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LUBRICATION.

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Lubrication is the name that is applied to the various means devised to overcome friction in machines, and, consequently, the existence of friction is the reason for Lubrication.

Friction may be defined as a manifestation of that quality of matter which offers resistance to the motion of contiguous particles, whether these particles belong to different bodies, or are component parts of the same body. This definition applies to solid, liquid, and gaseous forms of matter.

If the surfaces of solid bodies are placed in intimate contact under pressure, molecular adhesion will take place. This phenomenon may be readily demonstrated with such substances as ice, copper, glass and lead. The behaviour of liquid and plastic bodies under like circumstances is well known.

Professor Spring has proved that metallic dust may be formed into solid blocks when brought under adequate pressure; the pressure required varying with the hardness of the metals, and varying also inversely as the temperature. His experiments showed, further, that cylinders of dissimilar metals carefully scraped at the ends will weld together when brought into intimate contact under pressure, at temperatures very much below their melting points. The molecules at the point of contact actually became diffused into one another, forming true alloys thereby, and welding so firmly that when under strain they fractured otherwise than at the welding point.

That quality, therefore, of which Friction is a manifestation, is the force of Cohesion or Adhesion, and is that force on which depends the integrity of all bodies whether solid, liquid or gaseous.

In the ordinary machine bearing and journal, we have on occasion all the conditions required to procure the welding of the metals composing them, and it is not astonishing that the phenomenon of seizing takes place in unlubricated and overheated bearings. This welding is most likely to take place when the bearing and journal are composed of similar metals, and is least likely when they are constructed of dissimilar metals. Hence, the co-efficient of friction between similar metals is usually greater than that which obtains with dissimilar metals. The figures given in Table I. are merely relative values, but are a confirmation of the foregoing.

Table I—Ordinary Bearings for Shafting (G. F. Charnock).

Bearing	Admissible load per square inch.
Wrought Iron on Cast Iron	250 lbs.
Wrought Iron on Gun Metal	300 ,,
Mild Steel on Cast Iron	300 ,,
Mild Steel on Gun Metal	370 ,,
Mild Steel on White Metal	500 ,,
Cast Steel on Gun Metal	600 ,,

As all metallic surfaces in contact are liable to overheating and seizure, it is necessary that substances should be interposed between such surfaces to prevent or minimise the difficulty. The office of these lubricants is to adhere to the moving surfaces and to keep them so far apart as to obviate their frictional or adhesive tendency. They do this by reason of their own adhesive qualities, and in so doing they substitute their own internal friction, or resistance to shear, for the friction of the metallic surfaces of the bearing. The power of the lubricant to hold the surfaces apart is proportional to its adhesive quality or viscosity, and with increase of pressures between the bearings there is required a corresponding increase in viscosity.

In considering the lubricating question as a whole, careful attention must be given to the scientific designing and skilful construction of journals and bearings, to methods of lubrication, and to the wise choice of suitable lubricants for each and every service.

Chiefly to the experiments of Tower, whose results are recorded in the Proceedings of the Institute of Mechanical Engineers, and to the subsequent work of Reynolds, engineers are indebted for those data which make the scientific design of bearings a possibility. One result of their work is seen in the "Michell Thrust Bearing," which was recently described to this Association. The most practical point demonstrated by these two experimenters was, that in all fluid lubrication it was necessary to maintain a pressure film or wedge of lubricant between the two surfaces of a given bearing; and that, if the conditions were not such as to maintain this film, lubrication failed.

In Figure 1, reproduced from Mr. Taylor's paper, will be seen how the wedge-shaped film C A of oil is maintained above the pivoted segmental block S, in the design of the Michell Thrust Bearing.

In ordinary journal bearings the wedge is, of course, a curved one. Engineers, by a process of evolution, have secured in such bearings the conditions necessary for the formation and maintenance of this wedge-shaped film.

Figure 1.—Michell Thrust Bearing.

