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President: THE RIGHT HON. LORD PIRRIE.

VOL. XVIII

ON SOME PROPOSITIONS AND PROPOSALS REGARDING SCREW PROPULSION

BY MR. W. PREIDEL,

READ

On Monday, Novr. 5th, 1906.

CHAIRMAN MR. ALEX. BOYLE (VICE-PRES.).

INSTITUTE OF MARINE ENGINEERS

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PRESIDENT: THE RIGHT HON. LORD PIRRIE.

58, ROMFORD ROAD,
STRATFORD,
November 5th, 1906.

PREFACE

THE subject of the Screw Propeller and its mode of action has again been exciting a good deal of attention, and much controversy has been revived by the paper read by Mr. James Howden before the Institution of Engineers and Shipbuilders (Glasgow) in January. The paper read here this evening by Mr. Preidel, the discussion on which stands adjourned till Monday, December 17th, partakes also of the controversial element. Legions of experiments have been conducted by engineers and others to discover reliable data and to obtain the best form of blade, relative size of boss, and the most efficient propeller, and yet, with it all, we do not appear to have progressed much beyond the rudimentary ideas. Many forms of blades have been introduced, each one claiming to be the ideal. The theorist approaches the subject having in view certain principles and laws which he brings to bear upon the mode of action of the screw, and by these he explains what takes place according to recognized rules in hydrodynamics. Others have endeavoured, by means of models and an arrangement of feathers, to find the form of blade, relative diameter and pitch to give the highest efficiency by experimental data. Others, again, have tried, by means of small boats or launches, different shapes and modifications of screws, to find the point which can be used to work from as a standard for certain form and midship section of hull, and where the least horse-power will give the greatest speed.

Still others work from data obtained by models in the experimental tank, where finely graded instruments are used to obtain measures of power to speed so that these can be demonstrated.

In the discussion which followed the reading of Mr. Howden's paper, there appeared ideas set forth which were somewhat in the direction indicated by Mr. Preidel.

The further discussion which is to take place on this paper will be interesting, and ought to be of considerable value to those who study the subject and take part in the discussion, whether the result be of a more decisive character than previous discussions on the same subject or not, as it will at least tend to give a wider knowledge to practical Marine Engineers of the controversy on the various aspects of the question of how to drive a steamer through the water with the least expenditure of power, so far as the propeller is concerned. Contributions are invited in writing, as well as by speech at the meetings.

JAMES ADAMSON,
Hon. Secretary.

On Some Propositions and Proposals Regarding Screw Propulsion

BY MR. W. PREIDEL

READ

On Monday, Novr. 5th, 1906.

CHAIRMAN: MR. ALEX BOYLE (VICE-PRES.).

IT is a great pleasure to me to be permitted to read a paper before this Institute on a subject to which I have given a good deal of attention for some time past, and with which most of you are well acquainted. I hope that I may succeed in putting the matter before you in the same way that I see it myself. I am well aware that Screw-Propulsion has been the cause of perhaps more controversy than any other engineering subject, and although my object is not to start or renew controversy, I shall be pleased to hear as many opinions as the time will allow, and for this purpose I have attempted to keep the paper short, so that I may have an opportunity of dealing with the principal points raised, afterwards.

When the screw was first introduced as a medium for propelling vessels, the advocates of the same used to compare it to a bolt, the water supplying the nut. The phenomenon of " Slip " however was too soon evident, and the opponents of the screw denounced it on account of its " Slip," and many people worked hard to reduce it to zero, nearly all of them agreeing that so much " Slip " was so much power lost. Afterwards propellers were made which worked with little, or in fact apparently with no, " Slip," and according to the proposition that " Slip was loss," these propellers ought to have been the most efficient. Yet shipowners had propellers like these removed and replaced by others which worked with some positive " Slip," and generally obtained better results. The bolt and nut theory was consequently given up in so far as the idea that the screw should advance its full pitch, and " Slip " was accepted, so to say, as a necessary evil.

In 1865 Professor Rankine announced that all propelling instruments which act on the water, obtain their forward thrust by forcing a certain amount of water in the opposite direction. This proposition, which showed that " Slip " of the screw was necessary in order to obtain thrust, was almost generally accepted and is the fundamental principle of propeller theory still. To understand this clearly we must remember that the chief quality of all matter is " Weight," and the chief distinctive quality of all fluids is " Flexibility." So in the mass of water surrounding the ship we have a continuous flexible weight, against which a propeller can be made to act. This flexible weight will exert the same pressure in opposite directions against the propeller, as the pressure of the propeller against the water. So far the theory certainly seems to me to be correct. But when it is claimed that the screw propeller forces a column of water back, the sectional area of which is equal or nearly equal to the disc area of propeller, and the rate can easily be calculated from the "Slip ratio," and when further the action of a screw propeller is illustrated by a complete disc being moved in a straight line astern, I do not think that this is also all correct.

Simple as it seems, I think the fact that a screw propeller merely rotates round its axis, consequently its line of action is at right angles to a straight line astern, has been greatly overlooked, and I do not think that anybody would claim that the line of action of a reciprocating piston is the same as that of the fly wheel. When the propeller rotates, it presses on and eventually displaces the water between the blades to the axial or horizontal length and respective diameters, so that quantity of water acted on is represented by "*open disc area multiplied by mean horizontal length of blades*, divided into 2, 3 or 4 portions according to number of blades. We can now formulate the principal causes and effects with reference to screw propulsion as follows :—

Prime cause : Gravity and Flexibility of water. Effect of prime cause : Water surrounding propeller at all points.

Second cause : Rotating energy contained in propeller. Effect of second cause : Displacement of water. After this the prime cause will again come into operation, and so on.

The results of a propeller, that is speed of vessel for rotating energy, will depend on :—

(*a*) How it displaces water, which is the second effect ; and

(*b*) How it can be surrounded again, which is the first effect.

Both these factors are of equal importance, and whilst a great deal of attention has been paid to the displacement of water, it has generally been taken for granted that the screw can easily be fed if it is not put behind a very blunt stern, or even that we are practically helpless to assist the feeding of the screw, as shown in the reasons given for the phenomenon of cavitation. Before I go into details as to the effects of angles and shapes of blades regarding displacement and feeding, I should like to deal with one other theoretical illustration used very much, and which has been claimed to show that a propeller has no tendency to force any water radially outward. On the theory of the propeller acting against a disc, it is said that a column of water is having velocity imparted, or being accelerated. It is certain that if the velocity of a mass of water is being increased, its cross-sectional area must be decreased.

The illustration consequently shows a cone nicely contracting from a little way before, to a little way after the screw, and it is further said that the acceleration takes place, about half the amount ahead and the other half behind the propeller.

Nobody will want to dispute that the cross-sectional area of a mass of water must decrease as its velocity increases, but I cannot see in how far this affects the directions in which motion has been primarily imparted by the propeller and I cannot see what can cause the mean or total velocity, imparted by any propeller, to increase after the propeller ceases to act upon it. The final velocity as illustrated by the smallest cross-section of the column, represents the equalized residue of all motions imparted by the propeller. As a further cause for the contraction of the column must be cited the difference between gross propeller disc area and open disc area, that is the space occupied by the solids of boss and blades must be subtracted from the gross disc area. To understand fully how a propeller imparts different velocities upon different quantities, even with uniform pitched blades, we must again remember that the propeller rotates, that is, that it acts in the axial plane, and that most propellers, and especially the so called well-proportioned ones, have irregular shape in the axial plane, consequently act respectively upon quite different portions of the column at different radii, and further that the velocity imparted is not uniform throughout the whole of the water threads, for if this were so, complete rupture between feed and discharged water must occur, as is the case when the thread is in solid strips, and which actually happens when the phenomenon known as cavitation occurs, or else the velocity of the feed water must be equal to that of the discharged water, in which case the propeller could not obtain forward thrust.

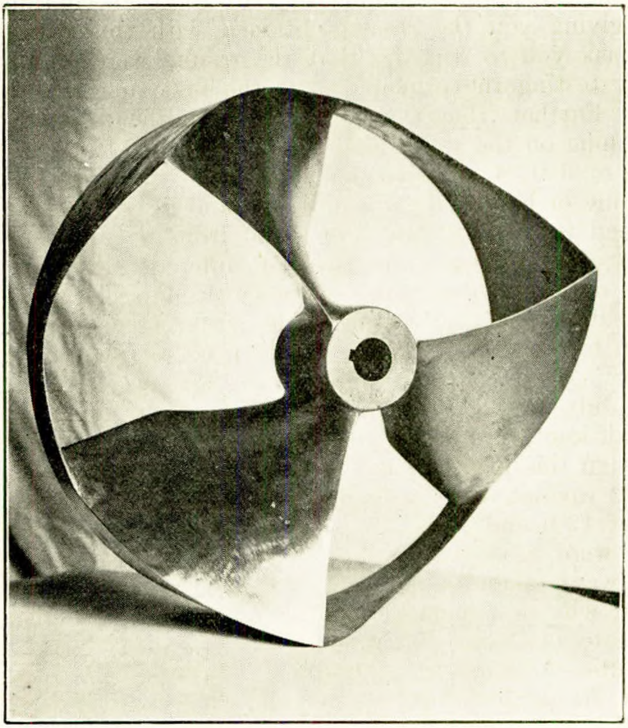
Further there is the mass of water surrounding the accelerated column, pressing equally in all directions and consequently also towards the centre of the column, so that if even the propeller itself was throwing the water off at a considerable angle to a straight line astern, the surrounding water would not suffer an increasing vacuum cone to have any existence after the propeller, or even a cone of dead water to follow centrally after the screw, but would force the nearest water, which in this case is the accelerated mass, towards the centre and so contract its outline. I do not think that the contraction of the column behind the propeller is of any advantage to screw propulsion generally, it only proves that a propeller as now constructed fails to impart even velocity to a column equal in diameter to the screw, and thereby shakes the disc theory as such; and I certainly do not think that it is a proof against lateral Slip. As I have said before that water having motion imparted in any outward direction would leave in the centre an empty space, as it would have to go out from the centre in all directions, whilst on the outside it has to overcome the surrounding pressure, it therefore generally happens so that the water which escapes from the driving face of a blade in a lateral direction is soon driven back by the surrounding pressure into the vacuum left by the blade, and as the astern component of all motions is generally the greatest, the mean or residue of all motions will be directed astern. This lateral Slip is a very variable and influential factor, and it will increase as the pressure on the driving face increases, and also as the horizontal length of propeller increases, or as we get a wide tip of blade. It is not only a loss in so far as it absorbs energy without giving resistance in the required direction but it also retards the flow of the feed water which comes in radially and thereby increases rotation of the water within the propeller, through keeping a reduced pressure at parts of backs of blades, and increases the velocity of that feed water which is straight ahead of the propeller which again re-acts detrimentally on the hull of ship. This is also the reason why blades with narrow tips of the Griffith type proved to be superior to blades of even width in the axial plane, as originally used by Smith.

