THE MARINE ENGINE

CONSIDERED AS

A MACHINE.

In the few notes that I have been enabled to put together I cannot lay claim to much originality of thought, but I hope to be able to lay before you some ideas that have come before me in reading up the Mechanics of the Marine Engine, which may be of service.

Most Engineering Students, when entering on the study of the Marine Engine, are too apt to look at it as a complex whole, from which I do not wonder that many retire crestfallen and beaten, whereas on being approached as a combination of simple machines, each in its simplicity may be attacked and studied with considerable satisfaction by anyone having only a limited knowledge of mechanical science and mathematics. My purpose to-night is to endeavour to show the junior members how some of the questions affecting the "Marine Engine considered as a Machine," may be shorn of their difficulties, and, when looked at from this standpoint, may seem somewhat easier of solution.

The only mathematics that I shall presume you are possessed of will be a good knowledge of arithmetic, more especially proportion, and a clear knowledge of the principle of the simple mechanical contrivances: the lever, the screw, the wheel and axle, and above all a clear conception of the principle of work.

No doubt many of our older members—who are better able to deal with this subject than I am—will bear me out in saying that a young man when first approaching a question in Mechanical Engineering should first attack it practically and then bring his theoretical training to assist him in arriving at the best result, and here I would say that all the mathematical ability he may have will be of very little use to him unless he reasons from a mechanical standpoint, and then employs his mathematical logic in solving the theoretical questions. A young man well grounded in mathematics and having no means of applying his knowledge may be likened to a would-be sportsman, fully equipped for the chase but lacking in knowledge of how to use his equipment.

I hope I shall not be charged with saying that a complete knowledge of mathematics is not conducive to his better understanding of those problems which may present themselves to him as an Engineer from time to time; far from it, I only wish to impress the remark further, that *theory only* is of little use unless backed by practical experience to develop it.

I would here show you how our early pioneers in Engineering greatly felt the want of mathematics. I quote from Professor Barr's address before the Engineering College, at Leeds. He there—quoting from Smiles—says that "John Rennie was the son of a Scottish Farmer, and left school at 12, he worked for 2 years with a millwright, and studied, we are told, the theory as well as the practice of mechanics; he returned to school and studied, especially Mathematics and Natural and Experimental Philosophy."

Sir W. Fairbairn was one of the few great Engineers who served a regular apprenticeship to the trade, his early education was a poor one, he worked for a short time at a colliery, and was afterwards apprenticed to an Engine-wright, when he set about in a very systematic manner to mend the defects of his early education; apportioning his evenings to study, he devoted three exclusively to different branches of Mathematics.

Again, R. Stephenson pays a great tribute to the value of Mathematics in an engineer's training. He won a prize at the Edinburgh University for Mathematics, and in a letter to his schoolmaster's son, he says, "It was to Mr. Bruce's tuition and methods of modelling the mind that I attribute much of my success as an Engineer, it was from him I derived my tastes for mathematical pursuits, and the facility I possess of applying this kind of knowledge to practical purposes and modifying it according to circumstances."

I think I have said enough to show that without Mathematics we, as Engineers, can do very little with mechanical problems, still, as far as the elementary questions of the mechanics of the Marine Engine are concerned I think all present, will be able to follow me.

Before we go any further let us be clear on one question, and that is—What is a machine? A machine may be described as consisting of an instrument whereby a force may be transmitted from one point to another; it may also be a means of changing the direction of motion. Now our Marine Engine fulfils both of these definitions, inasmuch as the force of the steam is transmitted from the piston to the crank, and we convert from the reciprocating motion of the piston into the rotary motion of the crank shaft. But, speaking as a physicist, a steam engine may be said to consist of a contrivance for converting one form of energy into that of another.

All machines consist essentially of parts which may be traced to one or other of the simple mechanical powers, or at least to have some relation to them. We shall see as we proceed how the conditions under which the Marine Engine works, bear out our definitions.

Now the function of the Marine Engine is to convert the reciprocating motion of a piston into the rotary motion of a shaft, and this shaft rotating either a screw propeller or a paddle wheel in a partially resisting medium, and here I would ask you to follow me in making one revolution with an inverted vertical direct acting Marine Engine.

In the first place the steam, having entered the cylinder and being possessed of an expansive force will push the piston onwards, it is when the piston begins to move that the mechanics, so to speak, of the Marine Engine commences. I think, therefore, we should make that our starting point. Let us trace the force given out by this steam on the piston, and see how each different part of the machine transmits its share to the next part, until we find some of it transmitted to the hull of the ship, and this force being able to overcome the resistance of the ship, it propels it with a certain speed through the water.

