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(OF TRANSACTIONS)

INTERNAL FRICTION IN STEAM ENGINES

BY

Mr. W. W. HOUFE

(MEMBER).

READ AT

THE INSTITUTE PREMISES, 58, ROMFORD ROAD, STRATFORD

MONDAY, OCTOBER 14TH, 1895.

THE UNIVERSITY COLLEGE, CARDIFF,

WEDNESDAY, NOVEMBER 6TH, 1895,

THE ARTS' SOCIETY HALL, SOUTHAMPTON,

TUESDAY, NOVEMBER 12TH, 1895.

PREFACE.

58, Romford Road,

Stratford, E.

November 11*th*, 1895.

A Meeting of the Institute of Marine Engineers was held here this evening, presided over by A. J. Durston, Esq., C.B., President, when the subject of the Paper, "Internal Friction in Steam Engines," by Mr. W. W. Houfe (Member), of Hong Kong—read at the meeting held on Monday, 14th October, Mr. T. F. Auckland (Hon. Member) presiding—was further discussed. The subject was also discussed at the meeting held on Monday, October 28th. The result of the discussions held on the three evenings follows the Paper, which has also been read and discussed at the Bristol Channel and the Southampton Centres.

JAS. ADAMSON,

Hon. Secretary.

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President—A. J. DURSTON, Esq., C.B., R.N.

INTERNAL FRICTION IN STEAM ENGINES.

BY

MR. WALTER WILLIAM HOUFE

(MEMBER, HONG KONG).

READ AT 58, ROMFORD ROAD, STRATFORD, ON MONDAY, OCTOBER 14TH, 1895.

AT SOUTHAMPTON, ON TUESDAY, 12TH NOVEMBER, 1895.

AT CARDIFF, ON WEDNESDAY, 6TH NOVEMBER, 1895.

In this paper I propose to deal in a practical manner with the subject of Internal Friction in Steam Engines, being of opinion that it has hitherto received too little attention. I am of opinion that internal friction in present-day engines is far in excess of what it should be, and that by its reduction economy would be attained in the working of the saturated steam engine, besides rendering possible the success of the dry or superheated steam engine.

All who have dealt with the theory of the steam engine have pointed out the benefit of the use of superheated steam. But the few attempts that have been barrel surface void of water film (save perhaps for a very small part at the end of each stroke where compression is taking place). Piston and tail end rods will be subject to the same tendency where their glands are tight and do not form pockets for condensed steam. The valve and cylinder faces will probably be alternately free from, and wet with, water film at their different bars according to whether they were last in contact with the exhaust or working steam. With priming or super-saturated steam engines no doubt all the internal rubbing surfaces tend to be continually wet.

As to water being an unguent for metal surfaces, Prof. Rankine, in his "Manual of the Steam Engine," &c. (page 16), says:—"Water, which acts as an unguent on the surfaces of wood and leather. It is not, however, an unguent for a pair of metallic surfaces, for when applied to them it increases their friction." That this is so I think there can be no doubt, for experimental results all show a higher co-efficient for a pair of metallic surfaces wet than when dry, and in acknowledgment of it we bush stern tubes and feathering float gear with lignum vitæ.

Since it is clear that water increases friction in metal pairs, the liquefaction of steam in the engine, whether deposited and retained in part as water film on the working surfaces or held suspended in the steam, cannot lubricate the internal moving parts, but it will anti-lubricate them. As to steam being a lubricant for these parts, the wetter the steam the more water there will be suspended in it, and since water anti-lubricates them, the wetter the steam the more complete will be its anti-lubricating action. The drier the steam, the less the water suspended in it, and, consequently, the less anti-lubricating it will be. Since it appears that dry steam is not a lubricant for these internal parts, I conclude that steam, whether superheated, saturated, or super-saturated, no matter of what temperature, is not a lubricant for the internal surfaces in a steam engine.

As the tendency to excessive wear or abrasion of the internal sliding surfaces has been found greater when using dry or superheated than with wet or saturated steam, and as this cannot be due to the hitherto advanced opinions that saturated steam or the water of its liquefaction acts automatically in lubricating these parts, the reason must be looked for elsewhere. My inquiries lead me to believe:—

1. That abrasion (as here understood) of metal pairs takes place when the drag of friction overcomes the cohesive force of considerable sized particles of the metal's surfaces or surface.

2. That abrasion is aggravated by the metal becoming overheated.

3 That overheating is due to the fact that excessive difference of temperature in the generating and transmitting mediums are often necessary in order that the rate of heat generation and dissipation may arrive at a state of equilibrium.

4. That the rate of final dissipation of heat is tremendously greater in water than in dry air or in dry steam, moist air and super-saturated steam being somewhere intermediate.

5. That the reason the internal rubbing surfaces have been found to wear far more with superheated than saturated steam, even though the rates of generation be the same, is due to the fact that wet steam and the attending water of its liquefaction are far more rapid dissipators of heat than is superheated or dry steam, even though their temperatures be the same; consequently, the surfaces in the former case must be much cooler than in the latter case.

6. That the heat returned to the steam by friction of the internal surfaces does not result in economy proper as is sometimes imagined.

7. That considerable increase in steam engine economy will attend the reduction of internal friction, and the way be paved for the success of the superheated steam engine. This reduction may be effected by good design of parts and a good system of lubrication.

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1. All metals have a cohesive force peculiar to themselves, and the greater this force in any metal the greater will be the force necessary to disintegrate it. But as all metals are capable of most minute sub-divisions the slightest force will detach very minute particles when applied in a proper manner. As the force increases or the cohesion of the particles diminishes so will the disintegration increase. For example, the frictional resistance of an old file over a piece of metal may be so slight that only the most minute particles are rubbed off, but if the resistance be increased by great normal pressure the particles rubbed off may assume considerable dimensions and come within the limits of the term abrasion, as here understood.

2. All metals have a temperature at which the cohesive force of their particles is a maximum, and with metals that concern us here this seems to decrease as their temperatures rise above the ordinary atmospheric temperature. It is also highly probable that the frictional resistance of metal pairs undergoes considerable changes with alterations of temperature, and I am inclined to believe that variation of temperature difference in them increases frictional resistance to motion. Although we have no experimental data of the effect of temperature, &c., on frictional resistance, it has become general to add to the old written laws of friction "so long as the surfaces are kept cool." The term overheated is necessarily somewhat vague, but may be considered as a certain condition of temperature at which in a rubbing pair frictional resistance becomes suddenly or greatly augmented. In order to convince oneself that abrasion

is aggravated by heating, it is only necessary to recollect how much more easily iron is rasped down with an old file hot than when cold.

In order to make my further views plain, I propose to take data from an existing engine.

The steam engine giving the indicator diagram from which the absolute steam pressures on the Figure 1. are taken had a cylinder 14 in. diameter and 30 in. stroke; connecting rod ratio to crank 4: 1, and ran 90 revolutions per minute; the shoe a rubbing surface of 9 in. by 12 in. = 108 square inches, and the guide, one of 42 in. by 9 in. = 378 square inches. The maximum shoe-load was, approximately, $14^2 \frac{\pi}{4} (154\text{-}68)\frac{1}{4} = 3{,}310$ lbs. and the mean, roughly, $\frac{3310}{2} = 1{,}655$ lbs. With the surfaces well oiled, the frictional work is $1{,}655 \times 2{\cdot}5 \times {\cdot}05 = 207$ ft. lbs. per stroke, and the heat units generated $\frac{207}{772} = {\cdot}268$ per stroke. As the respective areas of this sliding pair are 378 and 108 square inches, and the heat generated between them must be generated in each surface in inverse proportion of their respective areas to the total rubbing surface area, the heat generated in the shoe will be ${\cdot}268\left(\frac{378}{378 + 108}\right) = {\cdot}209$ units per stroke, or ${\cdot}209 \times 2 \times 90 = 37{\cdot}62$ heat units per minute.

3. Now this heat must be transmitted from the shoe's face just as rapidly as it is generated, or it will become infinitely hot, and the condition that the transfer may take place is that the face must be hotter than at least some of the surrounding bodies. This transfer will be more rapid the greater the temperature differences. In this case the temperature of the surrounding bodies will be mainly governed by the ability of the surrounding atmosphere to dissipate heat, and this atmosphere is air, so the colder it is and the better its circulation, the lower will be the temperature of the shoe's face. From

observation, this shoe's face is about 150°F. when the temperature of the surrounding air is 110°F., so that it appears that 37·62 heat units are dissipated by the air per minute for a difference in temperature of 40°F. Had the surfaces become dry, the rate of generation would be about $\cdot 209 \times \frac{\cdot 2}{\cdot 05} = \cdot 836$ per stroke, $\times$ $\cdot 836 \times 2 \times 90 = 150 \cdot 48$ per minute, and the temperature difference necessary for equilibrium to be arrived at would be such that the overheating of the shoe and guide would both be excessive and abrasion would have been taking place for some time. The particles of metal rubbed off or abraded would be so intensely hot that they would be rendered luminous, and their temperature would probably be considerably over 800°F.

4. Again, had the surfaces had a plentiful supply of water administered to them, the heat generated per minute would have been in the shoe's face $\cdot 209 \times \frac{\cdot 3}{\cdot 05} \times 2 \times 90 = 225 \cdot 72$ units, but as the water would absorb and carry the heat away very rapidly indeed, the temperature difference would be less than the 40° stated previously, but although abrasion would not be taking place the wear would be greater than when the surfaces were oiled in about the proportion of their co-efficients of friction, *i.e.*, ·3 : ·05, or six times greater wet than when well oiled. If the surfaces, when well oiled, had been surrounded with an atmosphere saturated with water vapour, the temperature difference would have been less than 40°F., for the rate of dissipation would have been greater than the rate of generation for such a temperature difference. This follows from the fact, as stated by Professor Rankine, that "The most rapid convection of heat is that which is effected by means of cloudy vapour, which combines the mobility of a gas with the comparatively greater conducting power of a liquid." Had the surrounding atmosphere been one of dry steam of the same temperature as the dry air, the temperature of the shoe would have been considerably less for the relative specific heats of air and steam at

constant pressure are respectively ·2377 and ·4805. A corresponding difference might also be expected for moist air and moist steam which evidently would be somewhere intermediate between dry air and water and dry steam and water respectively.

5. Returning now to our steam engine. The piston is fitted with a split ring which is a working fit between the junk ring and piston flange, but not a positively steam-tight one, so that a mean of the steam pressures obtaining in the cylinder may be expected to be continually pressing the ring outward on to the barrel face. This pressure will be $\frac{1}{2}$ (143·9 + 68·9) = 106·4 lbs. per square inch, allowing spring pressure of only 2·6 lbs. per square inch. The total outward load of the ring, which is 4in. deep and 1in. thick, will be approximately $12\,\pi \times 4 \times 109 = 16{,}437$ lbs. As this cylinder could not be considered as much else than dry so far as the piston path is concerned, the work expended in overcoming the frictional resistance per stroke will be $16{,}437 \times \cdot 2 = 3{,}287 \cdot 4$ ft. lbs. and the heat generated $\frac{3{,}287 \cdot 4}{772} = 4 \cdot 26$ units per stroke.

In passing it may be well to note that if the surfaces over which this piston is passing be wet the frictional heat per stroke will be $4 \cdot 26 \times \frac{\cdot 3}{\cdot 2} = 6 \cdot 39$ units. Of these 4·26 heat units, the ring surface has generated in it $4 \cdot 26 \times \frac{34}{38} = 3 \cdot 8$ units per stroke. This heat must be dissipated at the same rate, or the ring will become infinitely hot. It must be transferred by internal conduction in part to its other services and by external conduction to the cylinder barrel, junk ring and piston; from these surfaces the final vehicle will convey it. This final vehicle is the steam from which it was practically abstracted; for although the exhaust steam is colder than the steam on the other side of the piston, here the steam, for the greater part of the stroke at least, is super-saturated and water film probably plentiful. Had liquefaction been entirely prevented by superheating, or nearly so by jacketing, the rate of dissipation must have been enormously less, and consequently the temperature of the ring enormously greater.

Any attempt to mathematically investigate the probable temperature of any piston ring under working conditions would, I think, be futile. These temperatures might be readily ascertained, however, by means of small fusible plugs. As the rate of dissipation was ·209 heat units per stroke from the shoe's face when running only at 40° F. above the surrounding final dissipating medium, and before this rate could be increased fourfold the shoe fired (became overheated), and although air cannot be supposed to be a better dissipator than steam, what but the water of condensation could have kept the ring from firing with its rate of generation five times greater than that of the shoe when overheating was excessive with it? Had liquefaction been entirely prevented in this engine, who could doubt but that the temperature difference of the ring and its final dissipating medium would have been so great that overheating and excessive abrasion would have been obtained? As it was, the ring ran fairly well, and so far as wear was concerned it was not greater than might have been expected. I think that it is beyond a doubt that this ring, like many others that are supposed to be fairly satisfactory to-day, was only permitted to run without excessive abrasion in consideration of its being kept comparatively cool by the copious liquefaction of steam obtaining, or by the internal water service obtaining.

It is interesting here to consider the piston friction in the same engine with a differently constructed piston ring and an efficient system of lubrication. Let the ring be solid (unsplit) of the same depth but with 3in. of its bearing surface turned down a little, so that the bearing surface now is only ½in. deep at each end, that is 1in. effective (fig. 2 section). The ring being a tight fit exerts a pressure on the barrel face of say 3 lbs. per square inch. The load on the barrel face will be $14 \pi \times 3 \times 1 = 132$ lbs. As the surfaces are well oiled, the frictional resistance will be $132 \times \cdot 05 = 6 \cdot 6$ lbs., and the work expended per stroke $6 \cdot 6 \times 2 \cdot 5 = 16 \cdot 5$ ft. lbs., equal to the generation of $\frac{16 \cdot 5}{772} = \cdot 0213$ heat units per stroke; of which the ring surface takes up $\cdot 0213 \times \frac{34}{35} = \cdot 0207$ units. This rate of generation is over 183 times less than obtained with the other ring and surely could be dissipated with superheated steam without much of a temperature difference, and consequently without abrasion, if the temperature to which superheating is carried be reasonable.