It is this region where "Slip" and "Feed" take place alternately, and where the areas of feed and discharged water are, so to say, automatically regulated, and which has apparently been reduced to almost a vanishing point by cutting down the width of blade tips, which I think has put the greatest difficulties in the way of making the actions of propellers clear. It is also this region I think which is responsible for requiring a propeller to be suited so largely to the shape of hull and class of work, and therefore makes it impossible for propellers to be in any way standardized. To this region of the propeller I have paid a good deal of attention, with a view of obviating lateral slip, without in any way interfering with the feeding of the screw from the sides towards the centre in a radial direction, but before I explain the particulars I will again sum up the theoretical propositions :—

1. Forward thrust of a screw propeller is the reaction of a mass of water being moved in the opposite direction by the propeller.
2. The greater the mass and the greater the velocity in that direction the greater will be that forward thrust.
3. Mass of water acted upon by the propeller is obtained by horizontal length as well as diameter.
4. As much as possible of the velocity should be imparted to the water within the region, i.e. the space of diameter and horizontal length of the propeller.
5. Imparting to, or increasing velocity of a mass of water demands a larger area for the feeding water than for the discharged water.
6. The water will go to or feed the propeller there where the pressure of the water within the propeller has by its rotation been reduced to below surrounding pressure.

Coming now to the practical side of the question, I may say that I know that a great number of proposals have been made and tried which should counteract lateral slip. Roughly they can be divided into about four classes. Firstly there are those which make the blades hollow from the boss towards the periphery. Secondly there are a great number of proposals or patents to bend over the tips of blades to prevent the water from slipping off. Thirdly there are a number with corrugated blades or cross pieces fixed on the driving faces, and fourthly there are proposals of propellers working in cylinders or in having rings fitted all around them. I do not now intend to say anything about either of these proposals. I propose the use of a propeller with a recessed circular ring. The recesses are to be in front from the leading edge of blade to somewhere near the trailing edge of the preceding blade, and the ring to continue a little way complete behind the blades, as shown by the model now before you, and reproduced by photograph for the paper.

The shape of blades used will not be the general oval shape, but will be either of uniform width in the axial plane or widest on the periphery. The retained portions of the ring over the driving faces are there to prevent the water going away in any other direction but directly astern. The recesses are there that the screw may be fed from the sides towards the centre and thereby reduce rotation of the water within the propeller. The propeller can therefore be made of more than usual horizontal length. The projecting portion of the ring is to equalize the pulsation of the water caused by the blades and thereby reduce any vibration. This construction further enables the use of certain combinations of angles or pitch ratios almost independent of engine revolutions, and places the most effective portion of blade at the greatest diameter of



screw, where ample feed water can be obtained from the sides. This side feed enables propellers to be worked with higher slip ratios without augmenting the hull resistance, and it seems almost impossible that a complete rupture can occur as happens now with fast revolving propellers.

These propellers can be made smaller by from 10 per cent. to almost 30 per cent. of present diameters, which should amply compensate the skin friction of the ring, whilst increased length, better thrust angle and higher rate of acceleration make for more efficiency. The ring gives the propeller greater strength and therefore longer life, which should compensate for a little more weight. As the whole disc of the propeller is open at the back, these propellers will also answer quite well going astern if not quite as quickly rotated as going ahead. I will now give you some facts obtained at a number of experiments with these propellers on Steam Launches.

At the conclusion of the paper, Mr. PREIDEL continued :—

In giving you the results obtained with this propeller, I must ask you to consider that the results were obtained by simply testing the principle of it the first time it was on a boat. Further, that the launch used in the tests, which is 43 ft. long on the water-line, has a beam of 6 ft. 9 in., and a depth of 3 ft. 4 in. ; wooden hulled, carvel built by Messrs. Burgoine, of Kingston ; was not new, and in no case especially trimmed for trials ; but was taken from the river from its ordinary use. From two runs at different times with the boat's own propeller, which show a considerable difference in speed, it is evident that either the state of hull, or an extra person fore or aft, must affect the speed results in a marked degree.

On July 14th we ran the boat with the old propeller over the half knot, in order to get the speed, revolutions and power to design this propeller by, and obtained a speed of 7½ knots at 372 revolutions, developing about 13¾ i. h. p. On September 12th and 13th this propeller and the boat's own propeller were tested respectively. During these tests, observations were taken by Mr. Stephen H. Terry, of 17, Victoria Street, who is a member of Civil and Mechanical Engineers, Associate of Naval Architects, and also a member of this Institute ; and by Mr. James A. Smith, of 47, Leadenhall Street, Naval Architect, who is official measurer to the M.M.A. and B.M.B.C. On September 12th this propeller was on the boat, and a speed of 7¾ knots, at 359 revolutions with 11½ i. h. p., was obtained. On September 13th the boat's own propeller was on, and a speed of 8½ knots, at 347 revolutions with 13½ i. h. p., was obtained. So with the boat's own propeller the engines developed on this day 17 per cent. more power than the day before, and the boat attained 9·7 per cent. more speed. This propeller was consequently at the disadvantage of working with less indicated pressure per revolution, the engines were not suited to run faster, and also the finish of this propeller, as tested on September 12th, left a good deal to be desired regarding thickness and smoothness, which has since been attended to. It seems only reasonable that the thinning down of blade sections and smoother surfaces should improve the running of the propeller. To account for the different indicated pressures, I should like to say that, perhaps, the reduction of 22 per cent. in diameter was a little too much, and would have been better of only about 16 per cent. in this particular case. The following are the conclusions arrived at by Mr. Terry : "In view, then, of all the facts, there is justification in saying that the efficiency of the Preidel propeller is equal to the Burgoine propeller, or would give equal results if the i. h. p. had been the same ; and that with increased immersion, as suggested, and the reduction of section of blades and shroud, and the improvement of their surfaces, much better results than these herewith tabulated might be obtained, and there is the advantage of great reduction in diameter, being less by nearly a quarter, which saving can either be devoted to giving better immersion or reduced draught of water. This propeller seems, when modified as suggested, well adapted for use on canals and other waterways where avoidance of wash is of great importance." Mr. Smith says : "In conclusion, I would say that, all other conditions being equal, and apart from the question of centrifugal action, the small diameter of the Preidel propeller and the protection afforded to its blades are strong arguments in favour of its introduction in fast motor boats, shallow draught vessels of all descriptions, and light river and sea craft generally. My own conclusions are that the results obtained give support to the theory, and that in cases where the diameter of propeller is limited by circumstances, and where consequently now the wide-tipped blade is used, and where absence of wash and vibration are of importance, this propeller can be safely recommended in its present state of development ; whilst a little more experience with regard to relative dimensions and lines might bring about a uniform standard of propeller, which would give as good as, or better, results than the best propellers now made."

Before the discussion began, photos of the propeller were handed to the members, whilst a propeller of the Preidel type was placed on the table, as per the illustration on page 10.

Mr. J. R. Ruthven opened the discussion by referring to the movements of the water around the propeller when the same was being used. He explained his remarks by a direct reference to the propeller, and by a diagram on the blackboard. They had, he said, the water coming in at the speed of the ship, and going out at the speed of the ship, plus the slip. If they had a 30 per cent. slip, they had to have each cubic foot of water 30 per cent. longer over the square foot, in section, to make up for the slip. If they had 40 sq. ft. of sectional area going in at speed 1, they had a 30 per cent. loss in area if it was a 30 per cent. slip.

Mr. Preidel said that Mr. Froude, before the Institution of Naval Architects, had shown a diagram of the contraction of the column of water driven by the screw in a similar way, for which, however, he supposed a screw of minimum horizontal length, with very narrow tips, so that the water could not get motioned off much in a lateral direction. He would say that the pressure from the water pressed against the accelerated mass and made up the area of the increased velocity.

Mr. Ruthven said that with Mr. Preidel's propeller he imagined they would get sufficient area to make up for the slip.

