INSTITUTE OF MARINE ENGINEERS

INCORPORATED.

SESSION 1900-1901.

President—COL. JOHN M. DENNY, M.P.

SEA-BORNE TRAFFIC.

PART III (Propulsion).

BY

MR. JAMES ADAMSON, (*Hon. Secretary*),

READ AT

58 ROMFORD ROAD, STRATFORD, E.,

ON

MONDAY, APRIL 23rd, 1900.

CHAIRMAN:

MR. A. BOYLE (CHAIRMAN OF COUNCIL).

SINCE the days when each man paddled his own canoe, many forms of propeller and many varieties of these forms have been tried and experimented with, in order to obtain the greatest speed with the least expenditure of power.

The history of navigation is a most interesting one and the works of Charnock, W. S. Lindsay and others on the subject are almost fascinating in many pages; however, I do not propose to enter into the historical details of the propeller, but simply to place before you a few thoughts and experiences which may elicit in discussion, detailed information and opinions expressed for the common good.

The primitive means of propulsion applied on the water, as of locomotion applied on the land, were probably by the hands and feet. The movements of fish and aquatic animals led by observation and practice to swimming; further experience followed; vessels were built to float on the water, and the paddle with short quick, or lengthened slow stroke, to suit the requirements of the passage to be made or the individuality of the owner, was used until the season was ripe for a further advance.

The hand-paddle was succeeded by sails, and the power of the wind came forward to aid, and then supersede to a great extent the muscles of man, especially when the venturesome spirits of the age sought to risk themselves far upon the sea. The changeable element on which dependence was placed led to various styles and modifications in the shape of the sails which were set to woo the bride they sought, and as a lover seeks to win the favour of his mistress, so were the sails of papyrus, skin, or canvas, shaped and trimmed, ordered and fixed to meet each varying mood.

The power of the air has given place to that of steam, the pressure of which within the last twenty years has more than doubled, and now it is the rule rather than the exception for a pressure of over 120 lbs.

The steersman was a man of importance for navigating narrow waters in days gone by, and on his watchful eye reliance was placed to keep the vessel on her course. The primitive rudder was a paddle, or frequently two, the shape and area of which were gradually altered until the most effective and suitable proportion became known. As the motive power for the vessel changed, so it was found necessary to change the power for steering; the paddle rudder manipulated by hand direct was altered; the rudder was hung to the stern post actuated by a tiller, then followed a wheel with gearing to modify the power. As ships increased in size with the adoption of steam for propulsion, it became necessary to apply more power to the rudder, and soon after the *Great Eastern* was designed and placed on the water in 1858 there came also the application of steam by the invention and instrumentality of Mr. Macfarlane Gray to manipulate the steering gear. Since then steam steering gear has become almost universal, the exception being where the hydraulic system is in use, while recently discussions have taken place as to the application of electricity as the motive power. The reference to hydraulic power reminds us of hydraulic power applied to propulsion. In this system the water is drawn in from forward and discharged by means of pumps through an orifice aft, or directed by reversible pipes led through the ship's side. About thirty years ago several successful trials were made with the *Waterwitch* on this system, but it has not been adopted, except in some recently constructed lifeboats. The honour of advocating and working out this plan of water propulsion belongs to Mr. Ruthven, sen. One of the advantages claimed is that the pumps can be used to discharge any water which may enter the ship by a fracture due to collision or grounding, thus serving as a means of salving while propelling the vessel at the same time. This was the subject of a paper contributed by Mr. J. R. Ruthven to the Institute about ten years ago (Vol. II).

The steersman is still an important factor in the economical working of a vessel, and the ease with which the rudder is moved is not an unmixed blessing, often resulting in a tortuous winding on the course recorder, and an increase of revolutions per mile between ports.

The oars and sails lingeringly followed the sinking sands of the time-glass of progress, and while these means of propulsion held sway many experiments were made to apply power in different ways and by different methods in order to test the best for the varying circumstances of wind and weather.

The paddle wheel, worked by hand or foot, with or without gearing, by windmill or by trained animals, was tried in various positions in the boat, with side wheels, with centre wheel, and with stern wheel; the former and the latter only have come into general use, yet not many years ago a boat was built and fitted with a centre wheel, which, by the experimenter, was expected to do good work; the result, however, was not a success. The details of this experimental boat are known to one of our members who may perhaps place them before us, and there may be other interesting experiments, such as the recent roller boat of Bazin, and another of twenty years previous—an illustration of which may be seen in the *Marine Engineering News* of that time. The historical records of such trials or tests known to other members would be interesting to have, with the chief details given, recorded in our Transactions, thus serving to show the gradual steps and the painstaking labour of many men all endeavouring to converge to the end already referred to—locomotion across water by the most efficient and most economical means.

We have had in former sessions Papers on the Screw, the Paddle, and the Water Jet Propeller, but there is abundant material yet untouched upon in connection with each one, and I propose to deal with a portion of that material to open up questions for practical discussion.

The early attempts to move a vessel through the water by means of a screw were probably suggested by the screw nail, and the experimental forms of the screw propeller were of the continuous type, from the long worm running along the centre line of the boat to the one pitch thread on the shaft aft. Accident pointed out, and experience confirmed, that greater economy and efficiency could be attained by a portion of the pitch spiral with increased diameter to obtain the necessary area. Since then many modifications of blades have been tried and patented, and quite recently there was a patent taken out for a reversion to the original type, with a result similar to the early experiences of the continuous or spiral form of propeller.

Several steamers were fitted some years ago with stepped blades, the object of the steps being to catch and push the water in a more solid way than the plain blades. One steamer fitted with this style, which came under my notice fourteen or fifteen years ago, threw the blades, and the experiment was not repeated. A steamer I saw some years ago was fitted with blades having a pipe recess cast in them in order to draw the air away from the tips and prevent the pitting action, but the result was not a success. One of our members was specially interested in this case, and may perhaps refer to it further. The area of propeller allowed in proportion to the midship section varies with different builders, and it is a question of experience with different styles of ship what proportion gives the best result in so far as the actual efficiency of the propeller itself is concerned. Many experiments have been tried in order to establish this point, and possibly some of our members may be able to give the details of such as they have witnessed, whether carried on in the course of a steamer running with different blades or altered pitches, or carried on in the drawing office, workshop, and experimental tank by means of models in air or water, and to verify the results of previous data; trial trips and voyages have been made to note the most economical pitch suitable for different steamers, and as it is seldom that these experiments are considered of sufficient interest for publication, it may be that in the course of discussion some of the trials and experiments may be detailed by members who have been interested in them.

Attention has been several times directed to the almost entire absence of sails on steamers nowadays, and the experiences which have been brought to our notice of recent years, of steamers drifting and helpless with broken shafts, give point to the warnings. An article on the subject of propulsion by means of properly constructed sails has recently been published from the pen of Mr. H. C. Vogt, who enters very fully into the question of wind power and its application to forwarding the motion of vessels, giving the results of interesting experiments with and without the application of steam power applied to the screw propeller, in addition to results from various styles of fitting sails to vessels, and pointing out the best for sailing craft.

Propulsion by means of towing on canals and lakes with the different kinds of power—by men, animals, or small steamers, the towing of sailing vessels out and into rivers and ports, of broken down steamers or wrecks, of pontoons and floating docks, of special goods, like the Cleopatra needle case—each has features of interest which would repay study and thought sufficient for a short paper and discussion.

The towage of specially constructed barges or other suitable craft for coast traffic, to collect farm produce, fruit, minerals, etc., is a subject which might be worth discussing, although perhaps more from a commercial than an engineering point of view. The East Coast Development Co. will probably show in a short time many features in connection with coast traffic which will tend to improve the coastal trade and perhaps place our home producers on a better footing with Continental producers of every day food stuffs. Whether it is better to have a small cargo carrier propelled by steam power and fitted with machinery, or to have several such carriers towed to and fro, to meet the varying circumstances of market and trade, appears to be worthy of consideration, and not only so, but the latter alternative in many cases would seem to be a more suitable means of propulsion.

The questions which arise in connection with single, twin or triple screws are so many that a special paper might well be written on the subject, setting forth the advantages and disadvantages of each. A broken shaft or propeller renders the single screw steamer helpless, especially when little or no provision is made for sailing, as is now generally the case. Twin and triple screws give greater security, and a stand-by in case of one shaft or propeller breaking, greater manœuvring facility, with the disadvantage of greater liability to breakage in narrow waters, as in the canal.

The additional cost of machinery and shafting, the duplicating of the work of overhaul and upkeep, the extra running expenses in stores, and the supplement to the working staff, either by engineers or greasers, all fall to be considered in discussing the subject of propulsion by twin or triple screws, and such would form the elements for a paper on a very important subject.

The material of which the blades should be constructed to give the most satisfactory results and the greatest economy in running has been much discussed for many years.

Cast iron entirely throughout the full area of blade, cast iron centre body with the area increased by iron or Muntz metal plating to get thin cutting edges, solid propellers, and built adjustable blades, cast steel, gun metal and bronze of various alloys have been tried, and each at the different stage of progress has found its advocates.

Cast iron in the Mercantile Marine and gun metal in the Navy were in general use for many years, the question of initial cost ruling the choice in the former case until the introduction of steel and the cheapening of its manufacture brought about its general use for blades with lighter scantlings—now being superseded in turn by bronze of still lighter scantlings and smooth surface, thereby lessening the friction and allowing more of the power developed by the engine to do useful work.

It is an interesting question to work out and verify from practice what the actual gains have been by the change of material from iron to steel and from steel to bronze, as no doubt there has been a percentage of gain in economy, more so in the case of bronze, resulting in an increased speed on a lessened consumption. The enhanced cost of the blades militates to some extent against the lessened running expenses; at the same time the cost of repairs and renewals—due to the corrosive action on iron and steel blades—being reduced, may be reckoned to the credit side against extra outlay in capital.

The cost of bronze blades, like the cost of steel, has become gradually reduced with its more general adoption, and the element of competition leading to improvements in the mode of manufacture and lessened working charges on capital relatively to the output.

The re-ending of an iron propeller blade is an interesting operation, the re-ending of a steel one more so, the deftness of hand, and judgment matured by experience, having an important part in the successful amalgamation of the new and old metals to make a reliable job. The cost of re-ending blades is about one-fifth of the cost of a new blade, the steel costing more relatively than an iron one.

It is surprising how the blades—I may add, especially bronze blades—become coated with sea-grass. The floats of the paddle are, it is true, similarly affected, but in spite of the friction the growth is sometimes seen well up towards the tip of the blade. The growth varies according to the latitudes, the season, and the different waters through which the vessel passes, the southern seas being most prolific in growing a coat of green on the blade.

In all cases where bronze blades have been substituted for steel or iron, there has been a gain in speed along with a reduction in coal, and where no other alteration has been made than the change of material, we may be able to gauge the value of the lessened friction and the gain, due to the adoption of the more expensive metal. In many cases, however, the alteration in material has been accompanied by changes in the shape and surface or the pitch of the blade; a few figures from the results of several steamers will serve to show this.

The care which is taken in the casting and finishing of the bronze blades, and the consequent truer pitch, is an element in favour of this material. It has also been argued that on account of the flexibility of the bronze blade there is an advantage in its favour, in that although one would expect the revolutions to be increased with the same pitch over the revolutions of the same blade in steel, because of the lessened friction, the contrary is argued by some of the makers, who claim that the greater efficiency of the bronze blade is thus shown in reduced revolutions per mile run—the tendency of the blade to bend in the direction of the forward movement of the ship, absorbing revolutions with a decided advantage to the speed. To this view exception may be taken, and it is a matter which can be argued out and is now referred to with that object.

