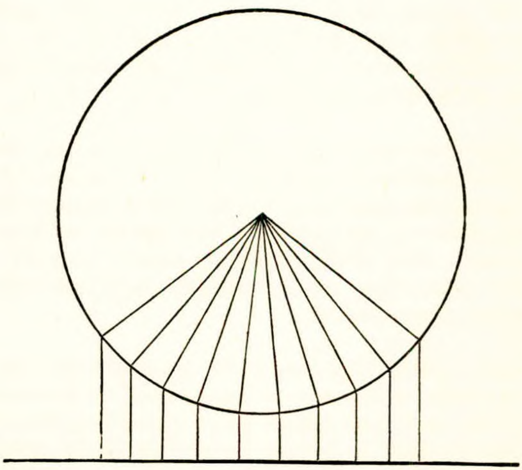
# PROPELLERS.

There are only two kinds of Propellers that have at present any commercial value, the paddle-wheel and the screw. The paddle-wheel first became a success about 90 years ago. Since then it has been greatly improved; and the fact of it being in common use to-day, and also that new paddle steamers are now being built for trades where the screw could be used if desired, point out that after the test of 90 years the paddle-wheel still has a commercial value.

The diameter of a paddle-wheel is determined by the speed of the ship, and the revolutions desired, an allowance also being made for about 15 per cent. slip. In English practice the length of float is about one-third the breadth of the vessel. The breadth of float is about an inch for every foot in the wheel's diameter. The floats are spaced from $2\frac{1}{2}$ to 3 feet apart if radial, but if feathering floats are used they are placed nearly twice as far apart. Feathering floats have about 6 per cent. less slip than radial or fixed floats. The immersion depends greatly upon the trade in which the steamer is to be employed, as well as upon the size of ship. If at a fixed draft, and in smooth water, a depth of a few inches over the top edge, when the float is directly under the shaft, is quite sufficient. But in steamers that have varying drafts, and also rough seas to contend with, the immersion requires to be more; but the immersion should never exceed one-quarter of the wheel's diameter, even then a great loss is incurred. Of course different builders modify these proportions greatly, either to suit the particular vessel they are building, or their own practice. In America the paddle-wheel is in much greater favour than in this country, owing principally to the greater amount of smooth water navigation that is carried on there. Their practice differs from ours in many ways. They make their paddle-wheels of a much greater diameter. They give a proportional immersion which is less than ours, and they adopt a form of fixed float, made up of three narrow strips. Two of these strips are on the same radial line, but with a space between them equal to the breadth of the third strip. This third strip is placed a few inches behind the space which parts the other strips. These floats appear to give a good propelling efficiency without disturbing the water as much as the broad float does.

As a propeller, the paddle-wheel has special advantages for river work. The paddles are always free, even though the ship may be aground, or passing over a mud bank. They are not liable to choke up with weeds, or other river growth. And in many cases the sternwheel is the only propeller practicable. But the paddle-wheel has, after all, so many disadvantages, that engineers were dissatisfied with it for ocean steaming and general work, long ago. The paddles hold a good deal of wind, and retard the ship when the wind is ahead. They work very unevenly in rough weather, often being quite choked with water or quite out of it. They are very liable to damage through seas striking them, or colliding with piers, or other vessels. They prevent the vessel being laid alongside piers or wharves. Their slip is very great. They reap no advantage from the return current of water, unless in the case of the stern-wheel, and it is doubtful if the stern-wheel reaps much advantage, for its slip is about the same as the slip of side-wheels. The efficiency of paddle-wheels is affected by every change of ship's draft, and on a long voyage this is a grave drawback. Again, each float has an increasing pitch for the first half of its path through the water, but a decreasing pitch for the last half, for although its circumferential motion is regular, its propelling motion is constantly varying; and as the float is about leaving the water, it is stopping the flow of water from the float following it.



**The spaces on the circle show the circumferential motion, and the spaces on the horizontal line show the relative propelling motion.**

The screw propeller became a success in 1836, and three years later a screw steamer of 237 tons was built. The best form of screw is generally arrived at by experiment; only, unfortunately not with actual screws in actual ships, but generally with models. It is not difficult to experiment on model screws in a rough practical way. Take a trough formed in a circle so as to present an endless water channel. Let it be just deep and wide enough for the models to work freely in, and to be well covered. Have a shaft fitted with fixed pulley at one end, and the other end made to carry the screw models to be tried. This shaft must run in two suitable bearings in the trough, and may either have a solid end to one bearing to act as a thrust block, or the thrust can be taken on a lever attached to a spring-balance, in which case the thrust can be measured.

Having fixed the screw to be tried, and filled the trough with water, wind several turns of cord round the fixed pulley, pass the free end of cord over a roller in the side of the trough and attach a weight to it. This fixed pulley, cord, and weight, represents the constant power that we are going to use in the experiments. Now if we let the weight go, it will cause the cord to unwind, thus causing the pulley and screw to revolve until all the cord is unwound. Now the best screw will cause the water to flow round and round the trough for the longest time; or in other words, it will throw the greatest volume of water behind it, at the greatest comparative velocity. Of course in a series of experiments such as these which have been indicated there are none of the refined calculations usual in similar experiments; but when did these refined calculations agree with practice?

We sometimes lose sight of the fact that the propeller, no matter whether paddle or screw, is our "Foundation Stone," and that in designing the machinery for any vessel, we should first fix the various particulars of the propeller and design the Engines to suit that propeller. One thing that is common to both paddle and screw is, the larger they are in diameter, comparatively speaking, the slower they turn round.

The best modern practice is to construct the Boss so that it presents as little resistance to the water as possible, and the blades as thin and fine edged as is consistent with the required strength, also to make and keep the surface of the propeller blades as smooth as possible. The different Bronzes lend themselves readily to this practice, as they do not perish or eat into rough places like iron or steel; and they retain any edge or polish that is put upon them, while their toughness enables them to be made light and thin ; this has the effect of lessening the load on the outer bearings, and of allowing the blades to be driven through the water with more effect, and with less horse power. There are two drawbacks to the Bronze Blades, the first is their cost, and the second is that it is necessary to protect the screw frame from corrosion. This is done by bolting plates of zinc along the top and bottom after corners of the Propeller aperture, that is, the after-edge of the stern frame, or forward edge of rudder post. It is the corners that corrosion seems to attack most.

I think that with a more perfect contact between the zincs and the iron frame, less zincs might be used without any loss of efficiency. I would suggest that each zinc be small enough to be held by one stud, this stud being screwed a fixture into the iron, and the projecting part screwed with a taper thread, like a gas burner ; the zinc should be tapped out taper, and only screwed far enough on the stud to make a tight and firm contact. Each time the zincs are taken off, the tap should be put in the hole just to clean it, and the die should clean the studs in the same way. The zinc would then screw a little further up the stud, and the contact be as good as when all was new. This might be applied to Boiler Zincs with even greater advantage.

Regarding the extra cost of Manganese-Bronze blades, I believe they are worth it ; for in my experience I find they save about 6 per cent. in fuel when compared with cast-iron blades—speed and other conditions being equal. Regarding increasing pitch, it is common practice for the following edge of a blade to have 10 per cent. more pitch than the leading edge ; I believe this could be further increased with advantage, but as in going astern the blade must have decreasing pitch in equal proportion, it thus loses some of its efficiency for going astern.

Fine pitches are in favour more than they were. They act much better against head winds, or when the ship is deep or dirty. They have less slip, and great slip can only mean great loss. Let us suppose a propeller at 27ft. pitch and going 50 revolutions per minute, then alter this same propeller to 25ft. pitch, and still drive it 50 revolutions per minute. I think you will agree with me that the 50 revolutions at 25ft. pitch costs the least in fuel. Now suppose that at 27ft. pitch the slip is 12·4 per cent, and at 25ft pitch it is 5·4 per cent, we get 23·7 more miles a day by the screw at 27ft. pitch, but the day's run by the ship is 280 miles in both cases.

A case of this nature came under my notice, in which with a 26½ft. pitch and a heavy slip the ship travelled less than with a 25ft. pitch and a light slip, revolutions and most other conditions being the same. True, in the first case the blades were thick edged and had a rough surface while in the second the edges were as fine as possible and the surfaces smooth. Still it was a case of great slip being great loss.

