FRICTION

OF

SCREW PROPELLING ENGINES.

FRICTION, the subject of this paper, from its importance in the practical science of machinery deserves special consideration in the study of the Marine Engine. It is, as you know, a source of heat, and by using heat to generate heat, we have a loss of energy which would otherwise have been used in performing useful work, and increasing the efficiency of the motor. In the construction of engines, and especially those of great weight and power, too much finish cannot be given to the working parts, and even where bearings are seemingly smooth, if they are examined by a microscope, they will be found to be covered with inequalities, and these are the best generators of heat in moving surfaces. Lubrication will not remedy the results of really bad or hurried workmanship, and this will readily be understood by noting the action of oil or other unguents between moving surfaces. The thin film of the lubricant partially separates them, but if the surfaces are not good, the area of bearing is reduced, and the large quantity of the lubricant required does not reduce the friction, but acts rather in conducting away the heat generated.

Excessive friction, of course, does not always depend upon the roughened condition of the surface in contact. The rapid wear of bearings, and the trouble they cause when working, can very often be traced to an insufficient area of bearing surface. As an example, I will cite an instance of a Compound Engine having fore and aft cylinders. This Engine was tripled on the tandem principle, and the surfaces of the guides, crank-pin brasses, and main bearings were not increased, although they had to take the pressure applied to an additional piston and its consequent thrust. The result was, that after one voyage, these instances of what I will term oversight in re-arrangement, had to be remedied in detail as far as possible.

I will now proceed to enumerate some of the principal details of the Marine Engine, and consider them respectively with regard to friction, from a practical point of view.

In comparing the Marine Engine of to-day with its predecessors, we find that the working condition of the piston within the cylinder has not differed much since the introduction of the metallic packing ring, but I think when using a stiff spring the adjustment is often very faulty—the packing ring is forced to bear too hard against the cylinder bore, and therefore the friction of the piston when working is greatly in excess of what it should be. The method of using a floating ring for the springs to press against must greatly equalise the pressure applied to the packing-ring, but I think there is hardly a better all-round method of keeping the piston steam-tight than with the "Ramsbottom" rings. They are very light and effective. By using a sufficient number, say three or four, and having them properly cut and butted, and fitted into a cylinder with a good bore, they will not allow much steam to pass, and the wear of the cylinder must be considerably less than when using some other forms of piston packing. They are easily fitted to any piston by putting a grooved block ring over the body of the piston in the place of the broad spring ring.

The viscidity of the lubricant applied to pistons is a source of some friction, but a point of primary importance is the condition of the surface of the cylinder bore. When a cylinder has become polished by use, it is then in the very best possible condition to reduce friction, and to obtain this result the cast iron should be very hard and close grained, and have a well finished cut in the process of boring. Compressed steel liners are better still in this respect, and appear to have given every satisfaction.

The superiority of the position of the cylinder in the Vertical Engine has been proved by experience. At the present time there are still a large number of Horizontal Engines at work in the older types of vessels in the Royal Navy; but the Mercantile Marine, for the screw propeller, has universally adopted the Inverted engine as the motor giving the best results, and the Government designers of this and other countries have followed suit, in the construction of the modern ironclads and cruisers. From the nature of paddle-wheel propulsion, the Diagonal and Oscillating engine—both great producers of friction—are still in extensive use both for sea and river navigation. In the matter of friction, both the Diagonal and Horizontal engine exhibit a striking defect, notably the friction of the piston upon the bottom of the cylinder due to the effects of gravity. This is, almost without exception, a matter of very serious trouble, both as regards renewal and waste, for it is difficult to keep the piston steam-tight in a cylinder which has become oval. As a natural result it follows that the packing ring is pressed tighter against the cylinder walls and the percentage of loss due to friction is increased. In a little forethought in design or improvement after construction, lies a partial remedy for this evil. By the use of very light steel pistons and a guide rod through the back cylinder cover, and in directing the motion of the crank-pin when going ahead to give the connecting rod an upward thrust, the wear on the bottom of the cylinder can be considerably reduced.

With increased boiler pressures, and the general introduction of Triple Expansion, and the partial introduction of Quadruple Expansion engines, the packed stuffing box and gland have been a considerable item in the per centage of friction. The gland in a good many cases is screwed down hard, and so no small amount of the initial energy of the piston is expended in moving the piston rod. The rod is also at every stroke wiped comparatively dry by the packing, though this can be partially remedied by improved methods of lubrication. It is found that the best way to reduce the friction of the gland is to have a deep stuffing box, as deep as possible, and then screw the gland in lightly, allowing a very small amount of vapour to escape through the packing, and at the same time lubricate the rod. The deep stuffing box will be found as advantageous to the various pumps as to the steam cylinders and valve casings, and some fraction of the 9 or 10 per cent. of the initial power required to work the pumps of a condensing engine will be saved, and a considerable amount of scoring of rods and plungers will be prevented. Gentlemen, you all know, that, as an illustration of stuffing-box friction, it is possible to stop some of the old Trunk Engines entirely, by tightening the gland. I should be pleased to know the opinion of those present in the matter of metallic and other packings, where friction of glands is concerned.

In the Piston-Valve we have an improvement over the flat D valve in the matter of friction, and if its efficiency in the matter of keeping steam-tight is as great as it is in reducing friction, it is a great gain indeed, and it must supersede the flat valves that are fitted to intermediate and low-pressure cylinders. I am rather surprised to see the piston-valve has been adopted for the high-pressure cylinders *only* in some of the latest and largest triple expansion engines of some recent magnificent Trans-Atlantic and Oriental Liners. It is remarkable, that when economy in working is the chief desideratum, the question of first cost should be considered. The comparison between the piston or equilibrium pressure valve as regards friction is extreme, for in the piston valve the friction is only that of its packing rings when working vertically, while with the flat valve (and here I am speaking of engines generally), it has been calculated that in some cases it has required as much as one-fourth of the total steam pressure on the valve to move it upon the cylinder face. There are a number of devices for reducing the friction of the flat slide valve, such as double-ported and trick valves, bronze cylinder faces, &c., but where there is a flat moving surface, with an excessive back pressure, there must be a waste of initial energy due to friction.

It is questionable if any of the different patented methods of moving the slide valve can claim any advantage, in lessening friction, over the old double eccentric and slot link motion, although their superiority in manipulating the valve has done much to economise the use of steam. This was very well illustrated in the paper on "Radial Valve Gear," read before this Institute, and the discussion that followed thereon. In all forms of valve motion we have about the same number of working parts, their weights are about equal or do not differ to any great extent, while the weight of the slide valve remains constant, thus the gain in economy is not in regard to friction, but in the cut-off of the slide valve and the saving of valuable space in the engine-room by the use of valve gears other than the ordinary. The crosshead shoes and guide-plates of the marine engine generally develop a great amount of friction, and there are times when this is greatly augmented. I allude to the heating of the shoes and guide-plates when the steamer has a list, and this should be remembered in designing marine engines. *Under ordinary circumstances the pressure on the guides of a marine engine has been computed to amount to from 2 to 3 tenths of the piston load itself. and sometimes as much as one per cent. of the energy of the piston is required to overcome the friction of one guide. The length of the connecting rod combined with sufficient area of guide surface reduces this friction to the minimum. But the connecting rod, and *especially* in Marine Engines, is made too often very short. In horizontal or trunk engines this cannot very well be remedied and some of the largest ironclads fitted with the Inverted Cylinder Engines labour under this disadvantage, as it is of primary importance to have the Engines below the water line. In the Mercantile Marine, where economy in working is severely questioned, this should not be a glaring mistake in the Screw-propelling Engine of to-day. The method of running white metal into crosshead shoes, although expensive, possesses some advantages over ordinary cast iron upon cast iron; it is easily renewed for lining up purposes and at the same time it gives less friction. In well designed engines with a long connecting rod and sufficient area of bearing surface the attrition of the metals should be very little indeed.