The toughness of bronze and the greater strength admits of a thinner blade and finer edges, but owing to the closer grain the weight of a blade in bronze is about the same as in steel. The following is a rule for comparing the different blades:

$$K=\frac{S\times d^2\times P}{b\times t^2}$$

K=constant, d=diameter of propeller, p=pitch, b=expanded breadth of blade at boss, t=thickness of blade at shaft, s=surface.

The tensile strength of the special bronzes being high, and the material being tough, the blades can be reduced to suit, by, say, a wedge of cast iron running approximately from $1\frac{5}{8}$ at the root to $\frac{3}{16}$ at the tip. A wedge of cast steel would be somewhat less on the same basis, the total weight being about the same; so that the cost of the blades may be reckoned at the market rate per ton of material, approximately.

The following formula is what I have found in practice for calculating strengths of blades :

$$T=\sqrt{\frac{d^3\times e}{l\times n}}$$

T=thickness at shaft, e=co-efficient, d=diameter of propeller shaft, l=length of blade fore and aft, n=number of blades.

Cast iron, $e=5$; steel, $e=2{\cdot}75$; bronze, $e=2{\cdot}5$ to 3; in one case I am aware of, a constant of 2·1 was used with unfortunate results.

In the event of the bronze blades striking or being distorted there is an advantage in being able to straighten them on account of the higher elastic limit of the bronze, but when the distortion is great and it is necessary to heat the blade, this must be done with great care to avoid too great a temperature and yet have sufficient for the purpose.

Reference has been made to the steersman and the rudder specially, as there are several interesting points which may be discussed in connection with both the human element and the mechanical gearing manipulated. With regard to the former the importance of keeping the vessel steady on her course and learning the "feel" and inclination towards port or starboard is not always given that prominence which it deserves. Some steersmen will by a species of instinct keep a course, after a short experience of a steamer, which would show well even on a sensitive course recorder, the movements of the rudder being few and small, thus keeping the revolutions of the engines per mile down to the lowest, and showing in the result a small slip per cent. on the propeller; while others will agitate the fish in the wake of the vessel for yards outside the intended course, turning the steering gear or rudder now this way, now that, giving no rest to the wheel, increasing the revolutions per mile, the slip and the mileage over the ground without having it all recorded in the log book.

The following figures show results gained by the use of iron, steel, and bronze blades respectively; the speed and consumption results are taken from a series of voyages, and the sets of figures for comparison in each case are from corresponding voyages or runs. The steamers cited belong to different lines of steamers, and I am indebted to the courtesy of several members and friends for the opportunity of seeing the figures now placed before the members of the Institute.

Steamer	Propeller				Engine Revs. per day	Ship		
	Dia.	Pitch	Surface	Material		Miles per day	Coal per day	Displc-ment
	ft. in.	ft. in.						
Z	18 6	28 6	101	Steel	75,330	310	63·8	6,158
Z[1]	18 6	27 6	101	Bronze	83,250	334	75·6	6,058

Z. The only alteration made in this case was the shape of blades slightly altered, and the pitch decreased by 1 ft. The revolutions per mile with steel blades are 243, and with bronze 249·2, while the miles per ton of coal are as $\frac{310}{63 \cdot 8} = 4 \cdot 86$ with steel, and $\frac{334}{75 \cdot 6} = 4 \cdot 42$ with bronze, but at an enhanced speed. The coal per ton displacement per mile with steel blades is ·0748, and with bronze ·0837. The area of blade is about one-eighth of the midship section. The speed is increased with the bronze blade by 7·7 per cent., at an increase in the consumption of 18·5 per cent., so that the gain in speed is nearly the ratio one would expect to the coal consumption, that is to say, about 76·5 tons. One would be disposed to consider that Z would give improved results by increasing the pitch of the bronze blades, as it appears from the comparison that the economy due to the change of metal is lost to a considerable extent in revolutions which are not effective in the propulsion of the ship.

Steamer	Propeller				Engine Revs. per day	Ship		
	Dia.	Pitch	Surface	Material		Miles per day	Coal per day	Displc-ment
	ft. in.	ft. in.						
Y	19 0	28 6	96	Steel	84,100	322	66	6,824
Y[1]	18 11	27 0	96	Bronze	90,500	338	69·7	6,504

Y. The only alteration made in this case was the shape of blades slightly altered and the pitch decreased by 1 ft. 6 in.; the diameter is slightly reduced. The revolutions per mile are, with bronze 267·75, with steel 261·18, while the miles per ton of coal are as

$$\frac{322}{66} = 4{\cdot}87 \text{ with steel, and } \frac{338}{69{\cdot}7} = 4{\cdot}84 \text{ with bronze,}$$

at an enhanced speed. The coal per ton displacement per mile with steel is ·067, and with bronze ·071. The area of blade is about one-ninth of the midship section. The speed is increased with the bronze blades by about 5 per cent., at an increase in coal of about 5.5 per cent., so that the gain in speed is greater in the ratio one would expect to the coal consumption, that is to say, the coal for the speed would probably be about 75 tons, thus showing an economy with the bronze blades. In comparison with the former, steel, blades the efficiency due to the metal with 18 in. less pitch is apparent. The weather in the course of some of the voyages with the steel blades may have been unfavourable, thus reducing the average results and adding revolutions by racing. The results, however, are based on the figures obtained from a series of voyages.

Steamer	Propeller				Engine Revs. per day	Ship		
	Dia.	Pitch	Surface	Material		Miles per day	Coal per day	Displcment
	ft. in.	ft. in.						
X	21 0	28 3	118	Steel	83,100	344	81·8	9,661
X^1	21 0	28 3	118	Bronze	81,800	347	75·8	9,510

X. In this case the results are taken from sister ships with propellers of the same shape, surface and pitch. The miles per ton of coal are as $\frac{344}{81 \cdot 8} = 4 \cdot 2$ with steel blades in the one steamer, and $\frac{347}{75 \cdot 8} = 4 \cdot 57$ with bronze in the other, at an enhanced speed. The coal per ton displacement per mile in the former is ·055, and in the latter ·051. The area of blade to midship section is about 1 : 8·8. The speed is greater in the bronze blade fitted steamer by ·8 per cent., while the coal is reduced by about 7·3 per cent. The gain here shown in favour of the bronze blade ship may be placed to the credit of the metal, but there are so many other elements which enter into the question that it is not easy to estimate the percentage of gain due to one cause or another. The decrease in the revolutions with the same pitch is very noticeable.

Steamer	Propeller				Engine Revs. per day	Ship		
	Dia.	Pitch	Surface	Material		Miles per day	Coal per day	Displcment
	ft. in.	ft. in.						
W	18 0	18 9	83	Steel	80,800	236	33·2	6,217
W_1	18 0	19 0	83	Bronze	82,250	262	30·7	5,948

W. These results are also from sister ships, propellers the same in all respects except material, and increase of 3 in. pitch in the bronze blade over the steel. The miles per ton of coal in the steamer fitted with steel blades are as $\frac{236}{33 \cdot 2} = 7 \cdot 1$, and in that with bronze blades are as $\frac{262}{30 \cdot 7} = 8 \cdot 53$, and that at an enhanced speed. The increase in the speed is about 11 per cent., with a reduction in coal of about 7·6 per cent. between the two steamers. The coal per ton displacement per mile for the steel-bladed steamer is ·0507, and for the bronze-bladed steamer ·0441. This shows a clear gain, but at the same time it is well known in practice that great variations are often found in the results of sister ships, so that it is somewhat difficult, if not impossible, to gauge the causes leading to such a manifest difference as appears in the results of these two steamers.

Steamer	Propeller				Engine Revs. per day	Ship		
	Dia.	Pitch	Surface	Material		Miles per day	Coal per day	Displc-ment
	ft. in.	ft. in.						
V (1)	19 0	21 0	95	Bronze	86,250	283	43·7	10,091
U (2)	15 6	16 6	120 (2)	Bronze	107,800	285	51·5	10,833

V is a single screw and U a twin screw. These results are of great interest, as showing from actual experience at sea, for voyages, the speed and consumption of two such steamers. The displacement of the steamer fitted with twin screws is 740 tons greater than the single screw. The miles per ton of coal for the steamer fitted with single screw V are as $\frac{283}{43 \cdot 7} = 6 \cdot 47$, and with the twin screw $\frac{285}{51 \cdot 5} = 5 \cdot 53$. The area of the blade to the midship section in the single screw is about 10·8, and in the twin screw about 8·6. The displacement per ton per mile with single screw is ·034, and with the twin ·037. The differences in the conditions are such in entering upon a comparison of these two steamers that, like the following case, it is not easy to lay down exactly what the differences are due to, but the economy lies apparently with the single screw.

Steamer	Propeller				Engine Revs. per day	Ship		
	Dia.	Pitch	Surface	Material		Miles per day	Coal per day	Displc-ment
	ft. in.	ft. in.						
S (1)	19 0	21 0	95	Bronze	90,500	297	48	10,782
T (2)	16 0	20 6	132 (2)	Bronze	119,520	372	85	9,130

The second of these vessels is fitted with twin screws; they are not sister ships, but almost distinctive types, S being more of the cargo type than T.

S and T. The miles per ton of coal in the single screw steamer are as $\frac{297}{48} = 6{\cdot}18$, and in the twin screw $\frac{372}{85} = 4{\cdot}37$ at an enhanced speed. The coal per ton displacement per mile in the single screw is ·033, and in the twin screw ·055. The area of blade to the midship section in the single screw is about 1 : 11, and in the twin screw about 1 : 7·3. There are so many elements at work in connection with the efficiency of the steamers here grouped for comparison that the question of efficiency in favour of single or twin screws can hardly be resolved. The results are of very great interest, however, and should form a basis for further comparison and analysis.

Steamer	Diameter of Screw	Pitch Set	Surface per Blade	Weight per Blade	Per Day		Displacement	Revolutions	Slip per cent.	Coal per Ton Displacement per Mile
					Miles	Coal				
	ft. in.	ft. in.	sq. ft.	tons cwt. qrs. lb.						lb.
R.	16 3	22 6	22	1 9 0 15	257·8	33·6	6,800	57·6	16	·042
R *	16 3	23 0	20	1 7 3 0	234·5	28·2	6,800	53·6	19·7	·039
P.	16 6	18 6	20·7	1 11 0 16	274·9	27·4	6,800	69·3	9·46	·0328
P *	16 6	17 9	18·75	1 4 2 0	264·3	26·1	6,800	69·2	9·14	·032
N.	16 6	18 6	20·7	1 9 2 7	257·8	26·6	6,800	65·4	10·03	·034
N *	16 6	17 9	18·75	1 4 2 0	241·8	24·4	6,800	64·8	11·3	·033

In the above cases the steamers are approximately similar to one another; they are all running over the same course.

The displacement given is the full load displacement, so that in the results showing the coal per ton displacement per mile, this factor is constant. It will be noticed that the slip has decreased with the bronze blades. R. P. N. bronze blades. R*, P*, N*, steel blades.

R. The miles per ton of coal with bronze blades are as $\frac{257\cdot8}{33\cdot6} = 7\cdot67$, and with steel blades $\frac{234\cdot5}{28\cdot2} = 8\cdot31$, and at enhanced speed. The increase in speed with bronze over the steel blades is about 9 per cent., but with an increase in coal of about 19 per cent. The advantages gained in these cases are very marked, and it would appear that the changes made in the shape and pitch of the blades, along with the change in material, have resulted in a very substantial gain in speed.

P. The miles per ton of coal with bronze blades are as $\frac{274\cdot9}{27\cdot4} = 10\cdot03$, while with the steel blades it is 10·12; the increased speed with the bronze is about 4 per cent., with an increase in coal of about 5 per cent. The coal per ton displacement per mile is slightly reduced, and on the whole the alterations made in the propeller have resulted in a slight economy.

