for five seconds is called the Fire Point. The same apparatus is used as for the open flash test. Users are apt to regard this of importance in selecting an oil for internal combustion engine use. When it is realised that fire points are practically unknown above 650° F. for a steam cylinder oil, and 520° F. for an auto oil, and that the temperature of the burning gases is of the order of 3,000° F., it will be appreciated that "Fire Point" value of a lubricating oil is not of major importance.

Viscosity:

The viscosity of a liquid is the coefficient of internal friction opposing its change of shape.

It is conveniently expressed as the time in seconds



Redwood Viscometer.

A. Oil Cylinder; B. Bracket; C. Copper Bath; D. Tap; E. Heating Tube; H. Stirrer; J. Agate Jet; K Stirrer Handle; R. Standard; S. Thermometer Clip; T. Thermometers; V. Ball Valve.

Fig. 4.

taken for a certain quantity of oil at a stated temperature to flow through a fixed orifice. The main

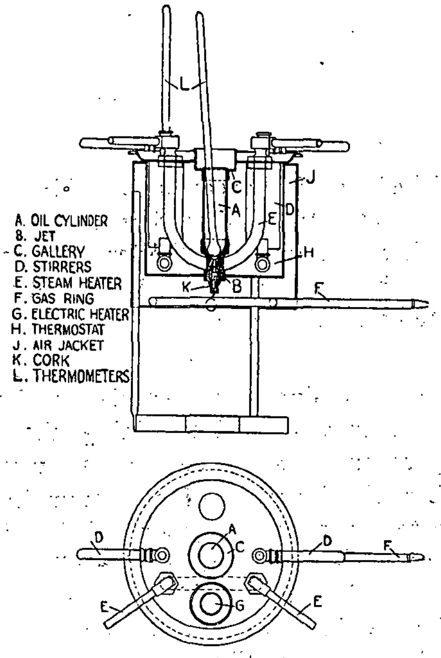


Fig. 5. Saybolt Viscometer.

instruments commonly in use for the determination of viscosity are the Redwood Nos. 1 and 2 in England, the Saybolt in America and the Engler on the Continent. The Redwood viscosity readings ordinarily stated represent the number of seconds taken for 50 c.c. of the oil at given temperatures to flow through the No. 1 Viscometer. This instrument is fitted with a jet of 1.62 mm. diameter and 10 mm. long made of agate, the hole being drilled

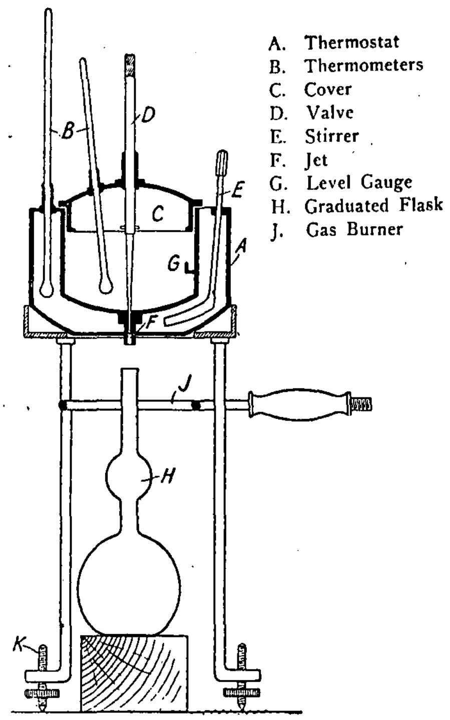


Fig. 6. Engler Viscometer.

and polished to the greatest possible precision. Fig. 4 illustrates the Redwood instrument. Fig.5 the Saybolt and Fig. 6 the Engler. Other instruments for the measurement of viscosity do not necessitate discussion here.

Other tests conducted for speciality oils are:— "Acidity"—a means of determining the increase in acidity of an oil after use. It is expressed as the number of milligrams of potassium hydroxide necessary to neutralise 100 grams of the oil. This test is used for such oils as turbine oils after protracted use, an increase in acidity beyond a certain point being an indication of the tendency of the oil to sludge more readily.

"Carbon Residue":—A means of ascertaining the residual carbon remaining after the volatile hydrocarbons have been driven off by heat applied in a certain manner.

Cloud Point:

This is the temperature at which contained wax or other solids begin to crystallise out when the oil is chilled under certain specified conditions. Fig. 7 shows the apparatus used.