The journals of the crank shafts of Marine Engines—those of

* A. E. Seaton.

the vertical type—are considerable producers of friction. The shaft, connecting rod, piston-rod and piston are all heavy parts in themselves, but when we add to this the total steam pressure applied to the down stroke cf the piston, necessity requires the main bearings to be very carefully designed. Amongst the improvements that have tended to reduce the weight of the crank shaft, the introduction of steel may be mentioned, and this was dealt with in a very exhaustive manner by Mr. Manuel in his paper on "Crank and Screw Shafting in the Mercantile Marine." With regard to the bearings of crank, tunnel, and screw shafting, I think there is really very little room for improvement. The improvement must be in the material of the working parts, by reducing weight, and consequently friction. White-metal as a bearing surface for shafting and lignum vitæ for the screw-shaft, are both admirably adapted for their work; but the friction of weight must be distributed to as long a bearing as possible, and great care should be taken in giving the finishing cut. A number of ordinary cargo steamers are allowed to run with their tunnel shafting out of line, which means a great amount of attrition on the bearings taking the weight, and I think this is noticeable in loaded and light steamers generally, more especially when the engines are placed near the centre of the ship, and I do not see why flexible couplings should not prove serviceable. The questions of shaft bearing, and the distribution of the thrust of the screw over a sufficient area of surface are about the most important, excepting the propeller, in the friction of Marine Engines. There is a fact patent to all engineers, viz. :—that rolling surfaces generate much less friction than sliding ones, and I do not see why roller bearings are not extensively used for one of the bearings of the Marine Engine at least. They would not be serviceable for the main bearings of Engines of great weight and power, but they can be adapted to the thrust bearing, and thereby greatly reduce the friction caused by the thrust of the propeller.

In the foregoing remarks I think I have touched upon all the important generators of friction in the details of the Marine Engine. I have not criticised the minor working parts, because when improvements are made in the most important parts, the working condition of the minor parts will also be improved.

The screw propeller claims some consideration with regard to power unnecessarily absorbed when moving. I will not deal with its shape because if it is properly moulded, yet has not sufficient area of surface, the loss caused by it partially churning the water will come under the heading of slip. As to the material used in its manufacture, here, I can stand upon firmer ground. Unprotected cast iron should be condemned. It is found after having been some time in use that the surface of the blade becomes pitted with small holes, the cause of which I believe is the inferior particles of iron being drawn out as the blade passes through the water. This is especially noticeable on the reverse side of the blade, the surface of the side striking the water being generally more smooth. The result of having a propeller blade with a very rough surface means a consequent loss of power. The friction of the rough blade passing through the water, although perhaps not much, may mean a considerable waste of fuel in the course of a long voyage. I believe the difficulty in using cast iron for propeller blades has been remedied to a certain extent by a process of fusing thin sheets of copper on the outside of the iron when the molten metal is run into the mould. But cast iron blades are heavy, and cause a great weight upon the stern tube bearing, and in the face of other and newer materials, cast iron for blades is becoming obsolete.

By using steel as a material for propeller blades, they can be made much thinner than when cast iron is used. They are stronger, more ductile, and in every way more efficient than cast iron; but it is a curious fact that steel corrodes very rapidly in salt water, thus requiring very frequent applications of paint. Phosphor bronze and manganese-bronze are the favourite materials, having proved themselves worthy of the great first cost incurred. As the metal is very tough and strong, the blades can be made light, and there is little loss by corrosion. They are very smooth, and create little frictional resistance in the water. Some little time ago a paragraph appeared in a leading Engineering journal, stating that one of Her Majesty's warships had been fitted with Phosphor-bronze in the place of Cast iron Blades, and that during her machinery trials, when running with her usual supply and pressure of steam, she developed a speed of fully three quarters of a knot more per hour, due solely to the reduced frictional resistance of her propeller, the surface of the blades being very smooth in comparison with cast iron. These are matters for very careful consideration, and demand the attention of all responsible for the economical working of steamships, being after all only a question of first cost. All the wished-for advantages are claimed for Delta-metal, and a large number of fast cruisers belonging to various Governments have been supplied with propellers made of this material. The thinness of the blades and the smooth surface of these alloys are the dreams of mechanical men realized, and with a carefully designed propeller, with protection caps for the nuts we can safely say that a great frictional resistance is removed from the screw propelling engine.

Gentlemen, this paper has been written not with a view of imparting information, but rather of receiving valuable hints and suggestions that may emanate from various speakers in the course of a discussion which I hope will follow.

CHAIRMAN'S REMARKS.

(Mr. L. P. Coubro.)

It has been a great pleasure to me to preside at the meeting to-night and listen to the Paper prepared by Mr. Brett, who was one of the apprentices brought up by the firm with which I am connected, and is still employed with us.

The Paper which has been read, I have no doubt will be of great service to the Juniors, especially when printed along with the Discussion, which I look forward to as likely to be very interesting and valuable.

Most of the working parts of the engine have been referred to, and there is ample choice for members to take one portion or another, and give their views on, whether it be the Piston rings rubbing on the walls of the Cylinder, Piston rods against the packing, journals working in brass or white metal, or the Propeller blades of iron, steel, or bronze working their course through the water.

The Honorary Secretary will read the remarks of an absent member.

MR. GEO. W. BUCKWELL'S REMARKS.*

(Read by the Secretary.)

I wish to say a few words in reference to the Author's remarks anent the Diagonal and Horizontal paddle engine. I have been for nearly two years in a paddle steamer fitted with Engines of this description, the high pressure Cylinder being horizontal and 48 inches diameter, the low pressure being diagonal, inclined at an angle of 67°, and 83 inches diameter, both being 5 feet stroke, and working at a Boiler pressure of 80lbs. Both Pistons have tail rods, working in trunks jointed to the back Cylinder covers, the trunks being fitted with bearing brasses, capable of adjustment by three set-screws in the bottoms of the trunks. The lubricating arrangements are I suppose as perfect as they can be, but it is almost an impossibility to keep the brasses from scrooping. Various descriptions of oils, paraffin, and soap and water even, have been

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* See Sketch on page 33.

used, but to very little purpose; the difficulty of adjustment is even greater, for a very little alteration of the set-screws causes the front-end Piston rods to heat up. The nuisance has been so great in one way and another that it has been seriously thought of cutting the tail-rods off altogether, but I suppose expense has prevented it hitherto. The engines are not new, and other engineers who have been with them are all of the opinion that the tails are a mistake. This expression of opinion bore fruit in two steamers of the same class that were built four years after this particular one and a sister ship. The tail rods were discarded and a shoe cast on the Junk ring, as shown on the accompanying sketch, which is a vertical section of the low pressure piston; the shoe extends round the bottom of the ring for a distance of nearly 8 feet, this of course considerably lessening the weight per square inch on the Cylinder liner. I was in one of the steamers thus fitted for about four months altogether at odd times, and can safely say that the engines appeared to run much freer, and the Cylinder liners keep very smooth.

With regard to the loss by friction through the Piston springs being too stiff, I am of the Author's opinion that the adjustment is often very faulty. The Cylinder of one steamer I was in was very much scored, and when the Piston was overhauled, we tested the springs to see how much pressure was put on the packing ring, and came to the conclusion that it was about 10 to 12 lbs. per square inch of bearing surface; the springs were reset and fresh tempered to give only about 3 to 4 lbs. pressure per square inch, the result being that we got two revolutions per minute more out of the engines.

In reference to metallic packing, I was in a twin-screw steamer fitted with Jerome's metallic packing, and we had to allow the steam to leak a bit through the glands for the simple reason that the speed at which the engines ran (142 revolutions per minute) rendered it impossible to keep the rods cool if they were any tighter, but they got a beautiful surface on them, the lubrication being with Crane's oil.