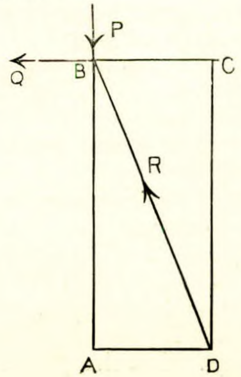
The driving part of a marine engine may be said to consist more properly of the piston, piston rod, connecting rod, crank and tunnel shafting and propeller. The pumps, valve motion, &c., may be said to be accessories only, they perform their proper allotted duties in the machine, but add nothing to the driving power of the ship, in fact they absorb some of that power.

Taking them in the order I have named, let us see how the strains are transmitted, and we will then see the conditions necessary to the good working of each part. Taking the piston on the top, the steam entering the cylinder, the piston being of itself strong enough to stand the crushing force of the steam, imparts a compressive strain or thrust down the piston rod; the resistance that the piston and piston rod offer to its motion will be the friction of the piston with the cylinder walls, and the piston rod with its stuffing box and packing. And, in speaking of this resistance due to friction, it may be minimised, firstly by the piston being made to move without friction. It should consist of a solid disc of metal fitting the bore of the cylinder so that we could only introduce a fine film of oil or other lubricating material between the two metallic surfaces so as to prevent their actual contact. The only friction that could be generated in this case would be when the piston fell over to one side or other of the cylinder on account of the heavy rolling of the ship. Assuming certain data, we will work up the frictional loss due to a piston that is put into a cylinder too tight, and for the sake of an example, let us say we have dropped this piston into the cylinder, and find that, owing to it fitting the cylinder too fine, it will just support its own weight by the lateral pressure due to the springs. Let this piston weigh 1 ton, or 2,240 pounds, and let us assume that the piston speed is 420ft., which would be, say 60 revolutions per minute and 3ft. 6in. stroke.

Employing the principle of work we have $\frac{2240 \times 420}{33000}$ ft. pounds, as the resistance to be overcome, nearly equal to 28 horse-power.

If we had sufficient data to guide us in determining the pressure exerted by the packing on the piston rod, and we could assume a coefficient of friction of, say ·1, we might employ the same method in realizing the loss here also.

The compressive thrust of the piston rod is met by the cross-head and transmitted down the connecting rod, the re-action of this thrust down the connecting rod acting backward in the direction of its length is split up into two component forces, one in a line with the piston rod and the other at right angles to it, and is met by the pressure on the guide, although the guides do nothing in contributing to the driving power of the Engine, they are necessary owing to the fact of the thrust of the piston rod having its direction constantly changing. The reaction of this force would tend to bend the piston rod, and if this tendency was not met by some means, the piston rod would yield, we therefore place guides parallel to the line of motion of the piston rod, shoes or slipper, being placed on the piston rod end, and by sliding up and down on the guides maintain the piston rod working always in a line. Now we have seen that part of the thrust of the connecting rod is met by the guide, and this pressure on the guide is constantly varying in amount; from nothing, when the crank is passing through the top or bottom centre to its greatest, when the crank makes a right angle with the centre line of engines. Of course this also depends on keeping up the pressure on the piston till the crank arrives at that point when passing round its circle, this point of greatest pressure will be seen by following this diagram :—



Let P be the thrust down the Piston Rod, due to the pressure of the steam; Q be the pressure on the guide; R the reaction of the thrust of the connecting rod. And, I think, in trying to realise these strains or forces, it is as well, perhaps, to conceive everything reversed, that is, for example: try and conceive the shaft to derive its motion from some other source than the pressure of the steam, and realise the thrust upward; then it will be easily seen that the force Q is greatest when the effective leverage of the crank is greatest, namely, when it takes the position of A D with respect to A B, that is when B A D is a right angle.

Now if we complete the paralellogram B C D A, then, by the parallelogram of forces, B C will be equal in magnitude and direction the force of the pressure on the guide; B A the force due to the pressure of the steam on the piston, and the length of the line B A will equal the magnitude of this force, and B D represent in magnitude and direction the force of the reaction of the thrust down the connecting rod. Now it is here that I would ask you to follow me closely, when three forces acting at a point, keep it in equilibrium; then if a triangle be constructed, representing these forces, the length of the sides shall be proportional to the magnitude of the forces:—

Thus, B C : B A : : the force represented by B C; force represented by B A: that is B C : B A : : load on guide; load on piston.