6. In present day saturated steam engines, it is sometimes imagined that the heat generated by internal friction results in economy proper. As already set forth, the working steam will suffer but little loss in heat units from performing the work, for it is at once again converted into heat and absorbed by the working steam. The imaginary gain comes in—I think—in our way of stating steam consumption, viz., "steam per I.H.P. per hour," and the oversight of not deducting the power expended on internal friction from the I.H.P. We do not include the work expended on compression at the stroke ends, because it is work (heat) returned to the working steam. No more right have we to include the work expended on internal friction. In an average engine, the work expended on internal friction is said to be about 14 per cent. of the I.H.P., so that an engine developing 1,000 H.P. calculated in the usual way, would really be developing only $1{,}000\ (1 - \cdot 14) = 860$ approx. in virtue of heat abstracted from the steam. This, of course, would make a very considerable difference in her steam per I.H.P. per hour. In engines where liquefaction is entirely prevented, by some such means as superheating, the heat resulting from internal friction will be absorbed more by the exhausting steam than by the working steam, and consequently the loss would be aggravated.

A. It is evident from what has been said that there can be no gain in steam economy attending internal friction. By its reduction less of the engine's I.H.P. will be absorbed internally; therefore, more would be available for performing the work for which the engine is intended. As friction is reduced so also is the wear, and in most existing engines the cost of upkeep might be considerably reduced by more attention being paid to the subject of this paper. That engines in which steam liquefaction does not obtain are the most economical steam consumers is beyond a doubt; and the best form of such an engine is evidently the superheated steam engine. As the drawback has hitherto been the abrasion of the internal rubbing surfaces, which was evidently due to their overheating through dry steam being a much less effective or rapid dissipator of heat than wet, by greatly reducing the rate of heat generation the superheated steam engine, I venture to say, will become a commercial success. This reduction must be attained by:—(1) Good design and upkeep of the moving parts. (2) Good lubricants and an efficient system of lubrication.

1. The internal parts which concern us here may be divided conveniently into three classes.—

(*a*) The piston and cylinder barrel;

(*b*) The steam regulating valve or valves and the port faces;

(*c*) The rods and their gland packings.

The most simple form of piston is the solid one, and if its rubbing surface is not deeper than necessary for practical steam-tightness it will afford the best advantages for minimum frictional resistance. To obtain practical steam-tightness it is generally held that a pressure of 3-lbs. per square inch is the necessary force with which the piston's rubbing surface must press against the barrel's face. Hence, if 1 in. depth of rubbing surface be considered sufficient, as I certainly think it is, the frictional resistance of such a piston with surfaces well oiled would be for our 14 in. cylinder 6·6 lbs. as shown before. Such pistons, however, soon become leaky when the frictional resistance becomes concentrated and tends to become Diam. × effective depth, × co-efficient of friction, × mean absolute pressure of leaking steam, which in our 14 in. cylinder, with surfaces well oiled, would be 14 in. × 1 × ·05 × 106·4= 74·48 lbs.

Local friction means local wear, and leakage means loss, so that obviously the upkeep of solid pistons is attended with much expense. In order to lessen the expense of upkeep and yet retain the advantages of a solid piston, solid rings can be fitted, and where the cylinder dimensions are sufficiently large these may be made adjustable, as shown in Fig. 2 (plan). These rings can be fitted so that the piston may be free to lateral motion with respect to the ring, the advantages of which are well understood. To obtain automatic adjustment of floating rings many patent piston packings have been introduced, but I do not know of any which even approaches the frictional advantages or is much less expense in upkeep than such as is represented in Fig. 2. As it is outside the limits of this paper to do more than briefly discuss two such packings, I have selected the Ramsbottom ring and a ring packing, having springs between top and bottom parts.

Ramsbottom rings are usually sprung into the recesses in the piston, but are sometimes fitted with solid ring distance pieces into the ordinary junk ring piston. They are of the split ring type, and their ends are often not even scarfed. That the steam accumulates behind them is evident, and when leakage at their joints or ends or flat surfaces becomes considerable the outward pressure of the ring on the cylinder barrel face will tend to vary with the steam pressures obtaining in the cylinder, thus causing the cylinder to wear into a varying bore. That this tendency will be increased with slow speeds and slack pistons is obvious. They should always be cut, drawn together with a band and then clamped on to the chuck's face to be turned to their finished size, as should be all other split rings. These rings are said to give satisfaction in small engines, especially in locomotive cylinders, where, of course, the stroke is small and the piston speed great. My own personal experience with them in marine engines is anything but favourable, and where deep ones have been fitted I have seen the cylinders worn very ununiformly and rapidly. In my opinion, their greatest failings are that their surface load is so very liable to follow the varying steam pressures, and that it is far in excess of anything necessary for practical steam-tightness at its circumferential surface at all times. Three rings are commonly fitted, but I think two ample. The frictional work is considerable, and may be taken as a mean throughout as equal to diam. $\pi \times$ depth, $\times$ number of rings, $\times$ mean absolute pressure obtaining in the cylinder $\times$ the co-efficient of friction, which in our 14 in. cylinder would have been $14\ \pi \times \frac{1}{2} \times 3 \times 106{\cdot}4 \times {\cdot}05 =$ 350 ft. lbs. per foot of travel, which is very considerable. As their surface contact with the piston is necessarily small, they are by no means suited for rapid transfer of heat.

The other packing is of the double split ring type having a number of steel springs placed in pockets acting between the two rings to keep them in practically steamtight contact with the junk ring and piston flange, a sectional view of which is shown in Fig. 3. As may be seen from the Fig. there is no outward spring pressure further than that due to the ring being sprung into the cylinder, as are all split rings. It is the only ring of this type that I know of that does not combine outward with the vertical spring pressure. These rings have a good section of metal and a good broad flat surface whereby the transfer of heat to the piston surfaces is facilitated. They are practically steamtight at all their bearing surfaces, but the steam will, in a short time, surely search through to the space at their backs, and then their frictional resistance will become great, and in our 14 in. cylinder to about $14 \pi \times 3 \times 106{\cdot}4 \times {\cdot}05 = 700$ lbs. roughly, but it will be constant. It is often advanced that steam pressure does not accumulate behind such rings, and that their flat surfaces are absolutely steam-tight against those of the junk ring and piston flange, although pressed together with no more force than admits of their easy lateral motion with respect to the piston. That this is impossible must be evident to all who have had anything to do with working faced steam joints. The condition for absolute steam-tightness is that the surfaces must be pressed together with sufficient force to compress the unavoidable irregularities into their own or opposite face, or partly both. This pressure will depend on the degree of smoothness of the surfaces and the compressibility of the metals. It may be well to remember here that if absolute smoothness were possible there would be no frictional resistance to motion between two bodies having such surfaces; but this condition of surfaces has never yet been attained. In practice we find it necessary for steam joints, &c., to allow a bolt section of about four times that necessary to simply support the load due to the steam pressure on the pipe's sectional area. The extra bolt section is allowed to draw the metal surfaces hard together (to compress the irregularities). Even when these bolts are well tightened up, we should not be over confident of absolute steam-tightness without having painted, or put putty on, the faces. Since we find such a stress necessary in fixed faced joints, how can absolute steam-tightness be expected to obtain between faces of cast iron, which are, moreover, to be capable of easy relative motion. As already stated, practical steam-tightness is said to obtain between two metal surfaces when practically smooth with a pressure of 3 lbs. per square inch, so that to go intentionally much beyond this in piston ring faces seems to be unnecessary. What has been said I think is sufficient to warrant the statement that absolute steam-tightness between the junk ring, piston flange, and the packing rings, when they are to be capable of lateral motion, is a practical impossibility. Hence, where pistons are fitted with floating rings, steam pressure will accumulate behind them, but will be constant when practical steam-tightness obtains and equal to the mean absolute pressure obtaining in the cylinder. The larger the space A, Fig. 2, the less the variation with leaky flat surfaces. With split rings this pressure will increase the frictional resistance enormously, but with solid floating rings the increase will not be worthy of consideration, unless their thickness be ridiculously small. It is an advantage, however, to construct practically solid adjustable rings so that their bolts have initial tensional strain in them. I believe it is the result of experience that dis-similar metals run better together than similar ones often do, and as good results are obtainable with cast iron and hard cast steel, I suggest that cylinder barrels should be of cast iron, and piston rings of Whitworth's compressed cast steel. That cylinder barrel liners are better than the old solid cast style is self-evident.

B. Of slide valves we have many varieties, but with all of them frictional resistance is excessive, and in order to ascertain its amount in any given case, it is necessary to find the mean total face load throughout the engine's revolution. In order to do this, it will be necessary to find the effective load for, say, the twenty positions of the valve corresponding to the twenty indicator diagram ordinates, and then take their mean. The effective load for any given position is equal to the algebraical sum of the absolute pressures obtaining, with their proper signs attached, × their acting areas. Having found this mean effective load and denoting it by Lm, the work expended on the valve's frictional resistance per revolution will be Lm × travel × 2 × π (the co-efficient of friction). The smaller this result, the less the work expended, and consequently the less heat generated. Any reduction in steam consumption should render possible the reduction of the work expended on slide valve friction. Relief frames undoubtedly reduce the face load considerably, but since absolute steam-tightness between such surfaces is a practical impossibility, and experience has decided that they do not last long, even fairly steam-tight, they have been abandoned. The faced load under any working conditions is a continually varying one, not only as a whole but also on its respective ends. Due to this fact, slide valves usually *hog*, or become convex in direction of their length. Piston valves are a decided improvement on slide valves, at least as far as frictional resistance is concerned. The only objection to them, I believe, is the room they take up and the increased clearance space and surface. Capital results are obtainable with this sort of valve, and where superheated steam is used, but few objections could be raised to the increased clearance space and surface. To economise space in such valves for large cylinders, double valves could be adopted either on the one spindle or otherwise. Much that has been said about cylinder pistons is equally applicable here, with the exception that it is necessary for considerations of steam regulation to have the circumferential surface flush (not turned away as in Fig. 2). Fig. 4 shows my idea of a piston valve ring, in section, which, when space permits, should be of the adjustable but practically solid type of Fig. 2 in plan. Having personally attended such a piston valve with an engine making very long runs, I have little hesitation in saying that such a valve might be run in reasonably superheated steam, with or without lubrication, but most certainly, if a good oil and system of lubrication obtained. I suggest that these rings should also be made of Whitworth's compressed cast steel and the chambers of cast iron.

C. The gland packings in the market are most numerous, and may be divided into two classes—metal ring packings and textile packings. Hitherto, metal ring packings cannot be considered to have given much satisfaction. Most of them are constructed so as to allow of slight lateral motion of the rod with respect to the stuffing box; but this, I think, is not a necessity where floating piston rings are used, and the distance between the crosshead and gland is considerable. Alternate rings of white metal and brass of a right-angled triangle section are often used. When properly attended to and put in with a couple of turns of good textile packing at the neck bush end it is fairly satisfactory. Textile packing should never be put at the gland end of such packings, for it will aid in the accumulation of steam pressure behind them and thus increase the friction. In probably all glands packed with floating ring packings, friction will be excessive. Textile packings have, so far, given the best results, and if good asbestos be used for hot steam glands, with proper attention, a practically steam tight gland will obtain. Canvas packings, are very good for moderate temperatures, and possess fair elasticity. Some kinds of semi-metallic packing appear to be a good combination of a textile packing with practically a metal rubbing face. Some are, however, somewhat too rigid for small rod glands where the difference of diameters of rod and stuffing box is considerable. I have no doubt, however, but that it could be made of circular form in order to overcome this objection. Having made long runs with H.P. glands packed with this packing, I can confidently say that, if properly attended to, it is capable of giving most satisfactory results. The friction with such packing, I think, need not exceed $D \pi \times 3 \times 6 \times \cdot 05$, which in a 7in. rod gland would be roughly 19·8 ft. lbs. per foot of travel. As good asbestos packings expand considerably with moisture, they should never be put in too tight, or unnecessary friction will follow. I suggest that manufacturers of asbestos packings should tack a label denoting the quality upon their packings, especially where several qualities of the same form are made, for I think packings are often condemned when they have been used for temperatures for which they were never intended.

2. That better so-called cylinder oils are in the market to-day than were when some of our older members were going to sea is unquestionable, and that

at least some of them are lubricants in steam cylinders and valve chests at very high temperatures is beyond a doubt. I know from experience that certain high-class cylinder oils retain some, if not all, of their lubricating properties in steam of 370° F. How much above that temperature this and other good oils retain their lubricating properties I cannot say, but since reading the article entitled "Magnolia metal and Anti-attrition metal" in the Marine Engineer of June, 1894, I have come to believe that in steam, whether superheated or saturated, these temperatures must be considerably over 600° F., as sperm oil did not fire till a temperature very much higher than this was arrived at, in the air, where of course, the oxygen is free. I venture to suggest that an oil's flashing point cannot have much to do with its value in the steam engine, where free oxygen does not exist. Its boiling point under different conditions of surface pressure is what concerns us more. From these remarks and what has been said about water and steam as lubricants, I think it may be fairly concluded that internal lubrication in all engines is most desirable; in high pressure and low pressure engines whether using saturated or superheated steam. In the latter case (superheated) the best possible system should be adopted and the very best oils used.