In all cases the thin edge of the wedge points in the direction of rotation of the journal, and with a plentiful supply of oil the film increases in thickness with increase of speed of rotation. The oil escapes at the point of the wedge and at the sides of the bearing. It is necessary, therefore, in order to maintain the pressure film, that a quantity of oil is carried into the butt of the wedge sufficient to supply loss and to maintain the pressure. Such a condition is known as perfect lubrication, and is probably only secured by means of an oil bath, in which the idle side of the journal runs, or under a good system of forced lubrication. When perfect lubrication

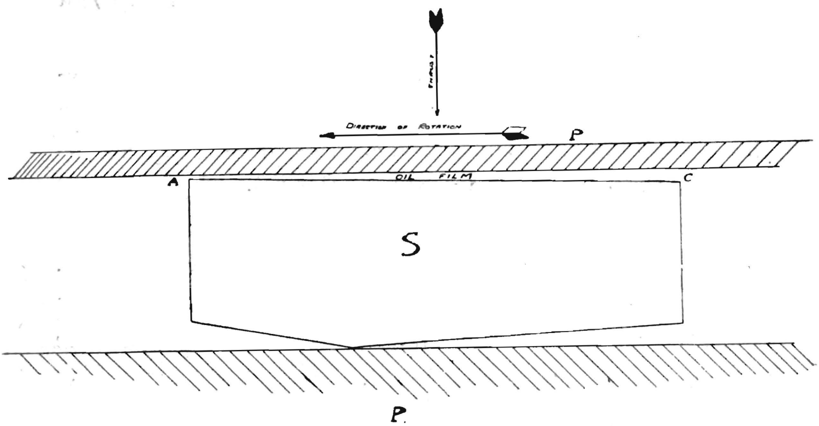

DIAGRAM SHEWING PRINCIPLE OF MICHELL BEARING

Fig. 1

is achieved, the whole load on the bearing is carried by the oil film, and there is no metallic contact of the moving surfaces. Under such conditions the friction is really independent of the load. A notable experiment was made by the Westinghouse Co., of East Pittsburg. A load of 94,000 lbs. was taken on a bearing 40 inches long, fitted to a journal 15 inches in diameter, running under conditions of perfect lubrication. The measurements taken of the butt of the oil wedge were .0019 inches, and .00314 inches at 470 and 1070 revolutions per minute respectively, showing that the thickness of the oil film increased as the speed of revolution increased.

Figure 2.

Figure 2 will serve to show how the wedge C A is automatically formed in ordinary axle and main bearings.

Where it is necessary to apply lubricants through holes drilled through the brasses of a bearing, such holes and their grooves should be placed to feed the oil so that it is readily carried into the pressure film through the base of the wedge. Where the speed of rotation of an axle is reversible, the wedge will automatically reverse itself, and provision must be made for oilways on both sides of the centre line of the brass, each so arranged as to allow it to feed into the base of its allotted wedge, and yet in such a position as to be clear of the point of the wedge formed by the reversal of rotation. The latter point is important, as an oil hole within the area of the pressure film is capable of relieving the pressure and destroying the film.

Figure 3.—Pressure of Oil Film.

In the case of an ordinary stationary bearing, the problem is simpler, as oil applied anywhere on the upper side of the journal has a good chance of finding its way into the pressure film on the lower part of the bearing. The formation of oil films between crossheads and their guides is a more difficult proposition. For a given direction of shaft rotation the pressure is always taken by the same guide for both the forward and return strokes of the piston. Crosshead shoes are famous for the facility with which they remove lubricants from the guides, and under the added influence of constant pressure between the surfaces, the guides are frequently dry.