Fine pitches allow the engines to be run at a greater speed, and if new engines are being designed for steamers about to be refitted, the required power can be obtained from lighter engines, through this increase of speed. If a finer pitched propeller is fitted to a steamer with engines already designed, there is still an advantage in piston speed, for the piston speed being designed for the maximum speed, and engines being rarely run at this maximum speed, the piston speed is thus usually too low, and the increase is an advantage.

For shallow draft steamers a screw is often used, and made to work in a tube built into the vessel. This tube either runs straight, and is quite under water, or the two ends slope down under water, but the centre part where the screw works is raised. The screw is partly dry when not working, and may be examined through a doorway. As soon as the screw starts it fills the tube and after that, has a constant supply of water. The great drawback to these tubes is that they easily choke up when passing over a bed of river weeds, or over a mud bank. The friction is also very great, especially in the curved one, for it presents the resistance of an inclined plane at its entrance, and helps to choke the screw at its discharge, besides imparting to the mass of water thrown out, a direction other than the plane in which the vessel is moving.

A simple way of finding out the pitch of a Screw Propeller is to find that point in the diameter where the face of the blade is at an angle of 45° to the line of shaft, the circumference of the propeller at that point is equal to the pitch, or in setting the blades to any pitch, take a circumference equal to the pitch required, and at the points where this circumference cuts the blades, set the face of the blades at an angle of 45° to the line of shaft.

There are one or two propellers with ingenious contrivances for automatically altering the pitch of the blades to suit the conditions under which they are working. These propellers are not in great favour.

It is most important for a Captain and Engineer to find out their ship's best trim for going, and to try and keep her about that trim. In some cases where the entrance is fine but where the ship is very full aft it will be better to keep the ship down by the head. In other cases where the entrance is bluff and the run fine it will be better to keep her down by the stern. But in nine cases out of ten the ship will go best when the line of shafting is in a true parallel line with the surface of the sea. Or, if you will permit me to introduce a spirit-level on board ship, when the length of shaft lies true to a spirit-level; generally this puts the ship down by the stern, but not always. There is a great loss of efficiency if the screw shaft is at an angle to the vessel's track, either through fault of construction, or through the vessel being down by the head or stern, or may I add the idiosincracy of the designer.

If the line of shafting is inclined at the screw end the go-astern side of the descending blade presents a surface of less obliquity to the rush of water than its normal one, and if the angle that the shaft makes to the surface of the water is very great the blade presents a surface, more or less, flat and at right angles to the vessels path. If the shaft declines at the screw end the same conditions exist on the astern side of the ascending blade. In addition to the extra resistance, the blades have a different pitch in every part of their path, besides throwing the water in a direction other than in the plane of the vessel's track.

This varying pitch is the cause of the unexpected races we are sometimes troubled with, for often there comes a race that the most experienced cannot anticipate and that even puzzles Dunlop's Governor. This race is also caused by the return flow of water to the trough or base of a wave. The topic of racing is only a little way removed from the subject of broken shafts, and I am sure you will permit me to digress that length for a minute.

It sometimes happens that a shaft breaks diagonally or zig-zag in such a way as to leave a pair of scarf-ends overlapping.

The usual practice in such a case is to put one or more pins through the overlapping parts, and then clamp them firmly together with a number of heavy clips.

I would suggest as an improvement on that method, that the two ends should be secured in a temporary manner so as to permit the engines to be turned with the turning-gear. Then secure a strong wire hawser to the shaft well clear of the fracture, lead the hawser through snatch-blocks to some suitable place, and keep a strain on it. Then go on turning the engines, and bind the hawser evenly, and tightly, well over the fracture; after one or two layers of hawser have been bound on in this manner, secure the end to the shaft, and I think it will be found to be a good job.

If the ship runs 300 miles and the screw 290 miles there is 10 miles to account for, and to give a name to. We call it "negative slip," but none of us believe that the ship has actually dragged the screw after it.

Now, one of three things must have happened, or a little of each. Either the pitch of the propeller has been taken at some point which is below the maximum pitch, and the conditions of weather or current have been such that the maximun pitch has taken effect. Or the pitch of propeller has been about correct, but the screw has reaped sufficient advantage out of the reverse current, caused by the filling in action at the stern, and by the drag of the ship's sides, to produce negative-slip. But this reverse current is always more intense with a head wind, and with a dirty ship; while negative slip is only experienced with a fair wind, and a clean ship. The third possible cause of negative slip is, ship and screw have preserved their usual relative speeds through the water, but the water has travelled in the same direction a distance equal to the negative plus the usual slip.

It is very interesting to watch, from a point of vantage, the apparent action of the screw upon the water about it. In observing this I was surprised how little of the surface disturbance is caused by the screw. The greatest part of this surface disturbance is from the natural wake, due to the vessel's lines, mixed with the broken water from the square surfaces of the screw-frame, and the almost square-ended boss. On the side where the blade is ascending it may be seen coming up without any disturbance round it, but along the side of the rudder an appearance of boiling is seen where the water escapes from the top after corner of the screw-frame; this is deep down and not surface disturbance.

On the other, or down stroke, side a white flash may be seen to leave each descending blade just before it gets to half-stroke. This white flash appears to shoot astern at a great speed but in small volume, and inclines a little towards the rudder; no twisting motion is apparent in it. It appears to be the escape of a quantity of air, taken down by the blade in passing the top centre, although at top centre the tips of the blades were covered with 6ft. of water in the case I observed. The disturbance, or boiling up astern, appears to be more violent, and to reach the surface nearer to the ship when the white flashes are greater in volume—or, when more air is taken down. This air must be in the water to begin with, and the nearer to the surface the more air is in the water.

Allow me to make a brief digression for an illustration and partial explanation. Take a glass vessel and fill it with fresh water, then place in it some fishes. At first of course they will dart about, but as they settle they will swim near the bottom of the glass, and after a time, unless you change the water, they will gradually swim nearer to the surface, because they have exhausted all the air at the lower depths. They will thus rise and rise, until they occasionally poke their noses through the surface to obtain the air above it, and they will swim as near to the surface as is possible. Now, if you stir this water about smartly, you aerate it, and after the fishes have recovered from the fright caused by the stirring they will again have a supply of air lower down and will swim lower accordingly. I think this is the way the air gets down to the blades and causes these flashes, which show distinctly the speed and direction of the water when it leaves the screw, for I believe the whole volume of water leaves the screw in the same direction and at the same speed as these white flashes do.

The adjustment for a patent log is simply done by the lengthening or shortening of the log line. If the log is not showing enough speed, you shorten the line and tow the log nearer to the ship. This proves that the ship and her wake are parting company much quicker the nearer you get to the ship, and that instead of a steamer drawing the water after her, it is thrown behind her by the propeller, and its velocity gradually decreases the further away it gets. This refers to water outside the influence of the inrush to her counter, and the reverse current set up by the drag of the ship's sides.

I have never been able to detect any apparent difference in the action of the water, whether the screw has been working at positive or negative slip.

If you watch a screw shaft going round when the engines are running about 40 revolutions per minute, you can notice the speed is not regular throughout the revolution. This irregular speed exists in the higher speeds although it is not so easily detected. Now this means that the propeller blade is not keeping a steady pressure upon the water, for at all the points where you observe the shaft turning more slowly the blades are relaxing their pressure through that slowing. Most of the single crank engines have a fly-wheel fitted to balance and carry them over the centre, and I think a fly-wheel would be very beneficial in the case of slow turning two crank engines, as it would help them to keep a steadier blade pressure.