The old fashioned pot lubricators are obsolete and we have now automatic sight feed lubricators which may be classed under two heads: the rising drop sight feed and the falling drop sight feed. The rising drop sight feed, must be placed below the cylinders, preferably on the lower platform, and the oil conducting pipe should be as vertical as possible, with no dipping bends in it and not less than ½ in. diameter. Its working depends on the fact that oil is lighter than water (volume for volume). I have seen this class of lubricator condemned when all that was the matter with it was that it had been placed above the cylinder level, and the conducting pipe, being small, held water and so prevented the oil from dropping. The falling drop sight feed must be placed above the cylinder level, and a large section pipe is fitted to it, so that there is no water suspension in it; consequently, this pipe, which should be vertical and without upturning bends, is full of steam. Its working depends on the fact that oil is heavier than steam (volume for volume). I know of a case where an engineer, wishing to have the drops of oil deposited in a certain spot, fitted a small internal pipe into a falling drop sight feed, the result being that the large section pipe became full of water, through which, of course, the oil would not fall; in consequence, the lubricator stopped working, but it resumed work again on the removal of this internal pipe.

Most sight feeds depend on steam condensation for oil displacement, but in the most recent ones, plunger or piston displacement obtains. These possess the great advantage of the force being considerable with which the oil is displaced, thus clogging is not liable to occur as is the case with water displacement ones. A lubricator of the plunger displacement class is good but even these are open to objections, for since this lubricator works with a ratchet geared to the engine, as soon as the engine starts so does the lubricator, and should its extreme outlet cocks be shut the glasses or some other part must give way. Again, although the plunger stands still on reaching the bottom, the crossplate does not always do so, for I have seen one break across. No doubt this was due to the thrust bearing in the plunger being dry or dirty, thus allowing frictional resistance here to become greater than in the nut.

Sight feeds should be fitted not only to the main steam pipe or H.P. receiver but to each cylinder and steam chest and to all the glands. Such a statement as this I know will call forth much adverse discussion, for the tendency to-day is to stint oil internally to the lowest ebb. In fact, the whole of this paper tends to be adverse to general opinion, but as I believe its statements to be truths, I have not hesitated to place them before you to be reasonably approved or disapproved.

When it is accepted that on an average 14 per cent. of the I.H.P. is expended in overcoming internal frictional resistance and that only 6 per cent. on external, knowing how elaborate is our system of external lubrication, is it not surprising that more attention has not been paid to internal lubrication? For an engine indicating 1,000 H.P. we use about three gallons of good oil externally and only about $\frac{1}{20}$ to $\frac{1}{30}$ of this quantity internally per day, then if the engines revolve without squeaking we imagine we are doing wonders. Had a good system of internal lubrication obtained, and about one-half to one gallon of good mineral oil been used, we should have had more power developed at the propeller and less wearing down of the internal working surfaces. That such a quantity of oil could be safely handled in the boilers by the scum valves and pipes, if properly fitted and used, I am confident. But since we live in the days of feed water filters no objections with any weight can be raised against an ample and efficient system of internal lubrication. In passing, I venture to remark that present feed water filters are placed at the wrong side of the feed pump, and to suggest that instead of feed water filters we want exhaust steam filters. It has been advanced that the rod swabbing supplies sufficient oil for internal lubrication. This may be so if there are sufficient rods and the oil be poured on at the tail rods. However, oiling should be done continually, and not by the feast and famine process.

I was present at the reading of Prof. Lewis' paper on "Boiler Deposits," in 1891, and had the pleasure of seeing his experiment. In his proposals, however, he did not allude to discontinuance of internal lubrication, but such seems to be the tendency of marine engineers of to-day.

I cannot conclude this paper without alluding to the much quoted grunting in cylinders; but as so much space has been devoted to other subjects I must be brief on this point. Given a triple expansion engine, fitted

DISCUSSION.

The CHAIRMAN: Owing to the length of the Paper, our time this evening for discussion is very short. However, I hope we shall have a few remarks to introduce what seems to me should prove a valuable discussion. This is a subject which I am not able to take much part in from a professional point of view, but the reduction of friction certainly is a most important element in the economy of the marine engine. I can appreciate the labour which the author has bestowed upon the paper, and I am sure we will award Mr. Houfe our hearty thanks for what he has done.

Mr. MACFARLANE GRAY (Member of Council): It is very pleasing to see such an outcome of the Institute as the paper just read. The author must have occupied much time in thus writing out his thoughts. It does anyone good to sit down and write out his ideas of any subject, but to write out ideas in connection with his own special business or industry does the writer much more good, and whoever may be benefitted by the discussion on this paper, the author himself will, probably, be more benefitted.

Mr. N. K. MCLEAN (Member): I am afraid that while the more liberal allowance for internal lubrication may be good for the cylinders and pistons, it might be at the expense of the boilers, and would thus cause more serious trouble than that represented by the saving in friction.

Mr. C. L. E. MELSOM (Member of Council): I have found a very great difference of opinion regarding the amount of compression which should be given to piston rings. I have seen in my experience much loss of power due to faulty piston rings, and my opinion is that if more attention were paid to the proper compression of piston springs and rings, there would be better results.

The most important points to consider in connection with oils for internal lubrication are, not so much the flash point as the smoke point, as if that were too low, a deposit would be formed on the surfaces. The best oil for internal lubrication is a pure hydro-carbon with the flash and smoke points higher than the temperature of the steam.

The CHAIRMAN: As the time is now too far advanced to continue the discussion, it is proposed to adjourn it till our next meeting, this day fortnight.

ADJOURNED DISCUSSION

ON

INTERNAL FRICTION IN STEAM ENGINES,

AT

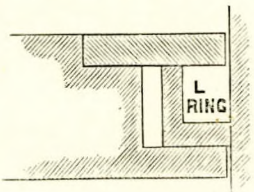
58, ROMFORD ROAD, STRATFORD,

On MONDAY, OCTOBER 28th, 1895.

Chairman—MR. T. F. AUKLAND (Hon. Member).

The CHAIRMAN: Gentlemen, we will now resume the discussion on the paper by Mr. Houfe, read at the last meeting, on "Internal Friction in Steam Engines."

Mr. J. R. RUTHVEN (Member of Council): At the last meeting, when this paper was read, several remarks were made on the question of the names of different makers of materials—packing, &c., being mentioned by the author. I think, perhaps, in continuing the discussion, we might leave out those names, and simply mention the materials and their qualities or special features. For instance, it would be well to have the opinions of those present expressed upon the different sorts of piston rings and packings at different pressures. I think there is a mention in the paper about a pressure of three pounds per square inch being the necessary force with which the piston's rubbing surface should press against the chamber wall. I should like to know the experience of members present on that point On the question of the amount of rubbing surface, we have an illustration, furnished by the author of the paper. At our last meeting Mr. McFarlane Gray mentioned another sort of piston ring, and I have seen a ring which appears to be of the same class. I will endeavour to sketch it on the black board.



The CHAIRMAN: With regard to the opening remarks of Mr. Ruthven, it did not strike me when the paper was read that the author intended to advertise any one particular patent. It was, perhaps, put in such a form that some might be led to that conclusion, but it did not strike me as such, and I doubt very much if the author so intended it.

Mr. J. T. SMITH (Member of Council): I quite agree with the Chairman's view that the author of the paper never intended to advertise anybody, and that when he named the makers of the different packings and piston rings referred to, it was done in perfectly good faith; and I think he was quite entitled to do so. I do not see how he could have described the things he speaks about without mentioning the names, because there are so many kinds of piston rings that have something in common, that unless the names are mentioned you would not be able to distinguish one from another. I do not think, therefore, that we should be tied down to keep back names. I think the author mentioned these things in perfectly good faith, so that his fellow members might have the benefit of his experience, and take it for what they think it is worth. With regard to the paper itself, I agree with the author in recommending the moderate use of oil. Of course, we know that in our boilers generally we get more oil than we know what to do with, and it is sometimes difficult to explain how it all gets there, when no oil for internal lubrication is put into the engines. Of course, the great objection to the oil is on account of the boilers, but, as a matter of economy, I believe the moderate use of oil is really a very great saving. But it should be oil of a very superior class; and I agree with the author in his remarks about its use.

Mr. John Kirkwood (Member): As far as my experience goes I think the less oil we use the better in a great many instances. Where trouble has arisen I have found on several occasions that by using less oil we have got along much better. There are times in working with different pressures when a little oil is an advantage, but I think that under ordinary circumstances the less oil we use the better. With regard to Mr. Mudd's piston, so far as I can see, it is an improved kind of piston altogether, although I have never had anything to do with it. So far as that sketch of Mr. Ruthven's is concerned, I am very doubtful about it being a success. But one can never tell unless you have had actual experience of a thing, and it is wonderful how things vary under conditions apparently similar. There are many different kinds of pistons at the present time, and you will find one kind of piston work well in one cylinder but not in another, although the conditions may appear the same. Ramsbottom's rings generally work very well, but there are ships in which they do not. It turns a good deal upon the kind of metal that the cylinder is composed of. With the ordinary style of piston any undue pressure put on the springs and rings causes them to work very badly.

Mr. H. C. WILSON (Member): I was, unfortunately, absent when this paper was read, and I have not since had time to study it. It certainly deals with a very interesting subject, and one of special interest to marine engineers. But really it is so long ago since I took a piston to pieces that I do not, for the moment, remember any special points to refer to; however, there is one point that I may make a remark about, and that is as to the amount of compression to be given on the rings of a piston. Now, how is anyone, say a second or third engineer, to know how much compression to put on a ring? Internal friction in marine engines may be greatly increased or reduced by a careful adjustment, or otherwise, of the internal moving parts, but it has always occurred to me to be almost a practical impossibility to estimate, with any degree of certainty, the amount of pressure put upon the barrel of the cylinder by the screwing down of the junk ring bolts. I refer, of course, to that type of piston having two split packing rings superposed, the one on the other, and exerting, by means of a spring ring behind them, a lateral and vertical pressure upon the cylinder barrel and piston respectively. This spring ring being compressed and held in its place by the junk ring, it is evident that the amount of "draw," or compression, allowed on the junk ring bolts directly affects the lateral pressure of the packing rings on the barrel of the cylinder, and, consequently, the friction of the engine. I am unaware of any reliable way of determining this pressure, or of finding out by how much, say an eighth part liner added to the circumference of the spring ring, would increase the friction of the packing rings on the cylinder. An excessive pressure put on when the parts are cold would be enormously increased when heat, due to friction, is added to the heat of the steam, and no amount of lubrication would prevent the rapid abrasion of the cylinder barrel. The slide valve also may be kept in good condition or utterly ruined by the adjustment of the pressure holding the valve on its face. This remark applies more particularly to high pressure valves. With regard to the necessity for internal lubrication, as a means of reducing friction, I think that some small amount of mineral oil should be used. The present practice of internal lubrication seems to be a compromise between the claims of the boiler and engine, and for my own part, if I could be sure of intercepting this oil and preventing any of it reaching the boiler, I should certainly use more of it, especially with compound engines. It appears to me to be very desirable in the first place, for the sake of the boilers, to use as little oil as possible for internal lubrication, but under present conditions the best compromise is, I think, to use a good quality of oil and little of it. Whether any oil is necessary when using perfectly dry and very hot steam is a point I should very much like to hear discussed, as there seems to be a limit of pressure and, consequently, temperature at which it is possible to work. There is also something to be said about the different types of pistons, but, as I said before, it is so long since I had to take a piston to pieces that I would rather leave that matter to be dealt with by others.

Mr. JAMES ADAMSON (Hon. Secretary): I have scarcely had time to read through this paper carefully, but there are one or two remarks which occur to me that may lead to further discussion. It struck me, when the paper was being read at our last meeting, that possibly the design of the valve in the case of the steamer cited by Mr. Houfe was more the cause of the trouble than the 75 lbs. pressure of steam. I have in my mind a steamer which was originally fitted with a design of valve that was not of the best, and the faces of the valve and cylinder were cut to the extent, in some instances, of five-sixteenths of an inch. That steamer had her valve faces renewed very frequently at considerable expense. A new design of valve was then fitted in the ship, and, after some years of work, there has not been the least trouble. Moreover, with the original design of valve, two steel quadrant blocks were broken, and a good deal of trouble with the valve gear was experienced. I think, therefore, the cause of trouble of this kind is often put upon the steam, when it is really due to the design of the valve or gear. With reference to the use of oil in cylinders, I see a visitor present this evening (Mr Leask) who may be able to give us a few ideas from his experience as an oil chemist and expert, as to the qualities of oil and the best kinds for cylinders and high-pressure steam. With reference to the pistons, I quite agree with Mr. Kirkwood, and also with Mr. Wilson, that probably the writer of this paper has been sometimes wont to see the junk ring bolts screwed up with an excessive amount of compression given to the ring. I have seen a set of the Buckley piston rings that had gone only twenty miles, with the cylinder torn up and bored out to a serious extent. I know another steamer that is now running with this same style of spring and rings, and, as originally fitted with these, she has been running for thirteen years steadily, and they are still good and giving satisfaction. I have been told of a steamer where they have run for twenty years without renewal or boring out the cylinder. These differences point to the fact that the human element has a great deal to do with the good working of engines, as also, no doubt, has the difference in metal surfaces. Again, if a job is done in a hurry, trouble generally arises. Another point that occurs to me is in regard to the edges of the piston rings. Some of them are turned with a very sharp, cutting edge, and I have found a great advantage to result from taking off that sharp edge all round. Mr. Houfe refers to Ramsbottom's rings, and perhaps his experience with them in the piston has not been in the way that they should be applied; that is to say, they should be turned twice—first to a certain diameter, then cut and turned again to the finished diameter. I believe that this is the most approved way of fitting these rings. With reference to the question of the differences of temperature affecting the different kinds of metal, Mr. Kirkwood shadowed forth that very often you may have one piston working well in a cylinder, and giving excellent results; then a change is made, new piston rings are fitted, and you have trouble. That may be due to differences in the homogeneity of the metals in the two cases. Mr. Houfe specially refers to that point, and advocates a liner of steel and a piston of a certain mixture of cast iron. Another point in connection with the Ramsbottom rings is that there exists a certain ratio between the depth and the thickness of the rings that gives the best possible results, the best ratio is what we want to get, and is a matter which is being largely studied by the makers of rings at the present time. Mr. Houfe calls our special attention to the question of what metal the piston and cylinder barrel should be made, so as to give the best results when they get hot, and the author has here touched upon a question to which more attention should be devoted, instead of looking so much to oil and lubrication as a means of getting rid of it. In my opinion, a change of design, rather than more oil, is preferable. With reference to the remarks of Mr. Ruthven, I would suggest that the question of making any alterations in the paper should be brought before the Council, as it is now in the form in which it was passed for reading. Exception has been taken to Mr. Houfe using the terms "saturated steam engine" and "super-heated steam engine," but the author is practically right, although we do not usually make use of the expressions in the way he has used them. Our object, of course, is to get our steam to the engine as dry as we can, and we do not talk about saturated steam if we can help it. Mr. Houfe has put forward his ideas of the ordinary steam engine without a super-heater, and I apprehend it is only when we have pressures of under 100 lbs. that we have super-heaters —steam domes having taken their places for the higher pressures.