Now, without taking you too far into Trigonometry, you will see that the longer B D, or the connecting rod, is made, keeping A D, the crank, the same, the more nearly will B A equal B D, which would be perfectly true if the rod was of infinite length.

Now, it is usual in Marine Engine practice to make B D at least from four to five times A D.

Then if $B\,D = N$ times $A\,D$ say 5
(Euclid 1·47) $B\,D^2 - A\,D^2 = B\,A^2$

$$\frac{B\,A^2}{B\,D^2} = \frac{B\,D^2 - A\,D^2}{B\,D^2}$$

Extracting square root of both sides, and assuming the value of B D, viz. 5 A D, we have—

$$\frac{B\,A}{B\,D} = \frac{\sqrt{25 - 1}}{\sqrt{25}} = \frac{\sqrt{24}}{5}$$

Now the square root of 24 to 3 places of decimals = practically 4·9—

$$\frac{B\,A}{B\,D} = \frac{4 \cdot 9}{5} = 1 \text{ (nearly)}$$

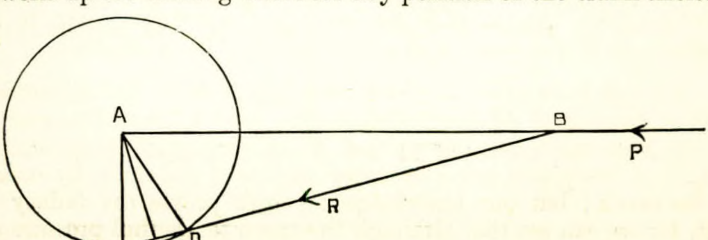
You will see, therefore, that the error is not great where the connecting rod is of a multiple, say 5, of the crank.

And, therefore, our proportion reads, the pressure on the piston : pressure on the guide as, B D : A D, or connecting rod : crank.

Now, leaving the crosshead, let us follow the thrust down the connecting rod, and see how that force, acting at the end of the leverage of the crank, causes the shaft to rotate.

When the Engine is on the top centre, the thrust of the connecting rod does not exert anything in turning round the shaft, but only puts the connecting rod in compression, and brings a weight on the crank pin, and so through the webs of the crank to the journals of the crank shaft; and, in working up this pressure per square inch, if we neglect the weight of the piston, piston rod, connecting rod, &c., we should divide the diametrical section of the crank pin, that is the diameter multiplied by the length, into the total pressure of steam, and the result will be the pressure per square inch; this pressure, of course it will be seen, depends on the length of the journal.

Taking any other position of the crank: the crank pin receives the thrust of the connecting rod, and is split up into two component forces, one in the direction of the crank, which only tends to force the shaft down in its bearings; the other at right angles to it, that is a tangent to the circle, described by the crank pin. It is only the latter force, namely the tangential one, that produces any turning effect on the shaft; this force, also, is continually varying in amount, not only on account of the pressure of the steam varying, but owing to the angle that the connecting rod makes with the axis of the cylinder continually altering, due to the rod swinging to and fro. As the crank pin moves in its circle again, the turning effort is influenced by the weight of the parts attached, and absorbs a certain amount of work in merely imparting motion to them. I will now show you how we proceed to work up the turning effort for any position of the crank circle.



If B A be a line representing the piston rod produced, and A D the position of the crank, B D the connecting rod, A C a line at right angles to B A, produce B D to cut the line A C; from A drop a perpendicular A E on the line B C.

Now we again call in the aid of Euclid's elements :—

The angles E A C and E C A are equal to the angles E C A and A B C, both of them being equal to a right angle; then by the third axiom, if E C A be taken from each, the remainder, A B C = E A C :—for convenience sake, let us designate this angle by the Greek letter θ.

If P be the effective force of the steam on the piston; R the thrust of the connecting rod; by the resolution of forces, P = R cos. θ; A E = A C cos. θ.

Now the moment of a force about a point is equal to the force multiplied by the length of the perpendicular let fall from the point on the direction of the force; or, the effect of the force R tending to turn D A about the point A, is measured by R × A E.