## Mr. JAS. ADAMSON'S Remarks.

(*HONORARY SECRETARY.*)

The Paper presented to the Institute by Mr. Drewry is on a very useful and practical subject, and should prove valuable as a starting point for an important discussion. I have been furnished lately with the results of some trials which were made on the Clyde with a new steamer of about 1,200 tons. As they are interesting and may lead to further discussion on a few points involved, I now lay them before you.

| | Deadweight on Board. | Mean Draught. | Trim. | Speed. Knots. | Revs. | Propeller. | Slip per cent. |
|---|---|---|---|---|---|---|---|
| 1st Trial | 480 tons | 13ft. 8in. | 4ft. 4in. by Stern | 14·709 | 86 | Solid, 20ft. Pitch | 13·3 |
| 2nd ,, | 473 ,, | 13ft. 8in. | 3ft. 8in. ,, | 14·746 | 87 | ,, ,, | 14·2 |
| 3rd ,, | 473 ,, | 13ft. 8in. | 3ft. 8in. ,, | 14·816 | 87 | Built, 19ft. Pitch | 9·2 |
| 4th ,, | 600 ,, | 14ft. 3in. | 3ft. 0in. ,, | 14·643 | 78·8 | ,, ,, | 11·0 |

The first two trials were made, it will be observed, with a Solid Cast Propeller, the last two with a Built Propeller, the latter showing the results to be more favourable. It would have been both more useful and interesting had these trials been performed on equal terms, except the alteration in mode of fixing the blades, as it is, there are several elements in the case to allow for, which render an absolute comparison somewhat unreliable. The figures are given with a view to an expression of opinion, or results from experience, as to "Trim," "Alteration of Pitch," "Solid," as compared with "Built Propellers," &c.

I have here noted some results from a steamer fitted with Bronze Blades, which I have compared with results from the same steamer fitted with Steel Blades, the comparison showing very favourably for the thinner and smoother Blade. The steamer in question is fitted with boilers of 180 lbs. pressure, and the machinery is of the modern—converted from the Compound Surface Condensing—type, and fitted with the usual appliances, evaporator, feed heater, and Weir's special pumps for the boilers. She has steamed three voyages over the same ground with the

Steel Blades and one with the Bronze Blades, the Draught leaving port being much about the same in each case, but the Pitch with the Bronze Blades six inches greater than with the Steel.

| | Tons per Day. | | Miles per Day. |
|---|---|---|---|
| 1—Averages of the lowest of three, with Steel Blades .. .. .. | 26·365 | — | 244·35 |
| 2—Mean averages of three voyages, with Steel Blades .. .. .. | 26·8175 | — | 248·805 |
| 3—Averages of one voyage, with Bronze Blades .. .. .. | 25·18 | — | 258·613 |

| | |
|---|---|
| In No. 1, the fraction representing displacement, mileage, and coal, is .. .. .. | ·0678 |
| In No. 2, the fraction representing displacement, mileage, and coal, is .. .. .. | ·0696 |
| In No. 3, the fraction representing displacement, mileage, and coal, is .. .. .. | ·0652 |

Without considering the alteration of Pitch involved, these figures indicate a gain in favour of the Bronze Blades of about 4 per cent. in coal and about 5 per cent. in speed. There is also an improvement in economy taking the figures in connection with the displacement into account, the gain being proportional to the difference between ·0678 in No. 1 and ·0652 in No. 3.

The per-centage of gain which may be attributed to the bronze blades is probably due to the smoother surface presented to the water, the cutting edge of the blade being thinner, and the whole blade lighter. Another element which has been suggested may have some effect, and doubtless has in many cases, in that the pitch is most carefully attended to in the construction of Bronze Blades, and greater exactness is secured. Whether that be the case or not, it seems to be in evidence that a fairly large per-centage of Propellers are found to be wanting in respect to uniform accuracy of pitch of screw. It has probably come within the observation of most of us that after a steamer has been docked, and the Propeller examined, some indications have pointed to the fact of one or other of the blades as having been set at a different pitch from the rest; no doubt this is of a somewhat rare occurrence, but we may gather from the remarks which have been made on the subject of the pitch, it may be found to vary between one blade and another, not by any means so infrequently, and it may be well for members to give their attention to see that those Propellers they are interested in should be properly adjusted. The question as to the best pitchometer or the best method of testing the pitch of the blades might be commented upon if deemed worthy of remark.

One of our Members has for some time past been experimenting on the subject of Propeller Blade corrosion, with a view to discover the definite cause and the corresponding reason by which a portion of the back surface of the blade becomes pitted or corroded and ultimately eaten through; and, the effect of the action on different substances. The experimenter considered that heat might be the element at work, generated by the high velocity and constant friction, tending to disintegrate the metal at the points of the blades, as the corrosion is found to be most severe with high velocities. As to the issue; since the results of the experiments did not indicate heat, it was presumed that the corrosion might be due to the presence or absence of air, and an experimental test is now being made by means of a blade which has a hole through it, about two feet to eighteen inches from the tip; around this hole a ridge is placed to direct the flow of water through the hole, there is another ridge on the back of the blade to assist the flow of water being directed and distributed across the blade in the direction of the point. The object of this is to "sweep" the cause of the action away (whether it is due to air or vacuum), by the distribution of the water.

I remember some years ago seeing one of the Glen Line Steamers fitted with an arrangement on the blade with a similar object to this referred to, but it was found to be not quite a success; had Mr. Roberts been present to-night he might have given his opinion on this case. One of our deceased members (Mr. M. Prior) considered that the pitting action was due to Galvanic or Electric action, generated in the first instance by the bearings of the engine and transmitted along the line of shafting and thrown off at the tips of the blades; he proposed to counteract this by introducing a disc of copper between the faces of the last tunnel shaft couplings, and copper brushes to collect the current; these were attached to wires led to buttons screwed into the skin of the ship, thus intercepting the current before it reached the Propeller. I am aware of one Steamer which was fitted with this arrangement, but as it was not fitted simultaneously with new blades, the exact result was difficult to predicate, on account of the pitting having to be gauged with the eye between one voyage and another; Mr. Wotherspoon would probably have given us his experiences of this had he been present, as it was fitted on a steamer under his superintendence.

The pitting at the back of the blades is similar to the pitting which is to be seen on many of the rocks of our sea-girt isle, caused by the constant impact of the drops of water falling from the crest of each successive wave. So it appears to me that as the screw revolves, and at the same time moves forward in the direction of its thrust, the water, cleft by the circular and thrown off by the centrifugal action, is divided and sub-divided, forms into swirls—somewhat similar to the wave crests—which rush against the blade near the point and by the force of their impact eat into the metal more or less according to the mixture of which the blade is composed.

I have seen cases where a solid Propeller has been at work for 10 or 12 years without the necessity of renewing it; this seems to point to a different mixture of metal or to a speed of Propeller such, that the same severity of action does not tell on the blades. MR. TAIT has made reference to the metal, as a probable reason why the corrosion appears to be greater with Propellers fitted in more recent years, and it would be interesting to know what the practice is now,—as to the mixtures which are being used by Founders, compared with what ruled some 15 years ago.

The re-ending of broken or corroded blades is a feature which has arisen out of the severe wasting of both iron and steel blades. The operation is rather an interesting one, especially where steel blades are concerned. The first steel blade on which, as far as I can learn, a new end was burned was some 5 to 6 years ago; the experiment was tried by MESSRS. STEWART, Blackwall Iron Works, and after the experimental blade was re-ended I examined and tested it carefully before accepting delivery, that blade was afterwards fitted and has been running for over 3 years, thus testifying to the success of the experiment. I have seen many more done, since then, by the same firm.

## MR. R. DUNCAN'S REMARKS.

(*MEMBER.*)

There is another point on which I should like to hear the opinions of some of the members present, namely, at what distance from the centre of the Propeller should the broadest part of the blade be? We all know that there are a great many different shapes of blades, some being broadest at the point, some at the middle of the blade, and others are broadest near the boss.

Two Propellers may be made the same diameter, pitch, and area of blades, and the one will require a greater power than the other to drive it the same number of revolutions. If the one be made with the broadest part of the blade at the point, and the other with the broadest part near the boss, the one with the broadest part at the point of the blades will require the most power to drive it, for in this case the largest surface of the blade will have to travel a greater distance than in the other during each revolution.

I think the vibration caused by the Propeller, greatly depends on the shape of the blades. One instance I know of where a Propeller with broad-pointed blades was taken off, and replaced by another the same pitch, area, and diameter, but with the blades narrower at the point, and broader near the boss, and the vibration was reduced to a minimum. The speed of the ship in this case was also increased by half a knot.