N. The miles per ton of coal with bronze blades are as $\frac{257\cdot8}{26\cdot6} = 9\cdot69$, and with steel blades $\frac{241\cdot8}{24\cdot4} = 9\cdot9$, the increased speed with the bronze blades is about 6 per cent., at an increase of about 9 per cent. in consumption. The coal per ton displacement per mile is the same at the enhanced speed. These three steamers were originally fitted with compound engines, but the comparisons are made with the new machinery, and over the same route.

	Propeller						Ship			Engines	
Ship	Diam.		Pitch		Area	Material	Miles per day	Miles per ton of coal	Coal per ton displacement per mile	Revolutions	Miles by Screw
	ft.	in.	ft.	in.							
L	19	6	25	0	103·5	Steel	266·9	4·78	·04	74,757	307·3
L	19	6	25	0	103·5	Steel	284·3	4·078		84,373	347·
L	19	6	25	0	103·5	Bronze	295·5	4·137		85,257	350·5
L	19	6	25	6	103·5	Bronze	301·11	4·247		82,843	347·4
L	19	6	25	6	103·5	Bronze	298·	3·94		83,722	351·1

L. Originally fitted with steel blades, results of which are shown at different speeds on the two top lines, bronze blades were substituted for the steel of the same size, shape and pitch; the results from this change are shown on the third line; the pitch was increased 6 in. with the results shown on the two bottom lines.

In this case the slip with the steel blades is about 15 per cent., and with the bronze blades rather more, while with the increased pitch there is a slight reduction in slip to about 14.

The coal used over 100 miles run with steel blades at the lower speed on the first line is about 21 tons, and with the increased speed 24·5 tons, with bronze blades at the same pitch 24·1 tons, and with increased pitch 25·3 tons. These figures are based upon the figures supplied as including the total coal used throughout the ship for all auxiliaries, freezing machinery included.

	Propeller				Ship			Engines	
Ship	Diameter	Pitch	Area	Material	Miles per day	Miles per ton of coal	Coal per ton displacement per mile	Revolutions per day	Coal per day
	ft. in.	ft. in.							
K	15 6	19 0	65	Iron	248·8	9·3	·0696	88,285	26·75
K	15 6	19 0	65	Bronze	257·25	10·1	·0648	86,145	25·35
K	15 6	19 6	65	Bronze	259·9	9.5	·0650	86,587	27·4
K	15 6	19 0	65	Iron	217·7	11·7		80,530	18·6
J	15 6	19 0	65	Iron	213·7	10·11	·0553	78,637	21·12
J	15 6	19 0	65	Steel	258·0	9·39	·0682	87,792	27·5

K. These show average results from one steamer originally fitted with iron blades and replaced by bronze, set at the same pitch, afterwards increased by 6 in. The first three lines indicate the steamer's results over the same route. The fourth line indicates the results gained with compound engines and 60 lb. pressure; the former lines indicate results after the engines were converted and fitted with new boilers at 180 lb. pressure.

J. These show average results from a sister steamer running over the same route; first line shows the compound engines at 60 lb. pressure; the last line shows results with converted engines at 180 lb. pressure.

Steamer	Propeller				Ship	Engines	
	Diameter	Pitch	Area	Material	Miles per day	Revolutions per day	Coal per day
	ft. in.	ft. in.					Tons
I	17 3	22 6	104	Cast iron	300	100,000	55
I	18 0	22 6	108	Cast iron	312	98,000	54

I. These results show what was gained by increasing the diameter and area of a propeller on the same steamer, the material of the propeller being the same in both cases.

	Propeller				Ship			Engines	
Ship	Diameter	Pitch	Area	Material	Miles per day	*Miles per ton of Coal	Days under way	Revols. per day	Miles per day
H	19·6	25·0	104	Steel	296·3	4·826	50	81971	337·0
H	19·6	25·0	104	,,	272·18	4.1478	77	78049	320·9
H	19·6	25·0	104	,,	290·7	4·384	50	81080	333·4
H	19·6	25·0	104	Bronze	292·48	4·1205	42	81681	335·8
H	19·6	25·0	104	,,	277·4	3·95	28	79477	326·8
H	19·6	25·0	104	Steel	273	4·79	91	76012	312·4

H. In this case steel blades were originally fitted to the ship; the averages of results are shown with the original blades on the first three lines. The next two lines show the results after the ship had been stiffened, the blades remaining the same pitch; these lines also show the results with bronze blades at the original pitch, and the last line shows an

* The miles per ton of coal in this case include all auxiliaries; the total coal used for all purposes—including frozen meat—having been given. The results shown on lines 2, 4, and 6 are *viâ* the Suez Canal and include all the movements consequent upon this.

average of several voyages run with steel blades. The displacement was not given in this case. For 100 miles on the best voyage with steel blades the consumption was 20·7 tons; after the structural alteration it was 22·8 tons. With the ship running on a different route—the former run not being through the Suez Canal—and with bronze blades, 25·3 tons.

The results shown on the first line are very good, and appear by analysis very economical; probably weather conditions were favourable to a high efficiency. The slip with the steel blades is from 10 per cent. to 12 per cent., increasing to 13 per cent., with bronze blades, and further, increasing to 14 per cent.

	Propeller					Ship and Engines			
Ship	Diameter		Pitch		Area	Material	Miles per day	Miles per ton of coal	Per mile coal per ton deadweight	Per day Revolutions
G	19	0	23	0	114	Steel	303·04	4·28	·1293	92,420
G	19	0	23	0	114	Steel	269	4·96	·09	81,098
G	19	0	23	0	114	Bronze	308·6	4·7	·1221	84,714
G	19	0	23	6	114	Bronze	313·4	4·9	·120	88,360
G	19	0	23	6	114	Bronze	296·5	4·67	·124	86,382

The slip with steel blades works out to about 12·6 per cent., bronze blades, 5 per cent. and 9 per cent. respectively.

G. These figures show results while running with steel blades—on the first two lines—these blades were replaced by bronze of the same pattern, and set to the same pitch; the ship was afterwards stiffened, when the pitch was increased by 6 inches. The deadweight of the ship only being supplied, the coal per ton per mile is based on this. The coal used with the steel blades for 100 miles run, including auxiliaries, in this case comes out to 27·73 tons, with bronze of same pitch 25·0 tons, and with 6 inch increased pitch to 25·6 tons.

	Propeller				Ship			Engines
Ship	Diameter	Pitch	Area	Material	Miles per day	Miles per ton of Coal	Per mile per ton deadweight	Revolutions per day
F	19·0	23·0	114	Steel	275·72	6·0	·074	80,725
F	19·0	23.0	114	Steel	310·57	4·54	·14	91,779
F	19·0	23·0	114	Bronze	290·75	4·05	·142	91,419
F	19·0	23·6	114	Bronze	310·35	4·77	·13	90,871
F	19·0	23·0	114	Bronze	298·26	4·86	·096	90,544

F. The results from the steel blades show 100 miles run for 22 tons of coal, and the results from the bronze blades show 100 miles run for 21·7 tons of coal. In this case the first two lines show results from the averages of several voyages run with steel blades; the following lines show the averages with bronze blades of the same pitch, and then with the pitch increased by 6 in. A structural alteration was made in the ship, which tended to stiffen her somewhat, simultaneously with bronze blades being fitted. The coal per ton per mile deadweight is given in this case, the displacement not having been supplied to work from.

	Propeller						Ship		Engines	
Ship	Diam.		Pitch		Material	Area	Time under way days	Coal	Revolutions	Coal per ton deadweight per mile
	ft.	in.	ft.	in.						
E	16	6	19	0	Iron	61	108	3370	60	·0734
E	16	0	19	0	Iron	75	96	3227	57·9	·0703
E	16	6	19	0	Steel	63	105	3043	62	·0573
D	16	6	19	0	Iron	60	96·2	3038	60	·0596
D	16	6	19	0	Steel	57·9	99·8	2977	57·9	·0585

E. These figures show results from a steamer fitted with the stepped blades referred to. The first line indicates results from the original iron blades, the second line shows the results with the special blades, and the third line shows results from steel blades of a slightly different shape from the original.

D. These figures show the results from a sister ship fitted with the same ordinary type of blade, iron and steel.

These steamers, it is understood, lost portions of the original iron blades during the voyages, from which these results are taken, the scantlings being, it is presumed, too light, hence the substitution of steel.

The foregoing results have been obtained from various sources; the steamers are by different builders and belong to different owners. The figures have been tabulated as nearly as possible on a common basis to show the comparative results from actual practice so as to facilitate profitable discussion and to pave the way for further papers on the subject now introduced. The sets of results are obtained from voyages over the same ground in most of the cases given, that is to say, the steamers were running similar voyages with the bronze blades as with the iron, or steel. In the case of "K," compound engines with 60 lb. pressure afterwards converted, with 180 lb. pressure, and in the sister ship "J," the results given are with the compound engines and with the higher pressure for both steamers to show the variations in the results.

One well-known engineer advocates the solid propeller in preference to the built type, for which he claims better results; and I understand that quite recently he has found that a cast iron propeller has given better results than a bronze one of the same form and dimensions. If such could be furnished after twelve months' work, an analysis of the results leading to this conclusion would be of very great interest to us.

An analysis of results by tabulating the figures shows a net gain in favour of bronze blades over steel of about 3 per cent. in speed, and 4 per cent. in coal, and in closing these notes at this stage the writer hopes that a profitable discussion may be evolved from what has been laid before you.

DISCUSSION

ON

SEA-BORNE TRAFFIC,

MONDAY, MARCH 12th, 1900,

AT 58 ROMFORD ROAD, STRATFORD, E.

CHAIRMAN :

MR. A. BOYLE (CHAIRMAN OF COUNCIL).

THE CHAIRMAN : I am sure that we have all listened with great pleasure and profit to a most interesting paper which seems to me to divide itself naturally into two parts, firstly, the historical section which sketches the natural evolution of the modern liner from the vessels of ancient times—the more or less mythical vessels of ancient times—and secondly, the section dealing with modern shipping. It has always been to me a matter of considerable interest to see how our present liners have been evolved from our earliest attempts in naval architecture. I suggest that it will be convenient if the discussion is similarly divided into two parts. As citizens of a great maritime community like Great Britain we must all be interested in a subject such as this, and to us—men who are very closely connected with shipping—it must be doubly interesting. I was greatly struck some time back by a phrase that was uttered in the House of Lords by a distinguished statesman who declared that Great Britain without her foreign trade would soon become an over-populated, impoverished and discontented island in the North Sea ; and I believe there is a great deal of truth in that statement. I believe that our prosperity as a nation is very much wrapped up in our shipping trade.

There is certainly ample room for discussion in the remarks that the author has made, and I suggest that we first discuss the historical part of the paper.

In reviewing the history of shipbuilding I do not know that we can go much further back than the days of Noah, but it does seem a little surprising that the proportions of the Ark are proportions that have not been much improved upon, even at the present day, for sailing vessels. The fitting of the vessel is quite another matter. As to that I am not so certain, but for a good sound stable ship the proportions of the ark can scarcely be improved upon. No doubt from the earliest times men have been fond of inventing boats and vessels for trading and other purposes, and it is really astonishing what voyages those old navigators managed to accomplish before the days of the mariner's compass. And some of their ships were vessels of no mean size.

Mr. G. HALLIDAY (Member): A paper which treats of shipping from the days of the Ark certainly gives a very fair scope of subject for one to speak about, but there are one or two things which I fear have not been laid sufficient stress upon. For example, I should have liked the author to dwell upon the building of Cæsar's fleet in the mud; and then he has entirely omitted any mention of King Alfred. We Britishers can hardly omit from any historical review of our shipping any mention of King Alfred. I should also like to have known something about the sizes, etc., of those old sailing ships to which the author has referred. Those of the Vikings, we are told, were about 100 ft. long, and we have seen views of them in pictures. Indeed, I suppose that some of the hulls are still left. Coming to the shipping of modern times and what is expected of some vessels there is one problem which I have been thinking about for a long time, and I should be particularly glad if some gentleman present can give me some information upon it. The problem is this: Supposing we have a steamer, for example, with a speed of say 18 knots, and burning a certain amount of coal. Now at 16 knots it will burn less coal, at 14 knots less still, and at 12 knots less again. What I want to know is whether there is any method, and what is the method, for ascertaining the most economical speed of a ship? We know that a very fast steamer—say the *Majestic*, which does 21 or 22 knots an hour—consumes a very large amount of coal. At a lower speed that ship would consume much less coal. Is it practicable to find out, or is there any method for working out, the most economical speed for each ship?