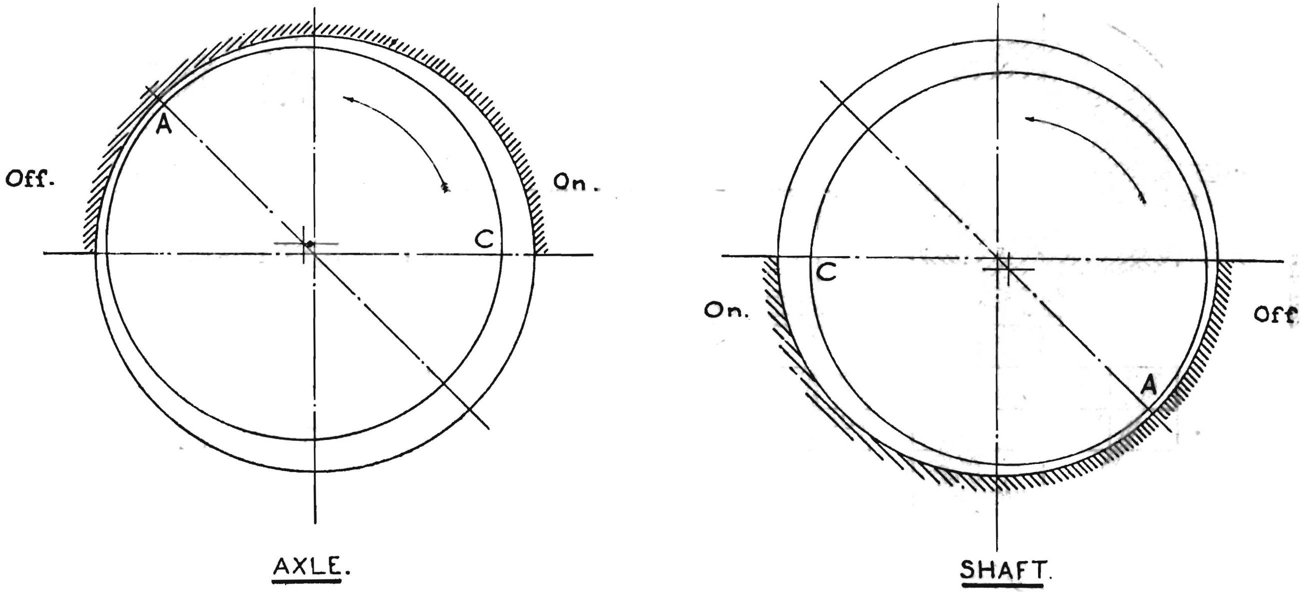

FIG. 2.

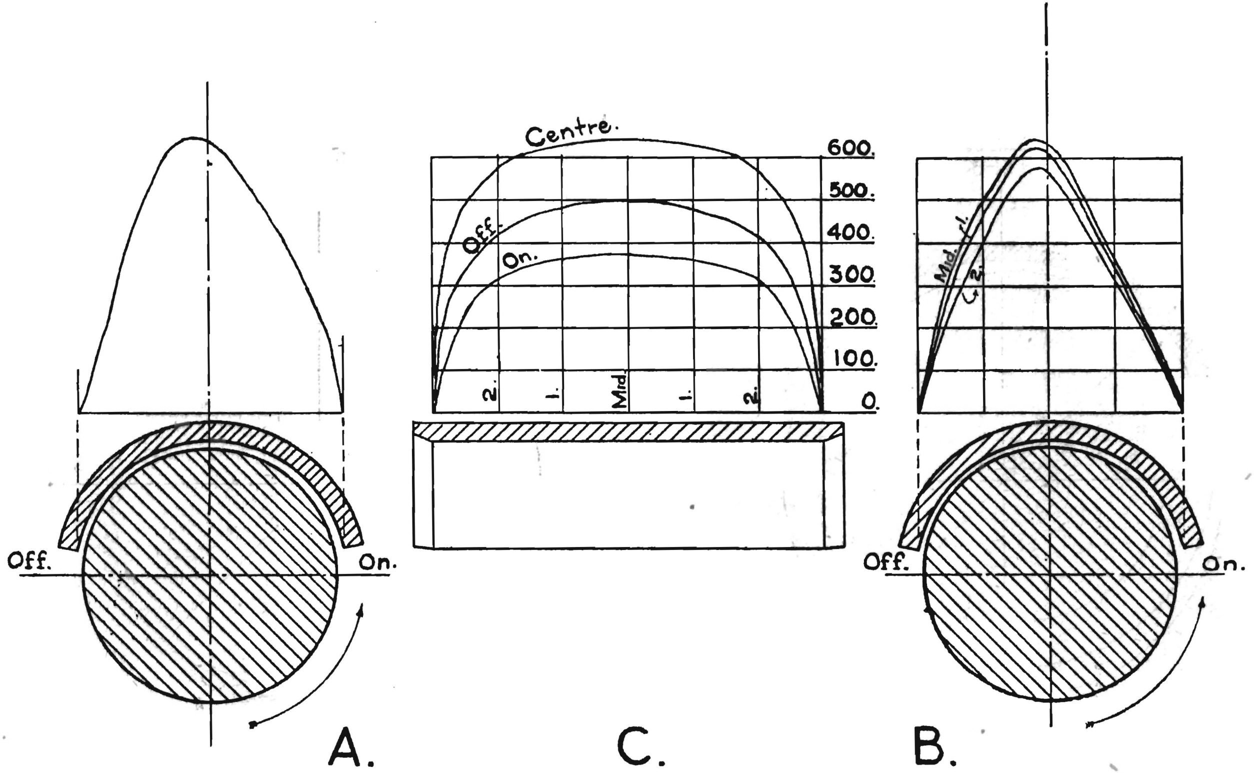
Centre.
Off.
On.
600.
500.
400.
300.
200.
100.
0.
2.
1.
Mid.
1.
2.
Mid.
1.
2.
Off.
On.
Off.
On.
A.
C.
B.