MR. F. W. SHOREY'S REMARKS.

This Paper has a special interest as being the first given to this Institute by an Associate.

Mr. Brett has touched upon most of the principal parts of the Marine Engine subjected to friction.

With regard to packing rings for Pistons, I do not quite agree with him as to the Ramsbottom rings. They may be certainly very good and cheap rings for small pistons, but when used for pistons above 2 ft. or 2 ft. 6 in. in diameter, I have found that they do not expand equally in the Cylinder, and that they invariably wear mostly on the two sides and are also likely to wear the Cylinder out of truth. Having to supply a great number of these rings, and often getting an old one sent as a pattern, in most cases we find it to be worn as described. Mr. Brett asks opinion in the matter of piston gland packing. I should certainly give preference to metallic packing for high pressure glands before any of the numerous other packings in use. I have been watching with interest a patent packing brought out by one of our members; he has had it tried for the past eighteen months, and has tried it himself in the vessel he is chief of with the greatest success. It consists of metallic segments arranged with asbestos or other soft packing placed at the back so that it gives an elasticity to the metal segments, whilst the metal only comes in contact with the rod, this style I consider to be one of the best at present in use. It is very simple and can be drawn readily.

MR. W. W. WILSON'S REMARKS.

I beg to differ from Mr. Shorey, and agree with Mr. Brett regarding the superiority of Ramsbottom's rings for Marine Engine Pistons. When I first went to sea the old D spring was the one usually in use for pistons. These were, as a rule, put in by entering one end and the centre, into the space between piston and packing ring, and then levering off the other end with a bar from the cylinder walls, till it also could be pushed down into its place. Some engineers, to make the work easier, formed a kind of half hoop of wrought iron, having a pinching screw in the centre with which they put on the necessary pressure to reduce the set of the spring to fit the space, and then when entered, the hoop was removed and the spring driven home. This was very handy, but still both systems were very unsatisfactory, as there was no gauge of the amount of pressure that was put on, and the consequence was, that in too many cases, the rings were far too firmly pressed against the cylinder, thus causing a very considerable amount of unnecessary friction. Besides those springs there is another pressure that I think is often overlooked. I allude to that of the steam which leaks into the piston, thus causing an extra force on the back of the ring. I know of one ship whose H.P. Cylinder was so badly worn and cut up (from the above cause I believe), that after two or three voyages the cylinder had to be bored out and a new piston fitted. This new piston was fitted with a set of Ramsbottom's rings, and the result is that the ship is running with these, and with very little perceptible wear on either cylinder or rings, although it is now over three years since they were fitted. In the Ramsbottom ring the pressure of steam alluded to above, does not matter so very much, as there is so much less surface to take the pressure, and I have seen in small pistons of this class provision made for letting steam to the back of the ring, two or three $\frac{3}{8}$in. holes being bored in the end of the solid block piston, and a $\frac{1}{8}$in. or smaller hole bored from bottom of ring groove, into these holes. By this means steam got in at the back of the ring, and not only assisted in wearing it out to its utmost, but kept it from setting fast in the groove. Altogether, I think that Ramsbottom's rings are the best.

The Gland Packing which Mr. Shorey speaks of is not a new idea, for about 17 years ago I fitted several sets for piston rod glands, the only difference being a single cone instead of the double cone.

With regard to the Friction in Crank Shaft Bearings, Mr. Brett says: "Amongst the improvements that have tended to reduce the weight of the crank shaft, the introduction of steel may be mentioned." Now I think Mr. Brett is in error in this, for I have examined the formulæ for Shafting in Board of Trade and Lloyd's rules, and don't see that any reduction of weight has been allowed for steel shafting. I may be mistaken in this, and I hope to hear what others have to say on this point.

Mr. Brett has left out one item, which I presume he includes in the minor parts, but which I think is of importance. I mean the Pumps. I think it is now nearly time that the system of packing buckets with rope or plaited gasket should be discontinued. For Air-pumps, I cannot see why a set of rings such as Ramsbottom's should not be fitted, and for Circulating-pumps, I believe that water packing is perfectly efficient. I am convinced that a very great amount of power is wasted in pumps through the friction of the packing of buckets.

As to Propellers, I understand Mr. Brett to mean that cast-iron is condemned owing principally to the corrosion that takes place on the front of the blades. Now my experience is that steel corrodes much quicker, and the reason for cast-iron being condemned is because of its weight, it requiring to be much thicker, thus causing an increased bluffness on the edges. There is no doubt that Manganese or other bronze blades tend very much to reduce the friction of propellers.

MR. ROBERT BRUCE'S REMARKS.

The subject with which the Author deals is one of great importance to the Marine Engineer, and no doubt improvements in design, combined with improvements in the quality of the materials at the disposal of the Engine Constructor, which enable him to combine lightness with rigidity in a greater degree than heretofore practicable, go a great way to reduce the inconvenience arising from the absorption of useful effect by the friction of the several moving parts of the machine.

The effect most essential in Pistons fitted with packing rings is not so much that they shall remain steam-tight side-ways, but that they shall remain steam-tight *endways*, as leakage on the top and bottom ends of the packing rings increases materially the friction of the rings against the Cylinder walls. The Piston of the "Crosby" indicator seems to me an ideal one, and if this principle could be employed in the larger pistons of the Marine Engine it would go a great way towards the reduction of piston friction. The Piston of the "Crosby" indicator is made as light as possible, and is provided with steam chambers in the outer surface on which the steam acts and prevents the piston from touching the sides of the cylinder.

In regard to the use of Piston-valves, I do not think that this type of valve in *any* form is an unmixed blessing. I think if they are to be used at all their use should be confined to the H.P. Cylinder, the steam taken from the *inside*, and the pistons *without* rings, the area of the upper piston being made a little more than that of the lower piston in order to balance weight of valve and valve gear. When of the common type, a danger in using piston valves arises from the fact that, in fitting the working chamber closely, there is no relief for the accumulated water of condensation; in other words the valve cannot lift "off the face," and this no doubt to some extent accounts for so many broken pistons in the H.P. Cylinders of triple expansion engines fitted with Piston-valves.

With regard to the reduction of friction by the adoption of "Radial valve gear" in place of the ordinary link motion, there can be no doubt that in the radial system less power is absorbed in moving the valves when the gear is of proper design, there being *no sliding* surfaces other than the valve spindle guide, and the leverage obtained through the ratio of the two arms of the valve lever, being an advantage over the smaller leverage of the eccentric arm in the common-gear*, besides *eccentric straps* become more or

* See Fifth Paper of Transactions, I. M. E., page 14.

less "break straps" on the eccentrics fixed to the shafts. Further, among other points of advantage derived from the adoption of radial valve gear, there is the gain in bearing surface for the crank shaft, which may be obtained with the shorter Engine due to bringing the Cylinders closer together, and as the tendency in Marine Engines is to increased speed of revolution, and as friction increases as the velocity of the rubbing surfaces increases, it follows that the extra surface required to take the wear, ought to be provided by the increased length of bearing available by using non-eccentric valve-gear.

MR. R. MARSHALL'S REMARKS.

Whilst agreeing with Mr. Wilson that the Ramsbottom Piston is best for H.P. cylinders I can not agree with him as to the cause. It is not sufficiently recognised that it is next to impossible to prevent steam getting behind the rings, pressing them against the Cylinder wall. So far as wear is concerned the steam pressure per unit of area being the same, a narrow ring will wear as fast as a deep one, but a deep ring will wear the Cylinder more, and at the same time act as a brake-shoe on the Engine. The reason the Ramsbottom rings last so well is, I believe, they are not quite tight, so that they allow steam to pass between them and the Cylinder wall, balancing, in a measure, the pressure behind them. The indicator card probably will not show this leakage and it is of less consequence as the steam has still two Cylinders to work through.