But A E was seen equal to A C cos. θ

$$\therefore \text{Turning effect} = R \times AC \cos.\ \theta$$

$$\text{But } P = R \cos.\ \theta$$

$$\therefore \text{Turning effect} = P \times AC.$$

i.e. :—the pressure of the steam × the length of the line, intercepted between the centre of the shaft, and the line of connecting rod produced at right angles to the axis of the cylinder.

Now this could be worked up for every position of the crank circle, and by a very simple graphical method the mean twisting force could be ascertained.

You can thus see that although the pressure of the steam may be constant, the turning effect on the crank is variable, from nothing, when the crank is on the top or bottom centre, to its greatest, when the crank is at right angles to the piston rod.

I would here incidentally remark that most of the old writers on the Mechanics of the Steam Engine were led into the error of saying that there was energy lost in converting the reciprocating motion of the piston into the rotary motion of the shaft, by means of the crank; but our knowledge of work proves the fallacy of that, for we can see that although the mean tangential pressure on the crank is less than the mean pressure on the piston, this first force moves through the arc of a semi-circle, while the force on the piston moves through the diameter, and these distances are :—

$$\text{as } \frac{3{\cdot}1416}{2} : 1 \text{ or } 1{\cdot}57 : 1$$

Then by the principle of work :—

Pressure of steam × 1 = the tangential pressure on crank × 1·57
And if a diagram of work be constructed equal to the latter, it should be equal in area to the Indicator diagram, and any difference between them would represent graphically the loss of work due to friction of piston, piston rod, &c.

This mean tangential force, multiplied by length of crank, is the utmost available force we have for turning round the shaft, and, by that means, the propeller.

Following the thrust of the connecting rod down to the crank pin, the outcome of which we have seen, is the mean tangential pressure acting with a leverage of the length of the crank to set the shaft rotating, and the resistance that the shaft offers to being turned round on its own axis, sets up a stress in its section called torsional, or twisting, the intensity of which is generally expressed by the formula :— $W\,L = \frac{\pi\, D^3\, S}{16}$ or $\frac{D^3\, S}{5{\cdot}1}$

Where W L represents the twisting moment, or force × length of lever.

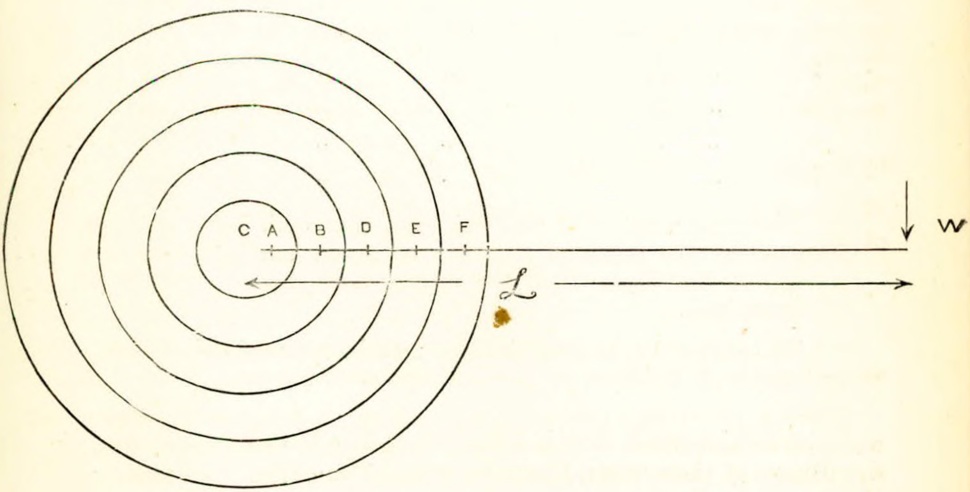
D represents the diameter of the shaft,

S represents the stress per square inch,

and 5·1 represents the constant depending on the shape of the section of the material under twist, in this case a circle.

Before proceeding further, as I may have occasion to use the words *stress* and *strain*, it may be well to properly understand the significance of these terms, I have found in my experience that many of our young engineers have a very hazy idea of the difference between stress and strain, and the following definition may be acceptable. All materials are possessed of certain properties, among which there is one of having *within itself* strength to resist any strain that may be brought to bear upon it. For example, I have a piece of bar iron, and if I try to stretch it in a line with its length, then the resistance that the bar offers in opposition to being stretched, is said to have set up a tensile—so that we see stress is the result of—strain, and is generally quoted as being directly proportional to it and during the time the bar of iron is being stretched, it is said to be put into tension.