The CHAIRMAN: Mr. Halliday wants to know, as I understand him, if there is any definite speed which may be called the most economical speed and which can be worked out for every steamer, when the best results can be obtained for a certain consumption of coal. It is a very wide question and there are a good many factors which come in. From a shipowner's point of view it is not a question of how economically you can run a steamer only in regard to coal consumption. A steamer is originally designed and built to go at a certain speed, and the shipowner generally wants her to go at that speed.

Mr. J. T. SMITH (Member of Council) observed that in deciding the most economical speed for a given steamer a good many factors had to be taken into account, but speaking generally, the most economical course was to run a ship at an easy full speed. There was no economy in going slow with a steamer built to run at a good speed.

Mr. HALLIDAY: I am still inclined to think that there is a cheapest speed at which to go from one port to another.

Mr. W. LAWRIE (Member of Council) said that one shipowner of very large experience had given great consideration to this question of the most economical speed, and he had come to the conclusion that under ordinary circumstances the most economical speed for an ordinary cargo boat was from ten to eleven knots, and this view was borne out by a good few of the leading shipbuilders. But this was not a speed that would answer for every trade. For instance, in the trade between Liverpool and Canada, they had to design the speed so that the steamers would make a certain number of voyages within a year. It would be useless for a steamer to make an extra half knot an hour unless it enabled her to make another voyage in the year. It was necessary to make a good advance from one speed to another in order to gain sufficient to make an extra voyage in the year. If a steamer was able to get another voyage within the year then there were other gains that came in her way. It was a very common thing for shippers of live stock in Canada to ask whether a certain vessel announced for sailing was an eight-day boat or a nine-day boat, and if she was a nine-day boat perhaps some of them would not give her any freight at all. There were many points to be considered in the running of a steamer besides the question of fuel, and the expenditure for coal was not the item in respect of which there was most room for saving. A friend of his was recently speaking to him about a diagram that he had been showing in percentages the expenses of running a steamer. The expenditure for stores, office charges, and a great many other expenses, besides coal, was indicated by separate lines showing the relative proportion of each, and taking the various items of outgo there certainly appeared to be most room for improvement in expenses other than coal. The answer to the question was that between ten and eleven knots was allowed, by men who had studied the subject, to be about the best speed for an ordinary cargo steamer, although this would depend a great deal upon the trade in which the steamer was engaged. Crossing the Atlantic with a heavy head wind a ten-knot boat would be a no-knot boat, or they would possibly even find her making stern way.

The CHAIRMAN referred to the methods of navigation in ancient times, and said it was really astonishing what voyages were accomplished before the days of the mariner's compass. Before the days of Cæsar, ships used to come from the Mediterranean to the Scilly Islands for tin, which under the conditions of those times was no small feat in maritime work. Even now it was no joke to cross the Bay of Biscay with a well found steamer, and that these ancient craft should have found their way from Gibraltar to the Scilly Islands was certainly very creditable to the navigators of those days. How they did it was a marvel. He thought some reference to the vessels of the Romans would be of interest.

After some further discussion,

The CHAIRMAN suggested that Mr. Adamson should reply to the short discussion which had taken place, and read the second part of his paper at the next meeting, with any additions he might have time to make to the subject matter.

Mr. JAMES ADAMSON : I would remind members that I only came in to-night as a stopgap in an emergency, and unfortunately the time was too limited to go into some of the points that have been referred to in the discussion. Mr. Lawrie has referred to a diagram showing in percentages the various items of expenditure on a steamer. I presume he refers to a circular diagram in which there are many items of expenditure included which we, as engineers, can only guess at. The gentleman who made it had within his reach all the data necessary for the construction of such a diagram, but very few engineers are in that position. We can only guess, for instance, at the amounts for brokerage, management, &c. We know the expenditure per mile for coal, oil, wages, Suez Canal dues and certain port charges, but particulars of such matters as general office charges and brokerages are very difficult to estimate ; these appear, however, to bulk largely in proportion even to the coal bill. Mr. Lawrie, I think, will bear me out in this, as the diagram he has referred to seems to be the same as the one shown to me. It not only interested but surprised me in some of the details.

The question Mr. Halliday placed before us has been previously referred to in our discussions—the most economical speed, as has been pointed out by the Chairman, Mr. Smith and Mr. Lawrie, depends on the class of ship and trade in which she is engaged, and for which she is competing. The illustrations we had when Mr. McArthur's paper on "The Performances of Two Steamships" was discussed showed fairly well where the direction of economy lay, and where the speed and consumption met to give the best results.

I shall be glad to reply to the discussion on Part I and to continue the subject, as proposed, at a future meeting. I agree with the Chairman in thinking it is well at times to dive into the past in order to see what was done in the days of old and consider also what bearing our present work will probably have upon the future ages of the world. I propose if time permits, before closing the subject, to place before you some data on propellers with the object of discussing the various forms of blades and material of which they are made.

The CHAIRMAN: We will now consider the discussion adjourned with the understanding that at our next meeting Mr. Adamson will again read the second part of his paper, but at greater length than he has done to-night. At the same time I hope the discussion at next meeting will not altogether ignore the historical part of the subject.

Mr. HALLIDAY proposed a vote of thanks to the author. His only regret was that there had not been a larger attendance of members to hear the paper read, and had the usual notices been issued he was quite sure that many more members would have been present.

Mr. W. LAWRIE seconded the motion and believed the members would feel greatly indebted to Mr.

Adamson for having guided their thoughts in the direction followed in the paper.

The AUTHOR in briefly acknowledging the vote explained that the difficulty in issuing special notices for the meeting was owing to the fact that the subject was undecided until that very day, when the question was resolved and the notes placed before the meeting was the result.

A vote of thanks to the Chairman, proposed by Mr. McLAREN and seconded by Mr. NOBLE, concluded the meeting.

DISCUSSION

ON

SEA-BORNE TRAFFIC,

MONDAY, MARCH 26th, 1900,

AT 58 ROMFORD ROAD, STRATFORD, E.

CHAIRMAN :

MR. A. BOYLE (CHAIRMAN OF COUNCIL).

THE CHAIRMAN : To-night we resume the discussion upon the paper entitled "Sea-borne Traffic," read at our last meeting. The paper is particularly interesting from the historical sketch that it gives of the progress and development of shipping from the earliest times. Perhaps we are more concerned with the condition of shipping as it exists at present, but it is particularly interesting to cast our eyes backwards over the centuries that have gone and note the condition of ships at previous periods, and as they are now. One point which has particularly struck me, as I dare say it has struck everyone who has thought about it, is the great progress which has taken place in sea-borne traffic during the present century, or during the last seventy or eighty years. I do not think that during any one of the previous centuries anything like the same progress took place. During the life-time of even the youngest among us we have seen great improvement and progress in shipping. The paper, as I said at the last meeting, divides itself into two parts—the first section consisting of the historical sketch, while the second part deals more with the steamer of the immediate present. I think perhaps it will be advisable if I first call upon Mr. Adamson for any remarks that he may make on the discussion that took place on the last occasion, and likewise for anything he may have to add to the paper itself.

Mr. JAMES ADAMSON: Having been called away at the beginning of the week and not getting back until late on Friday I have not had time to extend that part of the subject dealing with modern shipping so far as I should have wished. Before entering, however, on the second part I have made a few notes in reply to the discussion that took place, as arranged, at our last meeting.

Mr. Boyle suggested that a reference be made to the ships of the Romans. These were of two kinds—the *naves mercatoriae*, or merchantmen, and the *naves longae*, or ships of war. The former were propelled by means of sails (*vela*) and the latter by oars (*remi*). Some were decked, others partly decked at the prow (*prora*) and stern (*puppis*), joined by a fore and aft gangway—possibly this suggested the recently built turret types of steamers. The steering was effected by means of two paddle-helms, one on each side of the stern post, with projecting arms to the decked part of the vessel. There were several anchors carried, and are described as similar in shape to the modern. The anchors were cast out from the prow or poop according to circumstances, whether for riding or dragging. The mast was set in a socket and could thus be readily unshipped. Some ships had two masts, but these were rare. Above the yard was placed the cage for the look-out man. The ship in which Paul sailed, and which was wrecked, had on board 276 persons, and must have been of considerable size, as remarked by the chairman. She had four anchors. Those cast out from the poop were evidently so cast to place her stem towards the lee shore, that if she did drag them there would be a better chance of beaching the ship. Josephus was wrecked in a similar vessel in which there were 600 persons, and the tonnage has been estimated to be about 1,100 to 1,200 tons.

The ships of war were manned by slaves and freedmen, who laboured at the oars. The benches for the rowers were banked for two, three or more tiers. The ships were called, in respect to their power and size, according to the banks of oars they had, *biremes*, *triremes*, etc., and as the ships of war were longer, as their name implies, relatively to their breadth than the merchantmen, to give them speed and power to ram, the number of rowers was considerable in the large ships.

Reference was made by Mr. Halliday to King Alfred, whose memory is treasured as the unselfish, and encourager of all that was good, in whose reign not only were the arts of ship-building and seamanship forwarded, but the work now done by the geographical and similar societies was encouraged, and discovery and research were fostered. Reference was made to ships of war, but these were purposely omitted in the sketch, as to even attempt to give a brief outline of the history of ships of war would require a paper for itself. The *Great Harry* (1,000 tons), built in the reign of Henry VIII, is looked upon as a great advance in the art of building, and marked an epoch.

Reference has been made to the Norsemen who landed on the American continent before Columbus. In the days of Harold the Fair-haired, King of Norway, Eric the Red, whose father had left Norway and settled in Iceland, in turn voyaged on and settled in Greenland, whence Leif, son of Eric, sailed on an expedition and landed on the coast of Nova Scotia about 1000. Other expeditions followed; and, in one commanded by Karlsefin, whose wife accompanied him, after landing on the continent of America, a son was born to them named Snorro—the first European born on the new land, and whose descendants were famous in their day and generation.

While 400 to 500 years later Columbus was engaged in trying to get patrons to help him in his efforts to fit out an expedition, the merchants of Bristol were bestirring themselves in the same direction, and the great work of discovery and adventure was carried on under the leadership of John Cabot and his son Sebastian, in the reign of Henry VII, who did much to foster and encourage shipping. The landing of John Cabot in America was in 1497. The lives of the Cabots and the enterprise of the Bristol merchants are most interesting.

Coming to modern and practical questions of economy in running a steamer, the consumption of coal per day is not necessarily a primary one. If a steamer is advertised to sail on a certain day and occupy twenty days on the voyage to the terminal port, she has a better chance of freight than others that will occupy twenty-five or thirty days, while if she is fitted for passengers the advantage is very much in her favour. For a purely cargo steamer, where the saving of a few days on a voyage is not material, it is generally considered that from ten to eleven knots—inclining rather to ten than eleven—is the most economical speed; but every ship has a speed of her own, and it is a matter of experience to find it out. Steamers that are built for fourteen knots would not probably be found to work most economically at ten knots, but at twelve. Another point in connection with the speed of steamers, especially of fairly fine lines, for cargo and passenger traffic, is that the vibration of the ship increases or diminishes relatively to the speed. So that it seems to me that the pulsation of the engines should be kept from synchronising with the vibration of the ship, to get the best results and add to the comfort of those on board of her. This is a matter which is ruled by the power developed, and the balancing of that power to meet the circumstances of weather, displacement, centre of gravity and speed, on which depend the extremes of vibration of the vessel's hull.