This leads up to the question of the use of Piston-valves in Marine Engines. Piston valves involve large clearance spaces; they are great steam eaters. As with the Piston leakage in H.P. Cylinders, the evil effects are reduced on account of the other two Cylinders to be worked through by the steam, the loss of efficiency is not so great, but I do not believe in Piston-valves for intermediate and L.P. cylinders.

Sufficient attention I think is not paid to the Exhaust port of the ordinary Slide valve, for by keeping this as small as possible the area of the back of the Valve can often be much reduced. The minimum size need not be larger than the size of the steam port, for it is obvious the steam has to pass out of the steam port, and to make it travel a few more inches through an orifice of the same size cannot make any material difference.

MR. J. McFARLANE GRAY'S REMARKS.

This is the first Paper we have had from one of the juniors of this Institute, an Associate. The subject, Friction, is a most important one and it ought to be carefully studied by all engineer students. The author does not mention the experimental researches of the Institution of Mechanical Engineers upon friction, I therefore conclude that few of you know about them. The laws of friction were generally taken to be what Unwin had stated until these later experiments in 1883-4-5 which completely upset all our previously established notions. I have brought these reports with me and shall read portions to you, and now suggest that the author of the paper should write out a summary of the results from these reports, to be added to his paper. According to these experiments frictional resistance does not increase with the load, if the load be not too great for the oil. As long as the surfaces are separated by lubrication the resistance appears to be independent of the load, and is sometimes even less with a greater load. The resistance seems to increase when the velocity increases.

The co-efficient of friction is extremely small and it appears to me that it is even less than it is stated to be in the paper. As I read the report, the co-efficient is calculated upon the direct load on the journal, whereas the co-efficient of friction ought to be calculated on the total rubbing pressure. This difference is not clearly understood by all Engineers; I will therefore try to explain it. You know that the pressure per square inch on a journal is always calculated as the load divided by the product of length by diameter. Some men think the division ought to be the product of length by half-circumference, and few know why the former method is the correct one. Let the load be a vertical one; if it is borne by a flat, horizontal surface the total pressure will be the same as the total load. If the supporting surface be inclined as the two sides of a wedge, but the same in plan as before, the total pressure will now be increased in the same proportion as the area of surface has been increased, and the pressure per square inch will be the same as before over the increased surface. It is the same with a journal of which the pressure is the same per square inch over the whole arc of contact, the load is that due to this pressure on the area, length by chord, and the total rubbing pressure is that due to the same pressure on the area, length by arc. The pressure will not be the same all over, but however it may vary, the load supported by any portion of the surface is that due to the pressure per square inch on it over an area equal to this portion in plan, while the pressure upon it is actually due to the same pressure per quare inch over the inclined area. The additional pressure is created by the wedging action of the bearing. This reasoning shows how useless is the side surface of a bearing. A portion which is in plan one-fourth of an inch wide and on the circle one inch, has a rubbing pressure four times the load which it supports. If the young men who wish to grasp this will work it out on paper according to the principle of compounding forces they will then understand it better. They may afterwards note that this is also the same as fluid pressure upon inclined surfaces.

The principle of lubrication is very well brought out in the report of these experiments. I think it can be understood when we look upon the film of lubricant as a very acute thin wedge, which is drawn forward by adhesion to the journal, until it lifts the bearing off the journal, and the load becomes borne by the film of lubricant. It is in this way easy to see that the uniformly loaded bearings could not be oiled by an oil hole at the centre of the supporting surface. There the surfaces are closest, and, if a film were taken through, it would find itself in a wider space, whereas, when the oil is applied at some distance from the centre of pressure, it finds itself in a separating space, which is becoming thinner and thinner as the oil is carried forward, and the wedge action is established.

These experiments show how important good lubrication is, and they tell us that frictional losses may be reduced to be insignificantly small when this is attended to. Engineers were in a great measure prepared for this new teaching, because brake trials of Steam engines and Dynamo experiments, when compared with indicated horse power in many instances, did not show that there was a margin of deficiency sufficient for the friction due according to the old views. The extracts from the report will explain how the constant load upon a journal is different from the reciprocating load, and that the lubricating of the bearings of the steam engine by central oil holes has been possible only because the load has been reciprocating.

The great loss of power by the friction of the slide valve has been remedied in what seems to me to be a most beautiful way by the Church slide valve.

(Mr. Gray here sketched the valve and explained its construction, pronouncing it to be perfection in its simplicity and in its efficiency. A sketch and explanation is given at the end, p. 35).

MR. LESLIE'S REMARKS.

It has been a pleasure to me to listen to the paper read before us this evening by Mr. Brett, and I think that a subject of this kind is of great moment, not only to Marine Engineers, but also to all Steam-Ship Owners, in fact, I should say that any saving or economy in our mercantile marine machinery is of vital importance to all Ship-owners, and I think that this is a fact in which some have not taken (much to their loss if they knew it) any interest; but, as Engineers, it is our duty not only to point out all defects in machinery, but also to look into every corner so as to find out where improvements can be made, and we must not look upon it as a selfish interest, but rather as of National importance, and I may venture to mention two, which, I consider, main points in connection with this subject of friction, or rather, the reduction of friction in marine machinery.

The introduction of Phosphor Bronze metal for propeller blades, is, I think, a great step in the right direction, as the friction on the cast iron or pitted steel blades must (as we all know) be very great, and the surfaces of the iron and steel blades are, as a rule, rather rough, and do not unfortunately get any smoother after many voyages, as is the case with phosphor bronze blades. I have had the pleasure of examining a good many phosphor bronze blades, when the steamers have been in dry dock, and I feel quite convinced that both from a financial and mechanical point of view the phosphor bronze blades are a great success.

The friction on some of the Pistons used some years ago must have been very great, as the pressure applied to the packing ring against the Cylinder walls was sufficient to hang the Piston, Piston rod, connecting rod and brasses, but it is a pleasure to know that pistons of the present day in some steamers where they have three or four Ramsbottom rings fitted, show a great improvement, and I have seen them used with steam pressures of 150 lbs., and although the Piston was quite slack in the Cylinder, it was quite steam tight.

MR. DIMMOCK'S REMARKS.

I would remark briefly on two other additional sources of friction which have not been previously mentioned, viz:—1st, by the deflection of the vessel's hull; 2nd, by the resistance of the circulating pump. The hull deflects very considerably when the load of the cargo is not equally distributed, and when the vessel is in a sea-way, much more than is generally supposed, this is reduced to a minimum in smooth water. Of course, any movement of the hull affects the shafting, tending to put it out of line. As an example, a vessel took a permanent set which put the shafting out of line to an extent of seven inches, this does not mean the vessel hogged seven inches, but something like one-and-a-half inches, and this between the engine-room and stern frame, so that when the shafting was lined off from the stern tube it required the engines to be lifted as stated, no doubt this was an exceptional case.

With regard to the circulating pumps, excessive pressures are often caused by small valve areas. Sufficiently large areas being difficult to get where machinery space is limited, but chiefly to the friction of the water throughout the condenser tubes. I have seen indicator diagrams taken from circulating pumps where the pressure has actually reached 40 lbs. per sq. in., it is needless to say the power required to drive such a pump would be enormous.

MR. BRETT'S CLOSING REMARKS.

In regard to Mr. Buckwell's remarks, I think the method of making the Junk ring with a shoe, as explained by him, a very good one for diagonal or horizontal engines, where it can be conveniently fitted in the cylinder. The opinions expressed as to the use of "Ramsbottom" rings are varied, but no great objection seems to be raised against them by their non-advocates. As to their use when of large diameter, if they be made proportionally stiff, they ought to work well. The best sign in their favour is, that they are now extensively used for high pressure pistons. The best kind of packing for glands is still a matter of opinion, but I am inclined to think that a combination of metallic and softer material would work very well as mentioned by Mr. Shorey.