Mr. LEASK (Visitor) : Gentlemen, I do not think that I can add anything to this discussion; I know very little about engines. I certainly know a little about oils, and have been connected with the subject of oils for a good many years, and have a good idea of the oil that is used on most of the railways of the country. I do not know quite so much about the oil required by ships. So far as I understand the oil that is required for cylinders, the best oil is a pure hydro-carbon—that is, an oil that has not in it the element of oxidation and that will not produce deposits in the cylinders. For some sorts of cylinders a little fatty oil is considered an improvement; but for high pressure engines I understand that a pure hydro-carbon oil is the best. As to the quality of that hydro-carbon oil, it should be a very high running quality—that is to say, the heat of the steam should not have the power of evaporating the oil and leaving the piston dry. Therefore, the oil for this purpose must be the oil obtained in the latter part of the distillation, when the heats are so very high that they are above any heats that would be produced by steam in the cylinders, and therefore the oil would not be evaporated by that heat. A pure hydro-carbon oil would never in any case produce acids that would act upon iron detrimentally.

Mr. LEASK, again rising, made some general remarks as to the viscosity of different classes of oils and their relative values as lubricants. The lessons which his experience and inquiries taught him was that as the viscosity or body of the oil was increased, so was the friction increased and the power exercised lessened. By special request, he promised, however, to write his remarks on this part of the subject and forward them to the Honorary Secretary, or read them at a subsequent meeting if the discussion on this paper was adjourned.

Mr. A. W. ANDERSON (Member) said he was very much surprised at the remarks of the last speaker. He, without some further explanation or qualifying statement by Mr. Leask, did not at all agree that by increasing the body of the oil they increased the friction; he always believed that the greater the surface the less the friction of a troublesome nature; that is to say, a steamer with long journals should run much smoother than another steamer of the same power and style, with short journals or less surface to her bearings. The best oil that they could use was sperm oil, he thought the flash point of cotton oil was about 320°.

Mr. Leask: As a matter of fact, sperm oil is the oil with the least viscosity of any oil that is used.

Mr. Anderson repeated that he did not understand the observations of Mr Leask, that extra body in the oil caused increased friction, and remarked further that he should like to know the flash point of cotton seed oil.

Mr. Pillans Scarth (Member): I am not at all well up in this subject, and should be pleased if some member could explain something of the lubricating properties of saturated and super-heated steam, and if a high pressure, and consequently drier steam, acts better as a lubricant than a low pressure wet steam. I have heard of many ships which run their engines without any internal lubrication at all. This seems to be especially the case in triple expansion jobs; but I know of two sister ships, one of which ran her engines without internal lubrication with good results. The other ship then tried it, but scored badly, leaving doubts in the mind of the chief engineer as to the veracity of the chief of the first vessel. Mr. Northcott, in his paper on Initial Condensation, points out, if I remember aright, that the exhausting sides of the cylinder would probably be covered with drops of moisture. These are the surfaces that the piston ring will travel over, and the less watery these surfaces are the less likely is abrasion to be found. When I was engaged in boiler inspection, I was much interested in the different oils used for internal lubrication. Where a hydro-carbon oil was used I found very little harm done to the surface of the plate, but with tallow, or where they used the same oil for internal as for external surfaces, I invariably found pitting and corrosion, and in many cases plates eaten completely through. From what Mr. Leask says, I gather that a hydro-carbon is also the best oil for a lubricant under high pressure; it spreads over a larger surface and will not form injurious soaps. But how will it mix with the moisture on the walls of the cylinder? This alone might account for the better results without internal lubrication, with saturated or with super-heated steam, if the oil did not spread well with the moisture on the exhausting walls of the cylinder. If oils can be used which do not harm boilers, either by overheating or pitting, or when used, can be effectually caught before going into the boilers, then I think internal lubrication would add greatly to the efficiency of the engines. Mr. Wilson has spoken on the compression of piston springs, and that same point has often struck me. I cannot see how the exact pressure on a Buckley or a horse-shoe spring can be regulated; and, frequently, I believe, the springs are much overloaded. I have seen the horse-shoe springs doubled, the compression on the Buckley springs very much increased, and those spiral springs, which Mr. Anderson speaks so highly of, with thicker washers put between them and the piston, but never with any permanent improvement. There is no necessity, that I can see, for anything more than a slight pressure on the ring. If rings and cylinders are true, little will keep them tight, but if not, no amount of compression will force them to be so. The best piston-packing arrangement that I was ever with, was two rings with a coil. The coil lay in a recess formed by the flanges of the rings, thus causing a pressure outwards against the walls, and upwards and downwards against the flanges of the piston and junk ring. As long as I was with it this ring kept very tight, but I never made any alteration in the compression which was on it when I joined. And here again it is a difficult matter to tell the pressure put on the rings when the junk ring has been screwed down.

Mr. J. B. JOHNSTON (Member): The only thing I have got to say about internal lubrication is that I do not see where it is required. To my mind, using oils for internal lubrication is a fallacy. The space, or rubbing surface, to be lubricated is so large that in a triple expansion engine exerting, say, 3,000 h.p. indicated, three gallons of oil in twenty-four hours would only work out at one-millionth part of a drop on the infinitesimal part of a square inch per revolution, effective lubrication. That is my point, taking into consideration that all the oil used is not effective. On opening up boilers and cleaning out condensers, we find lying there, in the form of grit, grease, &c., a deposit equal to about 25 per cent. of what you had actually put in as oil. As a matter of fact, the last six years I was at sea as chief engineer, there was never a drop of oil put into the cylinder, unless it was just as the engines were easing up or starting again. Then, just for a turn or so, a little drop of oil was very effective; but let every sort of lubrication be properly watched, and put it in the place where it is required. Use it so that it gets to the spot where it is needed. Let it be like "Homocea," which "touches the spot." There seems to be a great deal of trouble about the setting of piston rings. An engineer who sets a piston ring too tight is very foolish. I have known Buckley Rings to be jammed up too tight. I knew a chief engineer who thought he could never have them too tight. No, he was never happy unless he was going round with a six-foot spanner, and everything had to be tight. And there was trouble But on the question of internal lubrication, the last six years I was at sea, I never swabbed a rod, and I never had a hot rod. I have known engineers, with the same engines, using oil and tallow, and they had hot rods.

The CHAIRMAN: I understand from the Honorary Secretary that there are two or three young engineers here this evening, and I desire to say that if either of them wish to ask any question we shall be very pleased to answer them. If there is any point which any one of those gentlemen does not understand, or in regard to which he would like any further information, I hope he will ask the question. It has been thought by many present that there has not been sufficient time for all the members thoroughly to look through this paper, and that it might be an advantage if this discussion were adjourned until another night. In addition to that, if there are any members who would like to send in any remarks in writing, they would be gladly received by the Honorary Secretary. In the meantime, I have to ask the opinion of those present as to whether we shall have another night's discussion on this subject, after the members have had more time to read the paper through :—

It is decided that we have an adjournment, and I hope that before our next meeting some members will write out a few ideas and bring them here for discussion. I think the subject would be much better thrashed out if we had somebody who would condense the subject, as has been suggested by the Honorary Secretary, and we shall be glad if Mr. Leask will kindly write out some of his views on the subject of oils for internal lubrication, and give us the benefit of his experience.

Mr. LEASK : I am not an engineer; my knowledge of oil is simply that of a chemist; but I have been engaged in connection with the investigation of oils for many years, and I will draw up a few remarks on the subject.

Mr. RUTHVEN proposed a hearty vote of thanks to Mr. Houfe for his paper, and

Mr. H. C. WILSON proposed a hearty vote of thanks to Mr. Aukland for presiding.

These were heartily applauded.

The CHAIRMAN : I am very much obliged to you. I consider it an honour to have been asked to take the chair at this meeting, but I am exceedingly obliged to you for this very kind vote of thanks. As we are now at the end of our business for the evening, you may care to hear a story which I thought rather amusing. An engineer had a friend who was gifted with the power of ventriloquism. One day he went into the engine room to visit his friend the engineer, and he thought he would have some fun, so he imitated the noise which might be caused by a supposed friction in one part of the engine. The engineer who was working the engines went very innocently to the place where the noise appeared to come from and applied some oil. The friend then imitated a similar noise in another part of the engine. The engineer, never suspecting the trick that was being played upon him, went again and applied some oil at the supposed point of friction. And a third time this noise was imitated in yet another spot; but this time it seemed to dawn upon the engineer that his friend was making fun of him, so going up to his friend he exclaimed, "I see now where the noise comes from," and he poured the oil over the ventriloquist.

PREFACE.

58, Romford Road,

Stratford, Essex,

November 11th, 1895.

A Meeting of the Institute of Marine Engineers was held here this evening, presided over by A. J. Durston, Esq., C.B. (President), when the discussion on a Paper "Internal Friction in Steam Engines," by Mr. W. H. Houfe (Member, Hong-Kong), was resumed.

The Paper was read at the Meeting held on Monday, October 14th, and was discussed on Monday, October, 28th, the chair being then occupied by Mr. T. F. Aukland.

Remarks by correspondence on this, and all Papers read at the various Meetings, are invited from Members at home and abroad.

JAS. ADAMSON,

Honorary Secretary.

INSTITUTE OF MARINE ENGINEERS

INCORPORATED.

SESSION 1895-6.

ADJOURNED DISCUSSION

AT

58, ROMFORD ROAD, STRATFORD,

ON

MONDAY, NOVEMBER, 11th, 1895.

ON

INTERNAL FRICTION IN STEAM ENGINES.

Chairman—A. J. DURSTON, Esq., C.B. (President).

The CHAIRMAN: Gentlemen, the business of the evening is the discussion on Mr. Houfe's paper on "Internal Friction in Steam Engines," and I understand that Mr. Leask has very kindly come to give us some remarks on mineral oils. Possibly, it will be the pleasure of the meeting that Mr. Leask shall make his remarks now, so that the discussion may follow and take enlarged ground as it were. I call on Mr. Leask.

Mr. H. LEASK (Visitor): I have studied Mr. Houfe's paper with considerable interest, and, so far as my scant knowledge of marine engine matters goes, I think it a very able paper.

I was aware that Mr. James Napier, of Glasgow, had proved by experiment on a steamer that water applied to journals in unlimited quantity was very much inferior to oil used in the ordinary way, and that he could get three or four more revolutions of the paddles per minute when he used oil, but I was scarcely prepared for the statement that water was an anti-lubricant when interposed between two metal surfaces, as vouched for by Professor Rankine, who is a recognised high authority in such matters. It follows that the excessive abrasion of metal which sometimes takes place in the high-pressure steam cylinder, when super-heated steam is used, does not arise so much from excessive heat production by friction as by the inferior heat-conducting power of dry steam, which fails to dissipate the heat so quickly as damp low-pressure steam does.

Hence the writer (Mr. Houfe) advocates the use of oil to lessen the friction which is the source of this undue heat which causes the mischief, and so obtain economy of power or saving of fuel.

I am not in a position to follow the paper in the details of piston construction, and of rings and packing; but looking at Mr. Adamson's statement in the discussion, as to the very important improvement made by rounding off the sharp edge of the piston, the result is what one would naturally expect. I could conceive that the vibration, which I suppose always more or less occurs in the circumstances, would cause such wear on a piston, however well originally fitted, as to produce excess of friction at times between the sharp edge of the compressed steel piston and the comparatively spongy cast iron of the cylinder, and a scraping effect, which in the case of oil would squegee it into the cavities at the ends of the stroke, where the torrent of steam would catch it up and carry it off through the exhaust port, and the scraping action continued would in time abrade and cut up both piston and cylinder, but especially the latter. In the case of piston rod guides given, the sweeping effect of the steam is absent, and the shoe in its return licks up a little oil from the pool at the ends to lubricate it in its path.

Mr. Houfe believes in the judicious use of an oily lubricant, and it seems to be his opinion that indicated horse power may not be a measure of useful effect. I think this is reasonable enough, and that the very fact of having so much power at command, makes the loss of a little not so very manifest. In the case of a spinning mill, driving thousands of spindles, and where lubrication of the most perfect kind is most necessary, the substitution of an oil possessing a very few degrees of extra viscosity will make itself felt, and has been known, where there was not much reserve steam power, to stop the mill. I have no doubt that a very great increase of cylinder friction will also make itself apparent, though not in such a striking way. It has also been stated that, while in many cases it has been found possible to get well along without cylinder lubrication, in other cases it has not.

One gentleman at the last meeting, arguing against the use of cylinder oil, said that in the case of a 3,000 h.p. indicated engine, oiled with three gallons of cylinder oil in twenty-four hours, it would only work out to one millionth part of a drop to the infinitesimal part of a square inch per revolution. I do not know by what process of arithmetic he arrived at this result. A gallon of oil is easily measured, and the number of drops in it might vary according to circumstances; but the infinitesimal part of a square inch, though doubtless very small indeed, is an unknown quantity. Probably all that was meant was that a drop of oil spread over the entire cylinder surface gave a very thin film. If so, I do not think the statement meets the case. A good cylinder oil will not be dissipated at once by the heat of the steam. In the case of six samples of filtered cylinder oil, tested by exposure in shallow dishes to a temperature of 360° Fah., the loss by evaporation was ·02, ·03, ·12, ·41 and ·69 °/o, only one of them showing a loss of over half per cent. Five samples of natural oils lost: nil, nil, 1·90, 5·73, 6·73, the last three showing that the reducing process had been stopped short in their preparation.