## Mr. W. W. WILSON'S Remarks.

(*MEMBER OF COUNCIL.*)

I think that in screw Propellers there is one thing that is too often neglected by engineers, and that is the maintenance of a good smooth surface on the blades. I consider this to be very essential to good results, in fact, by experience, I have learned that a perfectly smooth blade conduces to greater efficiency. Some few years ago a case in point came before my notice, in which a steamer having had occasion to remain in dry dock for two or three days, the Chief Engineer took the opportunity of rubbing the surfaces of the blades with holystone, he also removed some of the corroded portions round the brass sheathing plate at the points, and the result was a saving of about 4 per cent. in consumption with a slight increase of speed during the next six months running, as against the previous. The vessel in question was running on short voyages, and was docked regularly every six months. This improvement was maintained afterwards, so long as the ship remained on that trade, and every time she docked the smoothing operations were continued. I may add that there were no other alterations made to the machinery at the time the improvement was noticed. No doubt a good deal of the extra efficiency of Manganese Bronze Blades is the result of the better surfaces which they retain.

With regard to Mr. Duncan's enquiry as to what portion of the blade ought to have the most surface so as to ensure the greatest efficiency, it brings to my recollection a letter which appeared in *Engineering* some little time ago, in which the writer says that the shape of the blade has a good deal to do with the corrosion, which usually occurs on the back of steel and iron blades. So far as I remember, he there states that blades with broad points corrode less than those with narrow points. This conclusion was arrived at after a long series of observations of different styles of blades.

## CHAIRMAN'S Closing Remarks.

(Mr. F. W. Wymer).

(*VICE-PRESIDENT.*)

Mr. Drewry has in his paper opened up a large theme for discussion. He has gone over the several propellers in use, paddle, screw, and water propulsion. With reference to the large paddle wheels with radial floats which he describes, the circumstances of their being of large diameter and of shallow immersion brings them nearer to the results obtained by feathering floats in smaller diameter of wheels. Again, mention has been made of the fact of increased pitch of screw propellers having had a beneficial result in some vessels; there is much to be said as to this, and it will I hope form the subject of future discussions in the meetings of the Institute. The fact of a reduced speed of engine being more likely to be maintained in a seaway than a higher speed may however have something to do with the results. I remember thinking this when the question was raised on the East Coast of England some thirty-four years ago.

In dealing with water propulsion engines, the stoppage and reversal of the vessel's motion should not be lost sight of, but should be carefully studied, so that the vessel may be under command at any time. Mr. Drewry will now kindly reply to the several remarks made upon his paper and it gives me much pleasure to notice the spirit in which you have entered into the discussion.

It has been proposed to continue the discussion at next meeting—this day fortnight—and with your approval Mr. Drewry may prepare a supplementary paper and reply to the various remarks afterwards.

## *DISCUSSION CONTINUED, TUESDAY, 25th NOVEMBER.*

(Mr. Thomas Drewry.)

In addition to the paper I had the privilege of reading at the last meeting, I have written out a few notes, which, with your permission I will read, as they contain brief references to questions under discussion.

If the propeller blades are of iron or steel they corrode on the go-astern side and at or near the tips; generally the corrosion is most severe at the "following" corner, but sometimes it is so at the leading corner, although I have occasionally seen it at the centre of the tip of the blade, and in one case I saw the tip untouched but corrosion going on about six inches lower down the blade.

If there is any vacuum about a screw while at work it must be, I should say, at the part of the blade where corrosion is going on, viz. :—at the following surface that has the greatest velocity; and the blade with the broadest tip should have the highest vacuum behind the tip. At last meeting we were told that the blade with its broadest part at the tip was found to be the least subject to corrosion, I think it follows, therefore, that vacuum cannot be blamed for this corrosion.

If the blades are made of a non-corrosive material like bronze the ship's framework corrodes, especially in a line with those parts of the blades which would have corroded had they been of iron or steel. This appears as if the corrosive agent or action—leaving the blades—is carried off by the flow of water to expend itself on the first iron or zinc in its path. Some iron or steel blades are patched or protected with Muntz metal or bronze sheets, without causing the screw frame to be attacked, or producing the galvanic action which is found to result with blades of bronze or other non-corrosive alloys. This being the case, it follows that, whatever this corrosive agent or action may be due to, the question of a vacuum does not seem to affect it. Neither does it seem to me to be a galvanic action set up by the action of the screw. I think the action comes from further forward, and is intercepted by the blade tips as it flows aft with the water. If they are iron or steel blades they absorb all the corrosive agent that is within their radius; and, if non-corrosive they merely pass it on. If the blades are broad at the tip, they are often made so in order to get the registered blade surface on a screw of small diameter, and the blades, being shorter, would not intercept the corrosive agent. Bronze blades must waste away if they continue to set up a galvanic action powerful enough to cause the corrosion we see so frequently, but their waste is imperceptible.

On the other hand, what causes the waste so apparent in the multitude of copper pipes and brass tubes belonging to a steamer's equipment? I think they are wasted by galvanic action, and the results of this wasting pass out by the numerous discharges into the sea, some of the results being intercepted by the tips of the blades.

In reference to the question of shape I think experiment alone can tell us which part of the blade should be the broadest. But if the broad part is placed near to the boss, I think it may cause undue friction between the water and the uneven surface of the boss, this boss surface is generally very uneven, owing to the cement covering over the nuts. This friction would impart a rotary motion to the water. But, while avoiding this boss friction and the consequent rotary motion, we should remember that the smaller the circumferential travel of any part of the blade, the coarser is the pitch per foot of travel; and, consequently, the greater are the chances of slip; the broad part of the blade should, therefore, be kept down towards the boss.

Regarding the actual slip, of which I would name two kinds, one caused by the resistance offered to the ship's progress by abnormal draught, and by adverse winds, &c. In this case the increased slip gives increased thrust. The other is caused by *defective screw*, and gives no thrust. The slip we generally have to deal with is due to both causes.

If we try two different screws on the same steamer, and maintain the same speed, other conditions being equal, then both screws give the same thrust, and throw behind them the same volume of water. But if one screw requires more horse-power to drive it than the other, the difference is going in slip, for although it is acting on more water, it is not throwing more water behind it, or there would be more thrust, which the vessel would feel the effect of, by an increase of speed. A screw like this acts on the water in two ways; it throws a certain proportion behind it, and expends the extra horse-power required in imparting a wrongly directed motion to the water acted upon. All twist or spiral motion imparted to the water is so much dead loss: for although the same volume may be thrown behind and at the same velocity, still its velocity in the plane of the vessel's path is less, and although its direction is constantly varying, it is never in a true line with the vessel's path.

# CHAIRMAN'S Opening Remarks

(Mr. J. H. Thomson.)

A good many years ago, I had the privilege of assisting in a few experiments with various models of screws, and the conclusion drawn from them was, that a uniform pitch or true screw gave the best result, and I am still of opinion that it is bound to do so, if the surface, pitch, and displacement of blades are in proportion to the power of the engines for the speed the vessel is required to attain; it is no use to have a large screw if you have not the power in the engines to drive it. I recollect of a small vessel trading in China waters which had a large Propeller, and when fairly under way, if it was necessary to stop and go astern, the engines would not move until the way was almost off. The vessel was purchased by an engineer, who after making a trip, had a new screw fitted which had about one-third of the surface, and the result was an increase in the speed, of about two knots, and the engines were easy to handle.

In reference to the remarks which have been made regarding the necessity of having all the blades of a Propeller at the same pitch, engineers in charge cannot be too careful in respect to this, and should never trust the workshop setting, but test it for themselves.

We hear, and sometimes read, about the screw sending a column of water behind it, but, when the speed of the vessel is nearly equal to the advance of the screw for the pitch and revolutions, the water can only be thrown back the distance represented by the slip; if a vessel is on the ground or made fast in any other way, and the Propeller set in motion, then the water must be driven back, but not if the vessel is fairly under way. The disturbance near the surface of the water is caused by the displacement of the hull (as seen in the wake of a sailing vessel), and by the friction and displacement of the Propeller blades.

The screw which is designed to send the ship forward with the least amount of water driven back, will be sure to gain the day.

There is ample room for discussion on the subject again brought before us this evening, and I would now call upon members to resume where we left off last evening. Mr. Drewry has given a few additional remarks, which call forth several features passed over at our former meeting.