In reply to Mr. Marshall as to the increased clearance spaces being larger in the piston valve, I may say this is greatly minimised by keeping the ends of the valve containing the rings as far apart as possible. There can be no greater escape of steam than with the flat valve, which in one voyage will sometimes wear grooves in the cylinder face, and allow an escape of steam.

Concerning shafting, I think there is great necessity for flexible couplings. Mr. Dimmock has mentioned one notable instance, and I believe it is only one amongst many. It is only natural that, owing to the elasticity of the material of the hull of the vessel, and the variations in form due to it being light or loaded, these should sensibly affect the line of shafting. The wearing down of particular bearings, and not only that, but risk of broken or overstrained shafting must be the consequence.

The packing used for pump buckets is now principally a metallic spring ring, and I agree with Mr. Wilson in advocating a series of narrow spring rings. The friction of the water passing through the condenser is a considerable item, and will remain so until some clever Engineer suggests an improvement in condensation.

In my paper I mentioned an instance of a compound engine having been tripled on the tandem principle. I have since been told by a gentleman that increased bearing surface was provided for this engine, by replacing the old crank shaft with one of larger diameter, which has not, however, given entire satisfaction.

Regarding smooth surfaces, that they should not be brought to a high point of perfection, I am still inclined to consider they should be finished as fine as possible. When smooth surfaces are properly channelled out for oil to get between them the friction must be reduced to the minimum. Mr. Gray having introduced some data from a report of a Committee appointed by the "Institution of Mechanical Engineers" to enquire into, and experiment upon the subject, I should be very pleased, if I can only find the time, to prepare a supplementary paper on the subject to open the continued discussion upon this most interesting question.

SUPPLEMENTARY PAPER ON FRICTION

BY

Mr. W. J. NOWERS BRETT

(ASSOCIATE).

CHAIRMAN'S OPENING REMARKS.

(MR. L. P. COUBRO.)

DISCUSSION CONTINUED ON 1ST APRIL.

In opening the meeting this evening for a further discussion on Friction we may briefly refer to the proceedings which took place on the 4th March when the Paper was read. It has been suggested that the Honorary Secretary should read his report of the previous meeting, during which members may take notes and thus be prepared to resume the discussion at various points or enter upon new lines which were omitted.

REPORT OF MEETING HELD MARCH 4TH.

(READ BY THE HONORARY SECRETARY.)

A meeting of the Institute of Marine Engineers was held on Tuesday evening, 4th March, presided over by Mr. L. P. Coubro, when Mr. W. J. Nowers Brett (Associate) read a paper on the "Friction of screw propelling engines."

The paper dealt with the losses due to the friction on the various working parts of the marine engine, from the pistons to the propeller blades The question of rough surfaces and lubrication were first referred to, also the small bearing surfaces sometimes found in engine-shafting, and the consequently ensuing trouble. The forms of steam admission valves in use, past and present, and the rejection of the slide for the piston valves in more recent types of engine were noted, and the advantages of the Piston-valve pointed out. Reference was made to the different kinds of material used for bearing bushes, lignum vitæ for the propeller shaft in the stern tube; brass, white metal or phosphor bronze for various other bearings.

It was suggested that it would be an advantage to use roller bearings for some of the shaft journals. A model of roller bearings suitable for tunnel and other shafting, made and patented by Mr. Leslie, one of the members, was exhibited.

A passing reference was made to shafting being out of line, and the advantage of having flexible couplings fitted to the Tunnel Shafting, to obviate the trouble frequently experienced, whether due to original lining off, or to the alterations which take place from time to time in the hulls, owing to the loading of varying cargoes, or structural weakness. The best material to use for propeller blades was questioned, and reference was made to the extensive corrosion or pitting found to take place at the points of the blades, in both cast iron and steel, after a few months' running.

In the Discussion which followed the reading of the Paper, the question of the most suitable form of packing rings for pistons was considered, and several members expressed opinions favourable to a series of narrow cast iron rings as being economical and least liable to cause excessive friction. The once common practice of giving packing rings too much compression was commented upon strongly, this leading frequently to a system of packing being unjustly condemned on account of undue compression being placed on the rings.

The great unbalanced weight of the slide valves fitted to many engines—especially the high pressure valve of compound engines—was remarked upon as obviated to a certain extent in more recent types of engines by the piston form of valve, which cannot however, be looked upon as perfect in its duty of keeping steam tight in the chamber. The arrangement of a balanced or equilibrium slide valve patented by Mr. Church was commended in high terms by several present who were acquainted with its merits. The introduction of phosphor or Manganese bronze and Delta metal for propeller blades was considered by a few members who had experience of them as compared with cast iron or steel to be a very great improvement although expensive in first cost, the improved speed of the ship with less drag on the engines, and the fact that the action of the water at the periphery of the propeller does not cause any pitting action such as is found in the cases of iron, and especially steel, blades, involving frequent renewal, all tended to the view that, in the end, the new metals were the most economical.

The principles and theories of friction on moving surfaces were discussed, and a most interesting series of remarks on this subject, with data gained from experiments were given by Mr. McF. Gray, quoted from the "Transactions of the Institution of Mechanical Engineers."

The proceedings were brought to a close by votes of thanks to the author of the paper and the chairman, moved and seconded by Messrs. W. J. Craig, jun., and W. Gale, and Messrs. R. Adam and D. Greer, respectively.

It was decided to continue the discussion at a future meeting, early in April, when Mr. Brett was desired to read a Supplementary Paper, embracing the subject matter referred to by Mr. J. McFarlane Gray.

CHAIRMAN:—I will now call upon Mr. Brett to read the Supplementary Paper he has prepared in accordance with the suggestion made by Mr. J. McFarlane Gray.

In the discussion that followed my paper on "Friction of Screw Propelling Engines," some very interesting and important data from a "Report on Friction Experiments," by Mr. Beauchamp Tower, published in the Proceedings of the Institution of Mechanical Engineers, were given by Mr. J. McFarlane Gray, and by the courtesy of that gentleman I am enabled to lay before you a summary of valuable experiments on friction of lubricated surfaces.

These experiments dealt with the co-efficient, area of bearing surface, speed, load, lubricant, and its temperature and method of application, and the alternating motion found in some bearings.

*To give an idea of the method employed in these observations I will quote from the published report: "The journal experimented on was of steel, 4-in. in diameter and 6-in. long, with its axis horizontal. A gun-metal brass, embracing somewhat less than half the circumference of the journal, rested on its upper side. The exact arc of contact of this brass was varied in the different experiments." "Resting on this brass was a cast-iron cap, from which was hung by two bolts a cast-iron cross-bar carrying a knife edge. The exact distance of this knife-edge below the centre of the journal was five inches. On this knife-edge was suspended the cradle which carried the weight applied to the bearing. The cap, bolts, and cross-bar were put together in such a manner as to

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* See page 35 for sketch of apparatus.

form a rigid frame, connecting the brass with the knife-edge. If there had been no friction between the brass and the journal, the weight would have caused the knife to hang perpendicularly below the axis of the journal. Friction, however, caused the journal to tend to carry the brass, and the frame to which it was attached, round with it, until the line through the centre of the journal and the knife-edge made such an angle with the perpendicular that the weight multiplied by the distance from the knife-edge to that perpendicular, offered an opposing moment just equal to the moment of friction.

Suppose r=radius of the journal.
s=distance of the knife-edge from the perpendicular.
w=the weight.
Then, from above. $s \times w$=the moment of friction.
Now the friction at the surface of the journal

$$=\frac{\text{the moment}}{r}=\frac{w \times s.}{r}$$

Hence the co-efficient of friction =

$$\frac{\text{friction at surface of journal}}{w}$$

$$=\frac{s}{r}$$

So that the co-efficient of friction is indicated by s in terms of r, no matter what the weight is. As an example, suppose s was equal to r; the co-efficient of friction would obviously be 1; or if s was 1-10th of r, then the co-efficient of friction would be 1-10th."