L. Archbutt, chemist to the Midland Railway, recognises this test of exposure as a far more valuable one than the flash test, and regards 1 °/$_{o}$ loss as the maximum permissible, after an exposure of one hour to a temperature of 370° Fah. Cylinder oils which satisfy the requirements of this test should be effective, and although in the steam cylinder the conditions would be more severe than those of Archbutt's test, which is conducted in a stream of air as hot as the oven, yet I would expect that they would be carried over from the cylinder as a splash or spray, rather than as a vapour; and if they should carry out with them the abraded metal of piston or cylinder, it would be an advantage rather than otherwise, for the cylinder at least. It appears that the prime objection to internal lubrication is the pollution of the feed water, and deposits in the condensers and boilers, and corrosion of the last. I know of one instance where the leakage of oil from a paraffin works into a stream used for feeding the boilers of a weaving mill had the effect of keeping the boilers quite free from concretions, which had previously troubled them.

From their very constitution, tallow, and most animal and vegetable oils are open to objection. Generally supposed to possess far higher lubricating properties than mineral oils, they are liable under such circumstances to decompose, and their fatty acids to form soaps—not soda soaps, such as we are acquainted with, but iron and other soaps, insoluble in water, but such as would adhere to any surface they might come in contact with. Indeed, the conditions existing in the high pressure cylinder are identical with those in the autoclave, or digester, that is used for the purpose of converting neutral fats into fatty acids for soap, but especially for candle making. The high heat and pressure, and the presence of water, are just the agents which break up the fat and set free the glycerine from the fatty acid with which it has hitherto been chemically combined.

Hydro-carbon oils, whether of the C_nH_{2n+2}, the paraffin series, or of the C_nH_{2n}, or olefine series, are not open to the same objections, as they will not form such compounds. The lubricating mineral oils are mixtures of both of these, in what exact proportions it is difficult to say, as the theoretical percentage composition in the higher members of the series, approach so closely, that analysis cannot decide the question, but it is generally considered that the vaselines are mostly paraffins, and these saturated hydro-carbons have no affinities which will cause trouble in the steam cylinder. It has generally been supposed that fatty oils were more slippery, if we may use the term, and provided that the disadvantage arising from their composition could be got rid of, that they would absorb less of the power applied as friction than mineral oils; but, judging from some results published in the transactions of the American Society of Mechanical Engineers, 1890, this does not seem to be the case, in any high degree at least. This paper was written by I. E. Denton, Hoboken, N.J., a member of that Society, and refers to some experiments made with a piece of apparatus which has been constructed for the Lubricating Committee of the Standard Oil Company, for investigating the lubrication of steam cylinders. The details of construction of the apparatus are too intricate for me to describe, further than to say that the piston of a 6in. cylinder, 9in. stroke, is fitted with a special packing ring, carried upon spring levers, so that the force of friction created between it and the walls of the cylinder shall move a pencil arm, and as the piston reciprocates, form an approximately rectangular diagram on a piece of paper held against the pencil. One half of the width of the rectangular card diagram measures the total frictional resistance of the ring on a scale of 230 lbs. to the inch. The packing ring is made almost perfectly flexible by saw slits on its interior surface, and can be expanded by levers actuated by a screw, so that any desired intensity of pressure, up to 150 lbs. per square inch, can be created between the ring and the surface of the cylinder. Two ordinary packing rings prevent the steam pressure from entering the space devoted to the special ring, so that, by connecting this space with the atmosphere, the only pressure upon the packing ring will be due to the adjustment of the screw. One experiment was undertaken with the sole purpose of determining to what extent the friction of a packing ring under 70 lbs. per square inch pressure differed when a fair supply of cylinder lubricant was used, and when no lubricant whatever was used. The results were, with a newly-constructed cylinder of cast iron, and a test ring of cast iron :—The friction, with no lubricant, was about 7°/ₒ of the nominal pressure, and, with a supply of lubricant of average good quality, economically used, the friction was not greater than 2°/ₒ of the nominal pressure.

Another series of experiments was made to compare three petroleum lubricants of good reputation with good melted tallow. These had all a small percentage of animal oil, under 5°/ₒ, and that ingredient was different in each. These were described as being in general appearance and nature as similar, 550° flash point 26° Baume (about ·900 sp.gr.), 45° cold test and 135 units of viscosity at 212° Fah. The tallow, when melted, has practically the same gravity and flash point as the petroleum, but its viscosity at 212° was only 55 units, so that at that heat it was about 2½ times thinner than the petroleum oils. Twice the amount of tallow was required to give the best results, as of petroleum. After lengthened trials, after each experiment with tallow, a black paste covered all the interior of the engine to quite a tangible thickness, while, with the petroleum oils, an oily film of the same consistency as the oils themselves was left.

The analysis of the tallow deposit was—

	Per cent.
Animal Oil	28·2
Carbon	11·1
Oxide of Iron	4·2
Metallic Iron	53·3
Lime	0·5
Water	0.9
Undetermined	1·8
	100·0

A sample or two from the tables may show the nature of the trials and results.

September 22nd: Run of 2·75 hours; feed, 12 drops of tallow per minute, equal to one pint in 16 hours = 11,520 drops per pint; 288,000 square feet uncovered by piston per pint of oil; width of card, 0·7 inches lubricant tallow; 130 lbs. steam pressure; 140 revolutions per minute; total friction in lbs., 80·5; coefficient of friction, 0·119. By doubling the tallow feed the friction fell from $\frac{3}{4}$ to $\frac{3}{32}$ in 1·30 hours, *i.e.* the total friction was reduced to 12·65 lbs. and the coefficient to 0·018.

Cylinder oil A using $\frac{1}{13}$ pint per hour; piston uncovering 234,000 square feet per hour; width of card, ·08; steam pressure, 130 lbs.; revolutions per minute, 127; gave total friction, 11·50; coefficient of friction, ·017. Using $\frac{1}{10}$ pint per hour, the coefficient was reduced to ·010. On the whole, it appears to me that in other respects the results are similar, and the number of revolutions per minute for similar steam pressures seems to be slightly higher with the fatty oils.

It is quite possible that I have been attempting to describe an apparatus and results with which you are already familiar. If not, I have here the drawings of the instrument and the results fully tabulated.

Despite these results, which seem to prove that a lubricant is advantageous, perhaps it is my position not to indicate what I think the best, but those which are least injurious. There are two classes of mineral oils specially used for cylinders, namely, *dark oils*, left in the stills after the spirit and machinery oils have been run off, and which are filtered through iron gauze, canvas, cotton waste, &c., to remove sand or grit; and there are oils of the vaseline type, which are produced by filtering these dark oils through animal charcoal, by which the natural bitumen is removed and a pure petroleum jelly produced. Much difference of opinion exists regarding the comparative merits of these two classes of oils, each having its advocates. Charcoal-filtered oils when burned leave merely a trace of coke, while the dark natural oils leave from $2\frac{1}{2}$ to 4 °/ₒ; therefore, it is reasonable to suppose, they will be less likely to leave tarry deposits in the cylinders, boilers or condensers. In the qualities of viscosity and flash point, both of these classes of oils, when properly prepared, leave little to be desired. Taking, as a standard of viscosity, tallow at 180° Fah. = 100 :—There is American heavy dark, sp.gr. 900—905, which at 120° shows a relative viscosity of 1,750—2,000, and at 180° Fah. shows a viscosity of 350—400, a flash point of 500° to 550° Fah., and a setting point of 40°—45°. American extra, the same gravity, viscosity at 120° Fah. 2,000—2,500, and at 180° Fah. 400 to 450, with a flash point of 500° to 575°, and a setting point of 35°—40°. Then there are charcoal-filtered amber oils, heavy, sp. gr. 890—895 viscosity at 120°, 1,400—1,500, and at 180°, 300 to 350, with a flash point of 500° to 550°, and a setting point of 60° to 70°, and there are others within the margin of safety, so that, with the means of testing, there is no reason why a first-rate article cannot be got. It does not follow that oils nominally the same are actually so. This is also true with regard to engine oils. For example, I had two Russian, nominally 910 oils a few days ago from the same manufacturer. No. *a* was two degrees short of the gravity, 908, while the other, *b*, was exactly right in that respect. At 70°, taking sperm as the standard of viscosity = 100, *a*, the lighter oil, stood 987, while the heavier was 707. At 120° Fah., the lighter stood at 163, and the heavier stood only 127, and the flash points were, *a* 375°, *b* 340°; in all essential particulars the lighter being the better oil. There are many instruments for measuring the mechanical efficiency of various oils under ordinary conditions. The following are results of tests made on an instrument constructed by T. J. Pullin, and carried out jointly by him and J. V. Wilson, which show that, while it may be necessary to have enough body in a lubricant to withstand the shear of heavy machinery, the coefficient of friction increases with the viscosity of the lubricant, the conditions of speed, pressure, and temperature being equal, as had been previously demonstrated by Thurston, Tower, and Goodman. The first action of a journal is to reduce, by the generation of heat, the body or viscosity of the lubricant to the point of least resistance, and while the necessary temperature may vary, the viscosities of all oils at their respective working viscosity closely approximate. This I endeavoured to explain at last meeting. Taking the case of a bearing $3\frac{1}{8}$in. × 3in., running at 1,400 revolutions per minute, equal to a surface speed of 1,100 with a load of 60 lbs., and using sperm oil, which has a viscosity at 70 Fah. = 100, and at 120° of 67·4, and at 212°, 53·9:—the drag was found to be 18, the temperature developed 189°, and the viscosity at the working temperature 56·2.

Using rape, which at 70° Fah. is more than twice the viscosity of sperm, the drag was 32, the heat developed was 213° Fah., and the viscosity was reduced by this heat to 60·7.

Using castor, which at 70° Fah. was 2,188, or nearly 22 times the viscosity of sperm, the working temperature was 232, the drag being 41, and the viscosity was reduced to 70·8, or only 14·6 above that of the sperm.

These were only three of twelve samples tested; but they show the general result, which, while they have not a direct bearing on the matter in hand, must have an indirect one, showing that the lightest oil that will keep the surfaces separate is the best, other conditions of suitableness being present, extra viscosity meaning extra friction. Mr. J. V. Wilson's opinion is, that for steam cylinders, pistons and valves, working in connection with surface condensers, pure hydro-carbons are the only permissible lubricants, on account of the deposits in cylinders and condenser tubes produced by fatty oils, and also owing to the corrosion which must arise when those are used. When ordinary spray, or injector condensers are used, the addition of a little refined neutral tallow may be recommended, especially in the case of heavy horizontal cylinders and slide valves.

I have intentionally refrained from discussing the properties of the various fatty and hydro-carbon oils as lubricants generally, as outside the question, but before I sit down, I would, with reference to a remark made at last meeting, observe that the average flash point of cotton oil is 523°, not 320°, and instead of losing weight by Archbutt's test, would probably gain weight considerably. In no case has it any fitness for cylinders, and in any form, for other reasons, is an inferior lubricant.

The HONORARY SECRETARY, after expressing the thanks of the members to Mr. Leask for his valuable contribution to the discussion, read a report of a discussion on this paper that took place the previous week at a meeting of the Bristol Channel Centre at Cardiff, and afterwards read a communication that had been received from Mr. JOHN H. THOMSON (Chairman of Council), as follows:—"Mr. Houfe, in the second paragraph of this paper, refers to the difficulty there was with the cylinder faces and slide valves of the engines of two vessels built in 1868. About that time the compound engine was just coming to the front, and engineers, both in the drawing-office and on board ship, were only being educated to the new conditions. For several years we were frequently hearing of troubles with slide valves, &c., which were attributed to the then excessive high pressure. To those of us who do not know the history of the vessels referred to, it will be instructive and also interesting to learn what means were adopted to reduce the excessive wear, and to get the slides into comfortable working order, as 'the terror of all engineers' could not, in the interests of the ship-owner and engineer alike, have been allowed to exist for any lengthened period. In many cases I think it was not so much the high pressure or high temperature of the steam that was altogether at fault. Two cases which came under my direct observation were due to structural defects, which no lubricant could have cured, even if it had a thousand and one 'genuine testimonials.' The defects being remedied, smoothness in working, and durability was obtained, and instead of the valve and cylinder face wearing at the rate of about three-eighths of an inch in 6,000 miles, it was reduced to about 1-32nd of an inch in 30,000 miles. The defect was in the door of the slide valve chest, which, being too light, yielded to the ever-changing pressure caused by the opening and closing of the ports. A more rigid door being fitted, the improvement referred to was effected in both cases."