## Mr. CHISHOLM'S Remarks.

(*MEMBER.*)

I wish to mention a curious fact concerning the slip of Propellers. A steamer, with which I am well acquainted, has made a voyage of 22,000 miles with a negative slip of 1 per cent. I can testify to the correctness of the pitch. Average weather was experienced during the voyage, sail being on the ship for less than a quarter of the time occupied in accomplishing the distance. I do not for one moment imagine there is such a thing as negative slip, still, cases arise where we find apparent negative slip, and I should be inclined to include other causes, with defective design and incorrect pitch.

A great authority on the Propeller (Froud), has found that the run of a vessel in the vicinity of the stern-post, has a great deal to do with the efficient working of the Propeller.

We are also aware that careful navigation will certainly help to reduce the revolutions and consequent mileage by screw, in one voyage over another—reckoning table distances—and favourable circumstances of wind and current might also produce what is termed negative slip.

## Mr. W. W. WILSON'S Remarks.

(*MEMBER OF COUNCIL.*)

If I understand right, Mr. Drewry seems to doubt that there can be a vacuum formed at the back of a Propeller blade when at work. Now I think that we have very good testimony that there must be something of the sort in the action which takes place on the brass sheathing plates, which are often fitted for the prevention of corrosion at that part. Although perfectly close down on the iron when first fitted, these brass patches, after a voyage or two, begin to rise between the screwed rivets, and even draw these out of their places sometimes; a hollow space is then found between the plate and the blade, and eventually the sheathing has to be removed, and either renewed or re-fitted. If allowed to run too long the sheathing breaks and gets torn off (probably caused by the action of water getting behind, and the vacuum which I believe is the original cause of the bulging). If a vacuum is not the cause of the bulging, what is?

At last Meeting I briefly referred to a letter which had appeared in *Engineering* some time back, bearing on the point of the corrosion that takes place on Propeller blades, and I have since then looked this up. It appeared in the issue of 25th January, 1889, under the *nom de plume* of "Cast Iron." From the data given, it is evident that the writer has studied the subject very closely, and, from his observations, he draws certain conclusions which I think are well worthy our attention. I hope it may not be considered out of place if I bring a few extracts from this letter into this discussion. I also re-produce, for your information, some of the sketches, and a table of statistics relating to the Propellers mentioned, and, in explanation of these, by the kind permission of the Editor of *Engineering*, I shall quote, to a great extent, the writer's own words.

He says: "At a point midway between the tip and root of "each blade, a transverse centre line has been drawn across the "sketch, and the per centage of the developed area of the blade "lying outside and inside that line has been marked upon it, thus: "on A, 54 per cent. is outside, and 46 per cent. inside; on E, 40 "per cent. is outside, and 60 per cent. inside; two cross sections "are also given of each blade—section R at the root, and section "T at a point two-thirds of the length from the root, or one-third "from the tip. This latter is the point at which, and outside of "which, I have usually found pitting to occur, the portion inside "being generally in good condition."

Amongst other conclusions which the study of these statistics have suggested to the writer, are the following:—

1st.—"That the combined cross section of all the blades of a "Propeller at one-third from the tip should not be less than one "square inch for every three indicated horse-power of the engines.

2nd.—"That the shape of blade shown in sketches A, B, $B^2$, $B^3$, "is best suited to provide such section, without undue thickness, "and to enable a proportionate section to be continued to the tip."

With regard to these conclusions, he further says—"It seems "to me that the facts contained in the table, so far as they go, "bear them out. It is natural to suppose that the life of a blade, "as of anything else, should be affected by its strength, and it is "to be noted that the root portion of all the blades here dealt with "remains good, the root section being from two to three times as "great as section T, and apparently sufficient to stand all the "strains thrown upon it. The extra strength at this point is "given on account of leverage, but, at any rate, the strains here "seem, in most cases, to have been better provided for than else-"where, while the discrepancy between the various blades is "relatively small, as shown by Column 12. At two-thirds from "the root, however, the difference of section is great, the horse-"power varying, as shown by Column 13, from 1·7 to 4·3 per "square inch, with a corresponding variation in the life of this "portion of the blade, which is noted in Column 14."

"Keeping this in view, the pattern of blade to which I wish "to call particular attention is that which is marked B, $B^2$, $B^3$. I "have given only three examples of this blade, but these represent "twelve Propellers of various sizes, all of which have been working "from twelve to fourteen years, all with equally good results, that "is to say, the worst of them are only slightly pitted on the leading "edge or corner, and are likely to last as many years more. The "blade A may, perhaps, be considered an exaggeration of the "type, but as it remains, after twelve years work, absolutely as "good as new, it seems to show that even the beginning of decay "may, in some cases, be indefinitely postponed by a moderate "increase of section. Now all these Propellers whose endurance "has been so satisfactory, are of cast-iron, and are, as will be seen in "column 13, so designed as to transmit from 1·7 to 2·8 indicated "horse-power per square-inch of aggregate cross section, at two-"thirds from the root of the blade."

I think it is unnecessary for me to quote anything further on this point of corrosion, as the above supplies all the information that is required so far as the letter goes. I would, however, wish to call attention to the latter part of the last paragraph quoted. There the writer states that all the blades which have given such good results are constructed of cast-iron. I can understand that many will incline to say therein lies the whole secret of the success, for I think all will admit that it is a generally accepted fact that iron resists corrosion much better than steel. This was ably demonstrated by Mr. Phillips in his Paper on "The Relative Corrosion of Iron and Steel," which was read before this Institute in the first half of the present Session. It is, I think, a great pity that one set of this approved design of blades was not constructed of steel, so that we might have been able the better to judge whether it was the design or the material, that was the cause of success. Fortunately, however, we are not altogether without some evidence, for if we examine the sketches C, $C^2$, and D, we find that we have there two different shapes of blades, constructed of the different materials in question. By reference to the table we find that C and $C^2$, of similar design, are steel blades, with a per centage of 46 outside. We also find in Column 14 that, after 13 and 14 years' work, they are described respectively as being deeply pitted all over, and as having been renewed once.

Now, when we turn to the design D, a cast-iron Propeller with 41 per-centage, we find that after 16 years' work, it has had the blades renewed no less than three times, or an average life of a little over five years. Here, then, we see the cast-iron blade with small per-centage of blade outside, wasting considerably faster than the steel blade with the larger per-centage outside, and thus completely falsifying the generally accepted theory as to the corrosive action on steel and iron.

Unless, therefore, we can think that either the steel blades were of extraordinary good quality, or the various sets of cast-iron ones were of equally extraordinary bad quality (and of which we have no evidence), we must come to the conclusion that there is something in the shape of the blade after all. For my own part I am inclined to agree with the writer of the letter, and I have a Propeller in my recollection now, in which the shape B is very nearly approached, and which, although running something over 10 years, how much I cannot definitely say, has at the present time a very small amount of corrosion indeed, in fact, it is the Propeller that gives the least trouble of all that come under my notice. I may add, however, this blade is cast-iron.

With regard to the best blade for efficiency, the writer of the letter further says, before he concludes, that with regard to blade B, from annual records of the ships having these blades, and which records are " very carefully kept and worked out with reference to " tonnage, mileage, speed, power, and cost, they show that this " form is equal in efficiency to any, and superior to some of the other forms illustrated."

I think the information contained in the letter I have referred to, is well worth the notice of members of this Institute, and particularly so to any who have opportunities of observing the various forms of blade now generally in use.