When the motion of the shaft was reversed, the friction at the time of starting was about twice the normal friction, and it gradually diminished until the normal friction was reached, and this was greatest with a new brass, thus showing the more perfectly the brass fitted the journal, the less the consequent friction. When using a well-worn brass this was not observable, which fact bears out my remarks on surfaces in my preceding paper, that when surfaces are not good, the thin film of oil will not completely separate them.

The co-efficient of friction was found to be not constant, but to vary nearly inversely as the load, and the moment was much more constant than the co-efficient.

The journal was run in a bath of oil, so as to obtain perfect lubrication; but various methods of applying the oil to the journal were tried, viz.:—(1). By drilling a hole in the top of the brass and cutting an oil channel parallel to the axis of the journal. The pressure of the brass upon the journal would not allow the oil to escape with a head of 7-in., so this was obviously the wrong place to introduce oil; but it was pointed out afterwards, during discussion, that with an alternating pressure, as with a crank shaft, the oil managed to cover the surface of the brass, but perhaps in an imperfect way. (2). Oil was introduced to the sides by cutting two grooves parallel to the axis, and almost forming boundaries to the arc of contact. This was found to keep the bearing cool, but it seized with a load of only 380 lbs. per square inch. (3). Two curved grooves were cut, nearly enclosing an oval space in the centre of the brass, and fed by an oil hole to each groove, as in locomotive axle-boxes, and at the same time the arc of contact of the brass was reduced. The brass refused to take oil or run cool, and rapidly heated above a load of 178 lbs. per square inch, and seized with 200 lbs. It was stated that the success of this method of lubricating railway axles was probably due to end play in the bearing. In all these experiments the old grooves were filled up before cutting new ones. (4). An oily pad, contained in a tin box full of rape oil, was placed against the journal, which rubbed against it in turning. This pad was supplied with oil by capillary attraction, and the film of oil on the journal was just perceptible to the touch. With this method the oil was introduced like a liquid wedge between the brass and the journal, the bearing fairly carried a load of 551 lbs. per square inch, and this experiment showed the nearest approach to the oil-bath method of lubrication.

The greatest load carried by the brass with rape oil was 573lbs. per square inch, and with mineral oil, 625; and the method of lubrication was the oil bath. The friction of the journal was found to vary considerably with the temperature of the oil. Most of the experiments were conducted at a uniform temperature of 90°. But it was shown that there is "a very great diminution in the friction as the temperature rises," "Thus, in the case of lard oil, taking a speed of 450 revolutions per minute, the co-efficient of friction at a temperature of 120° is only one third of what it was at a temperature of 60°."

"The friction depends on the quantity and uniformity of distribution of the oil, and may be anything between the oil-bath results and seizing, according to the perfection or imperfection of the lubrication. The lubrication may be very small, giving a co-efficient of $\frac{1}{100}$; but it appeared as though it could not be diminished and the friction increased much beyond this point without imminent risk of heating and seizing. The oil-bath probably represents the most perfect lubrication possible, or the limit beyond which friction cannot be reduced by lubrication, and the experiments show that with a speed of from 100 to 200 feet per minute, by properly proportioning the bearing surface to the load, it is possible to reduce the co-efficient of friction as low as $\frac{1}{1000}$. A co-efficient of $\frac{1}{500}$ is easily attainable, and probably is frequently attained, in ordinary engine-bearings in which the direction of the force is rapidly alternating, and the oil given an opportunity to get between the surfaces, while the duration of the force in one direction is not sufficient to allow time for the oil-film to be squeezed out."

"Observations on the behaviour of the apparatus gave reason to believe that with perfect lubrication the speed of minimum friction was from 100 to 150 feet per minute, and that this speed of minimum friction tended to be higher with an increase of load, and also with less perfect lubrication. By the speed of minimum friction is meant that speed in approaching which, from rest, the friction diminishes, and above which friction increases."

	lbs. per square inch.	Co-efficient of Friction.	Comparative Friction.
Oil-bath	263	0·00,139	1
Pad under journal ...	272	0·00,900	6·48

In friction experiments at low velocities Professor Fleeming Jenkin ascertained that "the co-efficient of friction decreases gradually as the velocity increases, between speeds of 0·012 and 0·6 foot per minute;" and Professor A. S. Kimball found that "with a wrought iron shaft of 1 in. in diameter working in a cast iron bearing, well oiled, an increase of velocity of rubbing from 6 to 110ft. per minute caused the co-efficient of friction to fall to 0·3 of its first value. The pressure in this case was about 67lbs. per square inch. Other experiments on lubricated journals at smaller pressures gave a diminution of the co-efficient from 0·15 to 0·05 as the velocities increased from 1 to 100 ft. per minute. At such slow speeds as from 0·59 to 2·2 ft. per minute a similar decrease was found; while at the still lower velocities of from 0·002 to 0·01 ft. per minute the friction increased with the velocity." Experiments made by Captain Douglas Galton and Mr. Westinghouse on the frictional resistance between brake-blocks and wheels showed "a very remarkable diminution of the co-efficient of friction with increase of speed over the very large range of from 400 to 5,300 ft. per minute." Some curious results at a low speed were obtained by Mr. Beauchamp Tower. With a journal 4 in. diameter and 6 in. long running at 21 ft. per minute, he found by reducing the load from 443 lbs. down to 89 lbs. per square in. or a ratio of 5 to 1, the co-efficient of friction rose from 0·00132 up to 0·004 or in the ratio of 1 to $3\frac{1}{3}$.

The strange results obtained from these experiments are rather conflicting and confusing, but we may come to a few conclusions based upon them, as follows:—

1. That at low velocities the co-efficient of friction is greater than at high velocities, but after some point at high velocity the friction increases.

2. That additional loads at high velocities increase the co-efficient.

3. That friction varies with the temperature of the lubricant.

4. That the lubrication should be profuse as with the oil bath.

5. That the friction is less when the surfaces are true and at the same time perfectly oil-borne.

6. That the friction varies with the area of bearing, quantity, quality, and temperature of lubricant, and the material of the rubbing surfaces.

7. That a bearing will carry a much higher load when the pressure is intermittent.

MR. J. H. THOMSON'S REMARKS.

Mr. Brett in his paper referred to several methods having been adopted for reducing the friction and consequent wear in the Cylinders of Horizontal Engines, one of which was "In directing the motion of the crank-pin when going ahead to give the connecting-rod an upward thrust." Now I think too much credit has been given to this direction of the motion, for if we take an ordinary horizontal engine with guides and an upward thrust is given to the connecting-rod, the neck-bush at the bottom of the packing-box becomes a fulcrum, and the weight is thrown on the bottom of the Cylinders.

I have had some experience in various types of Horizontal marine engines, and I found the weight of the Pistons counteracted any virtue that was supposed to be in the direction of the motion.

I grant that with Trunks where the connecting-rod is connected direct to the piston there may be a slight advantage, but with return connecting-rods and with the ordinary guides there is little or none.

In respect to the wear of Slide-Valves I think it is not always due to the actual pressure that it is so excessive at times, I remember a case where, owing to the weakness of the steam-chest door, which was fitted with an equilibrium ring, the Slide-valve and Cylinder-face would wear about $\frac{3}{8}$ of an inch in a six weeks' run, the door vibrating with every stroke of the Piston, and causing a variable pressure on the Valve. After a short time the door gave way and a stronger one was fitted, and there was an end to the trouble in this direction, and after a twelvemonth's working the wear on the Cylinder-face and Valve was hardly perceptible.

MR. JAS. ADAMSON'S REMARKS.