Mr. SAGE (Member of Council): In answer to the President's call, I will endeavour to say a few words, although this is the first time that I have had the paper in my hands. I have been very much interested in the remarks just delivered by Mr. Leask on the properties of the different lubricants, for I think myself, that the less internal lubrication you have the better. I think it is a matter of mechanical skill to do away with it altogether. When we have a perfect piston and slide valve, the necessity for internal lubrication will disappear. Of course, the hydro-carbon oils that are now used, being pure, are the best that can be employed, but in my day, when I first went to sea, we used to have to use the same oil for internal and external lubrication as was supplied for the lamps. We used to use a highly refined rape or cotton seed oil, and we had nothing else. It was before the days of these hydro-carbon oils. I know we were then timely aware that it was injurious to the cylinders and boilers, and for my own part I never put it into the cylinders until we were nearing port, and then, as we were easing up, the engines grunted for it. It was only then—or when we were getting under way—that the engines appeared to want it, and it was only on account of the grunting that we used any oil at all. I consider that with a properly constructed mechanical piston that completes the contact with the wall of the cylinder with just sufficient pressure to prevent the escape of the steam, in fact, by maintaining the minimum of friction between the wall of the cylinder and the piston, that then we should have the perfection of two faces working together, and internal lubrication would not be required. I certainly disagree with the author when he says that steel piston rings should be used, for I think that two cast-iron surfaces are more likely to work well. I was looking recently at a small cylinder only 20 inches in diameter that I had not seen for four years, and I was very much surprised to find that immediately the cylinder cover was off you could have taken your pocket handkerchief and wiped it out without soiling it. I asked the engineer, "What did you use in the cylinder?" and he replied, "We did not put anything in until we were just coming into port, but we have to open up the piston rings every month, or else they get jammed and will not act." They were absolutely tight, the two faces. The engineer told me that he sometimes goes a whole voyage—they are short voyages it is true—without putting a drop of oil into the cylinder, and I know he does not use more than three-quarters of a gallon per voyage at any time. My experience has been, that the less oil you put into the cylinders the better the engines will work. There are some that will not, but if the mechanical arrangements are perfect internal lubrication is not at all necessary.

Mr. DUNCAN (Member): I see on page 6 of the paper that the author speaks about a pressure of 3 lbs. to the square inch being necessary to keep the piston out against the cylinder wall. In my experience I have found that entirely unnecessary. Some time ago I had a paper for using Buckley's rings, and it advised a pressure of half-a-pound per square inch of surface of the ring to keep it tight. I worked it at that pressure for some time, but I found that even that pressure was not necessary; now I work it at one-third of a pound per square inch of the surface of the ring, and I find it is quite sufficient. On taking out the piston I found water floating on the top when cold, showing that the piston ring was perfectly tight. If by giving this pressure of one-third of a pound the piston can be made tight, I cannot see how it can be made out that 14 per cent. of the work done is consumed in friction, as stated in the paper. The author, I see, recommends the use of steel piston rings, but this is a matter in connection with which the character of the material—the mixture of the metal—ought to be taken into consideration. If you cast a cylinder of a particular metal and cast the ring of the same metal, you will not find them work well together, but if you make the ring of a different mixture, you will find them work very well. Two cast irons of different mixture will, I think, be found to answer best. The interesting remarks of Mr. Leask this evening have shown me the reasons for a state of things that puzzled me for a long time. Some time ago I had a lubricating oil that was used for a while, and I noticed that the back of the low pressure slide valve and the nuts on the low pressure cylinder were getting eaten away. I drew attention to it and they changed the oil, with the result that it ceased at once. Before the oil was changed it had been getting so bad that the stops of the piston rod nuts were nearly wasted clean off. Subsequent investigation showed that this could not have been due to anything but the oil that was first used, and we also found that in the boilers there was a small amount of pitting going on. There was just a mark in the material, but when the oil was changed the pitting was stopped. It was evidently a dangerous oil to use. It is a difficult thing to get a good lubricating oil which is free from objection, because when it goes thorough the cylinders it is not done with. It has to go through the condenser and the boiler, and may perhaps do them more harm than any advantage gained by the use of the oil in the cylinders. In the case of the second oil that was used there was a larger deposit left, but still I have never seen under that deposit the marks of any pitting, or anything of that kind. But in the case of the first oil, I think, from what Mr. Leask has said to-night, that I see where the mischief came in. It was certified to be a perfectly pure oil, it was supplied by a well known manufacturer, and it is an oil that is very largely used. But there is much with regard to the sale or supply of these oils that ought to be looked into. With some oils they furnish a certificate of analysis by some celebrated chemist, and people take the oil on the faith of that certificate, but when they come to use the oil they find it develop qualities very different from what they had been led to expect. Whether the chemist's certificate was incorrect, or whether the oil is changed I am not able to say. Perhaps Mr. Leask may be able to inform us on that particular point.

Mr. MURPHY (Member): A great deal depends upon the quality of the oil used for lubricating purposes, and a great deal depends also on the design and construction of the machinery. I have noticed a great deal of difference in the results by using different sorts of oil on lots of occasions during my experience, and on the other hand I have seen many peculiar results from different classes of marine engines, in comparison with the consumption of different sorts of oil. I remember sailing out of London some years ago, when I had to do with a line of steamers running to New York. When those ships first came out, the wear and tear, particularly on the cylinder and valve faces, was something enormous—worse than anything I ever had to do with before or since. It was a common thing for those ships to wear out a cylinder face and a high pressure slide valve face in the run out to New York, but they scarcely ever did more than a voyage to New York and back. The qualities and quantities of the oil had been changed off and on during the first twelve months. This was allowed to go on during the first twelve months of guarantee. There was a good deal of opposition to any alteration while the guarantee of the builders lasted. Well, the qualities of these faces had been improved on as much as possible, until eventually, it came to my turn to try and lessen this friction. I ought to mention first of all that there were three of these ships built, and they were engined by the same firm. There was a very heavy high pressure slide valve and cumbersome expansion valve. The travel of the valve was excessive, to my mind. In working up the amount that the high pressure slide valve ought to do, it was found that there was a vast pressure that could easily have been done away with when the engines were first designed. This destruction of the cylinder led to an enormous amount of lubrication. It was a common thing to consume 42 gallons of oil from London to New York in eleven or twelve days, and the same coming home. When one considers that in doing from 22 to 25 days' steaming you use 84 gallons of oil, you must admit at once that such a consumption was enormous. When it came to my responsibility, the very first alteration I made was to take the expansion valves out altogether, and run without them. In consequence, the ships improved in their general working, and the quantity of oil used was reduced very considerably. As soon as I had the opportunity I took the high pressure slide valves out altogether and put new valves with a shorter stroke. By arranging accordingly, and using a better quality of oil I was able to bring down the consumption to seven gallons a voyage to New York and back, instead of 84 gallons as it was previously. Of course, improvement followed in everything accordingly—condensers, pumps, boilers—all gained by the alterations that had taken place. The cylinder faces and slide valve faces that were fitted at that time, now twelve years ago, are running yet, and certainly show no signs of being scarified. With regard to the quality of the oil, of course, every engineer knows, that there is a very great difference in the qualities of oil, and also the beneficial effects of using the best oil, but I do not think that it is wise to do without internal lubrication altogether. The judicious use of oil is one thing, but to do without it altogether is not a course which, according to my experience, is to be recommended. At least, I have never had to do with machinery where you could do without the use of oil to a certain extent.

Mr. GREER (Member): I think we have, in the discussion, arrived at nothing definite. As I understand it, the point we are driving at is the friction in engines, and the right principle to be applied to the friction in the cylinder first, and to the slide valve, perhaps, second. There is one member who says that he has learned the amount of pressure on the piston ring. I should like to done away with. The oil that goes into the cylinders goes in through the piston rods, and yet a great deal gets in, very often much more than we wish. Well, the other function of the water and moist steam to which I referred is this: The small quantity of lubricant that goes into the cylinders is very well distributed over the surfaces by the minute division of the water and the steam. Each particle of water and steam carries with it a very infinitesimal quantity of the lubricant. Of course, if, as Mr. Houfe very pertinently remarks, we could have a filter that would separate the oil completely in the exhaust passage it would be a very great thing. It would be in every way a great advantage if we could trap the whole of the oil in the exhaust passage, and you could then keep up a plentiful supply of oil round the engine without doing any damage. But we have not arrived at that stage yet, and it cannot be disputed that the general result of using large quantities of mineral oil is to bring the boilers to grief. It would certainly be a very desirable thing if, as Mr. Houfe has suggested, super-heating could be again used. The super-heating of our olden days was carried out under greater difficulties than we experience now, and we now know much more about the materials employed, and plans for regulating the super-heating of the steam. Very frequently there was not much control over the super-heating at all; but where the super-heating was used with judgment, as far as it went, it led, in very many cases, to increased efficiency. I would suggest that we give Mr. Houfe a vote of thanks for his very long paper. It bears evidence of an immense amount of work and thought which the author must have given to the subject.

Mr SAGE: Gentlemen, I know that you will all cordially agree with me when I propose a hearty vote of thanks to our President for coming down on such a wretched night as this and presiding over our meeting. I am sure you will all feel with me that we are very much gratified at his presence here this evening, and I am only sorry that the bad weather has prevented a more numerous attendance to meet him.

Mr. RUTHVEN seconded the proposition, which was carried by acclamation.

The PRESIDENT: Well, gentlemen, it has been a great pleasure to me to be present on this occasion. I should like to be able to be present more often than I have been; but, as in most other things, time is not always available, and the distance is also a difficulty. I am very much obliged to you for your vote.

[BY CORRESPONDENCE.]

Mr. P. SMITH (Member): I have had great pleasure in reading Mr. Houfe's excellent paper on "Internal Friction in Steam Engines," as it deals with the subject in a thorough practical manner. I agree with the author in his statement that internal lubricant will increase the economy of the steam engine. Unfortunately, since the introduction of the triple-expansion engine, with high-pressure steam, the commercial cylinder oil has been proved to be quite inadequate for the purpose required, and, in consequence, the continued use of an inferior oil has been the cause of serious trouble, compelling those in charge of high-pressure boilers to discontinue its use, thus adding to the tear and wear of the working parts and reducing the economy of the modern engine. The internal friction in engines has been considerably reduced since the introduction of triple-expansion, owing to the improvement in the internal working parts, such as pistons, slide valves, &c. I entirely agree with the author in his statement that it is impossible to prevent high-pressure steam from getting inside the piston, and thus increasing the friction on the walls of the cylinder to an alarming extent. This proves how futile has been the work of so many inventors in their efforts to produce a steam-tight piston, which, instead of increasing the economy of the steam engine, has had, unfortunately, the opposite effect. Some of those patent piston makers are still working in the dark, and fail to realise that high-pressure piston rings ought not to be steam-tight. A good many engineers will consider this a bold statement; but, from my ten years' experience in charge of high-pressure engines, I am convinced that such is the case. I had first of all to deal with ordinary slide valves and common piston rings; the trouble with the former was the excessive friction on the faces, due to the pressure of steam on the back of the valves, which has now been overcome by the introduction of piston valves. I am of opinion that a good deal of the abrasion referred to in the low-pressure engine is due to the slide-valve faces getting covered with rust during a few days' stoppage at an intermediate port. Every care ought to be taken to prevent vapour reaching this engine from the condensers or other sources. My experience with high-pressure pistons having deep packing rings has been that steam gets inside, and being unable to get out, the internal pressure gets bottled up there, forcing the ring out against the walls of the cylinder, and causing either cutting or enormous wear of both rings and cylinder, with a corresponding loss of power. I found that instead of trying to make the packing ring steam-tight between the piston and junk ring, which is impossible, that providing the means of escape for it, was a step in the right direction. This I did by leaving the ring about $\frac{1}{16}$in. slack vertically, thus allowing any steam that got inside to have a free exit to the exhaust side of the piston. This is practically what the Ramsbottom ring does, and hence their success in reducing the internal friction in high-pressure engines. I do not agree with the author in disparaging their use, but would recommend four to be fitted rather than two, which has the effect of baffling the steam, so that the leakage is trifling compared with the reduction of friction and consequent increase in the efficiency of the engine. This style of piston is, in my opinion, the best adapted for high-pressure steam in any size of cylinder. Another great source of increased friction in the modern engine is the piston rod and its packing. Why do we find so many scored rods, and from what cause? The obvious reason seems either inferior packing or excessive friction, with a corresponding reduction in the economy of the engine. The most of metallic high-pressure packings have the same fault as the old fashioned piston rings, only instead of the steam getting inside the rings it gets outside, and forces the rings against the piston rod, producing excessive friction. I believe, however, some inventors have got over this difficulty in their improved packings. I do not agree with the author in his objection to have textile packing next the gland. I think it is the proper place for it, to prevent loss in leakage from the rod. I have not had much experience in different textile packings, but sufficient to prove that a good many of those in the market are not only useless, but dangerous to use. Packing for a high-pressure piston rod ought to be entirely automatic, and the best results I have obtained have been from the combined use of improved metallic automatic rings next the neck bush, and a textile packing next the gland, with a good india-rubber backing to give the packing the right amount of compression to ensure steam-tightness without the aid of the gland compression. I quite agree with the author that to decrease the internal friction in steam engines is to endeavour to prevent the liquefaction of the steam that has to do the work; to accomplish this my experience has been that steam jacketing is important, and also a thorough system of draining steam casings, &c. The great question of the day, to my mind, for the marine engineer is how to run with safety and economy the modern steamship, with its increasing complications. Although I am convinced that the proper treatment for an engine is to have a thorough system of judicious internal lubrication, still, on the other hand, the carbonized oil being conveyed to the high-pressure boiler, with forced draught, is an appalling source of danger, which I am afraid can only be safely prevented by the use of filters, which I am pleased to see are being largely adopted.

The reason for making the above remarks is not so much to criticise the author's paper as to give support to his most practical ideas, and I am convinced that if more of the marine engineers of experience would come forward with their views, deduced from actual experience, the result would inevitably be the reduction of internal friction and a consequent increase of the efficiency of the modern steam engine.

A. J. DURSTON, Esq., C.B. (President).

Having re-read Mr. Houfe's paper, I desire to offer the following observations.

This paper calls attention to the subject of the internal friction of the steam engine in a practical and suggestive manner. The author has evidently bestowed much thought on the subject, and has displayed very considerable ability in his endeavour to elucidate the cause and extent of internal friction, and the manner in which the heat generated thereby is necessarily dissipated, in order to prevent overheating of the parts.

Whether or not water acts as a lubricant for metallic surfaces, it undoubtedly dissipates the heat generated by the friction of the internal working parts, and of course abstracts heat very rapidly when the metallic surface temperature exceeds that of the saturated steam with which it is in contact, and it may be granted that it is this rapid abstraction of heat by the water, produced by the liquefaction due to expansion, and initial condensation combined with the distribution of the oil from the rods by wet steam, that enables marine engines of the present day, working with saturated steam, to run without oil for internal lubrication, even with an initial pressure at the engines as high as 200 lbs. per square inch above the atmosphere.