Again, if I were to place two nuts on an inch stud, lock them and then exert a force of 800lbs. at the end of, say, a 12in. spanner, experiment tells me that I would twist the stud into two pieces, now the stud is broken by a strain of 800lbs. acting at the end of 12in. lever, and this is sufficient to overcome the cohesive strength of the material, and break it, and the resistance the material offered when in the act of being broken is called the *breaking strength* or *stress.* Now the net force of the steam applied at the end of the crank to twist the shaft round is just the same thing as breaking the stud by the spanner, only that the shaft is made sufficiently large in its diameter so that it can resist this strain. Let us see how we can work up this torsional stress. In treating this question it is usual to fall back on the differential calculus for a means of investigating it. But I would like to show you a method purely arithmetical that is approximately true, and it may be of use to our young friends in studying the laws, governing the stresses set up in bodies under different strains.



Let the accompanying figure represent the section of a shaft, and suppose it to be built up of, say, five concentric layers of the material, each one laid on the outside of the one next to it till we have arrived at the size required, that is to say, the estimated diameter;

Let this diameter $= D$

and let the *stress* at the outer layer, or the strength that this section has to offer, in resistance due to the weight W of the tangential force, or force turning the shaft multiplied by L, (the length of the crank throughout this investigation); imagine the journal of the shaft held by some means fixed, and then the *stress* set up in the section will be that due to the strain of this weight applied at the end of this lever.

If the stress or resistance at the outer fibres of the material be S; then, in the centre of that layer, the stress will be $\frac{9}{10}$ of S, and the leverage with which this force acts will be C F, or $\frac{9}{01}$ of the radius or $\frac{9}{20}$ D.

Now we may treat the whole of the layers of the material in in the same way and the more sub-divisions we make the more true will we be in our result.

Now stress is proportional to strain: this is apparent, for the length of C F being made equal to the length of the crank then the stress at the other outer section just equals the force applied at the end of the crank, and it is also apparent that the further we get from the centre the greater will be the resistance of the material, owing to its own leverage being greater. Therefore we may write

1st	Stress at	$F=\frac{9}{10}$ S	acting with	a leverage of	C F $\frac{9}{20}$ D
2nd	,,	$E=\frac{7}{10}$ S	,,	,,	C E $\frac{7}{20}$ D
3rd	,,	$D=\frac{5}{10}$ S	,,	,,	C D $\frac{5}{20}$ D
4th	,,	$B=\frac{3}{10}$ S	,,	,,	C B $\frac{3}{20}$ D
5th	,,	$A=\frac{1}{10}$ S	,,	,,	C A $\frac{1}{20}$ D

Now, the moment of the resistance that each layer offers is measured by the sectional area of the layer, multiplied by the leverage of that layer from the centre, multiplied by the stress per square inch.

The sectional area of each layer may be assumed to be the circumference of the layer at its middle point × the breadth of that layer.

1st Section $=\pi \frac{9}{10} D \times \frac{1}{10} D \times \frac{9}{10} S \times \frac{9}{20} D = \cdot 03645 \quad \pi D^3 S$

2nd ,, $=\pi \frac{7}{10} D \times \frac{1}{10} D \times \frac{7}{10} S \times \frac{7}{20} D = \cdot 01715 \quad \pi D^3 S$

3rd ,, $=\pi \frac{5}{10} D \times \frac{1}{10} D \times \frac{5}{10} S \times \frac{5}{20} D = \cdot 00625 \quad \pi D^3 S$

4th ,, $=\pi \frac{3}{10} D \times \frac{1}{10} D \times \frac{3}{10} S \times \frac{3}{20} D = \cdot 00135 \quad \pi D^3 S$

5th ,, $=\pi \frac{1}{10} D \times \frac{1}{10} D \times \frac{1}{10} S \times \frac{1}{20} D = \cdot 00005 \quad \pi D^3 S$

Total resistance the material offers $= \cdot 06125 \quad \pi D^3 S$.