Mr. Preidel said that was his intention, viz. to keep the discharge water in a column equal to the diameter of the propeller, and obtain the feed water from the front and all round the propeller where the pressure permitted. They could not help having a boss, and they must allow for gradual closing.

Mr. Ruthven said that from observation he believed the stream from the propeller apparently went away at the same diameter as the screw.

Mr. Preidel said he thought it depended a good deal on the shape of the blades.

Mr. Sharp said that the new propeller opened up a wide field for investigation, but he would like to think the matter over before committing himself in any way. There were so many things to be considered in connection with it, that he would not like to pass an opinion at that time. He would prefer to think the points over, and perhaps take part in the next discussion on the paper.

Mr. PREIDEL said he thought that rotational motion and centrifugal motion should be considered apart. The greatest cause of rotational motion was the suction at the back of the blades. The water nearest the blade at the back would follow it as fast as it could, whilst the centrifugal motion would be caused on the driving side of the blade. The centrifugal motion would be directed outwards, and the follow-up motion at the back of the blades in the line of rotation. If they had a wide blade without a ring, that blade would throw a great amount of water off centrifugally, and would not allow the pressure outside to come and fill up the space left. Consequently, the water would follow that much quicker. The centrifugal action was stopped by the ring over the blade, but the follow-up motion was stopped by the recesses. They had the same amount of water just falling back into the propeller which was driven off astern. If they had a narrow blade they did not get much in from the [illegible]de, because all over the blade it slipped out. Thornycroft's turbine propeller closely fitted into a casing, with very wide blades increasing in pitch. But Mr. Thornycroft tried a smaller propeller in a larger cylinder, and he found that the water slipped over, and reduced the efficiency considerably. Consequently, he had to fit his propellers as closely as possible into the casing to prevent the escape. Still, he did get greater rotation in that way, which he utilized through the guide blades. In his own opinion, rotation which he utilized on the guide blades was due more to the suction action at the back of the blade. The water might never touch the back of the blades, and the pressure on the driving side might have been very little. The whole pressure of the water was continuously following up.

Mr. NEIL K. MACLEAN said he could not altogether see the force of confining the water after it left the propeller, which was what Mr. Preidel intended to carry out by the ring. If he were using it on a steady basin of water, or a tank, and the propeller did not move ahead, he could understand him sealing up the feed and escape. But in the case of a ship at sea, the propeller was going ahead, and the lateral spread of water was left behind the vessel. What advantage would there be in having it in a straight column astern of the ship? The feed of the water was, he thought, influenced not by the shape of the propeller, or its blades, but by the run of the vessel, because, so soon as the displacement of the steamer passed through the water, the water came in, and the propeller then cut it, leaving behind the agitated water. He would like to know if, when Mr. Preidel was trying the propeller in the launch, he tried it astern as well as ahead, and what were the results. He could not see how the ring being round the blades would allow the vessel to go astern as well as the present open-bladed propeller would. Many years ago, propeller blades were made somewhat similar to those of Mr. Preidel's propeller, but without the ring; they were very soon discarded, as the engines did not get away freely, and they could not get speed as the slip was high. He knew of some instances where pieces were cut off, and every time they cut away a piece they got an increased speed of vessel, thus showing that it was no advantage having the blade wide at the tips. He had known instances that showed that the run of the vessel had more action on the solid column of water than anything else. He knew of one case where a shaft had been broken, and the new shaft which was fitted was 3 inches shorter than the old one. Working with the same propeller, the ship then made ½ a knot less speed than usual. Another longer shaft as originally fitted was afterwards put in, which thus placed the blades further aft, and without any alteration of the blades, the vessel came back to her original speed. He would like to ask Mr. Preidel if he had any experience of going astern as well as going ahead.

Mr. Preidel, in giving the results of the trials, does not improve on the old propeller, as his gives 43 % slips, while the old propeller had a slip of 32 %, 11 % less on its worst working. This to me is an unheard-of slip, as, given a good modern propeller, a slip exceeding 8 % under ordinary weather conditions is large. Mr. Preidel's is a new idea in propellers, and may be greatly improved; the ring allows the blades to be made lighter and imparts strength to the whole.

Mr. PREIDEL said they had tried the propeller astern, and he thought he was justified in saying that his propeller went as well astern as the launch's old propeller did. He did not mean to say that the propeller would answer as well astern as ahead, but if not too quickly rotated it would have just the same effect as the ordinary propeller. In regard to the shape of the blade, experiments had proved that with the open screw, the larger it could be, the better it would answer, for the simple reason that it would have a large body of water, and would impart little velocity.

Mr. Ruthven said it was a question of so many cubic feet having so many feet to move through, which gave the velocity imparted per second. If that ring were cut off and the propeller then tried on the same launch, it would work with much more loss. The pressure on the driving blades must increase from the forward edge to the after edge.

Mr. W. E. Farenden said there were one or two points to which he would like to refer. In an early part of his paper Mr. Preidel said : "When the propeller rotates, it presses on and eventually displaces the water between the blades to the axial or horizontal length and respective diameters, so that quantity of water acted on is represented by '*open disc area multiplied by mean horizontal length of blades*, divided into 2, 3 or 4 portions, according to number of blades.'" Then, later on, he referred several times to "lateral slip," and also that the "horizontal length of the propeller increases." Would Mr. Preidel show on the model of the propeller what he meant by the horizontal length of the propeller ? From the model he realized that it was a departure from what they had been accustomed to, and therefore it was very difficult to speak on it. He thought it required very careful consideration before they expressed their opinions on the matter. What slip had Mr. Preidel found during his trials ? If he had any more data they would be glad to have it. Did he claim more speed on less horse power with his propeller ?

Mr. Preidel said he thought that was rather a knotty point in the propeller theory. Most works on propellers spoke of the disc area of the propeller. The disc area gave simply a plain area surface, not a body at all. The disc area was the circular area of the propeller. The horizontal length of the propeller was found by projecting it down on paper : they got two lines, measuring the distance from the forward edge to the after edge. Lateral slip was the same as centrifugal action. Most of the inventions had been concerned with it, stopping the slip of the blades in that way, and had introduced different terms for it. The lateral slip would be a slip in a lateral direction, and not in a longitudinal direction : that was to say, a component at right angles to the shaft. The centrifugal action was greatest when the blades were in line with the shaft, and would be reduced when the driving face of the blades was at right angles to the shaft.

Mr. SHARP said they were confusing it with rotary motion. The centrifugal action was the flowing away from the centre. They must keep a clear understanding between the two.

Mr. PREIDEL said it would be very difficult to quite separate centrifugal action and rotary action.

Mr. SHARP said the rotary motion was turning the water round. It need not flow out. They could rotate it at that diameter. What they wanted was a propeller that would push the water aft. There was also a tendency for the water to spread out at the periphery. In referring to the action that took place, they must distinguish between the two. He thought the question which Mr. Farenden had asked was with a view to getting a clear understanding as to what was meant by some of the terms used, so that he could continue the discussion thereon.

Mr. PREIDEL said he was afraid it was not possible for him to separate centrifugal action from rotary motion. The water which was pressed on the blade might slip up in a line. Part would be due to centrifugal action and part, perhaps, to rotary motion. To get the mean effective horizontal length of an ordinary blade would, he feared, be a difficult matter. By the mean horizontal length he meant the mean length given by the blades when projected in the axial plane. Referring to the test he had carried out, he said they had tested the old propeller on the launch, and they got 372 revolutions, with $13\frac{3}{4}$ i. h. p., and a speed of $7\frac{1}{2}$ knots.

Mr. SHARP said he would like to know if there was any similarity between the two propellers, apart from the ring.

Mr. Preidel: No.

The following figures show the results obtained:—

Old Propeller (4 blades).

	KNOTS	REVS.	I.H.P.
Surface, 2·16 s.f. . Pitch, 3 ft. . . Diameter, 2 ft. 3 in.	7·44 8·4	372 347	13·84 13·33

New Propeller (3 blades).

	KNOTS	REVS.	I.H.P.
Diameter, 1 ft. 9 in. Surface, 1·625 s.f. . Pitch, 3 ft. 9 in. .	7·53	359	11·4

Mr. W. McLaren said he had had the advantage of seeing Mr. Preidel's propeller before it was cast, and had had a few words with him in reference to its efficiency. Looking at the figures given, they had the old propeller with a pitch of 3 ft., and the new propeller with a pitch of 3 ft. 9 in. It was a pity there was a difference, in regard to estimating the benefit to be derived from the new propeller. In the old propeller they had 372 revolutions, and with the new one 359 revolutions. It stood to reason that that containing ring was bound to bring the revolutions down, and he was inclined to believe that was where they got the effect. It was not, he thought, from the actual shape of the blades, but from containing the water and throwing it out, in the same manner as Mr. Ruthven's father's idea. There was no doubt that the water going away in a centrifugal motion gave a sort of swirl, and thus helped towards the propeller's efficiency. That, no doubt, had been the cause which had reduced the number of revolutions, and had given a greater efficiency. But he would like an explanation of the cause of the i. h. p. increasing. He would also like to know whether Mr. Preidel was favourable to further experiments with his propeller. He would suggest that he should pierce some holes round the rim and see what effect that might have by allowing a slight escape. Or he might experiment by gradually cutting away the ring. He had much pleasure in thanking Mr. Preidel for attending, and giving them an account of his experiments with such a propeller.