FIG. 3

Figure 4.—Crosshead.

The author suggests that the formation of the pressure film might be positively secured by the means shown in Figure 4, where the bearing surfaces of the crosshead shoes are finished with angular faces, not parallel with the guide bars in either direction. If it is found necessary to pivot the shoes as shown, in order to secure the ideal angle that should exist between the bearing surfaces, the rocking motion may be easily controlled by means of the shaping of the recesses in the head, in which the shoes are housed. Possibly the faces of rigid shoes may be finished at an angle approximating sufficiently closely to the ideal one, but in any case the amount of rocking to be allowed for will be infinitesimal. As the diagrams show, the pressure for any given stroke will fall on one end of one slipper only, and is in a direction opposed to the direction of the pressure of the oil film. It will be noted that the butt of each pressure oil wedge is toward the direction of movement for the time being.

In cylinders there seems to be little hope of attaining to the conditions of perfect lubrication. Fortunately many steam engine cylinders will run with practically no specially introduced lubricant. In such cases lubrication is doubtless performed by the wetness of the steam and by such oily matter as is carried inside by the piston rod. If the weight carrying quality of the piston rod be supplemented by the use of a tail rod, the whole weight of the piston, even in a horizontal engine, may be supported, so that no pressure, due to piston weight, will be borne by the cylinder walls, and the only mechanical friction in the cylinder will be due to the moderate pressure of the piston rings. This arrangement simplifies cylinder lubrication, and allows an increased engine efficiency, besides reducing maintenance costs.

In some large horizontal engines, designed by an English firm for cotton mill drives, the tail rods are supported on slippers and guides. A sufficient reverse camber is given to the tail rod, so adjusted that the rod is straight when carrying the piston load. According to the "American Electrician," an American rail-