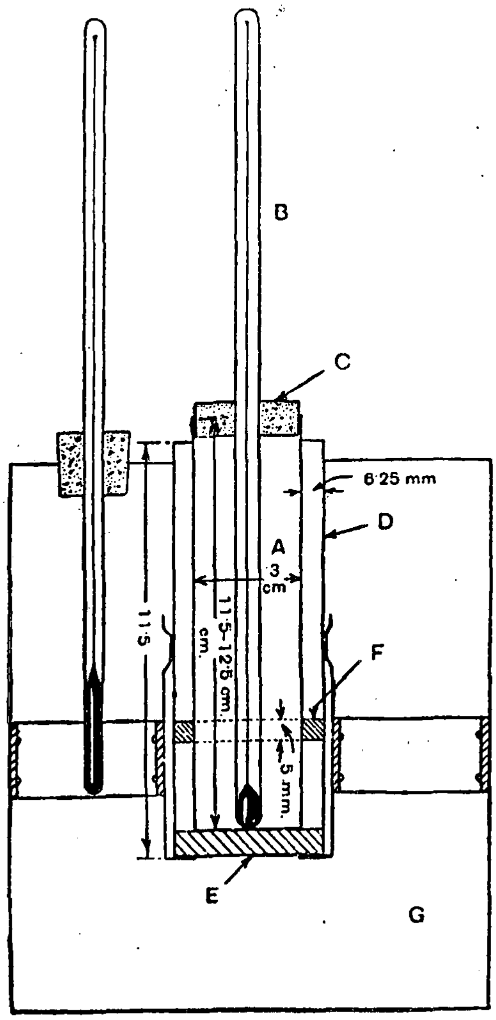


Fig. 7. Pour and Cloud Point.

Setting Point:

The temperature at which a sample of oil just ceases to flow when submitted to a pressure equal to a head of 5 cm. of water under defined conditions.

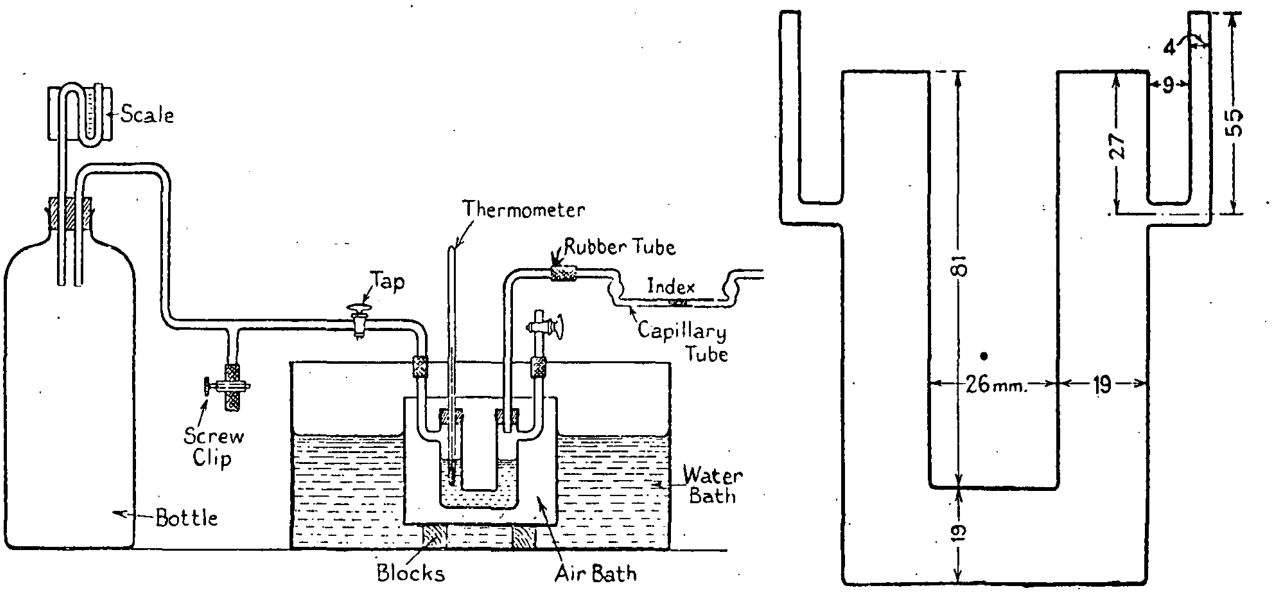


Fig. 8. I.P.T. Setting Point.

Setting Point

The apparatus used for this is shown in Fig. 8.

Demulsification Value:

The time required for an oil to separate when emulsified under prescribed conditions. Used for turbine—crank chamber oils, etc., where there is a likelihood of water leaking into the oil reservoir

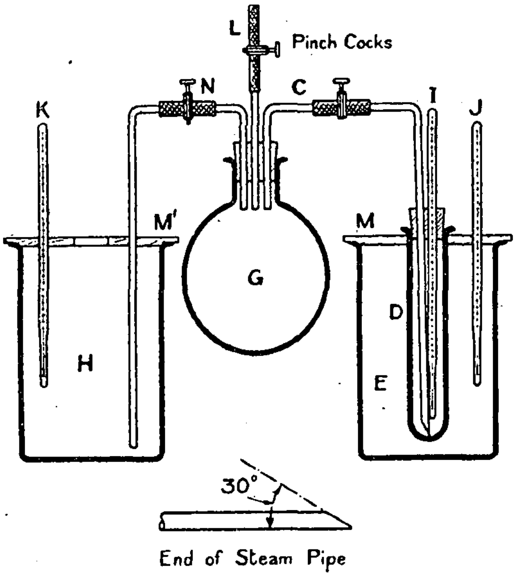


Fig. 9. I.P.T. Demulsification.

and is a useful test for indicating the liability of an oil to emulsify under working conditions. The I.P.T. standard method, the apparatus for which is shown in Fig. 9 consists of passing steam at a rate sufficient to maintain the temperature of the oil between 190 and 195° F. into 20 mls. of oil placed in a test tube until the total volume of oil and condensed steam reaches 40 mls. The tube is then withdrawn and placed in the beaker, "H," containing water at 200° F. to 203° F. The time is noted from when the steam pipe is withdrawn until separation is effected in the tube and the number of minutes is taken as the demulsification number.