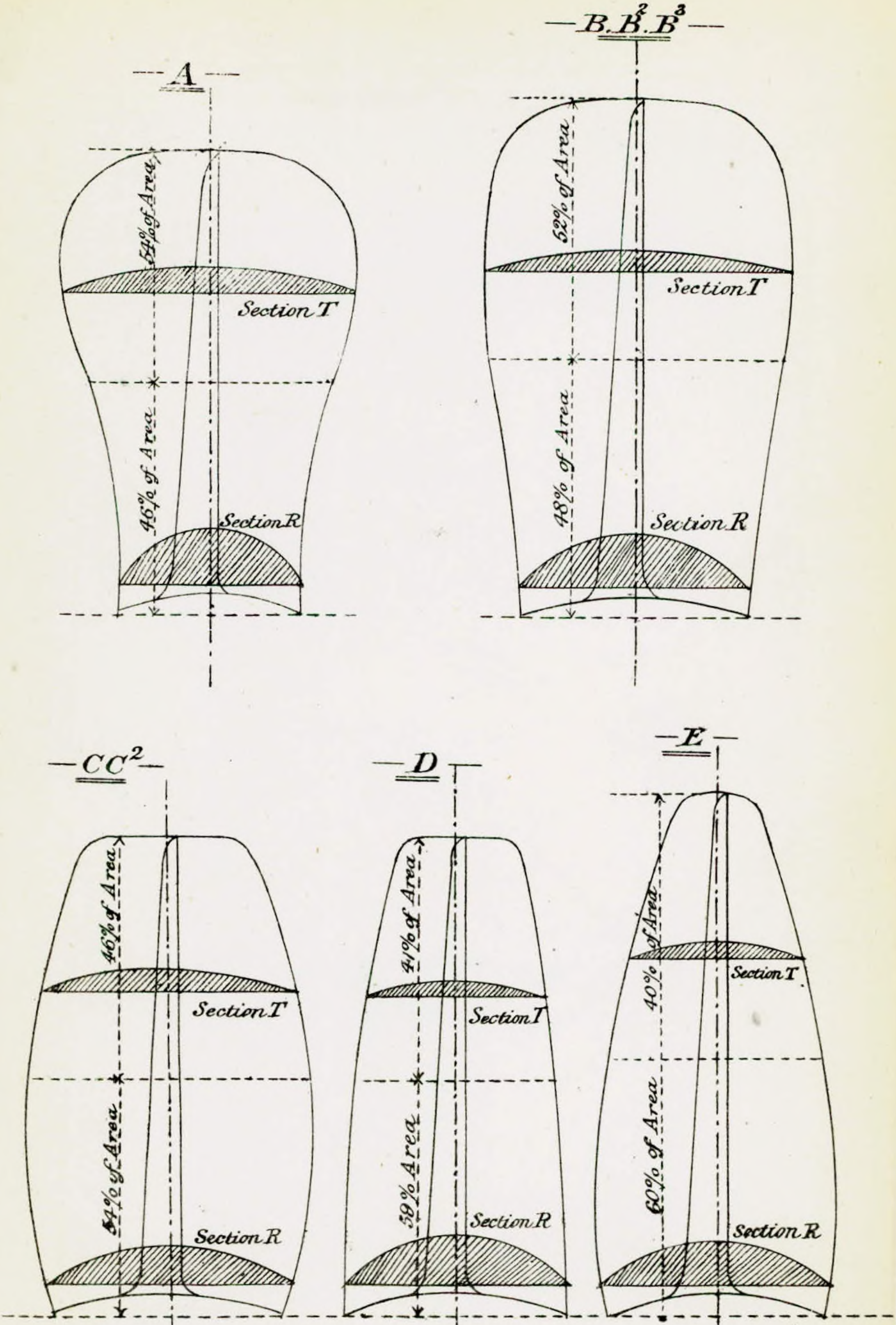
In the table and sketches I have taken note of those blades which are constructed of iron or steel only, and whose length of running has given better opportunities of comparing results.

# *TABLE OF STATISTICS REGARDING THE LIFE OF PROPELLERS.

| 1 | 2 | 3 | 4 | | 5 | | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Letter of Reference to form of Blade. | Material of Blades. | Number of Blades. | Diameter of Propeller. | | Pitch of Propeller. | | Average Indicated Horse-Power of Engines. | Combined Cross-Section of Blades at Section R. | Combined Cross-Section of Blades at Section T. | Combined Surface of Blades. | Per Centage of Surface outside Centre Line. | Indicated Horse-Power per square foot of Surface. | Indicated Horse-Power per square inch at Section R. | Indicated Horse-Power per square inch at Section T. | REMARKS ON THE DURATION AND CONDITION OF BLADES. |
| | | | ft. | in. | ft. | in. | | sq. in. | sq. in. | sq. ft. | | | | | |
| A | Iron. | 3 | 10 | 8 | 21 | 0 | 320 | 323 | 193 | 37 | ·54 | 8·6 | 1·00 | 1·7 | 13 years at work; no sign of decay. |
| B | ,, | 4 | 8 | 4 | 14 | 0 | 250 | 280 | 126 | 27 | ·52 | 9·3 | 0·89 | 2·0 | 12 ,, ,, very slightly pitted. |
| $B^2$ | ,, | 4 | 13 | 2 | 19 | 0 | 650 | 482 | 234 | 62 | ·53 | 10·4 | 1·34 | 2·7 | 12 ,, ,, slightly pitted. |
| $B_3$ | ,, | 4 | 13 | 0 | 15 | 6 | 550 | 440 | 192 | 50 | ·51 | 11·0 | 1·25 | 2·8 | 13 ,, ,, pitted on leading edge. |
| C | Steel. | 4 | 13 | 0 | 20 | 0 | 500 | 291 | 135 | 48 | ·46 | 10·4 | 1·70 | 3·7 | 13 ,, ,, deeply pitted all over. |
| $C^2$ | ,, | 4 | 13 | 0 | 20 | 0 | 550 | 291 | 135 | 48 | ·46 | 11·4 | 1·90 | 4·1 | 14 ,, ,, blades renewed once. |
| D | Iron. | 4 | 13 | 0 | 17 | 0 | 500 | 425 | 118 | 41 | ·41 | 12·2 | 1·17 | 4·2 | 16 ,, ,, ,, three times. |
| E | Steel. | 4 | 13 | 0 | 17 | 6 | 650 | 388 | 150 | 42 | ·40 | 15·4 | 1·67 | 4·3 | 12 ,, ,, ,, twice. |

*By kind permission of the Editor of *Engineering*, with slight alteration of lettering.

NOTE.—The letters in column 1 are not exactly those in *Engineering*, but they correspond with the sketches selected as best evidences of the arguments propounded by the writer of the letter in that Journal.



A
54% of Area
Section T
46% of Area
Section R
$B.B^2.B^3$
52% of Area
Section T
48% of Area
Section R
$CC^2$
46% of Area
Section T
54% of Area
Section R
D
41% of Area
Section T
59% Area
Section R
E
40% of Area
Section T
60% of Area
Section R

## Mr. JAS. ADAMSON'S Remarks.

(*HONORARY SECRETARY.*)

Reference has been made to the best shape of Propeller Blade, and the most effective part of it; the questions involved in this might occupy many evenings to discuss.

Many elaborate experiments have been conducted by well-known engineers, and many shapes have been evolved, each based upon a theory more or less fanciful. In many cases, after much time and labour spent, the nett result might be written "vanity and vexation of spirit." Yet not all, as every thinker, or experimenter, in whatever walk in life, assists,—and every original thought or idea given to the world tends,—to open up a new vein, in the yet richly laden store-house of nature, art, or science. Obviously the run of the hull has a good deal to do with the most suitable form of blade, and, speaking roughly, it is probable that a vessel with a full after body, carried well towards the stern post, will give better results with the area of the Blade fuller towards the periphery than the root, while one with a fine run aft will probably give better results with the area fuller towards the root than the periphery. There is much difference of opinion on the subject of the best design of Blade, involving diameter, area, and speed, these opinions varying, naturally, according to the form of vessel and the experience of the Engineer and Ship-builder.

It would be interesting to have a record of experiments from actual practice with different forms of Blades, the pitch remaining unaltered, on the same vessel. I may mention one case which came under my notice some time ago, of a steamer originally fitted with Blades, the area of which was about equally distributed throughout the length, the Blade being more parallel than pear-shaped. For experiment, these Blades were replaced for a voyage by "Stepped" Blades, the design of which is probably known to many, as having been patented by one of our Members. Unfortunately, one of these Blades was lost during the voyage, and, of the others, one was found to be cracked at one of the "Steps." They were, therefore, replaced by a new set, somewhat after the same design as the original Blades, with slight re-adjustment of pitch and area.