There are many points in connection with the subject before us this evening, which will serve as starting places, not only for an evening's discussion, but for future papers. The best style of piston is a much disputed question, the varieties of packing rings and springs almost form a legion or more. I think we will all agree that many piston rings and springs have been condemned and abused not for faults of their own, but of those who closed the pistons up with an amount of compression laid upon them, such as no metal could stand without damage. In some cases the packing rings wore to an alarming extent, in others the cylinder liner; in either event, the loss of effective horse power has been considerable.

I have noticed that the more recent practice in Buckley's Patent Rings and Springs is to reduce the depth of the rings considerably and lighten the steel springs, and if any members present have had experience with the old style of these rings and the new, it would be of advantage for us to know the result of the altered arrangement, which I believe to be an improvement.

In reference to lubrication, it would be a matter for a good discussion with a view to discover the most approved style, to consider the different methods pursued in cutting the *gutter ways* in brasses and other rubbing surfaces. I have heard of gutter ways being cut in the main shaft journals of an engine in spirals, this was not a marine but a land engine.

The use of a certain class of Mineral oils for white metal in place of Engine oils has in many cases been conducive to better and more satisfactory results. I know of one steamer which had constant service for seven years, using Mineral oil in the crank shaft journals, the bearings of which had not once been stripped during that time.

It depends a good deal on the kind of metal, which class of lubricant suits best, whether Castor, Engine, or Mineral oil.

The wear and tear on some valves, especially H.P. Slide Valves, are very great. I have seen several scored fully 5-16th of an inch deep, showing the friction was excessive, and the cure to be adopted to lie in the direction of an equilibrium valve, such as Church's, which has been already referred to in high terms.

I should like to hear some more expressions of opinion based upon experience with Bronze Blades as compared with Iron or Steel, I have made a rough approximation from what I am led to believe is the saving in steamers originally fitted with Steel blades and then with Phosphor Bronze, the percentage saved in coal being 3 to 4 per cent., and in speed 4 to 5 per cent.

There are several specimens and models in the Library Case which serve to illustrate some of the remarks which have been made as the cutting action on H.P. cylinder faces, pitting action on iron and steel blades; roller bearings, and styles of piston packing rings and springs. One model piston I would call attention to as illustrating a good form of ordinary spring and common ring. The springs do not touch the body of the Piston, but are held between the packing ring, bearing on the walls of the Cylinder, and a floating ring which may come and go within certain limits allowed for clearance, the rings and springs are thus floating free around the body of the piston; the springs are shaped somewhat different to the usual common spring, in form they are somewhat like the letter s doubled with one tail looking to the right and the other to the left, so as to give a good long bearing surface to each spring.

MR. R. DUNCAN'S REMARKS.

Friction caused by the packing-ring on the side of a cylinder is no doubt very great, and I believe there is often an unnecessary amount of it by having too great a pressure on the packing-rings.

Mr. Buckley, the well-known maker of Piston rings bearing his name, now gives in his instructions for using his rings that there should be $\frac{1}{2}$ lb. of pressure per square inch of surface on the packing-ring, pressing the ring against the side of the Cylinder to keep it steam-tight, and all pressure above this is only adding unnecessary friction. He has arrived at this conclusion from actual experiments. The rings supplied by his firm now are very much reduced in depth, as compared with those supplied formerly. One of these narrow rings (3 inches deep) was put in in place of one 5 inches deep, and has given much better results and shews less wear on both the Cylinder and the ring than the 5 inch one did. I think this goes a good way in proving that the rule of $\frac{1}{2}$ a lb. per square inch of surface is the correct thing.

MR. J. R. RUTHVEN'S REMARKS.

We are greatly obliged to Mr. Brett for his paper on this important subject. It is rather disappointing that the results are so indefinite, and shows that there are still some points for investigation. I hope some of our members will experiment when they can, and report to us the results. I would like to see a few friction diagrams, the smallest that can be made, this would give some information in comparison with the full power indicated.

MR. BRETT'S REPLY.

In reply to the remarks made on Horizontal Engines, a guide rod through the back Cylinder cover prevents a lot of wear on the bottom of the Cylinder, and of course where it is possible to fix a shoe on the end of the rod, the weight of the Piston is taken off the bottom of the Cylinder as has been remarked.

The suggestion to give the connecting-rod an upward thrust when going ahead applies only to Horizontal Trunk Engines; when an Engine has guides and shoes the angular motion of the connecting-rod does not affect the Piston in this respect.

The cause of Slide valves and Cylinder faces becoming grooved is due, in my opinion, to hard particles of iron working opposite softer particles, and eventually the harder particles wearing out the softer ones in the form of a groove.

By using a Manganese-Bronze face we partially overcome this difficulty, because it seems impossible, as Mr. Sage remarks, to get iron homogeneous, when cast.

On the question of Piston packing I take it from Mr. Duncan's remarks that the "Buckley" packing rings are becoming more after the style of "Ramsbottom" rings in the matter of reduced surface and pressure. I think a "Ramsbottom" ring could be extended by the pressure of the steam equally as well as a broader ring can be extended by metal springs, as suggested by Mr. Wilson at our former meeting. However, the opinions of the gentlemen who have spoken seem to be in favour of a narrow ring with very little pressure.

It was said that the wear of the eccentric straps is not a proof of the comparative friction of the flat Slide valve and the Piston valve, and what was remarked in the paper is in accordance with that remark. I may say I should very much like to hear a paper on Church's Valve.

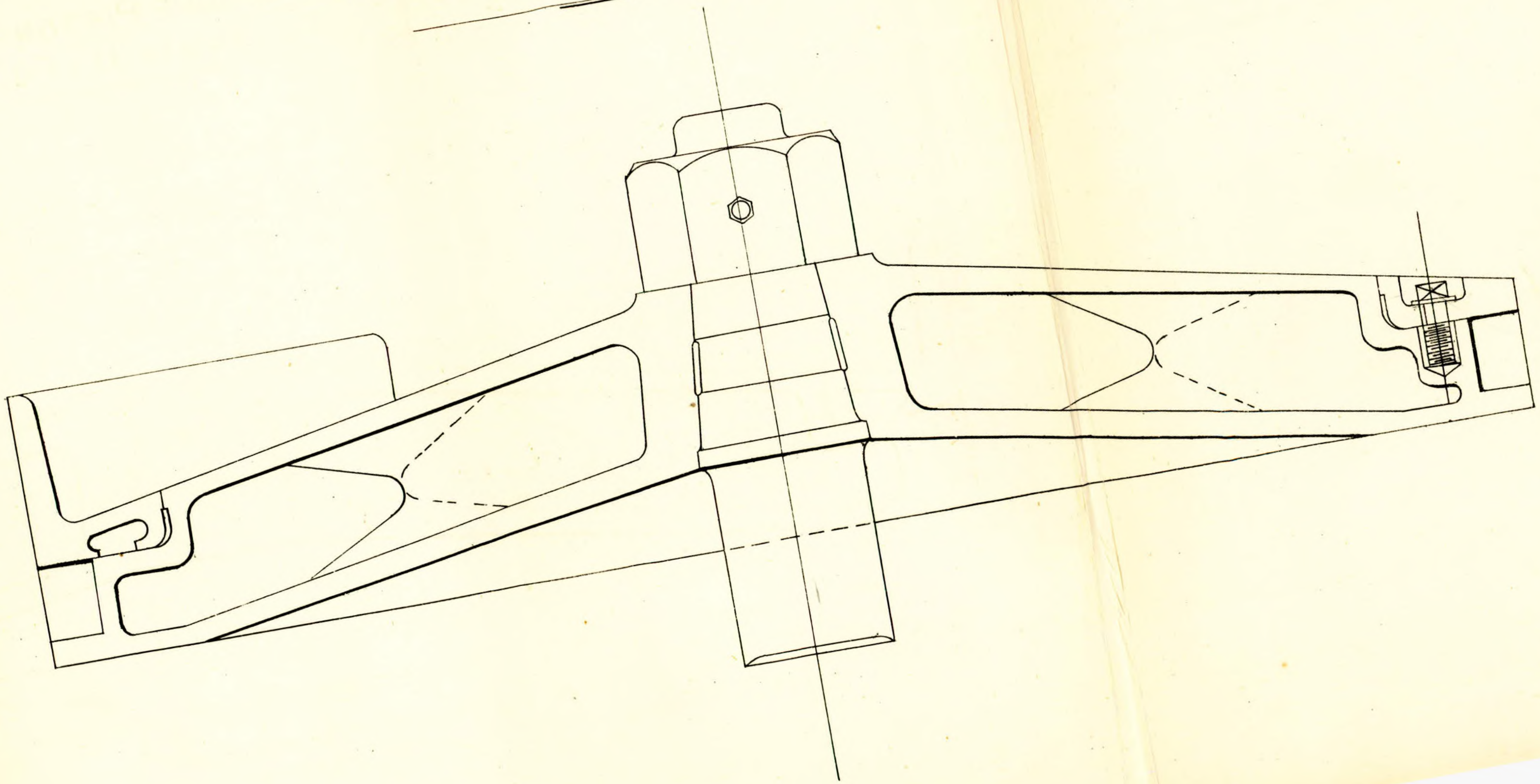
On the subject of Pump bucket packing Mr. Wilson advocates the use of packing rings, and so far as I know a series of narrow rings have always worked well in a Pump bucket. Whatever is applied to a steam Piston can be applied to a Pump bucket within certain limits.