At a time like the present, when the sinews of war are sprung to their tension, it is a matter of great importance to the Empire to know how the Colonies stand affected towards the Mother Country. Differences of opinion on the subject of free trade exist, and will exist so long as the complex mind of man remains, causing merchants and manufacturers of home and colonial goods to differ in their attitude to one another. We have recently seen these minor differences sunk and the pulsations of the hearts of the children beat in harmony with the heart of the mother, proving the origin and strength of the life-blood to be a more important element in the higher issues of life than the value of money and what it will produce when invested in merchandise; and one of the many good results which will follow the settlement of the South African question will doubtless be a strong desire to knit more closely the scattered Empire in bonds of commercial sympathy and mutual support, the hardening influences of harassing enactments and greed of gain being mellowed and softened by the feelings which have been aroused into strong action. And it may be that modification in the views and arrangements of those who rule the carriage of goods between the Mother Country and its off-shoots may result in an increasing preferential interchange of trade and commerce. Our commercial relationship with other nations is a potent factor which appeals to us at all times. We see the evidences ever around us, evidences which in some directions appeal to our instincts in an undesirable way; still we owe it to our commerce that the barter of all nations comes to our door.

Referring again to the question of the most economical speed, the following are the comments on the subject in the *Steam Manual:* "The most economical speed is determined by trial and in accordance with the varying conditions of wind and weather." This is further defined: "In determining the most economical rate at which to make a voyage, the coal expenditure for auxiliary purposes should be taken into account, especially where this is large"; while in a further note is added: "The most economical speed should also be used in those cases where the ordinary speed is less than the most economical speed."

Mr. F. W. SHOREY (Hon. Treasurer): In the early part of the historical section of the paper the ark of Noah is referred to as being 540 ft. long by 90 ft. by 54 ft. I do not quite know how those figures are arrived at. Assuming the length of a cubit to be 18 in., that would bring the length of the ark to 450 ft., not 540 ft.; and if we take a cubit to be 22 in., that would make the ark 550 ft. long, 91⅔ ft. broad, and 55 ft. deep. The ark was not built possibly on such good lines as the boats of the present day; but when we consider that not 2,000 years ago all were savages on this island, we can realise a little the great strides that have been made as centuries rolled on. It was 2,448 years before Christ that Noah was ordered to build the ark; and when we remember who the naval architect was who instructed Noah I have an idea that the ark was, for her purpose, a perfectly built ship. There was plenty of time allowed for the construction of the vessel. It was 2,448 B.C. when Noah was ordered to build it, and it was 2,349 B.C. when he was told to enter the ark; so that, assuming Noah was told to enter as soon as it was finished, the building occupied 99 years. It had only one skylight, that being on top. We are told that after the flood the ark settled on Mount Ararat. Noah lived about 400 miles distant from Mount Ararat. The ark must have floated to Ararat, and when the waters subsided the ark rested, and Noah and his family came down. In connection with this I should like to call attention to a paper I read some nine or ten years ago, when a number of gentlemen were appointed to inquire into the distress in Armenia. They went out from England, and as they were going towards Mount Ararat they were told that the remains of a large ship had been seen on one of the glaciers. At first the guides would not take them in the direction indicated, but after some persuasion one ventured. They had to pass through many difficulties in getting to Mount Ararat, but at a certain height up the mountain they found a portion of a vessel built of gopher wood. There was no such wood growing in the neighbourhood, and after discussing the matter they came to the conclusion that this piece of a vessel must have been a portion of the original ark. I think that Mr. Adamson might have mentioned the ship in which Jonah was a passenger from Joppa, as showing the combined cargo and passenger ship of that day. With regard to the Phœnicians—speaking of these people Mr. Adamson says: "They had for many ages no rivals; and as they delighted in establishing distant colonies their exertions in that particular were so numerous that, when it is recollected their country was in all probability little more than the narrow slip of ground extending between Mount Libanus and the sea, it must appear not a little surprising how they could furnish such extensive emigrations without causing an absolute depopulation of their whole country." In writing these lines I think the author has overlooked one thing. They were allowed a plurality of wives in those days, and of course might have immense families. And now a word about wages. In the days of Charlemagne, I see, the wages of sailors were £2 16s. 8d. per annum. That is rather low pay according to the present value of money, but I dare say that in proportion it was better than the wages that are paid now.

Mr. W. LAWRIE: In reading over Mr. Adamson's paper it has occurred to me that it would be a good thing if we possessed a collection of models representing as nearly as possible the various types of vessels—the design and dimensions—that have been used in carrying the commerce of the world during the period of its history. I may be reminded that this Institute is not a wealthy one; but a beginning might be made in a small way, and by a little energy and enterprise I have no doubt that a very good collection could be got together at a moderate cost. At any rate, if it was got together it would be a very valuable one, and the idea, I think, is entitled to some little consideration. The author of the paper has given us a very interesting comparison, showing the proportions of the ark and those of the best steam and other vessels of to-day. But in my journeys up and down the river Thames I could not help thinking that some of the descendants of Noah must have come to this part of the country, for you will find that many of the dumb barges on the Thames are modelled on something like the lines of the ark, and as these barges are solely dependent on the tidal action of the water for their motion the similarity is, I think, still further increased. But when we come to consider the language and manners of the Thames bargemen we are apt to think that there must have been a stowaway on the ark somewhere. The author devotes several paragraphs of his paper to the Phœnicians, who were, I believe, the first nation in the Mediterranean to engage in nautical affairs, and I think that in the history of navigation and shipbuilding they certainly deserve a foremost place. Their country, situated at the very extreme eastern end of the Mediterranean, was a very small patch of land with a coast line of about 230 miles and an average width of about fifteen miles, giving altogether a total of something like 3,000 square miles of territory. The proportion of ladies to gentlemen I am not much concerned about; but it seems to me nothing short of marvellous that this people, occupying a mere strip of land, should be able to push their trade from the extreme eastern end along both shores of the Mediterranean, and colonising several places on the northern shore until they got as far west as Carthage—and even then they were not content. They also pushed their way right through the Straits of Gibraltar, and traces of their work have been found as far down the African coast as Senegal and Gambia, while northward they came to the Scilly Islands and Great Britain. When you consider that all that was done 500 years before Christ and without the aid of the mariner's compass, I think we shall agree that they were really a marvellous people. We have no definite information as to the construction of their vessels. I have seen it stated that the vessels which they used in trading were broad and round shaped, and that each vessel carried a crew of about 25 men. For war purposes they used galleys propelled by oars, and sometimes these galleys contained as many as 300 sailors, so that you see they were a people who were bound to leave their mark wherever they went. And not only were they a great maritime people, they were also powerful by land. In fact they were, in a sense, intermediaries between the East and the West; and if you come to look at their position you will see that in their day they seemed to occupy much the same place in the world as we do now—namely, the carriers of the world's produce. There is some doubt as to where this nation originated. It has been said that they came from the shores of the Persian Gulf, but others say they were turned out by an earthquake from somewhere near the Red Sea. Then we come to the Vikings. They are always sure to turn up when navigation in early times is under discussion. But they were a very different class from the Phœnicians. We can almost think it a dream to imagine that the Norseman in those days considered the pirate's life the most honourable possible; and it was a common boast among some of them that they never slept under a permanent roof and never drank a glass of beer at home. But with this there was something of a noble generosity in their character, for when two fleets or squadrons met in battle, and one was larger than the other, the commander of the larger fleet would detach a number of vessels to join the weaker side so that they might have a fair and square fight to begin with. Mr. Adamson has referred to the Chinese as having stood still for something like 3,000 years. I suppose they may be regarded as exactly the opposite of the Phœnicians, and he says they have been held together by tradition and superstition. But this is hardly correct. The Chinese are held together more by numbers than by tradition and superstition. The Chinaman is only as good a man as the governing class will allow him to be, and if he had the opportunity he would, I believe, turn out a very different individual. I do not think that the early days showed much improvement in navigation or shipbuilding. It was not until the fifteenth or sixteenth century that a turn in affairs came along, and the progress has continued to this day. With the introduction of the mariner's compass in the fourteenth century and the other improvements and inventions which followed, of course there was a better opportunity of getting away from the coast. Previous to that there was a difficulty in leaving the land. I have not had time to go into the modern side of the subject, because I did not think that it was to be discussed to-night, but there is just one other point to which I will refer before I sit down. In the first paragraph of the paper Mr. Adamson says, "To a nation whose boundary is a girdle of water, the means of transit across the face of the deep is not only of interest but of importance, and when the increase of population exceeds the productive power of the land in respect of food supplies the question of sea-borne traffic becomes vital." I do not think it has ever been clearly proved that the population is greater than the productive power of the land. I am not going into the political aspects of the subject. But I do not think that the land has ever had an opportunity; and until the people of this country see that the land belongs to the Lord, and not to the landlords, they will never know its full productive powers.

Mr. W. McLaren said he was not able to go so far back as the two previous speakers, but he could say something as to the progress of the nineteenth century, especially on the east coast of England. Formerly the London and Edinburgh Shipping Company provided one or two guns on each of their vessels for protection, and the steamers of the Company still kept up the old usage of firing a gun when they got abreast of Leith pier. Formerly the voyage to the Thames occupied nearly two weeks, and now it was done in twenty-four or even twenty-three hours, from Leith pier to Gravesend. The growth of the trade was also illustrated by the increase in the number of shipowners running steamers on this coast. In addition to the London and Edinburgh Company, there were the General Steam Navigation Company, the Carron Company, the Aberdeen Company, and the Dundee Company, while the steamers seemed to increase also both in size and speed. It was most surprising where the trade came from to fill all these vessels. One of the Companies even ran steamers each way three times a week, and it was probably not generally known that there was a very large fruit trade by this route from Kent to the North. Then there were the great improvements that had been brought about in the matter of lights and in coaling facilities; and they must certainly not forget the great service which Lord Kelvin had rendered navigators by the introduction of his compass and sounding machine. Another improvement that had been brought about of late was in the method of transporting cargo or coal from one ship to another, and one great advantage that had resulted from the summer naval manœuvres was that it had been proved practicable to transport coal from the Cardiff colliers to the warships in mid-ocean. It should also be mentioned for the sake of this institution that one of its members, Mr. A. B. Brown, of hydraulic gear fame, had by the invention of his stern steering gear brought about a great improvement in the system of steering ships, doing away with those troublesome chains and rods along the deck that were so often breaking down.

Mr. JAMES ADAMSON: I am rather sorry that when Mr. Shorey was telling us that a portion of the remains of the ark had probably been discovered he did not tell us that the moulding loft had likewise been traced. We might thus have ascertained the lines of the ark and the co-efficient. With regard to the dimensions of the ark, it was specifically stated in the paper that the best sailing ships of to-day were built very much of the same proportions as the ark. Of course steamers have increased in length in proportion to breadth. But in regard to sailing ships it is understood that the best ships of the present day are of proportions very similar to those of the ark, which, however, was designed simply to float and to give sufficient buoyancy with stability, and Mr. Lawrie's remarks in this connection in reference to the dumb barges are very appropriate. In reference to the Phœnicians, the portion of the paper that Mr. Shorey read was a quotation from a standard author, who has studied the subject much more deeply than I have. Referring to Mr. Lawrie's suggestion, I think it is an exceedingly good idea that we should try and establish in our museum a collection of models of old ships from the days of the ark. Of course it was quite impossible in a short paper to refer to all the ships, seamen and passengers who have ever lived, otherwise I should have referred to Jonah, but his history is so well known that I thought it unnecessary to give it in detail. I do not know that the Phœnicians were so gifted with large families as Mr. Shorey would have us infer, but, with regard to Mr. Lawrie's remarks as to the productive power of the land, I was considering the productive power of the land as compared with the reproductive power of the race in referring to Great Britain; and if you consider these two elements together, you will, I think, agree with me that the paragraph in the paper is quite appropriate. Mr. McLaren has referred to the trade on the North

E

East Coast, and to the inventions of Lord Kelvin and Mr. A. B. Brown, but there is one thing connected with the steering gear not yet invented—to control the steersman on a straight course.