$$\frac{\pi D^3 S}{16} = \frac{D^3 S}{5 \cdot 1}$$

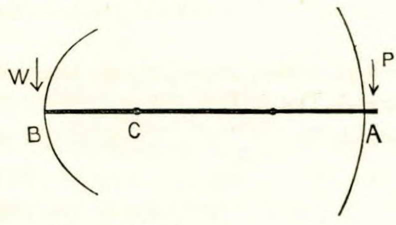
$$W L = \frac{D^3 S}{5 \cdot 1}$$

Now, having seen that the stress set up in the material is equal to the twisting force transmitted through the crank shaft, let us analyse this force, and see how the propeller is turned round by it. In the first place the tunnel shafting is connected to the crank shaft by coupling bolts, and this force is transmitted through them; and to realize this, knock out the whole of the coupling bolts, we shall never turn the tunnel shafting. Following this force into the tail-end shafting, it is evident that the fore and aft key, if there be one, plays the same part in imparting the rotary motion to the propeller that the coupling bolts do in transmitting it from one length of shafting to another. I would here mention that the grip of the propeller boss to the taper of the shaft assists the key in transmitting this turning effort; this is due to friction proper, of the two surfaces in contact.

Now the strain that the coupling bolts receive in transmitting this force, tends to shear them across that section where the faces of the couplings come together. And I should now like to show you how to determine this shearing force in the coupling bolts, in performing their share in rotating the shafting; and here I would call to my aid that simple mechanical contrivance, known as the wheel and axle, which is only another simple application of the form of the lever.

Try and conceive that the length of the crank is the radius of the wheel, and the force the tangential pressure acting at that leverage; and the radius of the bolt circle the radius of the barrel; and the resistance that the shafting has to overcome, the weight to be lifted.

Now, it is well known that circumferences of circles are to one another as their diameter or radii.



A C B is a lever of the first order.

C is the fulcrum or centre of the shaft.

B is the centre of the coupling bolts.

Then C B equals the radius of the pitch circle. A the centre of the crank pin. A C the length of the crank lever.

By the principle of the lever reduced from the wheel and axle

$$\text{Force } P \times A\,C = \text{Force } W \times C\,B$$

or by the principle of work through the whole circle. So we get from the principle of work the same thing, that is the net thrust down the connecting rod × length of crank = the shearing force × radius of pitch circle of bolts.

Exactly the same method may be employed to find the shearing force per square inch put into the fore and aft key—for, knowing the section of the key, and the mean radius of its position, the same or a similar equation may be made.

As soon as the propeller is made to rotate, it endeavours to force itself up on the shaft, but being prevented by the taper of the shaft, it gives out a reaction against the water in an opposite direction to that in which the propeller wishes to move. The reaction of this water to being forced astern sends the compressive strain up the shaft, which is called the thrust of the shaft, and may be likened to the thrust of piston rod; only, in the case of the piston rod the thrust due to the pressure of the steam has power to move the piston rod in a line in the direction of its length; but in the case of the shaft, this thrust is met with by the pressure on the thrust block, which is made rigid in some manner to the keel, and so the keel receives the thrust wholly or in part. In analysing the duty of the propeller in the driving of the ship, we start with that mechanical axiom that action and reaction are equal and opposite; and to properly realize how the propeller propels the ship, let me ask you to follow me. As soon as we begin to rotate the propeller, the water is driven astern with a certain velocity, namely, that due to the speed of the ship through the water in the opposite direction; if the sectional area of the disc of water pushed astern be multiplied by the feet travelled by the propeller in a fore and aft line in one revolution—supposing it worked in a wholly resisting medium, this would give us the weight of water acted upon; and if there were no loss due to the slip and friction of the ship through the water, this weight would be the force that pushes the ship onward; and in calculating the work necessary to push the ship forward, we should only have to apply the principle of work, that is, multiply the weight of water moved astern by the feet it is moved in one minute to get at the foot-pounds of work expended in propelling the ship. Now there are losses in a ship moving through the water, one of which is the slip, that is, the ship does not go through the water with a speed of pitch of propeller × revolutions, and the other is the friction due to the surface of the bottom and sides of the ship in moving through the water; and the work done on the ship may be calculated by assuming data. Assuming that the diameter of the propeller disc is, say 15 feet, making 60 revolutions per minute, and 15 feet pitch, if we neglect the diam. of the boss of the propeller, then $(15)^2 \times \cdot 7854$ = area of disc, (60×15—slip in feet) = distance travelled by ship in feet in one minute, let us say this ship has 10% slip

$$(60 \times 15 - 10\% \text{ of } (60 \times 15) = 900 - 90 = 810 \text{ feet.}$$

$$(15)^2 \times \cdot 7854 \times 64 \text{ lbs.} = \text{say } 11{,}000 \text{ lbs., practically}$$

$$\text{Then } \frac{11{,}000 \times 820}{33{,}000} = 270 \text{ h.p.}$$

This is the actual work necessary according, to our assumption, taken to propel our steamer, say 810 feet per minute, or 8 knots per hour.