So far, all engineers may go with Mr. Houfe, and it is also axiomatically true that increased economy would result from the reduction of internal friction, combined with the use of superheated steam. Putting the latter aside for the moment, and dealing only with internal friction, we are confronted with many difficulties. The author states that this friction may be reduced by good design, and a good system of lubrication, but the remedial measures he suggests are, in my opinion, inadequate to effect a satisfactory solution of the problem. These measures shortly stated are:—

1. The employment of piston packing rings and slide valves, specially constructed to obviate the surfaces being forced against each other by the steam pressure to an unnecessary extent.

2. The use of certain dissimilar metals for the working surfaces, and

3. The use of improved gland packings, lubricators, and lubricants.

All these points have, however, been carefully considered by many eminent engineers on the lines suggested by Mr. Houfe, and so far as I can see there is very little prospect of internal friction being reduced to any considerable extent by improvements on the best modern practice in marine engine design.

It may be doubted whether the single piston packing ring, with junk ring, has been materially improved upon. The various types of narrow rings, which answer well when new and carefully fitted, soon become inefficient, and allow steam to pass, and it is a matter of fact that, with electric light engines for the Admiralty, where heavy penalties are enforced for excess steam consumption, makers have been enabled to come within their guarantee by substituting a single broad ring with junk ring for two Ramsbottom rings.

That the friction in the cylinder is often unnecessarily increased by the steam pressure behind the packing ring may be admitted. This defect may, however, be obviated, by fitting stops at the tongue piece to secure the ring from opening or closing, and by carefully fitting the ring to the cylinder when hot. A good working piston may be thus obtained, combining the advantages of both solid and expanding packing rings.

In one of H.M. ships so fitted it was found that by wedging the rings out to fit the hot cylinders, and then allowing $\frac{3}{32}$ in. less opening for H.P., $\frac{4}{32}$ in. for the M.P., and $\frac{5}{32}$ in. for the L.P., that the surfaces were kept up to this work, with practically no wear. The diameters of these cylinders were $30\frac{1}{2}$ in., 45 in. and 68 in. The cylinders referred to were worked for three years without any lubricating oil except that which entered by the rods. With regard to the benefit to be obtained by dissimilarity of metals, it may be said that in the Royal Navy, after a lengthened experience with Whitworth compressed fluid steel for the working barrels, and phosphor bronze and cast iron for packing rings, cast iron working barrels and cast iron packing rings have been reverted to, and it is found that cylinders open up better with the two cast iron surfaces working together than with dissimilar metals.

Mr. Houfe states that the internal friction may be taken as 14 per cent. of the I.H.P., presumably the maximum I.H.P. is meant, but he does not give any authority for the statement.

Some experiments have recently been made with one of H.M. ships, fitted with triple expansion engines of modern construction. It was found that the internal friction and external friction up to the stern shaft, coupling together, absorbed considerably less than 5 per cent. of the natural draught power, and although single experiment results cannot be regarded as trustworthy, this result certainly points to the conclusion that Mr. Houfe's estimate is excessive for well designed engines. I will simply remark, with regard to gland packings, that there are metallic packings that work well with high pressure steam, when carefully fitted, in combination with a small outside gland containing a block packing made of asbestos and wire woven sheet.

The subject of internal lubricators has occupied the attention of engineers to a much greater extent than Mr. Houfe supposes to be the case The presence of oil in boilers is a matter of such paramount importance, that the subject is continually forced upon the attention of engineers. The only present practical method of lubricating the internal parts is by the use of sight feed lubricators, which carry oil in with the steam. This is, however, admittedly a wasteful and objectionable method, as only a fractional part of the oil admitted comes into contact with the rubbing surfaces, and the whole of it has to be dealt with, and prevented, as far as possible, from passing into the boiler.

Grease filters are extensively made use of on board H.M. ships, but the best of them only partially extract the grease; and the author scarcely realizes either the difficulty of extracting oil from feed water when it has been beaten up, and intimately mixed with it, emulsified as it were, or the danger of overheating that occurs with very slight oil deposit on the heating surfaces when boilers are forced, as they have to be occasionally. He suggests exhaust steam filters, and it has occurred to others that as the globules of oil when mixed with steam are very heavy, as compared with the globules of steam, that they could be more readily separated than when incorporated with the feed water. This method has obtained a limited success with auxiliary machinery.

Sinclair Stuart's grease extractor is probably known to members of the Institute. It consists of a series of gratings with the bars of one opposed to the space of the next grating, and if a large quantity of internal oil is used, as in certain types of electric light engines, this extractor does separate a considerable amount, but a considerable amount also passes to the condenser.

Our constant endeavour in the Royal Navy is to use the smallest possible amount of oil in the cylinders, as the lesser of two evils, so long as the working surface show no sign of abrasion. The additional friction being preferred to the danger and difficulty attendant on a more copious supply of oil.

If Mr. Houfe could show us how to apply a sufficient quantity of oil to the internal working surfaces, and to recover it all, or practically all, before the feed water enters the boiler, the use of superheated steam of high pressure would fall within the region of practical engineering, for the heavy filtered mineral cylinder oils now obtainable are undoubtedly efficient lubricants at high temperatures. In my opinion he has not done so.

Superheaters in the uptakes were commonly fitted on board H.M. ships many years ago, and their use did not give rise to any trouble with the engines when judiciously worked. It was a frequent practice to mix saturated steam with superheated steam, to an extent sufficient to prevent overheating of the internal working surfaces. They were, however, found to wear rapidly by corrosion, and, as it was thought that the weight involved by fitting them could be better applied in other parts of the design, they gradually fell into disuse.

If a practical method of separating oil from exhaust steam or feed water can be found, the use of high-pressure superheated steam will, no doubt, receive proper consideration from marine engineers.

Only pure hydro carbons are used for internal lubrication in the Royal Navy, but with regard to the use of undistilled filtered oils, I may say that the Admiralty have made some trials during the past three years with distilled and undistilled oils, in a vessel fitted with high pressure steam boilers and making regular voyages, under practically the same conditions. Some boiler troubles, caused by greasy deposit on the heating surfaces, had been experienced, in the vessel referred to, and the supply of the ordinary service mineral oil had been reduced to the lowest possible limit. The service oil is a pure distilled American oil, with the paraffin scale extracted, so that the oil will remain fluid at 32 F., minimum density, ·91, and minimum flash point, 400 F. The undistilled oils tried were well-known kinds.

The broad results arrived at were—that one gallon of undistilled oil was equivalent, in lubricating effect, to three or four gallons of the distilled oil, in this particular ship, and that the boiler deposit was less in quantity, and of a less objectionable nature.

Former trials, made with steam of lower pressures, had not shown the marked superiority of the undistilled filtered oil, over the service distilled oil, and in point of fact, at the lowest pressures the service oil, which is much lower in price, gave equally good results in practice.

The later trials show, however, that the choice of a suitable cylinder oil is a matter that requires the most careful consideration with increasing steam pressures.

I cannot conclude these remarks without congratulating both the author and the Institute on the character of the Paper, which, embodying as it does the intelligent observation of an able and practical engineer, should command a thoughtful consideration of the various points raised by our members, and be the means of eliciting information of value to the whole profession.

PREFACE.

35, Stacey Road,

Cardiff,

November 20th, 1895.

The opening Meeting of the Session of the Bristol Channel Centre of the Institute of Marine Engineers was held at the University College, Cardiff, on Wednesday, 6th November, the Chair being occupied by Professor A. C. Elliott, D.Sc., and the Vice-Chair by Mr. David Gibson (Vice-President). A Paper by Mr. W. W. Houfe (Member) on "Internal Friction in Steam Engines" was read by Mr. C. L. Ryder (Hon. Treasurer), in the absence of the Author, and a discussion followed.

The discussion on Mr. Houfe's paper was renewed at a Meeting held on Wednesday, 20th November, 1895, at the University College, Cardiff.

Reports of both Meetings are appended hereto.

GEORGE SLOGGETT,

Honorary Secretary, B.C.C.

INSTITUTE OF MARINE ENGINEERS

INCORPORATED.

SESSION 1895-6.

President—A. J. DURSTON, Esq., C.B

BRISTOL CHANNEL CENTRE.

DISCUSSION

ON

"INTERNAL FRICTION IN STEAM ENGINES,"

Wednesday, November 6th, 1895.

CHAIRMAN:

PROFESSOR A. C. ELLIOTT, D.Sc. *(President, B.C.C.)*

After some opening remarks from the Chairman, the discussion on the paper was taken up by Mr. D. Gibson.

Mr. GIBSON: In calling attention to the tremendous waste from friction, amounting to over 14 per cent. of the work done, Mr. Houfe is doing good service to all engineers. I cannot, however, bear out the author in his statements concerning Ramsbottom rings. These rings I have found most suitable, and they are a type which is gaining in favour in marine practice. It is astonishing to see in what large diameters they are now being fitted. I also take exception to the author's view that this type of ring should be fitted of steel. Cast iron is most preferable. I do not think a pressure of three pounds per square inch necessary to produce a tight ring. Water does, in a manner, increase friction, although it helps to prevent abrasion by dissipating heat. Tail rods should be dispensed with as far as practicable, or adopted in only very large cylinders. I cannot approve of an extensive use of oil in the cylinder, as practice goes to prove that its use is unnecessary in well designed engines.

A MEMBER: I think most engineers would agree with the author's points. The ideas put forward in the paper are not adverse to the general opinion. In regard to liquefaction, most of us have had experience of priming, and knew the result of getting water into the cylinder. I consider the friction of most engines to be 20 per cent., rather than 14 per cent., but I have found that the percentage of frictional loss often varies with the speed at which the engines are running. The co-efficient of friction on the guides does not altogether depend on lubrication; bad workmanship has a lot to answer for in this respect I have lessened the friction of an engine by making an alteration in the propeller; in this case, the trouble was priming, and when the engine used to take steam in gulps, the alteration made the supply more regular, and the cylinder and valves were not cut up as they had been before.

Mr. ROBERT DAVISON (Member): I think Mr. Houfe has been rather unfortunate in his experience with cast iron piston rings. I could quote many cases where an improvement has been effected by the substitution of cast iron rings for steel ones. In one instance, three steel rings were fitted in a small locomotive; the rings wore out in six weeks, but the two cast iron rings put in to replace them lasted for two years. In a 9 in. cylinder, three steel rings were fitted, but wanted renewing continually, they were also replaced by two cast iron ones, and at the end of six years were found to be almost steam tight, although being so free in the cylinder that the piston when disconnected could be easily moved by the hand. This proved that there was very little friction from the rings. The condition of the cylinder walls has been sometimes improved greatly after Ramsbottom rings had been working some time. I have seen Ramsbottom rings fitted with perfectly successful results in marine engine cylinders up to 63 in. diameter, and I know of no reason why even larger sizes should not be used. It was found advisable in the larger diameters to turn these rings so as to allow an extra thickness of about $\frac{5}{8}$ in. at the back of the rings, more than that at the joints. In a cylinder over 60 in. diameter fitted with cast iron Ramsbottom rings, after three years' running, the condition of the cylinder walls and piston was found to be perfect, and the rings had only worn $\frac{1}{8}$ in. in the diameter, or $\frac{1}{16}$ in. on each side. I had experience, many years ago, of a boiler fitted with a superheater, and could only think that with a proper system of lubrication, such as Mr. Houfe proposed, superheating might yet be adopted successfully.

Mr. John McCallum (Member): I consider the paper a very complete one, the author having gone very carefully into the matter of detail. The author is quite correct in stating that there are no means of measuring internal friction. The indicator diagram certainly does not do so, but the revolutions are the only means of arriving at some conclusion in the matter, Modern appliances have done much to reduce friction, but, as the author says, much yet remains to be done. An engine may run well at the outset of a voyage, but a few months' run will altogether alter the conditions. Piston valves and efficient lubrication are steps in the right direction. I am not an advocate of superheated steam, though with modern appliances it might be more successful. I also agree with the other members, that cast iron is preferable to steel for Ramsbottom rings.

Mr. C. L. Ryder (Hon. Treasurer) and Mr. Mitchell also took part in the discussion.

Professor Elliott: Electrical engineers are not content with a less mechanical efficiency than about 90 per cent., whereas the marine engineer concentrates his attention on the coal consumption per indicated horse power, and is not shocked by contemplating a mechanical efficiency of about 80 per cent. The dynamo is a handy dynamometer, and measurements of power by its means are capable of showing, for example, that the total efficiency of a new compound is frequently greater than that of a new triple, the difference being, of course, due to the greater frictional resistance of the latter. When the engines have worn down to their bearings, the superior steam efficiency of the triple prevails on the whole. It is impossible to wholly prevent liquefaction by superheating, since, to effect this, the steam at admission would require to be heated to the temperature of melting glass. A moderate degree of superheating is quite practicable, and likely to be again introduced with a beneficial effect. The introduction of oil into the cylinder is undoubtedly at present attended by serious difficulties, which it is not impossible might be overcome in the future. Apart from these difficulties, the lubrication of the cylinders is desirable. The author has not drawn a distinction between liquefaction due to wall action, and liquefaction which attends the performance of work. The first is wholly an evil, while the second is of the nature of a figure of merit, and the wetter the steam the more work is taken out of it.

Mr. George Sloggett (Hon. Secretary): My intimation is, that members who intend contributing papers during the session should give notice of this as soon as possible. Messrs. Robert Davison and R. J. Field have papers in course of preparation, while Mr. M. W. Aisbitt (member), will read one on "Ballast Tanks," in a few weeks' time.

A vote of thanks to the Chairman terminated the meeting.

BRISTOL CHANNEL CENTRE.

ADJOURNED DISCUSSION

ON

"INTERNAL FRICTION IN STEAM ENGINES,"

Wednesday, November 20th, 1895.