Mr. Lawrie has expressed the opinion that the Chinese have been held together in their old ways by the power of the governing classes and by their numbers. On what I have read and seen of China and the Chinese I based the comment as to tradition and superstition keeping them in check. If the Chinaman leaves his native land—the China woman is not allowed to—he never leaves it but with the intention of returning or having his body brought back; the pains and penalties threatened to the surviving relatives in the event of the body being buried on a foreign shore are such that—apart from the traditional filial piety which is strongly inculcated by precept and illustration—their superstitious fears compel them to subscribe to bring home the body; hence the origin of the saying that it pays better to carry a dead Chinaman than a living one.

I have often thought it is a providential circumstance that the 410 millions in China have been held in check, by whatever cause, as the inroad of a few millions upon adjoining territory would create considerable trouble if they were energetic and hungry, even with the ancestral tablets before their eyes. Their religions—Confucianism, Buddhism, and Mohammedanism—have each their good maxims and tenets covered over by the inveterate and seeming inborn passion for gambling, and the outcome of it, fatalism.

The CHAIRMAN: One suggestion has been made in the course of the discussion which I think is a very valuable one, and I hope we may be able to take some steps to carry it out, and that is that we should endeavour to collect some models of the earlier ships. It may not be easily done, but it is astonishing how many gentlemen will help in a work of the kind.

Mr. LAWRIE : I think that some of our members would help us if they knew what we want.

The CHAIRMAN : I am sure that Mr. Adamson would be extremely pleased if that was one result of his paper.

Mr SHOREY : If we are to get models of the ships of all times I think they should be limited as to size. We have not much ground to spare.

Mr. LAWRIE : What we want more especially are models of ships of particular periods.

Mr. J. R. RUTHVEN : One thing which appears to me to be missing from this paper is any mention of the sand barges of the Thames whose proportions seem to be about two beams to one length, very much after the model of the ancient coracle. They seem to prove very satisfactory for knocking up and down the river, and they are about the broadest vessels in proportion to length that I have seen. Reference has been made to the model of Noah's ark, and I think it a great pity that such models of the ark as are generally sold should be made for children, because there is no flotation in them. They ought to be built with more bottom to carry the top house. We ought to have a reasonable model of the ark, and it is wrong to give children a false impression to start with. I am very glad that such a paper as this has come before us, because it will be very interesting to our members who are away at sea to notice the things that have gone before us. What will come after us is another matter altogether. It would be very interesting if we attempted to foreshadow what is coming in the future.

Mr. LAWRIE : There is one point I intend to raise, and that is the possibility of our having to revert to sailing ships. If members would look that up and give us their views we might get something original.

The CHAIRMAN : Our views about the ark, as a rule, are rather shadowy ; but, as regards the design and method of building, it has often struck me that those fast sailing barges with a beam to length of about 1 to 4 or 1 to $4\frac{1}{2}$ have great stability even when empty. They go along splendidly without any ballast at all. The enormous bottom gives them stability, and their great stability enables them to carry a great press of canvas which again gives them their great speed.

Mr. LAWRIE : Most of those fast racing barges could not pay as cargo carriers. They are not built as cargo carriers.

After some discussion as to the most convenient course of procedure in discussing the subject,

The CHAIRMAN said : We understand then that the discussion upon the historical part of the paper is closed, and we now come to the second part. As Mr. Adamson has made several additions to this section since our last meeting it will perhaps be convenient if Part II be read, especially as there are several gentlemen now present who were not here at the last meeting.

Part II was then read, and the discussion on it was adjourned until the next meeting.

Mr. F. W. SHOREY proposed a vote of thanks to the author for his paper, which, he said, had been prepared under great difficulties and disadvantages as to time, but nevertheless it was an exceedingly good paper, and one that would furnish matter for a good many nights' discussion.

Mr. SAGE seconded the motion.

A vote of thanks to the Chairman for presiding concluded the meeting.

DISCUSSION

ON

SEA-BORNE TRAFFIC,

MONDAY, APRIL 9th, 1900,

AT 58 ROMFORD ROAD, STRATFORD, E.

CHAIRMAN:

MR. F. W. SHOREY (HON. TREASURER).

THE CHAIRMAN: The subject before us this evening is Part II, of Mr. Adamson's paper on "Sea-borne Traffic." We have already discussed Part I, and we have now before us Part II in which I think you will find a great many points for discussion.

The HON. SECRETARY: The following has come to hand from Mr. Walter Pollock (Member): "In the paper there was no mention of the conveyance of sea-borne traffic by sea-going towing lighters. There are nearly 30 of these vessels regularly trading round our coasts and across to the Continent. The most recent have a length of 125 ft., breadth 25 ft., depth 10 ft. 8 in., and carry 475 tons d.w. on a draught of 8 ft. 10 in., and have the highest class at Lloyd's. They are worked with a crew of four hands, and the towage is by steamer or sea-going tug. The advantages claimed for this system of sea-borne traffic are: firstly, they can be towed by a coasting steamer of, say, 600 I.H.P., with a reduction of only 15 per cent. in the speed of the steamer; secondly, they save the discharging into small barges for transport up the rivers and to wharves with small draught of water to get alongside, and thereby reduce breakage of cargo and cost of transhipment; thirdly, the demurrage of the lighters through detention or other causes is only one half that of a steamer of the same size. The disadvantage of these lighters is that they dispense with the marine engineer."

Mr. JAMES ADAMSON: The diagram showing the variation from voyage to voyage in the running of a steamer, which was referred to in the discussion on "The Performances of Two Steamships," and shown on the blackboard at that time, may again be appropriately cited this evening as illustrating points already raised in the discussion relative to the most economical speed and method of running a steamer.

Mr. J. G. HAWTHORN (Member of Council) said that at the previous discussion on this paper a question was raised as to whether it was possible to work out by some system the most economical speed at which a steamer could be driven. This inquiry recalled to his mind some questions published by Professor Greenhill in the course of his examinations, and one of these questions involved this very point. The professor quoted certain data concerning a vessel, and the problem was to work out the most economical speed at which that ship could be driven. He (Mr. Hawthorn) had endeavoured, as far as his memory allowed, to reproduce these questions, and he had worked them out, with results which he detailed on the blackboard. He was presuming that they were dealing with a large passenger steamer or trooper, and that the cost of provisioning the crew and passengers was about £400 for every day that she was underway. He assumed also that her coal consumption was 50 tons a day, and her speed 8 knots an hour, while he took the market price of coal as 20s. per ton. Mr. Hawthorn explained his calculation in detail, and said he found that the most economical speed at which this ship could be driven was 12·7 knots per hour. He would endeavour to show that that result was absolutely correct. Supposing they took the case of a large liner which had been chartered for a voyage to the Cape and back, to carry 800 first-class passengers at a cost for provisions of 5s. per day, and 1,600 passengers at 2s. 6d. per day, which came altogether to £400 per day; assuming that the length of the voyage was 12,700 miles, the number of days underway, travelling at 12·7 knots an hour, would be 41⅔ days. The cost of provisions for this period at £400 per day would be £16,666⅔, while the cost of coal at £200 per day would work out at £8,333⅓, making the total cost for the voyage in respect of these two items £25,000. Now in order to show that 12·7 knots was the most economical speed at which the ship could be driven, he would take the speed at 1 knot less—11·7 knots—when he found that provisions would cost £18,080, and coals £7,069, making the total for the voyage £25,149, so that at this speed there was a net loss on the round voyage of £149. Again, taking the speed at a knot higher—13·7 knots an hour—he found that the cost of provisions would be £15,448, and the cost of coal £9,700, making the total cost of the round voyage £25,148, so that as compared with the expenditure at 12·7 knots there was a saving in provisions of £1,218, but an increase in the cost of coal of £1,366, showing a net loss on the round voyage of £148. A remarkable feature in connection with these figures was that supposing, for the sake of argument, the cost of coal decreased 25 per cent., to 15s. per ton, wages and provisions remaining the same, then the most economical speed of this steamer worked out at 14 knots. If the cost of coal was reduced another 25 per cent., to 10s. per ton, then the most economical speed was 16 knots. But if they decreased the cost of provisions it was necessary to decrease the speed, and if the cost of provisions was reduced by 25 per cent., to £300 a day, coals remaining the same, then the most economical speed was 11·5 knots. He was not taking into account any of the freight-earning capabilities of the ship, but was simply discussing the matter from an engineering point of view. He assumed that the freight earnings would pay all the other working expenses. If they reduced the cost of provisions another 25 per cent., to £200 per day, coals remaining the same, then the most economical speed worked out at 10·08 knots. These figures, he thought, clearly proved that, in the case of a large passenger steamer, as the cost of coal increased the speed should be reduced. In other words, the most economical speed varied inversely with the cost of coal, and varied directly with the cost of provisions. He would also take the case of a 5,000-ton cargo steamer, whose consumption at eight knots was 12 tons, and he would assume that her consumption varied with the cube of the speed. The cost of provisions and wages was £50, and in this instance he found that the most economical speed was a little over 10 knots. These were the two factors in the running of a ship that must be reckoned with. Of course if merchants would pay extra freight for rapid transit then they could build ships whose most economical speed would be 16 knots, but he was considering the actual accounts of the ship herself, and when the time of the voyage was not considered as an item in the cost of carrying the freight. At the present price of coal, and under present conditions as to wages and provisions, the most economical speed at which they could drive such a cargo steamer as he had indicated was about 10 knots.