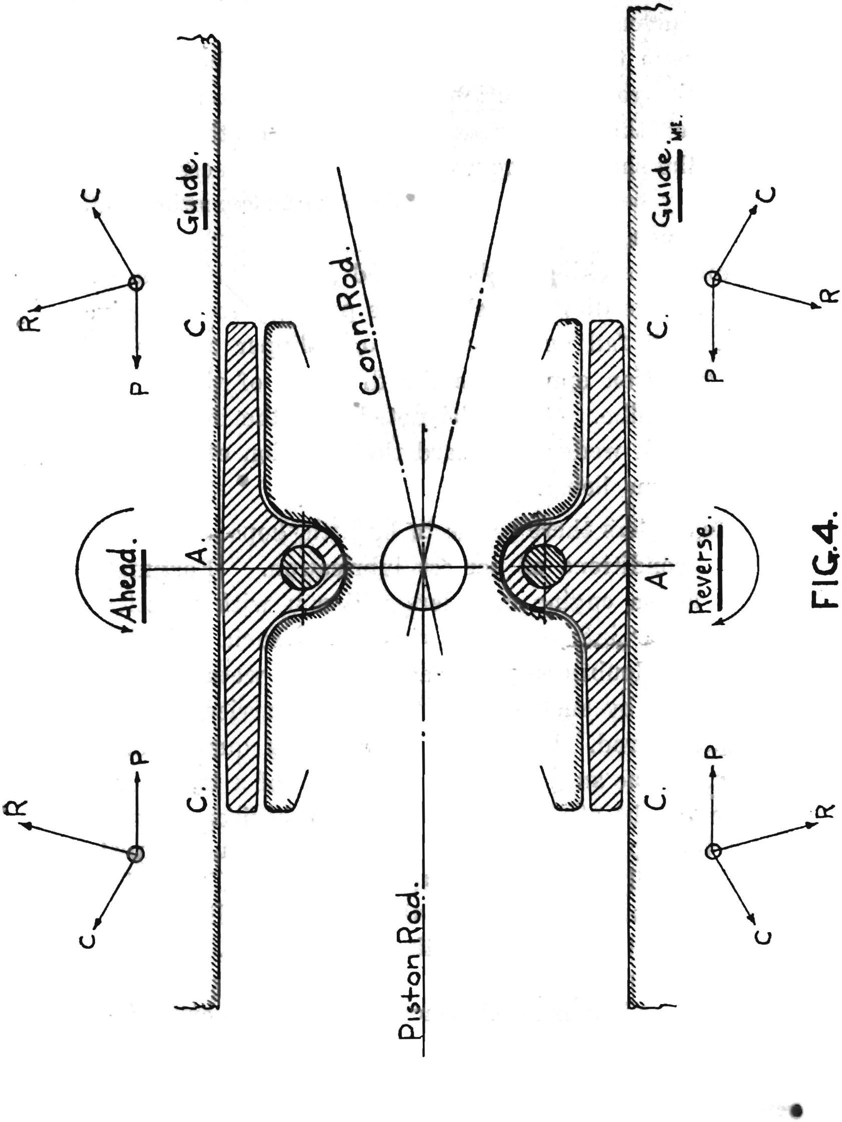

FIG.4.

way company stated that the fitting of tail rods increased the capacity of a 1,000 horse-power cross-compound condensing Corless engine by 10 per cent. The actual increase in efficiency is not recorded, but mention is made of a regular saving in steam consumption.

Lubricating Oils and Greases may be tested for their physical properties by standard instruments, which ascertain the gravity, viscosity, flash point, firing point, setting point, colour and volatility. Their chemical properties may be examined by such means as the sulphuric acid tests, free acid test, iodine test and acetic acid test. The mechanical properties may be examined in many standard testing machines, in which are determined co-efficients of friction, temperature rises, and the wearing of bearing surfaces under the influence of various lubricating media.

The ordinary hydrometer is generally used in the gravity test, but with the Westphal Balance, and particularly with the specific gravity bottle, more accurate results are obtained. Hydrometer readings vary inversely as the temperature: the co-efficient of expansion for lubricating oils being .00034. Naturally the viscosity of oils varies somewhat as the density, but in practice no reliance can be based on the hydrometer test in this respect.

Table 2.—Specific Gravities of Various Oils at 60° F.

Name of Oil—	Average Specific Gravities
Castor Oil	.964
Rape Oil	.914
Olive Oil	.916
Cotton Seed Oil	.924
Linseed Oil	.934
Lard Oil	.914
Neatsfoot Oil	.916
Tallow	.947
Sperm Oil	.882
Whale Oil	.923
Rosin Oil	.960—1.02