Mr. Preidel said that in the two runs with the old propeller there was a difference in speed of just about a knot. To make the matter clear perhaps it would be better to wipe out altogether the top row of figures on the blackboard. It would show that the revolutions had increased by 10, but that the i. h. p. was lower. He had referred to that when giving them the results. They could have got more revolutions had the engine been balanced well enough. At 372 revolutions the boat shook. When they had the test again the boat had been cleaned and repainted and the revolutions were kept down. If the boat had not vibrated they could have got more revolutions, and the same power out of the engine, and more speed. There was nearly 2 i. h. p. lost.

Mr. Preidel said that if the engines had been balanced well enough they could very likely have got the horse-power and speed. We made six runs: three with, and three against the tide.

Mr. J. Anderson said Mr. Preidel had spoken of line of action of a reciprocating piston and fly-wheel. What did he mean by the line of action of a fly-wheel? They could not get a line of action by a fly-wheel. They could get plane of rotation. Mr. Preidel said: "When the propeller rotates it presses on, and eventually displaces the water between the blades to the axial or horizontal length and respective diameters, so that quantity of water acted on is represented by 'open disc area multiplied by mean horizontal length of blades.'" He would like to ask whether "per rev." should not come in after that to make it clear. That amount of water had to be acted upon every revolution. Then in regard to "prime cause," he thought it would be better if Mr. Preidel altered it. He thought the second cause should come first, for it appeared to him that the actual movement of the ship was caused first of all by the rotating energy which the propeller imparted to the water, and not by the gravity and flexibility of water. The gravity and flexibility they had, but unless the propeller was rotated the ship did not move. Were the blades of that propeller an ordinary helical surface? Was it a pitch which altered as the diameter?

Mr. Preidel: It is an increasing pitch, about 20 per cent. from the leading tip to the root and after edge.

Mr. Anderson said that if the pitch were greater towards the centre of the propeller than at the tip there was bound to be a greater rotative action of the water which clearly imparted centrifugal energy to it and threw it to the tips. When it got to the tips the water had to be suddenly forced from the radial to a fore and aft direction. That had to take place against a sharp corner. Consequently there must be a loss of power, and he thought that propeller would work more satisfactorily if there were a nice easy curve at the tip of the blades. He would like to look into the figures and see how the new propeller compared with the old one.

Mr. Preidel said he thought it would be a most difficult mathematical problem to work out exactly the quantity of water which passed through a propeller at a certain slip ratio. He thought that Professor Rankine, when he drew up the early formulæ, must have overlooked that. They could not get uniform velocity of the water during passage through the propeller at any time. They had a negative and a positive pressure. Between those pressures there was all the difference in the water. He thought from the slip it would be very difficult to calculate. A propeller might slip 3 per cent., or 15 or 30 per cent., and the one with the 15 per cent. slip might drive the most water through. He had considered and worked at it, but he was not sufficiently a mathematician to give them a formula. Regarding the prime cause, that was another matter. When the screw propeller was first introduced, it was supposed that it would go through the water as a nut on a bolt. That theory treated the water as if it were a solid, but if the water were a solid the propeller would not go round. It was the weight and flexibility of the water which enabled them to move ships through it. Air was flexible, but it had not sufficient weight : that was why they could not fly. Water had a certain amount of weight, and was also flexible. He thought that after all the prime cause of navigation generally was the water with its qualities of weight and flexibility. The rotating motion was the prime cause so far as the engines and the ship were concerned. Still, they must have flexible water, not frozen, to drive a propeller through.

Mr. Savage said the paper was one which required some digestion. It opened up so many questions which were strongly opposed to the present ideas of propellers now in use in the mercantile marine. He thought there was a great deal in the idea, although there were probably many points which militated against it. It was a question which required great consideration, before giving any opinion as to its value.

Mr. ROBERTSON referred to the possibility of accident, remarking that in the event of the propeller breaking or snapping at the end of the blade, if it were a cast iron propeller, it would possibly break off at the leading edge of the blade as it would offer a great amount of resistance. If made in bronze it would not break so readily. Would a propeller of that type be as efficient, in regard to the question of accident, as types now in use ?

Mr. PREIDEL said that was a difficult question to answer until they had had more experience. Still, he thought the new propeller quite came up to the efficiency of the usual propeller. Regarding the propeller breaking away—if the theory held good the propeller could be made smaller by a certain amount. If the signs of the times were followed the engine revolutions would keep increasing, and that would keep the diameter still smaller. If propellers were 10 to 15 instead of 18 ft. the danger zone was so much smaller. With the new propeller there ought to be a greater safety than with the ordinary blade. When the ordinary propeller came out of the water it might go down again flat on the water. But with the new propeller the rim would always act as a cushion. If anything struck the propeller it would always be driven off. It was very seldom that anything struck the propeller dead against the centre. From the point of view of safety, he thought the new propeller should have the preference. He would not like to say anything in regard to the efficiency of the new propeller as against another of 18 or 20 ft. diameter, as he had only tested it in smaller sizes.

Mr. SHARP said that during the evening he had been looking into the figures. The new propeller $3\frac{3}{4}$ pitch, with 359 revolutions and $7\frac{1}{2}$ I.H.P., had 43 per cent. slip. In comparing the two propellers which had been used in the trials, he had arrived at the conclusion that they were too dissimilar to allow of any comparison being made. The pitch was a variable quantity, so also was the surface and diameter; this being so, they were unable to determine to which of these variable factors any improvement might be due. He would like to throw out a suggestion to the author, and if carried into effect, he thought it would be the means of settling the point right away. His suggestion was that Mr. Preidel should have another propeller made similar to his new one, but without the containing ring. Then he would have two exactly similar, except in this one particular. After trials had been made, he would be able then to say without any uncertainty whether the circular ring was the cause of any improvement or not.

Mr. PREIDEL said the point raised was the great difference in the pitch, slip, and area of the two propellers. He thought the most important item was speed for power. That, he thought, was the question which shipowners troubled about, and if a propeller worked with 99 per cent. slip, and yet gave a knot more speed than the one with 5 per cent. slip for the same power, the former would be the propeller preferred by the shipowners.

Mr SHARP said that possibly the propeller with which Mr Preidel had compared his new one might have been of poor design. The most important thing noticeable was the diminished surface; he thought a lot of the gain might be due to it. Perhaps the effect of the other propeller was to overload the engine. An engine would only give out its maximum power at certain revolutions. If they took an engine and braked it, and ran it at different revolutions they would be able to arrive at a speed where they could get the most Indicated Horse Power. Those were the revolutions that engine ought to run at, for they got the best results. It seemed to him the other propeller had been too big, preventing the engine from making its best revolutions.

Mr. PREIDEL said that on one run they had 372 revolutions, but then the engines were running too fast. On the other trial the old propeller did 8·4 knots. The question of comparison was, he thought, one which would have been better settled by the speed, the horse-power, and the size of the boat required, to be considered together. He thought he had shown that they were not testing against a bad propeller. He had asked naval architects what they thought of the results which had been obtained, and they had said that they considered them all right for that power. They could go on testing wide blades and broad tips for propellers in an open screw. When Smith made his propeller he improved it by gradually cutting pieces away. He cut the corners off and improved it. It would be very difficult to arrange a comparison test in that manner, because a ring such as he proposed would not be any good at all on the narrow tipped blades.

Mr. Sharp : You contend this propeller is of such a shape that if the ring were taken off it would be of bad design.

Mr. Preidel : Yes, quite so, therefore take the best propeller of the ordinary type and compare the new one with it.

Mr. Sharp : What is there objectionable with the ring off ? Are the blades too big at the tips ? Well, why not cut them down until you get to the ideal condition, and then compare the propeller with the ring, against the other. With a tug propeller, of course the conditions are altogether different. I think, irrespective of the type, it would show conclusively what advantage you are getting from the ring, if one is tested with and the other without it. If it is desired to make a comparison of the two propellers, they should be dissimilar in one respect only : during each trial, for instance, keep the pitch and diameter the same, and vary the configuration of the blades to some extent.

Mr. Preidel said that first of all they had to answer the question, By what should the efficiency of a propeller be judged ? In the beginning the efficiency was judged by its slip. In 1862 the matter was discussed before the Institution of Naval Architects in reference to a paper by J. Simon Holland, Esq. Then it was said that, all other conditions being equal, the best propeller was the one that gave the least amount of slip. Five per cent. of slip was 5 per cent. loss of power. That was the opinion expressed in 1862. They wanted to get speed out of the ship and no slip of water. To work with a higher acceleration it was necessary to work to a greater pressure on the surface of the blades. He thought the efficiency of a propeller ought not to be judged by anything less than the result in speed and by horse-power.

Mr. Sharp said the efficiency was very easily settled. It was the work put into the propeller as compared with the work it gave out, so that slip or no slip did not count. If they could get a propeller that would give out as much work as was given to it they would have a 100 per cent. efficiency. The efficiency of the present day propeller was $62\frac{1}{2}$ to 65 per cent., or more often 55 per cent.

Mr. Preidel said the efficiency could be judged by the speed of the ship, or by dynamometer. He thought it would not be difficult to get at the efficiency by the forward speed of one and the same boat, at the same horse-power with different propellers under equal conditions.

Mr. Farenden remarked that if Mr. Preidel would have a propeller of the same surface and pitch as the one under discussion fitted to a boat, they would be better able to compare the results, because at present they seemed to be in a fog as regards the comparison.

Mr. Preidel said the owner of the launch told him that the old propeller was a good one, and that it was as good a one as would be found on any launch. He would not say that the propeller was the best propeller that science could produce of the ordinary type.