I should suggest that, judging from the successful result obtained in the experiments with lubricated journals, when having the oil channels cut in the brass at the extremities of the chord of contact, that that method be used in connecting-rod brasses and main bearing brasses in Marine Engines instead of drilling the oil-hole into nearly the centre of the brass and cutting the channel from that point.

In thanking you for your kind vote of thanks I may say that when I commenced my paper I did not think it would embrace such a very wide field of matter. As to something more definite on the subject of friction; well, we want to know more than those eminent Engineers have learnt, who have experimented on the subject.

Low Pressure Piston - Diar 83"

Scale 1½" = 1'-0".



FRICTION
TESTING MACHIN

Sketched by kind permission of the Counc
the Institution of Mechanical Engin

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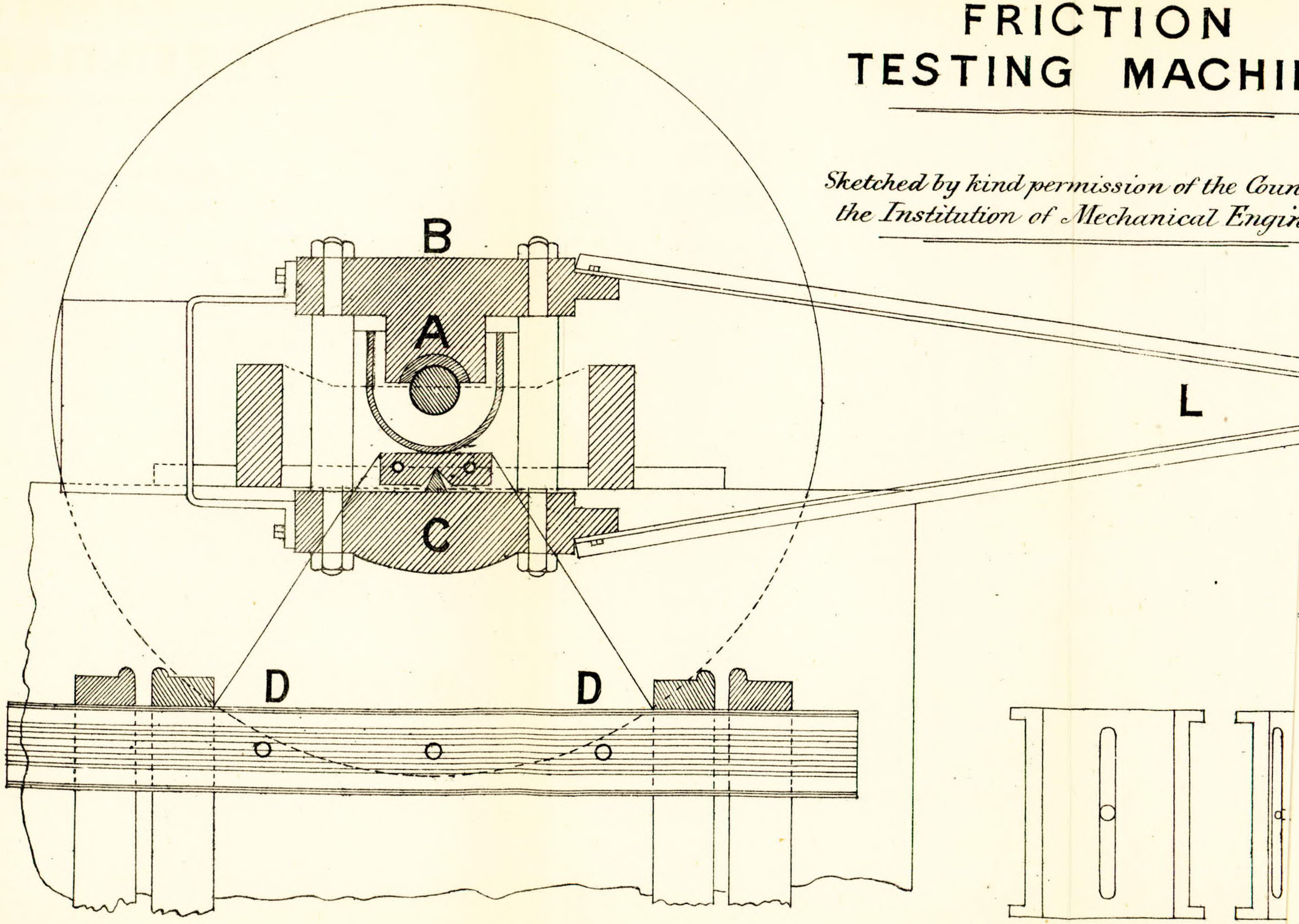

Nº 1
OIL CHANN

PREFACE.

THE LANGTHORNE ROOMS,
BROADWAY, STRATFORD,
11th March, 1890.

A Meeting of the Institute was held this evening, presided over by MR. J. MACFARLANE GRAY, when MR. G. LLOYD MORGAN read a Paper on Coal, which, with the consequent discussion and remarks, will be found in the following pages.

The subject is wide enough to give fruit for several papers, while its importance and interest is no less wide. Probably the second portion of the current session may be found convenient for some member to bring the subject forward again.

The Chairman made a few preliminary remarks after the paper was read, and in the course of the discussion, he explained how coal, or indeed, any fuel burns, *i.e.*, what *burning* really is, and how it comes about that heat is produced. The explanation given was that which is based upon the ether-pressure hypothesis.

He then compared the energy producible by burning a pound of coal with that produced by the explosion of a pound of gunpowder, showing that coal is many times more powerful. He explained that the cause of this difference was, that in gunpowder we had all the elements required in combustion, whereas coal had only the element which unites with oxygen, being only 5 % of the materials employed in combustion. That the other 95 % of the fuel was not carried in the bunkers, but put on board free of freight, no charge for porterage, and out at sea where there were no quays, hundreds of tons of it tumbled into the stokehold every hour in some of the large steamers, while the firemen were standing under, night and day, wet or fair; and that although 80 per cent. of this cheap stuff was ash, every particle of that was immediately swept overboard for us by the Friend who supplied it. In other words coal or fuel only gives 5 % of what is required for combustion, the 95 % comes and is supplied from the atmosphere.

JAS. ADAMSON,
Honorary Secretary.