There are one or two more questions I should like to show you, one of which is the loss due to the friction of the thrust collars, the other due to loss of effective driving power in pumping overboard the circulating water. With respect to the loss at the thrust block, let us suppose that the reactionary press of 11,000 lbs. finds its way up the shaft, and this press of the thrust is met at the thrust block; now the coefficient of friction of metal upon metal, well lubricated may be taken as, say ·1 of the pressure; this makes the drag of friction, say $\frac{1}{10}$ of 11,000=1,100 lbs., and if we assume the mean radius of the rubbing surface to be, 9″, then the work done in overcoming this friction may be expressed.

$$\text{As } 1100 \text{ lbs.} \times \frac{9 \times 2}{12} \times 3 \cdot 1416 \times \text{by (say) } 60 \text{ revs.} = 31{,}101 \text{ft. lbs.}$$

$$= \text{say } 9 \cdot 4 \text{ h.p.}$$

In considering the loss due to the pumps, more especially that of the circulating pumps. Let us assume data again, and say our engine indicates 800 h.p., and assuming that we use 2 lbs. of coal per I.H.P. per hour, and each lb. of coal evaporates 9 lbs. of water.

Then 800×2×9=14,400 lbs. of steam used per hour, and assuming us to exhaust at, say $2\frac{1}{2}$ lbs. back press in the condenser, which is steam of, say a temperature of 135°, then if we wish our feed to be put into the boiler at, say 135°, we shall only have to absorb the latent heat of the steam at 135°, using Regnaults formulæ for the latent heat, which is $1{,}115 + \cdot 3 \times 135 - 135$ = say 1,100 units of heat; then if the temp. of the inlet-water be 60°, and the discharge 110°, each lb. of water absorbs $110^{\cdot}-60^{\cdot}$ units of heat $=$ 50, and so $\frac{1,100}{50}=22$ lbs. of water to condense 1 lb. of steam:

Then $14,400\times22=$weight of cir-water used per hour, or $\frac{14,400\times22}{60}$ $=240\times220$ ft. used per minute, and if we assume that the pump has to lift this water, say 15 feet, then $\frac{240\times22\times15}{33,000}$ is an expression representing the loss in h.p. of the circulating pumps $=2.4$.

And now I must draw my paper to a close. I have tried to show you how some of the questions affecting the Marine Engine considered as a Machine, may be met and conquered; and if I have contributed in any small way in assisting any of you to correctly analyze and argue as mechanics, any of the questions that you may meet with day by day in your ordinary work of Junior Marine Engineers, I shall feel greatly repaid. Gentlemen, I thank you for the cordial attention that you have accorded me, and probably next session, I may, and I hope I shall, be able to get a few notes together, and lay them before you on "The Marine Engine from the stand point of a Heat Engine"

CHAIRMAN'S REMARKS.

(Mr. J. D. Churchill.)

I think Mr. Hawthorn is entitled to our best thanks for the interesting and valuable paper he has just favoured us with. The worst of it is that the paper is so full of examples and illustrations, that it is almost impossible to carry away even a small portion of what has been set before us. I fear this will be particularly difficult for our junior members, for whom it is stated the paper is more specially intended. There is a lot of information in it which will be valuable for the seniors as well as the juniors. It is an impossibility to deal with this paper in detail, so there is no alternative but to wait until it is printed with diagrams and examples of the different formulæ clearly worked out, so as to enable our young friends thoroughly to understand the question. There can be no doubt that the study of mathematics is of vital importance to all engineers, and I am of opinion that the course pursued in connection with Marine Engineers is the most true and perfect system of technical education that can be adopted. Here the youth enters the shops, where he remains five or six years, getting a good practical knowledge of his trade. He then takes the position of a junior assistant on board a steamship, and it is then that he begins to feel his want of technical knowledge, and turns to the study of the theory and scientific principles of the machines he has to manipulate. By pursuing this course he sees what he is striving for, whereas in the so-called Technical College they cram to the bung with principles, theories, etc., so that the youth emerges, in the opinion of professors and himself, a full-fledged professor of engineering. This is a mistake, a youth who has been through such a course has a tendency to look on work in the shops as derogatory to his special mental acquirements, and masters do not care about such clever apprentices. Many of the Technical College engineers could twist their masters (many eminent engineers) round their fingers so far as theory, principles, and the calculus are concerned. Such a course is bad both in theory and practice. When our young friends have got a good practical experience from the shops, I cannot too strongly urge them to stick hard and fast to their theoretical studies. The higher they can go the better men they will make.