Mr. Ruthven said he had much pleasure in proposing a vote of thanks to the author. He had designed a propeller which was new to him, and he thought there was some promise in it, as Mr. Preidel had increased the area of suction and had decreased the area of discharge, and that was in the direction which he believed all progress must go. He had got up to 43 per cent. slip, and still got a good result. If they compared the speeds with horse-power they would find that in the first trial he had compared favourably. He would be interested to hear if he did more in that direction and came and gave them the results. Mr. Preidel had opened his mind to some points which were very interesting, and he had much pleasure in proposing a vote of thanks to him for his paper.

Mr. SHARP seconded the proposition, which was at once carried.

Mr. RUTHVEN then moved that the discussion be adjourned. Mr. J. Anderson seconded. This was agreed to.

Mr. PREIDEL: Thank you for the response so far. I shall be pleased to come here again and discuss the matter further.

A vote of thanks was then accorded Mr. Boyle for presiding, who, on responding, said he was very pleased to be with them. Mr. Preidel had given them a very interesting paper on the subject, which, as Mr. Ruthven had remarked, was very novel. By considering the matter they would realize that there would be a good deal to say about it on the date of their adjourned meeting. It was not a subject one could get up and discuss merely after hearing the paper read.

ADJOURNED DISCUSSION.

Monday, December 17.

CHAIRMAN—MR. ALEX BOYLE.

The CHAIRMAN, in opening the meeting, said Mr. Preidel's propeller was one of novel design. At the previous meeting, when the paper was read, several members took part in the discussion, but it had been felt that the paper was one which required some thinking over before they committed themselves to an opinion for or against. Mr. Preidel was now present, and he thought it would be well for him to re-open the discussion by adding a few supplementary words. Most of those present had doubtless read the original paper, and that evening they would find the printed report of what had been said on the previous occasion. From the propeller on the table they would see that it was largely different from the ordinary type.

Mr. PREIDEL said that at the opening meeting he had given them a certain number of facts that had been arrived at by testing, and he had read out the particulars of the test, of which he gave them some figures. They had had another test on November 1, but the figures of that test were not in his hands when he read his paper. He was glad to say that those figures had turned out more in favour of the propeller than he had anticipated. One question which he thought he had not answered at the previous meeting was in regard to the line of action of a fly-wheel. The line of action which he meant to express was synonymous to the line of motion. Mr. Preidel then read the report made by Mr. Terry upon the propeller.

17, Victoria Street,
Westminster, S.W.,
November 8, 1906.

Messrs. Preidel's Patent Propeller Company, Ltd.,
110, Cannon Street, E.C.

GENTLEMEN,—At your request I conducted a further trial of the Preidel Propeller on Thursday, November 1, boarding Messrs. Burgoine's launch, *Atalanta*, at 3.10 p.m. on that day.

The propeller had been, as I understand, altered on the lines suggested in the former reports by Mr. Smith and myself. The alterations had thinned the rim of the propeller and somewhat reduced the blade area as given later. The propeller which formerly weighed 60 lb., now weighed $47\frac{1}{2}$ lb., and the surface had been greatly improved in smoothness. The boss of the propeller formerly ending in a flat circle 4 in. in diameter, had therefore a suction area of 12·5 in., which had a retarding effect, and at my suggestion a torpedo-shaped boss had been fitted over the propeller nut. This boss is 12 in. long, cylindrical for 4 in., and the last 8 in. tapered to $\frac{5}{8}$ in. To get the best effect from this last portion, of permitting the water to close in upon the propeller boss, the taper should begin at the junction of this last piece with the propeller nut. As this matter was pressed for time, the piece was made of wood only, and probably is not so true in running as gunmetal.

The propeller now runs at all speeds either backwards or forwards with great freedom from vibration, and causes the vessel to quickly attain full speed; the propeller is also very prompt in stopping the *Atalanta* from full speed, and she turns well either ahead or astern with the Preidel propeller, there being a marked improvement in the decrease of size of the circle in which a half turn can be made.

The conditions of wind, tide and traffic, and smoothness of water were noted by Mr. Smith and concurred in by myself.

We made nine runs, five up and four down, but for the reasons stated in Mr. Smith's report, we disapproved of the course kept during the earlier runs which appeared to us to be up stream (against tide), too much in the middle of the river, and down stream (with tide), too near the bank on the Middlesex side, thereby giving results as to strength of tide hostile to the efficiency of the propeller. During these runs also the boiler pressure and revolutions varied considerably, so we decided to cancel the first three runs, and to base the trial on the remaining six runs. I should like here to say that it would have been desirable to have had the trial commenced at high water, namely at two o'clock, as they were run with an ever increasing tide which is also hostile to with and against results, as it impedes more than it favours, the effect of the tide acting on the boat over a longer period in the "against" runs than in favour of the boat in the "with" runs. For these reasons slack water trials would have been more reliable. The effect of tide in velocity results is of course much greater in boats under 10 knots, than at torpedo boat speeds, as the proportion of water speed over the ground is so much less relatively than the boat speed in high speed vessels.

I also feel, and I may state that Mr. Smith concurred with me, that for these trials, a marine type boiler containing a large volume of water and therefore not liable to fluctuations of water level, or high ranges of variation of steam pressure, would have given more constant revolutions and more uniform speeds; for instance, towards the end of most of the "up" runs, there was a great fall of pressure and also of revolutions due to inability to maintain full steam continuously at full speed, whilst the water feed was on. I wanted to start one run up with a three-quarter full glass, but although the vessel was fitted with a condenser (which, however, does not create a vacuum, but merely recovers the water), and therefore we should not have been inconvenienced by visible external priming, it was feared by those in charge of the boat (the builders' sons) that priming into the cylinders might take place to an extent sufficient to do damage, or at any rate to vitiate the indicator diagrams, so I waived this point; hence we ran several times with a falling steam pressure and consequently fewer revolutions.

At a later date, if this propeller or a modified copy of it be tried, I should advise its being tested in a boat with an ample fire-tube boiler, so that the steam may remain at an uniform steady pressure of, say, 180 lb., not 180 lb. to 200 lb. one minute and 140 lb. the next.

With this fluctuating pressure, if the boat has a critical speed within our reach, it is impossible to attain it, pass it, and hold a speed above that critical speed. Nevertheless, despite these disadvantageous conditions of the trial of the modified propeller, it gives considerably improved results ; and I believe that trials made under conditions which I have sketched out would show even more in its favour.

Owing to the absence of wash with the Preidel propeller and to its evident grip of the water, as proved by the promptitude with which the boat attains full speed either ahead or astern, and further remembering how quickly it arrests the motion of the boat when stopped suddenly from full speed and put to full speed astern, I am of opinion that it possesses (especially since altered) good manœuvring qualities. Steeriny being easy both ahead and astern, the movement of the boat when going astern is remarkably free from that sluing action which takes place with unshrouded propellers, which vitiates accurate steering when going astern.

Owing to the smaller diameter of the Preidel propeller giving as altered, within one-third of a knot of the Burgoine propeller's results, I am of opinion that it is well suited for twin screw purposes, as also possibly for three or four screw purposes for steam turbine or electric motive power or for motor boat propulsion. The same reasons, small relative diameter and freedom from wave making, would seem to prove it well adapted for canal towing either single or twin screw, which, with the probable growing use of our water-highways throughout the kingdom, and the gradual substitution of mechanical propulsion for horse-towage, would further enlarge its field of usefulness.

Comparing the results shown below with those previously obtained with the Burgoine propeller, the figures are as follows :—

Burgoine, 8·41 knots ; improved Preidel, 8·076 knots ; now only ·335 of a knot slower.

The i.h.p. figures were—Burgoine, 13·335 ; original Preidel, 11·4 ; 1·935 less h.p.

I.H.P. Burgoine, 13·335 ; improved Preidel, 10·68 ; 2·655 less h.p.

From these figures it is evident that the Preidel propeller as improved, gives very good results with nearly $\frac{1}{5}$ less horse-power than the Burgoine propeller. In other words it attained within ·335 of a knot the speed of the Burgoine propeller with only $\frac{4}{5}$ of the horse-power required by the unshrouded propeller. The figures for the Preidel propeller as altered are : Area of ring (both sides 4·4 square feet), area of blades (one side), 1·503 square feet. (Signed), Stephen H. Terry, M.Inst.C.E., M.Inst.Mech.E., Assoc. Naval Architects, M.I.Mar.E.

November 8, 1906.

Mr. Preidel, continuing, said the blades were cut off by a slight corner, to the extent of about 6 square in. in the three blades. But the chief point gained was in the thinning down of the blades. They took off about 10 cubic inches from each blade. All the thinning was inside the rim. That meant so much more water when going ahead, and less space to fill up behind the blades. Now they had 30 cubic inches less metal to go ahead, and 30 cubic inches more water to give assistance to the propeller. The engines were not suited to run faster than 350 revs., so a suitable propeller for that engine would have to be slightly larger in order to take the indicated pressure and the full steam which could be used at 350 revs.

Mr. W. E. Farenden asked what slip the propeller gave.

Mr. Preidel said he had not worked out the slip percentage during the last test. At the previous test they had 44 per cent. slip as against 30 per cent. slip with the old propeller.

Mr. Farenden : Then you had 14 per cent. higher slip with the new propeller than with the old one. Is not that a big percentage of slip ? Does not that mean a big loss ? I think you will find that 10 to 15 per cent. slip is about the average for a large number of steamers, and is generally recognized to give the best results.