The results given by the "Stepped" Blade were rather better than with the original Blade, as under :—

*Taken between same Ports.

| | Tons per day. Out. | Home. | Avg. | Miles per day. Out. | Home. | Avg. | Total coal. Out. | Home. |
|---|---|---|---|---|---|---|---|---|
| Original Blade .. | 30·48 | 35·2 | 32·8 | 246·65 | 240·1 | 243·37 | 371 | 445 |
| Stepped Blade .. | 32·9 | 33·3 | 33·1 | 281·37 | 233·7 | 257·4 | 350 | 427 |
| Re-adjusted Blade.. | 27·9 | 31·2 | 29·6 | 248·07 | 284·65 | 241·36 | 341 | 394 |

*Averages from one voyage of each.

The figures representing displacement, mileage, and coal in each of these cases, outward only, are as follows :—1=·0690, 2=·0639, and 3=·0565 respectively.

As to the most effective part of the Blade, I have usually based my conclusions on the theory that the line of greatest efficiency is two-thirds up from the root of the Blade, with the ordinary run of passenger steamers, and Blades of a normal shape and style.

## *Mr. D. PHILLIPS' Remarks.

*(MEMBER.)*

On first glancing over Mr. Drewry's Paper I concluded not to offer any remarks upon it, thinking it more suitable for Students than for practical men—intended perhaps to be so, as they certainly should not be neglected by Members of the Institute—except that it might elicit, from some of the most experienced of its members, some valuable information on the many points involved. However, there are points in the paper upon which a few remarks from me will not, perhaps, be considered inopportune. (1) The supposed effect of bronze blades on propeller frames ; (2) the mode adopted to protect the frames from corrosion by zinc plates, the necessity for making the contact between the zinc and the iron or steel as perfect as possible, and the mode recommended by the Author to secure the same ; and (3) the cause of the extraordinary corrosion, or eating of the cast iron and steel blades, in the form of honeycombs at the back, or reverse side, of their tips.

In the first place I have to acknowledge that I have had no experience in the use and effect of bronze blades on the surrounding iron or steel surfaces, but I must say that I never heard of any ill effects from using gun-metal propellers in the early iron hulls of ironclads in Her Majesty's Navy, and I am strongly impressed

* Communicated by correspondence.

that if the propeller frames suffer more since the adoption of bronze blades and steel frames, that it is due to a combination of causes, such as lightness in structure, vibration and friction due to greater speeds, and carelessness in the attempt to protect them,—mostly done by daubing the surfaces, often covered with grease, with some so-called anti-fouling paint when the water is being, or about to be, let into the dock. Between the rudder and propeller, vibration must be great, especially in rough weather, and if the paint should be mixed to dry quickly, as is generally the case, the more liable it is to blister in patches and soon fall off; and I may just mention that steel, under such conditions, suffers considerably more than iron. (2) I was not aware that zinc plates attached to studs were in use to protect propeller frames from corrosion. However, if it is necessary to apply zinc for this purpose it should be as the Author suggests, in convenient size, and each plate fixed on a single stud, as adopted by me in boilers and recommended in my circular dated so far back as April, 1877. It is, as the Author submits, most important that perfect contact between the metals should be secured, which is done by the collar on the one side and a nut on the other side of the zinc, and tightly screwed up. In this matter, as applied in boilers, carelessness and ignorance are very often the cause of more or less failure. Indeed, it is not very long ago that I was told by several Superintendent Engineers, and also by a high official of Lloyd's Registry that they "did not believe in contact being at all necessary," but whenever they got into difficulties through severe corrosion in the form of "pitting," the stud attachment was resorted to, at the affected parts, in addition to their own rather fantastical mode of applying zinc. For this there was a reason which it is unnecessary for me to explain.

I have written and said, as most of the Members of the Institute are aware, a great deal on the questions of treating and protecting *boilers* from corrosion, and though I feel that I am wandering, somewhat, from the subject of the paper, the protection of boilers is akin to the protection of propeller frames, which is my excuse for trespassing. As to taper threaded studs, they would be of no avail in boilers and quite unnecessary in *cold* sea-water. The principal reason that contact becomes impaired in boilers is due to the greater expansion of the zinc compared with iron and steel, whereby water, in a very short time, finds its way in between the surfaces of the two metals, resulting in oxidation of the most vital parts of the zinc plates, through which contact becomes destroyed. The same would take place with taper threaded studs and holes, and the zinc plates would be far less secure than with collars and nuts. In cold water there is no expansion to contend with and the tapered thread would be of no practical use.

I would also point out that greater care should be taken in drilling (not the slovenly way, punching) the holes, so as to fit the plain part of the studs, which should have a slight taper, as often recommended by me. And further, care should be taken to obtain zinc as pure as possible, as on this depends, and very considerably so, the amount of protection to be afforded by it. On this point again, and not long ago, a very erroneous impression existed in some quarters, which was that the less the zinc was affected and the longer it lasted, the better. I have often been surprised at intelligent engineers advancing and supporting such a fallacious theory. I have also often seen zinc plates, of which I have many samples, both cast and rolled, in my possession, which would be very little better than pieces of cast-iron for protecting boilers (internally). This sort of metal—commonly called "zinc bottoms"—has been melted over and over again for galvanizing purposes, and contains, for that reason, a large percentage of iron. The better sorts of ordinary zinc plates are often made of an admixture of nearly worn-out plates, and commercial zinc. For engineers, the best test is to nick and break a plate, the fracture of which will show pretty correctly the quality. Good zinc will show large, or coarse, crystaline fracture, while the common kind will show a fracture similar to hard cast-iron. I prefer cast plates and made thicker in the centre than at the edges, for all purposes.

As to the cause of what the author calls "flashes" leaving "each descending blade just before half-stroke," and their effect on cast-iron and steel blades; by half-stroke, I take the author to mean the third or fourth part, according to the number of blades at work, of a revolution when looking over the stern, beyond which point the flashes, or broken water, immediately behind the blades, are lost to sight; but this, no doubt, goes on in a less degree throughout the revolution. The deeper the immersion, the greater is the pressure of the water on the descending blade, and the less is the water broken, which means that the air, sucked in by the blade, becomes more compressed, and the water more solid, until the air, on its way to the surface, is gradually relieved, owing to which the receding water becomes less and less broken, until it has exhausted itself of all superfluous or atmospheric air.

And lastly, the cause of the honey-combing on the reverse side of the cast-iron and steel blade ends. This is, no doubt, due to the action of air, influenced, in a greater or lesser degree, by the inadaptability of the Propeller to the speed of the engines, and hull of the ship. In other words, the greater the "churning" of the water, the more is the mischief done to the blades. On the other hand this action is not confined to iron and steel, as all the old gun-metal propellers I have come across,—and I have had opportunities of examining a great many at the various Dockyards,—were all more or less affected in the same way, but very slightly, compared with iron. As to the time they had been at work, I had no opportunities of ascertaining. This question may be said to have been but very little understood 15 years ago. I have known cases of iron Propellers that were only slightly affected after 11 and 12 years' service, whilst others had to be protected (not uncommon at the present time) after two or three years' service. In the former cases the result was due, no doubt, to the speed of the Propellers, suitable pitch, and, for the tonnage of the vessels, good immersion.

As to efficiency, it is scarcely necessary to observe that it all depends on the form of the blades, pitch and distribution of their surfaces, in fact, to the adaptability of the Propeller generally. No hard and fast rule has ever been, neither can it ever be, promulgated in respect to this, as so many things are involved, especially the lines of the after-part of the hulls, and besides, every engineer simply follows, and will continue to follow in this respect, his own fancies. I doubt whether any improvement has been made on the Propeller known as "Griffiths,'" except as to securing the blades to the boss.

## *Mr. C. G. NEWBY'S Remarks

(*MEMBER*).

Adverting to Mr. Chisholm's remarks upon negative slip, I am of opinion that this phenomenon is occasionally observed, and when clearly demonstrated to be outside the influence of irregular navigation, currents or other causes, no time should be lost in replacing this screw with one producing the opposite element, viz., positive slip of not less than 5 per cent., I should look to better proportions, rather than shape of blade.

I know of one instance where the thickening of the blade on the forward side, near the leading edge, was productive of this undesirable feature.

* By correspondence.

With regard to form, I think the well-known Griffiths type stands highest in reputation among engineers, having the broadest part of the blade at one-third of the diameter of the disc, and the breadth at the periphery from one-third to two-fifths the maximum.