Mr. J. R. RUTHVEN'S Remarks.

I am glad to hear such a paper read, and wish that a greater number of our junior members could be present. The system of taking such a machine as the Marine Engine to pieces, as it were, and examining each detail is the only way to thoroughly understand the action of such a complex apparatus. I hope Mr. Hawthorn will give us another paper, and still further examine the almost endless details of our wonderful modern Marine Engines.

The paper itself at first glance does not give much room for discussion in regard to its subject matter. I hope, however, to hear some of the younger members present make some remarks, as it is more especially intended for them to enter upon the discussion.

Mr. W. G. WINTERBURN'S Remarks.

As one of the younger school of Engineers for whom this paper has been specially prepared, I have pleasure in stating that I have been greatly edified and instructed in listening to it.

The opening remarks made by Mr. McFarlane Gray were I thought rather severe, and I felt inclined to sympathise with Mr. Hawthorn, but subsequently I was pleased to find the paper as a whole had his approval, and it was only to the absence of illustrations by means of the calculus that Mr. Gray took exception. For my part I was glad to find it absent. Had the paper been bristling with differential and integral calculus, I think I am safe in asserting that quite a number of the gentlemen present would not have understood it.

To anyone of Mr. Gray's mental calibre no doubt it is an easy operation, and in its first stages perhaps easy enough to anyone, but before dipping very deep we come across those very "sines and cosines" which Mr. Gray seemed to consider unnecessary in dealing with the subject matter of the paper, and my contention is, that before a student can use the calculus intelligently, he must have a good mathematical training in other branches, especially in algebra, a fair knowledge of which is indispensable.

I have great pleasure in moving that the hearty thanks of this meeting be accorded to Mr. Hawthorn for his paper.

Mr. W. J. NOWERS BRETT'S Remarks.

In rising to second the vote of thanks to Mr. Hawthorn, proposed by Mr. Winterburn, I should like to make a few remarks. I do not think this interesting and instructive paper has given much room for discussion. The formulæ he has introduced to-night we have taken for granted, knowing also that he has many more than we juniors have at command. Regarding the question of mathematics opened by Mr. Macfarlane Gray, I must say that Engineering text books by some Authors introduce too many problems in complex mathematics, when a simple arithmetical formula would do as well and be better understood by the majority. I say this knowing full well the value of trigonometry (of which I am a student myself) and the higher branches of mathematics. It is a well-known fact that our best reasoners are our best mathematicians, but, for the ordinary practical purposes of the Engineer the simpler the mathematical expression, the better.

THE LANGTHORNE ROOMS,

15 AND 17, BROADWAY,

STRATFORD,

ESSEX,

February 18th, 1890.

PREFACE.

A Meeting of the Institute was held this evening, when the discussion on Mr. Sommerville's paper, read on the the 31st January, was resumed.

The Meeting on the 31st January was presided over by Mr. G. W. Manuel (Vice-President), and on the 18th February by the writer.

The Paper and Discussions which ensued will be found in the following pages.

The subject of ventilation is of the utmost importance to all concerned in the efficiency and popularity of steamships, at the same time it is of no less importance to the general health of the community. It has therefore been proposed that the various ideas suggested by the paper, and the subsequent discussions should be embodied in another paper on the subject, which Mr. D. G. Hoey (Honorary Member), who has given considerable attention to the ventilation of large halls and buildings with a good deal of success, has kindly undertaken to write, with special reference to the requirements of all the departments of steamships.

The special attention of Members is called to the notice given as to the Annual Business Meeting to be held on Saturday, 29th March, at 7.30, in the Langthorne Rooms, and to the voting papers, which should be returned not later than the 24th March.

As a desire has been expressed by many Members for copies of the Papers read previous to the date of their election, it has been decided to reprint those now out of print, if a sufficient number should apply to cover the cost of republishing at 1s. each paper. The first year of the life of the Institute closes with the date of the present paper. The first volume of the transactions may therefore be said to be completed on its publication.

It is proposed that Members should bind their own copies, and any papers wanted to complete the set, will be supplied on application as far as possible. Members who have been elected subsequent to the date of the papers they receive should contribute towards the expense of publishing them as far as convenient.

JAS. ADAMSON,

Honorary Secretary.