Mr. Preidel said he thought a 10 to 15 per cent. slip was the average for large merchant vessels, and that for small craft they would generally have higher slip ratios. As he had pointed out, the slip of the screw had really very little to do with its efficiency. In the propeller they had to have a certain amount of rotating energy. For that energy expended, what was required was speed of vessel. Consequently, the efficiency of the propeller was quite independent of any comparison between angles of the blade and angles of advance, or any proportion of the propeller. The efficiency would only be judged by the amount of power they put in, and the amount of power they realized for propelling the vessel. An ordinary open screw could not be made to work with high pressure, say, to the square foot of the driving face on account of the water not having sufficient resistance and velocity. The velocity was determined by the angle to a certain extent, and would tend outward with high slip ratios on ordinary propellers. Consequently, the low slip ratio of 10 to 15 per cent. was an empirical rule. Suppose they could twist the old blades round at a low angle and drive the boat with no slip. It would not be of any advantage to reduce the slip and increase the power to drive the screw. When negative slip was obtained the screw was either reduced in area or replaced altogether. The pressure had to be exerted against the water, as transmitted from the shaft. The centre of the shaft was the beginning of the leverage. If a certain pressure was exerted on the tip of the large blade they had a large leverage of action; consequently, it would take more power to exert a certain amount of pressure at a long radius than on a shorter radius. If the ring were removed from the propeller they would not get anything like the pressure on the last inch of the blade that they now obtained with the ring.

Mr. J. G. Hawthorn said he had looked at the propeller for some time, and the conclusion he had arrived at was that Mr. Preidel was endeavouring to convert rotative energy into longitudinal energy. Mr. Hawthorn then dealt with the theory of propulsion in detail, elucidating his remarks by diagrams on the blackboard. With a screw propeller, he said, they were endeavouring to do a certain amount of work, which was the measure of the weight of the water shifted in a unit of time, and the velocity it was shifted at. Rotative velocity on the part of water was a dead loss. If they could convert rotative velocity into longitudinal velocity they would get a better result for fewer revolutions. It was most astonishing to see 10·68 i.h.p. for 351 revs., and 13 i.h.p. for 347 revs., as shown by the trials of this propeller against another. Then, how was it that the propeller made more revolutions for a less horse-power—either the propeller was making more slip, or, well—if the engine was giving out more work, more speed would have been got out of the boat; but yet they got practically the same speed for 30 per cent. less horse-power and yet more revolutions. Where had the work gone ? If the revolutions were greater, the pressure must be less. If they said that $\frac{P \times R \times T}{33,000}$ gave the indicated thrust of the propeller, then he failed to see how they were to get those knots from it with such a small power and bigger revolutions. To get higher revolutions with a smaller power made him ask where the power had gone between those two.

Mr. Preidel : The pitch is really coarser.

Mr. Hawthorn : If the pitch is coarser, then the revolutions ought to be more reduced.

Mr. Preidel : The diameter is reduced by 6 inches, and the pitch increased.

Mr. Hawthorn said he considered Mr. Preidel was tending to the conversion of rotative energy into longitudinal energy. If that were so, then the propeller was a step in the right direction. His conception of the propeller was, that they did too much work, rotating water on its axis, which was absolutely lost so far as propulsion was concerned. If they could apply that energy and convert it into longitudinal energy, then they would get a better thrust on the smaller revolutions. That struck him at the first instance. It appeared to him that they wanted to try and centre the rotative energy. It was just like a converging nozzle. They were endeavouring to converge the stream of water as it came in through the ring, and it was centred, and directly up the centre of the shaft they were getting a bigger thrust.

Mr. Preidel : There is one point I should like to mention again, to which I also have referred in my paper, and which

Mr. Hawthorn is illustrating here, which I think is generally called the disc theory. [Mr. Hawthorn : Yes.] Well, according to that you would only require—if we imagine a direct push-out of an endless screwed shaft to impel the ship forward—a flat disc covering the whole disc area. If you could get a shaft to give out this continued push in a straight line you would always have the complete disc area filled by a circular blade on the shaft without any pitch. As soon as you have a limited shaft fitted on a ship and the propeller is to work itself forward and drive the ship by merely rotating, the conditions are greatly altered. First of all you must have a pitch on the blade or the blades at an angle ; secondly, you have never or seldom either the total blade area or the projected area equal to the disc area. With the endless shaft proposition rotation would serve no useful purpose for propelling, as you could also drive the shaft out with rack and pinion, and pressure would be exerted by the circular blade against the water. The water nearest the edge of the circular blade would give little resistance to pressure, as it would fill in behind the disc where the pressure had been reduced ; you would here get a pressure curve highest in the centre of circular blade. Whereas with the ordinary rotating shaft and screw you would get pressure curves very low near the centre, as the blades near the centre or shaft cause the least amount of longitudinal resistance and the greatest amount of rotation.

Mr. Hawthorn : But your propeller tends to minimize the rotative velocity of the water.

Mr. Preidel : The rotation of the water is reduced by the large amount of entrance water. There will be a diminution of pressure all over the back of blade. That pressure is at once made up by pressure which comes in from the side. With an ordinary screw that slides off round the edges of the blades, the feed water comes only in from the leading edge.

Mr. Hawthorn : But you have a high rotative velocity at the tip of the blades if you take the ring off. You are tending to draw the water more into the centre. You are tending to reduce the rotative velocity and convert it into longitudinal velocity. If that is the true conception, and if that is the idea you wish us to carry away as to what you are doing, then it is a step in the right direction. If you do that, undoubtedly it is a good thing. I want to get hold of your idea before going further into the argument.

Mr. Preidel: I think the theory of the propeller is wrong so far as it takes the amount of water merely by the area of the disc.

Mr. Hawthorn: Suppose the propeller to be before you, and you are looking forward. When these blades are fined off at the tips, is it to throw the water with a certain velocity: from the centre outwards, so that we get a calmer stream of water to act on? Your idea appears to be to catch that and bring it more to the centre-line of shafting. As your water comes in and again goes out, it must come in from forward between the rim and the edges of the blades. In the ordinary propeller the water moves out from the centre of the shaft, while in this style it is converging towards the centre, between the stern post and the propeller; there is freedom for the water to go through, while it is prevented from going off at the periphery by the band, and it converges, which gives a bigger stream to work on at the aft side.

After a brief discussion, by the aid of diagrams on the blackboard,

Mr. Hawthorn, continuing, said: We all know we can get a negative slip, and we know very well the thrust is the same whether we have a positive, negative, or no apparent slip. Slip does not affect the thrust. We can tie the ship up in dock and get 100 per cent. slip, and yet we get the thrust. If that be so, why do we want slip at all? Simply to produce the energy. We must have a velocity to drive the water astern. Without that, Newton's laws are of no good to us. If you are converting rotative energy into longitudinal energy, then the propeller is working in the right direction. That is the great point which has puzzled all our great engineers for years—that is to say, the loss of the rotative energy. If yours tends to minimize it, we shall be very pleased to commend you for what you have done in that direction, and for the care and attention you have bestowed on the subject.

Mr. PREIDEL : What I am trying to do is to shift the line of most effective pitch further out, and get more slip ; but my object is to work with more slip to get more speed at the same or less horse-power.

Mr. HAWTHORN : Your true slip will be increased the more you increase the longitudinal velocity of the stream. If we speak of slip let us define it as being the difference between the calculated and actual distance that the ship runs in a given time. If we call that slip—and that is actual and true slip—then the difference that now exists between the true and apparent slip will be minimized. We have a difference between the true slip and the apparent slip. To our apparent slip we have to add on the speed of the wake of the ship. But there is a point in propulsion where slip becomes a loss. We want to know what slip is the most advantageous slip for the propeller to have. If our slip becomes too great, we are doing too much work on the water.

Mr. FARENDEN : You have 44 per cent. slip.

Mr. HAWTHORN : That only holds good with the very small class of vessel.

Mr. PREIDEL : I think I have mentioned that too. The water driven back gives the thrust in the right direction. If the ordinary open screw be working on too high a slip ratio, then the proportion towards the periphery is much greater than the normal, consequently there is a high slip ratio and a very low thrust combined. If the ring were removed from this propeller, and the propeller put on the boat again, and made to work with 100 per cent. slip, you would throw nearly all the water outwards from the points of the blades.

Mr. HAWTHORN : If we are to presume that the slip energy is taken up in sending the water out radially, if we can convert radial energy into longitudinal energy, the slip will increase. If it increases with the same revolutions and the same horse-power, then we are going to get a bigger thrust. Have you any data as to pressure per square foot of blade area ?

Mr. PREIDEL : I cannot say I have data of thrust per square foot of blade area.

Mr. Hawthorn : Can you give us any idea of the total thrust for the pitch and diameter ? If we are to get a bigger thrust we shall get a larger pressure per square foot for every foot of blade area, in place of the 40 to 60 lb. usually allowed.

Mr. Preidel : And convert all the longitudinal energy into the right direction.

Mr. Hawthorn : I think it shows a great deal of courage in the face of opinion nowadays from some of our greatest and most scientific leading engineers. It shows a good deal of conviction of individual opinion to come and try to demonstrate that it is possible to convert some of that rotative energy into longitudinal energy. I think the thanks of the Institute are due to Mr. Preidel, and we are indebted to him for the manner in which he has brought the subject before us here. The propeller is still in some respects an unknown quantity. It recalls one of the early pioneers, who saw how the plough-share turned up the clods, and so got the idea of the screw propeller. It almost seems that the propeller is where he left it, and for any one to have the courage of his opinions, and what I may call self-conviction sufficient to bring a propeller out of the usual stamp and show it, I think it reflects great credit and great courage, and these are certainly due to Mr. Preidel.