Formula for maximum breadth of blade $= K\sqrt[3]{\frac{\text{I.H.P.}}{\text{Rev.}}}$
Four bladed screw $K=14$. For three bladed $K=17$.

For light draft vessels I have found this form not so effective as one having the broadest part nearer the tip and bent aft, though the vibration was more marked in the latter than in the former.

With regard to material, manganese or phosphor bronze possesses great advantages over steel or iron, the qualities which render the former so well suited for this purpose are its great strength, which transversly is double that of gun metal and, up to the elastic limit, double that of steel, its non-liability to corrosion, and its adaptability to adjust its pitch to suit the resistance due to a thinner blade.

One primary objection to its use is the damage done to the iron in the vicinity by galvanic action. Mr. Drewry, however, has very ably dealt with this difficulty in his paper, and so removed cause for anxiety on that account.

The cost of bronze blades as a first outlay undoubtedly is much greater, but if we take steel blades at about £40 per ton, which require renewal every three years, we may calculate that by the time the second set are fitted the expense is approaching that of the former, say £115 per ton, and which may be accepted as lasting the life of the vessel and then highly valuable as old metal.

## CLOSING REMARKS.

(Mr. Thomas Drewry).

As is often the case, the discussion upon my paper has proved more valuable than the paper itself.

Mr. Adamson's remarks and tables are of special interest and value.

I think that a built propeller gives better results than a solid one, for three reasons. First—The blades are much better in shape and finish when cast separately. Second—They are adjustable and are generally carefully set to the pitch, found by experiment, to be the most suitable for them. Third—A propeller with a large boss has been found to give better results than a similar propeller with a small boss, and the built propeller necessarily has a large boss.

I quite agree with Mr. Wilson that blades well repay the trouble of smoothing them.

I cannot answer Mr. Wilson's question "What causes the brass sheathing plates to bulge out?" but if the vacuum at the back of the protected blade causes this, I think there is a great opening for that sort of vacuum in our condensers. The brass sheathing for propeller blades is from $\frac{5}{16}$in. to $\frac{5}{8}$in. thick, and is held on with $\frac{1}{2}$in. to $\frac{5}{8}$in. screws pins, spaced only a few inches apart, and they are strong enough to resist a perfect vacuum.

Mr. Wilson has brought some very valuable matter into this discussion, and the extracts from *Engineering* are particularly interesting, and of great value.

Mr. Duncan has raised a very important point—the part of blade that should be the broadest. Experiment and practice decide in favour of keeping the broad part near the boss. In a blade of uniform pitch, I think it is a mistake to have any part of it very broad, for the leading edge and the surface immediately following it do the work, and the rest of the surface is of little use.

I find that reducing the pitch lessens the vibration considerably, and bronze blades only cause about half the amount of vibration that cast-iron blades of the same shape do.

I quite agree with Mr. Chisholm that the "breadth of the voyage" has as much influence on the results as the "length of the voyage" has.

Mr. Phillips is quite right in thinking that my paper was intended for students. The best members we have in this Institute are the hardest students, and when an engineer, either in or out of this Institute, ceases to be a student he begins to lose ground.

I think Mr. Phillips is wrong in attributing the corrosion of propeller-frames to such a combination as—lightness of structure, vibration and friction due to increased speed, carelessness in attempts to protect them, such as painting over greasy surfaces, &c. Lots of ships have run for years with iron or steel blades, and their propeller-frames showed no signs of corrosion. But when these ships were fitted with bronze blades, in every case corrosion at once set in. But the combination mentioned by Mr. Phillips existed quite as much in these ships before the bronze blades were fitted or corrosion set in.

I cannot agree with Mr. Phillips about the taper-threaded stud being quite unnecessary in cold sea-water. If you examine a zinc slab, that has been a voyage or two on a propeller-frame, you will find inside the holes and on all its surfaces a scale that crumbles into powder—the surfaces have become oxidised. This means that, owing to bad contact with the propeller-frame, the zinc has partly decomposed itself in the salt water and a corresponding loss has taken place. If the contact had been perfect, the surfaces of the zinc would have been free from this scale, and they would only have eaten away in places, corresponding to the places on the iron frame that would otherwise have been eaten.

This goes to prove that the present way of fixing the zincs is imperfect, and as practically there is no difference between bolting up a small zinc slab with one bolt or stud, and bolting up a large zinc slab with a number of bolts or studs; or between the present way of fixing them, and the way recommended by Mr. Phillips, and claimed as his own, I think the taper-threaded stud worth a trial.

Following Mr. Phillips into "Boilers," I desire to call attention to the fact that all zinc slabs have very much the same appearance after being a few weeks in a boiler. No matter how they are put in, they may be laid on the bottom, placed in pockets, or firmly screwed up on studs, but they all come out presenting a flakey-scale of considerable thickness which crumbles away to a fine powder.

The zinc "Electrogen" has a different appearance altogether, its surfaces are much more like zinc that has gradually wasted away, it has scarcely any of the flakey-scale upon it. The reason can only be that its contact has been perfect; wires have been joined to the boiler by soldering, or other means as effective; these wires have been carefully moulded into the zinc, and in its case there can be no doubt but that it had perfect contact with the boiler; neither can there be any doubt as to why none of the other zinc slabs have the same appearance—none of them had as good contact.

I have great faith in the taper-threaded stud and hope to obtain as good results from it as from the "Electrogen." I have tested it for expansion under various temperatures, and for long periods, but it never slackens perceptibly.

Boiler zincs may have no contact, except what they make through the water, and still be of great service.

If we consider the boiler-water as the exciting fluid causing galvanic action to set in between the different qualities of iron or steel in the boiler, we must also consider that if this exciting fluid decomposes the zinc in the boiler, no matter whether the zinc be in mechanical contact or not, the exciting fluid becomes neutralized or robbed of its power for evil.

If we have plates of one quality badly pitted, and consider them electro-positive to plates of another quality not pitted, we must, leaving out the water as an exciting fluid, consider this current to flow through the water so as to complete its circuit, in which case the zinc slabs are in circuit with the plates under electrical action, even though they are not mechanically in contact.

But to stop pitting in this way requires a good deal of zinc, and fewer zincs might be used if good contact be made between them and the parts to be protected.

Returning to propeller blades, Mr. Phillips has evidently misunderstood what I said about the white flashes leaving the blades, I said nothing about their effect on cast-iron or steel blades. Mr. Phillips seems to think that the more unsuitable the propeller is to the speed and design of the ship, the more likely it is to honeycomb. This is not so. The old clumsy blades scarcely honeycombed at all. It is the modern blade, whose shape and size experiment and practice accept as the best, which honeycombs worst of all.

In closing, I must recognize the advantage I have had in having Mr. Wymer in the chair; his experience and thoughtfulness have had the effect of making me feel perfectly at home, and the feeling that I was in safe hands has helped me through my task wonderfully. By his management we have obtained a valuable discussion upon a less valuable paper, and he himself has dropped some very valuable hints, and has clearly shown us that 34 years ago engineers were wide awake to the advantage of ventilating questions of public interest.

# PREFACE.

THE LANGTHORNE ROOMS,
BROADWAY,
STRATFORD, E.,
*May 21st*, 1891.

A MEETING OF THE INSTITUTE OF MARINE ENGINEERS was held here on Saturday, December 20th, 1890, presided over by Mr. F. W. WYMER (Vice-President), when a Paper on "*The Efficiency of Air Compressors*" was read by Mr. Jos. WILLIAMS (Member).

The Paper,—modified from its original form and corrected in respect to an erroneous conclusion,—and Remarks made upon it will be found embodied in the following pages. The subject treated by Mr. Williams is one of very great interest to all users of compressed air, either as a motive power, or in connection with Refrigeration; and the close attention and painstaking shown in the preparation of the paper entitle it to careful perusal and study, especially as some of the reasoning has been carried into debatable ground.

A Meeting of the Members of the Institute resident on the British Channel was also held in the University College, Cardiff, on the 25th February, presided over by Professor ELLIOT, when Mr. Williams read his paper.

By the kind courtesy of several gentlemen, whose researches and experience on the subject entitle them to more than ordinary consideration, some remarks have been contributed by correspondence, to these Mr. Williams has replied.

JAS. ADAMSON,
*Honorary Secretary.*