CHAIRMAN:

PROFESSOR A. C. ELLIOTT, D.Sc. *(President B.C.C.)*

MR. A. C. MITCHELL: While agreeing with Mr. Houfe that the internal friction of marine engines should be reduced as much as possible, I see no good reason for the adoption of superheated steam. The enormous cost that the up-keep of a superheater would entail, and its liability to give out, condemns its use in the opinion of the best practical engineers of the day. Mr. Houfe says, "All who have dealt with the theory of the steam engine have pointed out the benefit of the use of superheated steam;" but, if he had said, "All who have dealt with the practice of the steam engine" I would have been more convinced of the truth of some of his assertions. While saturated steam gives such good results and prevents excessive friction by reason of its properties as an unguent in comparison with superheated steam, I don't see why we should discard it. That saturated steam acts as an unguent, I firmly believe, in spite of the statement of Professor Rankine, and the simplest illustration I know of is a locomotive on a wet rail as compared with a dry rail. I expect most engineers are aware that locomotives have fittings which contain a supply of sand, and the purpose for which it is used, and in this case, temperature plays no part in the matter. Mr. Houfe makes a quotation from Mr. Munro Ross's paper, with regard to the absence of lubrication for h p. and i.p. cylinders, and says that the l.p. cylinder suffers most, but I don't think the cause is properly understood. In my opinion the reason why l.p. cylinders have been found scored is owing to sudden contraction of the cylinder by loss of heat when the engines are slowed down or running at reduced speed. Assuming that the engines have been thoroughly warmed up before starting, the cylinder having a smaller body of metal, warms sooner than the piston, which has a much greater body of metal, and expands quicker, and after starting, while the engines are running at a good speed, there is a sufficient supply of steam to the l.p. cylinder to keep it expanded; but if afterwards the engines were slowed down the l.p. cylinder would begin to grunt, owing to the sudden contraction of the cylinder as compared with the piston. Many engineers, I am sure, can picture to themselves the "lively scurry" made up the stairs to the l.p. cylinder oil cup with a quart pot for the purpose of quieting the sound, and I believe, with a certain maker's engines, that was quite a well known peculiarity. With the introduction of the piston valve, internal friction has been very much reduced, and it has been highly appreciated by all engineers. No matter how perfect the design of any engine may be, it requires sound judgment and experience to get the best results out of it, and the barbarous manner in which I have seen pistons adjusted tended to destroy the best efforts of the designer. One instance that I know of was in the case of a certain well-known Australian trader, where the chief engineer gave orders to fit a new set of rings to the h.p. piston valve. Steam was opened on the h.p. cylinder jacket to warm it up, and the rings, which were of Mudd's solid type, were fitted cold to the body of the valve, which was also cold. The piston valve, with rings fitted, was tried in the chamber, and moved very easily and passed as being a good fit; but, alas, when boxed up and the engines well warmed through, the reversing gear failed to move the valves. The cause was not difficult to find out, being simply owing to the effect of the expansion of the piston rings by heat. The cover was taken off, and several pieces of chain and stretching screws were broken in the attempt to extract the valve. The ship was detained nearly a day as a consequence. The author of this paper speaks of a slide valve becoming hogged, and thereby increasing internal friction, which I must say is quite correct, and whenever we hear of a ship having her h.p. cylinder valve face broken, the cause is nearly always owing to the valve and cylinder face becoming convex and concave respectively. Speaking of packing rings, I have used Ramsbottom rings up to 60 inches diameter in cylinders, and always with the very best results; in my opinion they are second to none. Thunder and Marshall's packing is the best I ever used, so far as durability and perfection of working is concerned, but my experience has been that the article that wears longest is not adopted. The oil pump is a relic of barbarism, and with the automatic sight-feed lubricators now obtainable a constant supply of oil can be relied on, and regulated to the greatest nicety required. I hope Mr. Houfe may prosecute his study of superheated steam, and reduce internal friction to the lowest possible limit.

Mr. John Brock: In relation to Mr. Houfe's explanation as to the reasons for giving up the use of superheated steam in engines, I think Mr. Mitchell is, possibly, more accurate than Mr. Houfe in attributing it to the fact of the excessive corrosion attending the use of superheaters, in every form of construction known up to the present. This has proved a source of great danger to life and property, numerous fatal explosions having occurred, and no satisfactory means have been found to combat this corrosion. With reference to the cutting or abrasion of valve faces, &c., I do not doubt that a large proportion of it may be attributed to the heat not being absorbed, through the absence of the water film between the faces, as suggested by Mr Houfe. Yet, as I just now said, a great deal of corrosion takes place in the superheater, and reasoning from what we are all conversant with—that is, the amount of scoring which results from heavy priming—may we not imagine that gritty matter is constantly being brought over with the steam from the superheater, and as this corrosion will be continuous while the superheater is working, it seems reasonable to suppose that this may be looked on as an important contributory to the cutting or abrasion mentioned. A considerable amount of scoring and unequal wear in both valve and cylinder faces is due to their being sometimes badly proportioned; insufficient surface or breadth of bars being the principal defect. Sometimes, too, the metal used is unsuitable. A fairly hard tough mixture is best for the purpose, excessive hardness or softness being both detrimental. I have seen good results attend the use of steel mixtures, from 10 to 13 per cent. of steel being a good proportion. A fairly efficient means of minimising the consequences arising from these defects is to bore a number of recesses in valve faces, which are sometimes left open to permit the access of steam, thus forming a series of springs, or cushions, between the rubbing surfaces. In other cases these recesses have been filled with patent metal with good results. Of course, either of these processes is applicable to all slide valves. Mr. Houfe's remarks on the working conditions of piston packing rings seem to give a reasonable explanation of their fairly satisfactory results in actual use, as they are constructed at present. It seems to me that 14 per cent. as an average allowance for loss by internal friction may be considered reasonable; to this, of course, must be added external friction, from guides, bearings, &c. In this connection I think that Mr. Williams, when calculating the power absorbed in moving one l.p. piston of the steamship Paris is somewhat in error. If I remember rightly, he based his calculation on the fact of 15 tons being moved 10 feet (that is twice the length of stroke) 80 times per minute. I think he forgot that gravity would have something to do with this, as during half the time mentioned the piston and rods would be descending, thus simply leaving the amount of friction, and not of weight lifted, to account for. The weight lifted would, of course, also be partially balanced by the other pistons, &c., thus further reducing the h.p. really expended in this case. While agreeing theoretically with Mr. Houfe that a solid piston is the simplest and best, it must be remembered that it is almost a practical impossibility to bore out a cylinder so as to be absolutely parallel throughout its entire length. It stands to reason, therefore, that with such a piston anything approaching steam-tightness throughout the entire stroke could not be expected, this proving both a source of loss and a danger in handling the engines properly and promptly. I am of Mr. Houfe's opinion regarding Ramsbottom's rings, that they cannot be kept steam-tight at the back, and they often prove very troublesome in use. While some persons' experience of them seems fairly satisfactory, other, and very experienced engineers condemn them—at any rate for use above certain limited sizes. I may say that, even in such pistons as those of steam winches, their use has not at all times proved satisfactory, only being tolerated in consequence of their simplicity and readiness of renewal. I consider that Mudd's form of packing ring is a very good one, and there are others equally efficient. So far as continued good results in the use of any piston is concerned, much depends on the way they are put together after cleaning, and this, I think, is an important part of the duty of every chief engineer, who should in all cases personally superintend this operation. Mr. Houfe thinks that cylinder liners might be made of cast iron, and piston rings of Whitworth's compressed cast steel. I have never, so far as I am aware, seen a piston ring made from this material, and I do not know whether many people have had that advantage. I see no reason whatever why such a combination should not work satisfactorily, as we know that in many war steamers cylinder liners of compressed cast steel are fitted with good results. I am not aware of what material the packing rings used with these liners is made, though, so far as my memory serves me, they were simply a suitable mixture of cast iron. Mr. Houfe speaks favourably of piston valves, as compared with common slide valves, so far as friction is concerned. I have not got the volume containing the proceedings at hand, but some years ago, in the North-East Coast Institute of Engineers, Mr. F. C. Marshall (of Messrs.

Hawthorn, Leslie and Co.) read a paper, giving the result of experiments made by him in this direction, showing that the amount of power necessary for moving piston valves was much greater than generally believed, the particulars given coming as a surprise to many of the members present. The solid type of piston ring is the most suitable for piston valves; but there is no doubt that piston valves cannot be kept so steam-tight as ordinary slide valves, and are, therefore, not so economical in everyday use. There are very few kinds of packing in the market which are suited to the high pressures now in use. Many metallic packings are said to give good results. The compound packing brought out by the late Mr. Eastwood, a former member of this Institute, is giving excellent results in use; being practically steam-tight at back, the friction is capable of adjustment to any desired degree. With reference to cylinder lubricants, there is no doubt that several good oils are in the market. The trouble arises from every petty oil mixer thinking he can make an oil suitable for internal lubrication, when, as a matter of fact, he has very often not the slightest idea of what is required in such an oil. Store dealers get in contact with such men for the sake of cheapness, and in this way the oils are foisted on shipowners, often leading to the engineers having much trouble during a voyage, and sometimes, on their return, to their being held responsible for mishaps over which they had no control, such being due to the character of the oil supplied in the manner described. I may say, further, that such cases have come under my personal notice. I think the design of the sight-feed lubricator, shown by Mr. Houfe, and formed by two rams of different diameters, is a very good one. This principle has been practically carried out, I understand, with most successful results, by Mr. Kitchen of West Hartlepool, in the lubricator designed by him, and which has now been fitted to numerous steamers. Mr. Houfe has pointed out a curious anomaly in his comparison between the amounts of oil used respectively for external and internal lubrication. I have always been of opinion that the quantity of internal lubricant now generally allowed is quite insufficient for carrying out its purpose in an efficient manner. On account of the injury inflicted on boilers when considerable quantities of oil are introduced into them, its use for internal lubrication of cylinders, &c., is almost practically prohibited, but it does not follow that the quantity usually supplied is anything like what is required for the purpose of overcoming internal friction, being entirely regulated at present with the intention of minimising injury to the boilers, and not at all in relation to its primary purpose. Regarding Mr. Houfe's remarks on feed-filters, I am quite at one with him that the proper place for them would be on the exhaust pipe, so as to allow of condenser-tubes and air and feed pump valves being kept permanently clean. If not possible to place it there, I see no reason why it should not be placed in the suction side of feed-pumps, instead of the delivery side, as at present. At any rate, this might be arranged for where independent feed-pumps are fitted. Mr. Houfe's paper seems to me to be a well reasoned and practical one, and his conclusions appear to be generally accurate.

Mr. A. KENDRICK: I cannot speak too highly of the Ramsbottom ring. It is free from such accessories as tongue pieces and springs, which have been known to do great damage by getting adrift. Mr. Mudd's piston is as ancient as the hills, except that it has been made more rigid than formerly. The spring in it is of no use; in fact, springs should not be in pistons at all. Piston valves are far from perfect. Some makers go so far as to supply the ship with a boring bar and tools for re-boring the chest, which, when done, would mean new rings and piston head. The friction on ordinary slide valves could be easily reduced by having relieving pistons attached to the back of the valve. Most metallic packings could be tightened up to act as a brake on the engine, they having no certain method of adjustment. I have recently seen an improved arrangement of metallic packing, produced by a local firm, in which this difficulty has been overcome. It seems practically impossible to over-tighten it, and it adjusts itself automatically. After running continuously for over eighteen months, the wear is practically nil. I should state that the piston rod was in good condition when the packing was put in, but I hold that no metallic packing will work on a bad rod without great friction.

Mr. R. J. FIELD: I believe nothing can be stated definitely as to the amount of internal friction. A good deal has been said about tail rods that is faddish. The piston in its path wants more than the piston rod to keep it in line. Some engineers claim that they reduce friction by cutting off the tail rod; but do they know the increased amount of friction this causes on the cylinder walls, particularly if the guides are not properly lined up? I think superheated steam would be best if the difficulty in regard to lubrication could be overcome.

Mr. J. L. O'FLYN: I cannot approve of superheated steam. When steam is used at a pressure of 200 lbs. per square inch, I consider it sufficiently superheated for all practical purposes in the modern triple-expansion engine. Cast-iron Ramsbottom rings I have found to be excellent. A perfect lubricator has not yet been produced, but the sight-feed plunger type is the best. Some means of distributing the oil in the form of a spray would answer well. Metallic packing ought not to be used for piston rods. It is unnecessary to trouble about boiler corrosion now, for with the modern appliances in the way of feed filters, zinc, &c., it has become a thing of the past.

Mr. DAVISON and Mr. GIBSON also took part in the discussion.

Dr. ELLIOTT: I have made some experiments to determine the effect of water on metallic surfaces in contact, and am firmly convinced by these experiments that the coefficient of friction is less with the surfaces wet than when they are dry. The idea of increasing the efficiency by using superheated steam is a fallacy.

The drier the steam the less the initial condensation, and the present marine engine loses about 20 per cent. on the score of initial condensation. The hot jacket may in the future give superheated steam a chance. I should advocate the tail rod if by experience it was found to be of any service. The principal objection to it is its action in condensing steam.

A vote of thanks to the author (Mr. Houfe) for his very able paper was proposed by Mr. Gibson, seconded by Mr. Field, and carried by acclamation. A vote of thanks to the Chairman terminated the meeting.

PREFACE.

58, Romford Road,

Stratford,

December 9th, 1895.

A Meeting of the Institute of Marine Engineers was held here this evening, presided over by A. J. Durston, Esq., C.B. (President), when, by the kindness and courtesy of Mr. Thornycroft, a working model of the Thornycroft Water-Tube Boiler, for Torpedo Boats, was exhibited, and a descriptive lecture was delivered by Mr. J. E. Thornycroft.

The proceedings were highly appreciated, and the interest excited by the subject was manifest from the large attendance of members and friends.

JAS. ADAMSON.

Hon. Secretary.