Mr. Preidel : I am very much obliged to you. I can only assure you I have not done it hurriedly. I have thought it over for four years, and I practised my efforts for about two years, and I should very much like some of the leading authorities to give their opinion. I have put the idea before them, but have never succeeded in drawing an opinion from them. They say : "We do not think it would be suitable." I have gone through all the papers read before the Institute of Naval Architects on this subject, and I still think you must have the quantity to start with. Here you have the quantity measured by the diameter and length. If you can work on that quantity and send the water back in the right direction, you must get the reaction of that water. And that reaction is equal to thrust. The shorter radius you can have, the less power you will require to impart the pressure on the water that is being thrown back, the weight being equal where it presses. I was myself surprised at the indicated pressure dropping so considerably.

Mr. J. Lang : I understand this was tried on a single-screw launch. What effect had it on the rudder, forcing that water back ? Was it harder or easier to steer the boat ?

Mr. Preidel : Mr. Terry spoke favourably of turning the boat round. When the rudder was set it kept a straight course. In turning round I think the circle might have been slightly larger, but very little, as compared with the ordinary propeller. The rudder answered directly to the tiller.

Mr. F. M. Timpson said : I do not think this idea is entirely new. In 1884 I attended some trials of a steam launch which was fitted with a propeller of that principle. The invention belonged to a London company, and it was claimed to give less vibration with more speed for the steam launch. The inventor succeeded in doing that with much less vibration. Certain alterations had to be made with the overlapping pieces, which were placed at the tips of the blades, presumably to prevent the water racing off at the periphery. The launch ran for three days, and the blades and the pieces on them were trimmed down to a point at which they gave the best results. It was very similar in principle to that of Mr. Preidel, but the ring was not carried right round. If the inventor of the propeller referred to had been prepared to accept moderate terms, they would have tried them on a larger scale, but the patentee had too big an idea of the value, and it fell through. With that propeller they had less vibration with increased speed. In France there was a steamer brought out with the propeller running in a tube, but it has evidently dropped out. It was mentioned in the engineering papers some time ago. In regard to the propeller I referred to, the blade point was merely turned over. There was more speed obtained in a practical test. I was the only engineer on this job, and we shifted propellers many times during the two or three days. There was a triangular piece on the tip of each blade. We got results that were better than with the ordinary propeller, and, also, there was decreased vibration. Before that propeller was put on you could not sit and write in the stern of the boat, but afterwards I could sit down and take notes.

Mr. Hawthorn : With the propeller fitted to large steamers of larger diameter, there would be a large amount of centrifugal force with that ring. With any little wear or tear on one side at high revolutions there would be a tendency to wear the shaft oval in the tube. That was the only point he saw in working, and the fact that it would be rather difficult to apply the propeller to large steamers. But he thought that three propellers of this type behind one another, driven by turbines, would work exceedingly well.

Mr. Preidel : I believe I mentioned that a great number of patents have been applied for and which have a portion of a flange on each blade ; they recur time after time. The fault, I think, is in their construction, because these pieces catch against floating drift, and anything in the water is easily caught by the ordinary blade, and much more easily caught if it has a lip upon it. A piece of wreckage is bound to break it off, or bend it, and the propeller is working worse then. It is losing more through the tip being at a different angle than the efficiency of the blades can make up for. I think that if the water could be smooth always, and with nothing in the water to strike it, that propeller with the flange on the blades would be more applied. I believe it has been applied over and over again, but the fault is that it catches débris. Here with my propeller you have a continuous line. If it strikes anything in a general direction the force is minimized at once, and the blow is staved off. Regarding ropes and chains which might be in the water, they cannot get foul of it unless they enter it. Then they might slip off that edge. If the rope came in touch, it would be thrown off. There is an angle of 35 degrees where it would slip off. Regarding weight, I said I should not like to make a propeller 22 ft. in diameter. The diameter has now got to 14 feet with turbines in some of the biggest ships, and if there was any chance of reducing the diameter in any way near the same percentage, I should have no hesitation in trying it on a sea-going steamer. The propeller referred to as tested is 22 per cent. smaller than the original. Consequently, there would be a great reduction even on these propellers, and I think it is admitted that the efficiency drops much more in the high speed than in ordinary propellers with larger diameter and less area to the blade which could be used. I think propellers on that principle could be made up to 14 or 15 feet diameter without incurring great risks. I do not think it would be necessary to make them any larger.

Mr. Timpson : I think, as regards catching sea-weed and debris, I may say that the propeller to which I referred remained in use for two or three years, so long, indeed, as the boat was in this country, and there was no trouble in the way of catching. It had been remarked that one inventor was very near a theoretical solution. He used the propeller in the inside of a tube, and let it have a good clearance in the tube. The effect was that they went ahead all right, but so soon as the boat lost movement the propeller was rotating inside without any water. If the boat took a slight turn the feed water was partly cut off. In swinging round the boat would have some effect in cutting the feed water off. Going ahead there would be no chance of cutting the feed water off.

Mr. A. G. Rainey : If a fair-sized radius were fitted where the blade tips joined the circumferential ring instead of a sharp corner, would it not increase the efficiency of the propeller by making the change of direction of the water flowing radially along the blade less abrupt. Would it not facilitate the feeding of the water behind the blade ? Where the blade joined it, would it not make the propeller more effective ? It seems to me it would facilitate the feed water behind the blade.

Mr. Preidel : I do not think it would make a great difference, having the corner of blade and ring rounded. You would lose part of the effectiveness in going astern. I doubt whether it would increase efficiency in going ahead, and it would reduce efficiency in going astern. In reply to the question of making propellers of this type, I think that even larger propellers could be made in parts. You could have the blades with a lip on, and fix the ring over, either by rivets or screw. They would have to be as flat as possible. If it were impossible to make them solid, I see no impossibility of making them in parts. Having bolts projecting you would lose a little of the efficiency, but it depends upon how much efficiency can be gained above the other, and what other advantage would be in the larger size. It is generally admitted that in the new bigger boats the results obtained are more favourable than on smaller boats.

Mr. Hawthorn: I rise to propose a vote of thanks to Mr. Preidel for his paper on propellers, read before us on a previous occasion and discussed again to-night. I think the Institute is very much indebted to him for coming forward and giving us something which is outside the ordinary routine of the theory of propellers, and to come here with a certain amount of original research. I am going home to think this matter out very much, for it is not one to be answered hastily. The subject of propellers is a mystery. I could never understand how the propeller could do the work. I have an old work in my possession published in 1838, and one of the pictures shows a large concourse of people assembled on the banks of the Thames to see "that great ship of 810 tons burden being propelled without sails or oars, but by that great invention, the Archimedean screw—the small tiny screw at the stern of the ship propelling such a large vessel, which made the trip from Blackwall to Gravesend in 9½ hours!" That was recorded in 1838. When we come to look back we find that the principal inventions have been brought about mostly by the courage and conviction of individuals by trying their own ideas. Propeller progress has been purely experimental. There are lots of theories, but the facts are before us, and if we go on in this direction, I think the engineering world must become indebted to inventors if only for the able way in which seekers go to work to elucidate mystery. I think this Institute can do nothing less than award Mr. Preidel a very hearty vote of thanks for his paper, and for the kind manner in which he has answered our questions. He has done the very best to elucidate all his ideas.

Mr. Lang seconded the proposition, endorsing Mr. Hawthorn's remarks.

The Chairman said they would all agree with every word that Mr. Hawthorn had said. They had that evening had a very interesting discussion. Not only had Mr. Preidel given them a very able paper, but he had also displayed his readiness to try and make clear any point which had arisen during the discussion. In addition to the discussion they had also had some very illuminating remarks from Mr. Hawthorn, which were very interesting, thus making the evening much more valuable. In moving the vote of thanks to Mr. Preidel he did so as representing the wishes of the Institute. Mr. Preidel's paper had required a considerable amount of time and thought.

The vote of thanks was cordially agreed to.

Mr. Preidel said he thanked them very much for the favourable reception of his new idea, but he was sorry to say that certain well-known men had absolutely refused so far to give him a word or have a look at the propeller. But their reception of his idea at the Institute of Marine Engineers would decidedly be a consolation for some of the trouble and hardship he had gone through.

A vote of thanks to the Chairman closed the proceedings.

Mr. Preidel.—Reviewing the discussion on this paper for a few concluding remarks, I should like to say that for the purpose of compiling it I carefully perused the various papers and discussions recorded in the *Transactions of the Institution of Naval Architects*, as well as a number of books by leading authors on the subject. Although apparently there is a great difference in the various theories advanced by different theorists as to whether a propeller pushes water backwards, or oblique blades push a vessel forward, it is certainly quite safe to state as a first principle of propulsion, that the forward thrust obtained by a propeller is the longitudinal component of the reaction of the water caused by the pressure of the propeller against the water. The pressure of the propeller against the water, when driving a ship, and the re-action of the water against the propeller must always be equal and balance each other in opposite directions. Therefore, whether there be slip or no slip, pressure there must be. The pressure exerted by the propeller can, however, be caused by various amounts of energy, according to its application and also in various directions. It seems certain that pressure can be exerted with less power near the shaft than at a great radius. The problem of propulsion resolves itself into causing the greatest amount of longitudinal pressure with a given amount of energy from a rotating shaft. As the pressure to the square unit in the ordinary open screw is governed by the surrounding pressure, it should be evident that there is ample room to improve the propeller so as to make it work with higher pressures by increasing the area of feed and decreasing the area of discharge, which, in the propeller shown, is in the ratio of 1.75 : 1. The object of this was rightly understood by Mr. Ruthven when opening the discussion. The various questions regarding Slip, Pitch, Blade Area, etc., could be cited as a proof of the uncertain foundation of propeller theory, whilst the contributions to the discussion by Mr. Hawthorn clearly seemed to favour my theory.