Mr. W. LAWRIE (Member of Council): The second, or modern, part of this paper covers a very important period in the history of shipbuilding and navigation—a period during which science, invention, and improvement have been very busy in perfecting the means of ocean traffic. The author has dealt very lightly with the time when sailing ships had pretty full sway on the water, but even in these times of prosperity it is just as well to cast a glance backward and give some thought to the antiquated part of the subject. I refer more particularly to the fact that at the time when sailing ships were making very speedy passages we in this country did not boast the fastest clippers. I do not mention this fact for the purpose of croaking over it, but I think it is just as well to remember such incidents, as it may be helpful in reminding us that we must not stand in the way of improvement, as our opponents are very likely to take advantage of any remissness on our part. Mr. Adamson gave us some very interesting figures as to the cost of carrying dead meat between New Zealand and London, and at first it seemed rather astonishing that this meat should be carried at such a low rate of freight, seeing that cargoes of this description require a very special and costly plant, in addition to the ordinary expenses of a vessel. This low rate of freight reminds me of an argument that was very freely used during the agitation for the repeal of the corn laws. Those who prayed for protection maintained that the home producer ought to have some protection against the foreign grower, while those who advocated free trade retorted that the home grower would always have protection in the cost of the carriage of the wheat from foreign parts. I wonder if any of those who took part in that agitation ever thought it possible that dead meat would be brought from New Zealand to London at from $\frac{5}{8}$d. to $\frac{3}{4}$d. per pound, although I fear that the British farmer will not be very jubilant over the success of the marine engineer in this connection. Of course the low rates of freight now charged are due to the advent of huge steamers, splendidly equipped, and provided with every appliance suitable for the trade in which they are engaged. When I first went to sea in the very early seventies the steamers were for the most part vessels of from 1,500 to 2,000 tons register. They were fitted with compound engines and carried a pressure of 70 lb. of steam. I was second engineer of a steamer that had neither high-pressure steam nor spring-loaded safety valves. She had no fittings in the way of evaporator, feed filter or feed heater; neither had she steam steering gear nor water ballast, and the electric light was not thought of, but still that vessel did a fairly successful trade. She had inverted engines, direct acting, and the thrust was taken on the after bulkhead of the engine room by means of a bracket fitted for the purpose. That vessel did very well, and comparing her with the vessels of to-day it shows to some extent why modern vessels are able to carry at a very much less freight. The case of the *Great Eastern* has been referred to, and the author says that she "became a mark for progress to work from." I saw the *Great Eastern* in her degenerate days, and her hull seemed to be capable of some useful service. What occurred to me was that her machinery was rather behind the age, although it was said that her consumption was 3·7 per I.H.P., which was fairly good at that time. I think that if they had interested some of the marine engineers of the day with the machinery of that vessel they might have had a slightly better result. After referring to the progress of recent years the author of the paper says "The necessities of commerce and of competition are met year by year by our merchant princes most nobly." That is a statement with which very few of us will quarrel, but if we are to maintain our present supremacy in maritime commerce I think it will be necessary for the shipowner, the shipbuilder, and, in fact, everybody connected with shipping, to exert themselves to the utmost. In the year 1855, when the Hamburg-American Company first went into steam, their first steamer was built on the Clyde. Many of their succeeding vessels were also built in this country, but in looking over the returns for last year you will find that the Germans built 260,000 tons of shipping, as against something under 172,000 tons in the previous year. Of course we cannot expect to go on building for foreigners as in the past, but there are some things in these returns that we should study. For instance you will find that among the seven largest shipbuilders in the world the Germans take the third and the fifth places, while the Vulcan Engineering Works at Stettin hold the world's record for output in indicated horse-power. These facts deserve our consideration. No doubt German shipping is very largely subsidised by money given by the Government; but the Germans are also very enthusiastic, and I think it will be a good thing if we keep our eye on them. I have seen something of them, and they have a great capacity for hard work. We are also told, and it is generally admitted, that under normal conditions the Americans can turn out shipbuilding material at a less cost than we can ; and if that is so, at the present time, we only beat them on the points of applied science and labour. It is worth while considering how long this will last. The Americans are in deadly earnest in this matter. They have always been at it, and if they can now produce shipbuilding material cheaper than we can it is about time we were learning a lesson. It is our business to see that they do not swamp us in the shipping and shipbuilding trades. There must be some things that we can learn, and the sooner we learn them the better. I am one of those who believe that we have still a good deal of grit left in us; but we must not fall asleep, and unless we are fully alive to the progress of the times we may be left behind in the race. I have looked at those figures of Mr. Hawthorn's and so far as the figures go I do not find much fault with them, except that when he puts the cost of provisions for passengers at 5s. per day I think he puts it rather high. I have not had an opportunity of going into figures of that sort very recently, but when I was in the Atlantic trade I know a third-class passenger cost less than a shilling a day and had fresh meat every day. Certainly 5s. a day seems to me to be too high. Mr. Hawthorn's figures are given for a very long voyage ; but it is a very noticeable fact that our shipowners to-day, by a very large majority, go in for very much higher speeds for first-class passenger steamers. There are so many considerations that come in. For example, if one ship has numerous passengers and another has none, the ship having the passengers can afford to use more coal and go at a greater speed. It costs so much to feed the passengers, but if they are not teetotallers you make a good deal out of what they drink. The figures given by Mr. Hawthorn as to cargo steamers have been borne out by experience. About ten knots has been proved by the most recent experience to be the most economical speed for an ordinary cargo steamer, although there are so many considerations to be weighed that it is very hard to say absolutely what is the most economical speed.

Mr. J. R. RUTHVEN (Member of Council) furnished statistics in support of the view that the size of the steamer was a very important element as affecting the coal consumption. Quoting from a return showing the results of a large number of voyages, he stated that a 9,000-ton steamer, running 267 miles a day, showed a consumption of ·036 lb. of coal per ton displacement per mile. An 8,000-ton steamer, running 266 miles a day, used ·038-lb.; and a 7,000-ton steamer, running 264 miles a day, showed a consumption of ·048 lb. A 6,000-ton steamer, going 257 miles a day, used ·054 lb., and a 5,000-ton steamer, travelling 260 miles a day, ·067 lb.; while a 4,000-ton steamer, going 269 miles a day, consumed ·081 lb. So that the cost of the 9,000-ton steamer for coal was less than half that of the 4,000-ton boat, per mile per ton displacement. Thus the element of the size of the steamer was a very important one. The larger the steamer the less the coal consumption *pro ratâ*. Double the size of the steamer, and they halved the coal consumption per ton displacement. On the question of the number of vessels built in this country he found from the shipbuilding returns issued by Lloyd's Register that the total number of new vessels built last year was 854, with a gross tonnage of 1,185,961, while others added to the Register numbered 183, with a tonnage of 89,000, giving a grand total of 1,037 vessels of 1,275,000 tons. Compared with the totals for the previous year these figures showed a decrease in the number of vessels of 195, but an increased tonnage of very nearly 400,000 tons. This showed how the size of the vessels was increasing.

The CHAIRMAN: I take it that the inference to be drawn from your remarks is that the larger the vessel the more cheaply it can be run?

Mr. RUTHVEN: Yes.

A MEMBER: For coals only?

Mr. RUTHVEN: For coals only.

The CHAIRMAN: Mr. Lawrie has told us that a vessel in which he was engaged in 1870 paid very well, but all vessels paid very well in those days. Of late years, however, there have been so many more vessels put on the routes and competition has become so keen that freights have been cut down. At the period which Mr. Lawrie spoke of, freights were much higher than they are now, and ships paid much better. A ship is not such a good investment now as it was. With regard to the cost of carrying frozen meat I do not think that ¾d. per pound is such a low freight. It may look small on a single pound, but when you consider that it amounts to about £7 per ton I do not think that the rate is so very low.

Mr. LAWRIE: What would you consider a low freight?

The CHAIRMAN: I am not in a position to say, but I do not consider that £7 a ton is very low.

Mr. N. K. MCLEAN (Member): You have to take into consideration that those ships carrying dead meat have to go out with their refrigerating chambers empty, or nearly so, and only pay on the return voyage.

The CHAIRMAN: That is so. Mr. Lawrie also spoke about the Germans topping us in shipbuilding, but the German Minister of Marine stated last week that in England we could build ships a great deal cheaper than they can in Germany, and he showed it by figures. I am sorry I am not prepared with those figures at the moment.

Mr. LAWRIE: I did not say that the Germans were topping us in shipbuilding. What I said was, that in view of what the Germans are doing it is time for us to look out. The Germans are still our best customers, and we ought to keep our eye on them.

Mr. G. HALLIDAY (Member) said that Mr. Ruthven had raised the question of the variation in the coal consumption as the dimensions of a steamer were increased, and the same question was raised by Professor Biles at the recent meeting of the Institution of Naval Architects. Professor Biles was investigating the question of the effect of increase of size upon working expenses—whether the working expenses, including coal, wages, etc., were less per ton carried in the large than in the small steamer. Taking a steamer 500 ft. long and 60 ft. broad, with a draught of 27 ft. 6 in., he found that by increasing the length to 700 ft. with a proportionate increase in the breadth, but keeping the draught constant at 27 ft. 6 in., the cost of carrying a ton of cargo per mile increased from 8s. 6d. to over 11s. But if the draught, instead of being kept constant, was increased in proportion to the increase in the other dimensions, then the cost of carrying a ton of cargo per mile decreased from 8s. 6d. in the case of the 500 ft. ship to 7s. in the case of the 700 ft. ship. Professor Biles thus showed that if draught be increased proportionately to increase of dimensions the cargo could be carried at a steadily decreasing cost as size increased. The question of draught was therefore a very important factor to remember in this connection. He (Mr. Halliday) was a little disappointed that in connection with this paper they had not been furnished with particulars of the different refrigerating machines employed on board ship, and he hoped that before the discussion concluded they would have some more information before them on this subject. He was particularly anxious to know to what extent, if at all, the cost of running refrigerating plant was affected by the temperature that had to be maintained in the chambers.

Mr. J. T. SMITH (Member of Council) said that one point referred to in the paper was as to the possible future of aluminium as a material for shipbuilding. Three or four years ago a paper on this subject was read before the Institution of Naval Architects by, he believed, Mr. Yarrow, who built a vessel largely of aluminium for the French Government; but that experiment, he thought, proved a failure. He (Mr. Smith) had seen aluminum tried on board ship, but it was a dead failure. It would not stand exposure to sea air. They might get a composition largely mixed with aluminium which would stand, but up to the present, so far as he had seen it tried, it would not stand the sea air.

Mr. W. McLAREN (Member of Council) expressed his conviction that the next yacht to race for the America cup would have very little aluminium in it, for what had been put into the *Shamrock* had been very misleading. Reference had been made in the course of the discussion to the *Great Eastern*, but he thought that Brunel ought to be complimented on her construction, for at that time she was the only vessel suitable for laying an Atlantic cable, and he did not believe that submarine telegraphy would have advanced as it had done if it had not been for this ship. There was another instance now at Silvertown, the *Hooper*, which was unfit for carrying cargo, because she would not pay, but the tanks were first built and the shell built round them. The *Faraday* was a ship of the same kind, and she had been tried as a cargo carrier, but would not pay. It paid better to lay these ships up until there was some cable work to be done rather than send them on general voyages.

Mr. J. THOM (Member) said he had not had the pleasure of reading this paper, but with regard to the frozen meat trade there were many ships now carrying frozen meat cargoes which were not built for that purpose, and they were doing the work satisfactorily. If they took a ship with fine lines, the insulation of the holds for frozen cargoes reduced the carrying capacity of the vessel by some twenty per cent., and a good freight was required for the meat in order to make up for this loss. Frozen cargoes were not carried both ways, and with other cargoes of a certain class the space occupied by the insulating material and refrigerating plant might easily reduce the ship's carrying capacity by thirty or even forty per cent., a serious item when freights were low. The methods of treating frozen cargoes on board ship differed according to the character of the meat or produce carried, and the distance that it had to be carried. For instance, beef and mutton from Australia were brought over in a frozen state—frozen hard—while most of the meat brought from North America was only chilled; chilled meat will keep quite good for six weeks. There was nothing more done to the meat brought from America than was done to the meat killed at Deptford. A great deal depended also upon the manner in which the meat was frozen in the first instance, and special care was likewise necessary in the thawing, or the effect would be seen in the condition of the meat when it was put on the table. In freezing beef or mutton the temperature must be brought down slowly, so as not to enclose any heat in the centre of the meat by freezing the outside prematurely. Of course the carrying of chilled meat from America was an entirely different process from carrying frozen meat from Australia, and chilled meat from America sold for twenty-five per cent. more than frozen meat. There were many things besides meat that were carried in refrigerated or cold chambers on board ship. Fruit was carried in this way; but most of the perishable fruits, such as grapes, were not easily carried because of the difficulty of circulating air through them. Then again such fruits as apples and oranges gave off noxious gases which had to be got rid of by pumping.

Mr. N. K. McLean (Member) remarking upon the large extent to which the people of this country were dependent upon our sea-borne traffic for food supplies, asked what temperature was maintained in the refrigerated chambers when frozen mutton was carried on board ship. In carrying beef, the temperature was not allowed to go below 30 deg. Fahr.; if it went lower the beef became too hard, and if it went higher the beef got too soft. It had to be kept at one certain temperature, and he believed that more care was required in carrying beef than in carrying mutton. He had never figured out the actual cost of carrying these meat cargoes, but he believed that in carrying, say, 2,000 carcases of beef across the Atlantic the running of the refrigerating machines cost, roughly, about £36.

The Chairman: You say there is more risk in the transit of beef in the cold chambers than in the transit of mutton?

Mr. McLean: Yes, I understand it to be so.