There are many other tests for specific purposes, but these are too numerous for inclusion in this paper, neither are they necessary in discussing practical lubrication problems.

CONCLUSION.

It is felt that in attempting to compile a paper on lubrication to be of some interest to engineers and others in the Sugar Industry, the subject tackled is too comprehensive to be effectively dealt with in so short a space.

The author must therefore apologise for the superficial manner in which certain details of such an interesting subject have been touched on and would crave the indulgence of his audience in this respect.

The CHAIRMAN: Well, gentlemen, we are very much obliged to Mr. Rhodes for the very interesting paper on lubrication which he has given us, and especially for the fact that he has come all the way from Johannesburg to read this paper. The paper is now, gentlemen, open for discussion, but please make your remarks as short as possible, because we still have another paper to get through before we close down for the day. Naturally we all know—especially the engineers know—of the importance of the subject of lubrication. We have all more or less had our bad quarters of an hour with hot bearings, and so forth, and in past years there has been no end of theories—usually made up by the victims of accidents—as to why bearings got hot, or why machines wore out before they should. And the tendency, on the whole, in the past has been to blame the oil. Well, the oil companies, I reckon, are asking for trouble when they place so many variegated kinds of oil on the market. Most of them are under more or less fanciful names. Some companies name their products after the stars in the firmament. Others name them after something else—animals in the zoo, and so forth. Most of the names convey practically no indication of what the oil is; they are broadly classed into engineering oils, cylinder oils and greases. That is as far as sugar factory use is concerned. Now in this paper we have a coherent account of how these oils are produced, their various characteristics, and the various different types of machinery for which they should be used. Mr. Rhodes' paper is quite a welcome one on this subject. I think it has been a most illuminating paper on the subject of lubrication. It is now open for discussion by members.

There is one point on which I would like Mr. Rhodes to enlarge, and that is the shape of the oil grooves, especially those required for a large sugar mill roller bearing. The difficulty, of course, as he has pointed out, in the lubrication of roller bearings, that is mill rollers, is the large mass of metal. The pressures, of course, are uncontrollable. We have no means of controlling the maximum pressure in a sugar mill. It might go up to almost anything, and one of the main difficulties in designing a mill roller bearing lies in getting the appropriate form of grooving. Some makers put in fanciful cross grooves, thereby using a considerable percentage of the bearing surface. Nowadays, the more reasonable method is adopted of putting in a single oil groove straight across the surface of the bearing, a little in front of the assumed line of maximum pressure. Now the shape of the oil groove has a great deal to do with efficient lubrication. Mention is made, of course, of the "Mitchell" thrust bearing in this paper, and whereas we cannot adopt such a bearing for a mill roller —the Mitchell thrust bearing is applicable only to collar thrust, in the case of a journal bearing like the sugar mill roller bearing, we can get somewhere near it by designing the oil groove so that the section of that oil groove is wedge-shaped, with the wedge tending towards the direction in which the journal surface is moving.

Mr. RHODES: I think Mr. Camden-Smith has answered the question very ably himself.

Mr. JOHN MURRAY put a question with regard to the lubrication of Diesel engines, and the possibility and desirability of filtering the oil and using it over again.

Mr. RHODES: Diesel engine oil is perhaps the most difficult oil to filter of any, because it contains so much finely-ground carbon and dirt, which it is very hard to separate out from the oil. If an efficient filter can be put in to take out these impurities, then I say there is no harm in filtering good oil. The chief test as to whether the oil can be filtered is the amount of foul oil which is carried down and mixed with it. That can only be done by physical tests, seeing that the flash point is lowered and the viscosity at certain temperatures. If the oil answers these tests, there is no harm in filtering it and mixing it again with fresh oil, used, say, 50-50 in the mixture. The nature is not taken out of the oil.

Mr. JOHN MURRAY: Is there any difference between two-stroke and four-stroke in that respect.

Mr RHODES: No. The oil, after being recovered, should be in a very, very thin condition. In a two-stroke engine you use more oil, because you blow it out of your exhaust. There is no harm whatever in filtering the oil through an efficient filter.

The CHAIRMAN: I would ask you, gentlemen, to pass a hearty vote of thanks to Mr. Rhodes for his informative paper.

Carried by acclamation.

The CHAIRMAN: I have much pleasure in calling upon Mr. Pilkington to give us his paper on "The Tendency of Design in Modern Diesel Transport."