There remains only the point of skin friction, which no doubt at first sight appears greater than it really is, and against which the superior efficiency of the blades has to be put. From the results obtained with these propellers one conclusion can be stated as incontrovertible, namely, "That this propeller will give a greater amount of thrust within any given diameter and given revolutions than any open screw, by very economical expenditure of power." There are many opportunities in practice where the diameter is limited by external circumstances and within which the greatest amount of thrust is to be obtained, as, for instance, shallow draught, towing, and high engine speed purposes, all of which would obtain advantages with the use of this propeller.

Then, after the superiority should be proved for such cases, would be the time to judge whether the reading of this paper and the discussion had been of a decisive character regarding screw propulsion generally. For the present I wish to express my sincere thanks to the Hon. Secretary, the Chairman, those that took part in the discussion, and the Institute generally, for making it possible for me to read a paper like the foregoing, and for its favourable reception.

CONTRIBUTIONS BY CORRESPONDENCE.

Mr. W. J. Harding (member). It may be pointed out that whilst the paddle wheel has its counterpart in the animal world as a propeller in steamer-ducks, and perhaps in the turtle and others, there is no action equivalent to the screw propeller to be found in any swimming animal. As the Archimedean screw was the first actual propeller tried in this country (for Trevithick the clever Cornishman seems to have been the first proposer of the screw propeller in its present form, but not a user), it was but natural that engineers and others should compare the screw propeller to a screw working in a nut or to an auger boring wood, and the term "slip" was a convenient term.

As the Archimedean screw had the same pitch on the front side as on the back side of the propeller the term slip might be applicable, but when in later propellers, as indeed in all present propellers, the average pitch of the front side of the propeller differs with that of the driving, or back side, slip becomes an anomalous term, and possibly it would be fair when speaking of slip to calculate it using the average pitch of both faces of the propeller blade.

I am well aware it has been laid down that you *must* have slip, some advocate as high as 30 per cent., very few advocate a low percentage, but that is a matter which all present experience points to being still problematical. Indeed, speaking from memory, the best propeller in the celebrated *Iris* experiments was one that worked with a small *negative* slip. This propeller gave the highest speed, but was discarded on account of vibration.

I differ from the author in his explanation of the very modern term "cavitation;" I give a story told me by one known to many marine engineers, Mr. Henry Warriner, still among us, who in the fifties of the last century had a great deal to do with the 40 and 60-horse power gunboats, built for war purposes. These were to give indicated horse power, and up to a certain speed of revolutions the steaming was comparatively hard, after that the propellers cavitated, and the power could be largely exceeded. According to him the effect was that though the revolutions were much increased, the speed of the ship was *actually decreased*, so that though the engine was going full speed for all that it was worth, yet on easing down the speed of the ship actually *increased*, thus showing that the cavitating propeller is merely a churner, or it may be compared with what is called a swizzlestick, and this defect is due primarily to insufficient area.

I think a great deal might be learned by studying the action of a propeller in a phosphorescent sea where it will be observed that the effect of the delivery of the water from the propeller is first to make a cone of water slightly revolving, and this extends up to a certain diameter of base, and after that it becomes a cylinder of water, the whole movement of the water gradually subsiding at a certain distance from the ship. In high speed vessels the distance of the disturbed wake from the counter gives a very fair idea of the amount of slip, after a few observations.

Coming down to the author's ideas I see that he speaks of propellers working in cylinders. About the year 1864 a cylinder enclosing the propeller was fitted to a gunboat at Portsmouth; this was the proposal of Mr. John Samuel White, of Cowes. This greatly decreased vibration, which in those days (as horizontal engines were used) was generally horizontal vibration, and it had the effect of a slight increase of speed. It would be noted that there should be an increased skin resistance due to the dragging of that cylinder through the water, and so far as I can gather from the author's invention he would get an increased friction due not only to the passage of his blades through the water, but revolving in the water.

I need scarcely point out that if the propeller was only wanted to force the ship ahead and never astern, it could be made much more efficient with a decreased coal bill. He claims that his propeller will answer "quite well, going astern." As "quite well" is a comparative term, and it may be but once in a few score years where to avoid collision with an iceberg, or another ship, or a rock, that the going astern capabilities of the propeller are to be proved, one must see to believe.

There are many among us who think that some propellers in present use have not the desired reversing-the-ship virtues.

The whole subject of propellers should be a national matter for investigation. It may be known to a few of the members that I have often advocated the spending of large sums of public money, say even up to a quarter of a million sterling, with a view of making experiments, all to the effect of lessening our marine coal bills. It was certainly a very great gain some years since when it was found that Manganese Bronze, by its lesser skin resistance, greatly decreased the coal bill, and we have had recently in the *Dreadnought* the propellers polished in a manner said never to have been attempted in any large battleship the world over.

Primarily the diameter is the crux of propellers: the small diameter propeller has never been so efficient as the large diameter propeller, and one must be very judicious as to receiving the author's assertion that his propellers may be made smaller by from 10 per cent. to almost 30 per cent. on present diameters. One is aware that such have been made, but they cannot go astern satisfactorily.

After the diameter is the subject of pitch, and with twin screw propellers all our experience in high speed vessels points to low slip as being most efficient, and this low slip is given by defined area (but not by coarsening), and by the straddle of the propellers. In this straddling perhaps imitating nature where the legs of the swimming bird are generally wide apart.

I suggest to the author that one of the most important matters in the screw propeller is the diameter of the boss; this was the one great improvement which Griffiths made. We have gradually deviated from this, and I give it as my opinion that the small boss is a mistake. As to the shape of the blades, the pear shape seems about as good as can be desired for vessels of speed, but in tug boats generally a compromise has to be fitted, due to the fact that large diameters cannot be given, and hence the many irregular shapes of blades.

I cannot agree with the author that his addition to the blades will prevent vibration. Vibration is primarily due to weakness of hull, and is set up because of propeller greatest and least resistances. In two-bladed propellers there are two periods of greatest and least resistance to turning at each revolution, in three-bladed three periods, and so on. Thus with a three cylinder engine; having three maxima and minima turning moments, if the maximum turning moment be opposite the minimum resisting moment of the propeller, the engine runs away and you get vibration. This is often slightly remedied by uncoupling and coupling in a different position. Hence possibly with a three cylinder engine, a five bladed propeller would cure vibration.

In reply to the contribution by Mr. W. J. Harding, Mr. Preidel writes as follows:—

With reference to the contribution by Mr. W. J. Harding, I should like to remark that, as a leading principle, I do not think that Mechanisms are or should be copies of Organisms. Although many mechanical motions have been suggested by actions in the animal world, it must be conceded that some imagination is necessary to see a great similarity between a pair of paddle wheels and a pair of duck's feet.

I have nothing to say against the use of the term "slip," except that it should not be used as a synonymous term for loss of power, or for deciding the efficiency of a propeller. I still think that the percentages of "slip" can be calculated from the mean pitch on the driving side only; but one could also count the revolutions during runs over a knot and calculate the actual advance of vessel per revolution under ordinary good test conditions, and compare this with the power units expended, using this as a basis for further calculations under various states of trim and weather.

Regarding cavitations, it certainly seems much more reasonable to me that at a certain rate of revolutions, and at a certain slip ratio, insufficient feed water is being obtained, and by this means a partial cavity is caused within the propeller, which again allows the engine to run away without obtaining adequate thrust. If, as Mr. Harding suggests, the cavitating propeller were merely a churner, why should it be easier for the engine to revolve a complete fill of water each revolution at high revolutions than at slower engine speeds? If sufficient feed water could be obtained, and each fill in its turn should be churned round, it appears to me that the propeller would require more energy for this churning than for driving the water back and the ship forward.

I hardly think it would be found a very easy matter; as Mr. Harding says, "if the propeller was only wanted to force the ship ahead and never astern, it could be made much more efficient with a decreased coal bill." I feel certain that if "*much more efficiency*" could be obtained, different means of reversing the motion of boat could be devised, and, at least, for certain classes of vessels, such as racing boats, it would have been employed. Regarding the reversing capabilities of my propeller I can refer those interested to the reports by Messrs. Stephen H. Terry and James A. Smith, from which also the reduction in diameter, power, revolutions, midship-section, etc., can be had.

I agree with Mr. Harding that "primarily the diameter is the crux of propellers"; consequently that type of propeller which gives the greatest speed to a vessel for a certain diameter and given h. p. per revolutions per minute does present advantages. It should be possible to bring pitch and area of blades to a more or less uniform relation to diameter, which is also one of my objects.

I do not think that large bosses would be beneficial to my type of propeller, instead of which I make differences in the pitch. No doubt many causes can be responsible for vibration of a vessel when under weigh.

I do not expect that any one would like to answer for the expenditure of large sums of public money mentioned by Mr. Harding for experiments, but I certainly think that what has so far been done with this propeller, should justify the expenditure of the moderate amount of money required for one test to satisfy the authorities, especially since private enterprise has borne such a large proportion of the costs of improving the propulsion of ships already.