Mr. Atkinson (Member) related his experience in connection with a steamer that was not originally built for the frozen meat trade, but which was subsequently fitted with insulated chambers and refrigerating plant; and said it was estimated that her carrying capacity outwards was diminished by at least 15 per cent. In carrying mutton, his practice when chief engineer of a steamer in the trade was to keep the temperature anything below about 26°—from about 26° to 18°—and he never had any bad meat; but with regard to the homeward freight it should be borne in mind that mutton was a very light cargo, and the ship to which he referred when carrying 40,000 carcases and full of mutton fore and aft would be on light draught. The tonnage of the ship was just under 2,000 tons, and her deadweight capacity was about 4,000 tons. He estimated that the running of the refrigerating machines would require from four to five tons of coal per day, and then, of course, there were the extra hands necessary for attending to them.

Mr. THOM: The deadweight of 40,000 carcases of mutton would probably be less than 1,000 tons.

Mr. ATKINSON: The ship was in very bad trim.

The CHAIRMAN: That was the case of a ship which was not built for the trade. I believe they are building ships now to carry mutton that will go down to their marks.

Mr. THOM: I do not believe that any ship is being built which will go down to her marks with mutton alone.

The CHAIRMAN: It is suggested that we now adjourn the discussion on this paper until this day fortnight—Monday, April 23rd—when the Author will reply to some of the remarks that have been made.

The discussion was adjourned accordingly; and a vote of thanks to the Chairman, proposed by Mr. McLAREN and seconded by Mr. HALLIDAY, concluded the meeting.

Mr. W. M. TAYLOR (Visitor): It affords me much pleasure to make some contribution to your discussion on the series of papers which have recently been read to you by my friend Mr. Adamson. I do not pretend to have any special fitness or qualifications for the task, and if you confined your studies to subjects of a strictly departmental character I should have no claim to be heard. But I observe that you interest yourselves in matters more remotely connected with your business, and of this kind I may be able to add something to that store of information which you are collecting in your library. In the face of the fierce competition which nowadays presses both upon the individual and the nation, we must all be students from the cradle to the grave, and any Association such as yours, whose object it is to further our progress in the use of those forces which nature has placed at our disposal, is entitled to succeed.

A perusal of Mr. Adamson's paper has brought to my mind two subjects upon which something further may be said. These subjects are separate and distinct, and not connected the one with the other. The one may be termed a national or political question, the other a class or trade matter. In the second part of his paper Mr. Adamson refers to the growth of our imports of frozen meat from the Colonies and foreign countries. The extent to which this country was assuming dependence upon other countries, for food supplies especially, formed a subject of public consideration some years ago, and I myself was interested to some extent in the question of the importation of such articles as could be produced at home, and in special reference to the proportion which these imports bore to the home products.

I did not propose to deal with such an article as sparkling wine, which is occasionally an object of much solicitude on the part of the Chancellor of the Exchequer, or with Havana cigars, of which I believe engineers are particularly, though not exclusively, fond. But I deemed it an interesting question to give some attention to those imports upon which the health and stamina of our people more immediately depend, and which may be shortly spoken of as corn, butcher meat, and dairy produce. An account is appended to this contribution which gives in intervals of four years the quantities and values of these imports, and a second account showing the percentages which they bear to the produce in the United Kingdom of like articles is also annexed.

In looking at the account for 1894, and comparing the value of wheat imported in that year with the value of the imports of 1890, you will observe that there is a decrease of nearly £6,000,000 sterling. But if you compare the *quantity* of wheat imported in 1894 with the quantity imported in 1890, you will find that there is an increase of 13,000,000 cwt. Though the money value was less the wheat imported was considerably more. This is accounted for by the fact that there was a drop in the price of that commodity in that year of about 2s. 6d. per cwt., or nearly 30 per cent. In 1898 there was a recovery in the price, which works out at 8s. 9d. per cwt. In 1890 the price per cwt. was 8s. 6d., and in 1894 it fell to 5s. 11d. or 6s.

A word of caution may be given here. If you look at the sterling value of wheat, barley and oats imported in 1894 and compare it with the value of the imports during 1890 you will see there is a decrease of nearly four millions sterling. These figures may be used, and possibly have been used, by those who delight to tell us such things, as evidence of a decline in the trade of the country. Yet there was no decline. The quantity of corn imported in 1894 is nearly 30 million cwt. in excess of the quantity imported in 1890, though we had to pay less for it, and surely the less we have to pay the foreigner for our supplies the better. But the cheapness is more apparent than real. The whole account shows that there was a considerable fall in prices in 1894 which would apply to exports as well as imports, and so it is that the country goes on and prospers notwithstanding the gloomy predictions of those who are continually telling us that we are going to the dogs.

With regard to the value of fresh meat imported, which amounts to nearly 6 millions sterling, over 4½ millions is imported from America. And in the case of mutton, of the £4,900,000 nearly £3,000,000 is the value of the imports from Australasia. You will observe that the national bill for butter amounts to nearly 16 millions sterling, and of this sum nearly 7½ millions is the value of the butter imported from Denmark.

Turning now to account No. 2, the consideration of which is perhaps more interesting, you will observe that the imports are set down in relation to home products and the percentages on the whole account appertaining to each are given in the margin. In the case of wheat it will be seen that the British farmer is still able to contribute 33 per cent. of the whole quantity available for consumption. But it is only right to say that the produce of the crops at home in the year 1898 was considerably greater than some previous years, and 25 per cent. to 27 per cent. would be a fair average of the amount of the home production. With regard to barley and oats, the percentages of the home supply look satisfactory, being 58 per cent. and 79 per cent. respectively.

There are, of course, no official figures relating to the value of beef and mutton raised at home, but after a good deal of trouble I secured the figures here given and I think they are thoroughly reliable. From them you will see that of the total value of beef consumed in this country we are able ourselves to provide 68 per cent. If the quantities were available different percentages might result, but, inasmuch as from 10½ to 11 millions sterling of the imports is the value of beef brought over from America, which sells at a figure little less than English meat, the percentages might not differ much from those here given. With regard to mutton the figures are quite startling. It must be a revelation to most of us to discover that as much as 78 per cent. of the total quantity consumed in this country is produced at home, or if we take another calculation as much as 70 per cent. The relative prices of English and frozen mutton show a greater disparity than those of beef. Probably the price of frozen mutton would be two-thirds of the price of English mutton, so that if we add half as much again to the value of mutton, as has been done in this account, we may get a closer estimate of the relative quantities consumed, and even then, as I say, the proportion raised at home is 70 per cent. It would appear that in a time of stress we should not in this country be left in such desperate straits as the defenders of Mafeking.

In 1898 butter cost us nearly 16 millions sterling. Why this should be our farmers can perhaps explain, but it would appear that there are other ways open to them of increasing their profits besides the making of jam.

Coming now to the second branch of our inquiry, which concerns us here more immediately, I am afraid I must deal with it more briefly as I have already occupied much of your time. Mr. Adamson makes reference in one of his papers to the great expense incurred for a voyage of one of our large passenger liners and contrasts it with the expenses of a cargo steamer of the type with which we are now becoming familiar. Undoubtedly the expenditure entailed in running a line of large passenger steamships is very heavy, as an examination of the accounts of some of the principal Companies trading from our own shores will show. Let us take six out of the leading companies and look at their accounts. The six which I have selected employ a capital of £6,869,040, and the result of the year's working in 1898, if we take into account only their ordinary receipts for the carriage of passengers and cargo, was a loss of £234,744 or about £3 8s. 4d. per cent. upon the amount of capital involved. In this loss there is a charge included for depreciation of the ships. The amount written off for depreciation is shown as a debit in the Profit and Loss accounts of the Companies, but the depreciated value and not the first cost of the ships has been set down on the balance sheets, and therefore it is impossible to say at what average rate depreciation has been charged. British shipowners have a legitimate grievance when they complain of the severe hardship to which they are subjected in being forced to compete with highly subsidised foreign mail companies. The subsidies received by the chief French and German companies are out of all proportion to the receipts of British companies. In a paper which he read in October, 1893, to the Engineers' Institute of Scotland, Dr. John Inglis says: "Another mode of comparison shows that the four foreign countries quoted (France, Germany, Russia, and Italy), pay for mail service a sum which bears to their total import and export trade the ratio of 1 to 336, while in the case of our own country the ratio is 1 to 1,161." It is easier to state this than to suggest a remedy. The Chancellor of the Exchequer has to find £154,000,000 sterling as the estimated national expenditure for the current year, and it is hopeless to expect any increased subsidies from the British Government. What the mail companies do receive even now is not to be despised. Of the six companies whose accounts we are examining, five receive mail-money. It is somewhat difficult to ascertain what the amount of it is, but I think it is very approximately stated at £561,874. This converts the loss from what we have called ordinary revenue into a profit of £327,130, or about $4\frac{3}{4}$ per cent. on the amount of capital employed, or, if we exclude the P. & O. Company, equal to about £3 8s. for the remaining five companies. This is not a very handsome return, but it is quite evident that without postages it would be impossible nowadays to carry on a service of fast passenger steamers to any part of the world.

The ordinary passenger seems to have little notion of these things, and of the extent to which he is benefited by the receipts of passenger lines other than passengers' fares. To cross the Atlantic in five days is a magnificent performance, but it is not business.

In reference to the cost of running individual steamers Mr. Adamson has given us an example. His illustration exhibits the cost at so much per mile run, but I have not been able to find time to follow his figures on this basis. Another mode of comparison might also be adopted showing the cost at so much per *ton* (gross) for the voyage.

On a future occasion we may be able to pursue our investigations on this subject. In the meantime I have to thank you for your acceptance of these observations.

Account showing the Quantities and Values of the following kinds of Agricultural products imported into the United Kingdom during the years 1890, 1894 and 1898 :

	1890		1894		1898	
	Quantities	Values	Quantities	Values	Quantities	Values
		£		£		£
Wheat, Wheat Meal, and Flour, Cwts.	76,247,516	32,658,906	89,268,960	26,757,242	86,245,439	37,681,963
Barley .. .. ,,	16,677,988	4,985,406	31,244,384	7,090,079	24,457,004	6,791,472
Oats .. .. ,,	12,727,186	3,908,497	14,979,214	3,900,096	15,577,900	4,383,457
	105,652,690	41,552,809	135,492,558	37,747,417	126,280,343	48,856,892
Cattle .. .. No.	642,593	10,505,547	476,021	8,293,785	569,066	9,399,793
Beef (fresh) .. .. .. Cwts.	1,854,593	3,923,015	2,104,094	4,213,671	3,100,221	5,915,615
		14,428,562		12,507,456		15,315,408
Sheep and Lambs .. .. No.	358,458	696,312	484,764	804,995	663,749	984,863
Mutton (fresh) .. .. Cwts.	1,656,419	3,447,776	2,295,065	4,341,227	3,314,003	4,902,183
		4,144,088		5,146,222		5,887,046
Butter .. .. Cwts.	2,027,717	10,598,848	2,576,063	13,470,419	3,209,093	15,960,571
Cheese .. .. ,,	2,144,074	4,975,234	2,263,287	5,467,137	2,339,452	4,970,247
Eggs .. .. .. Gt. huns.	10,291,246	3,428,802	11,876,968	3,786,320	14,424,582	4,456,123
Grand Total		£79,128,343		£78,124,971		£95,446,287

Account showing either the Quantity or Value of the following leading Articles of Food produced in the United Kingdom and imported from Abroad during the year 1898 :

Home Products			Foreign Imports		
	Quantities	Per-centages		Quantities	Per-centages
Wheat ..cwts.	42,791,429	33·2	Wheat ..cwts.	86,245,439	66·8
Barley .. ,,	34,696,536	58·7	Barley .. ,,	24,457,004	41·3
Oats .. ,,	61,635,000	79·8	Oats .. ,,	15,577,900	20·2
	139,122,965			126,280,343	
	Sterling Values			Sterling Values	
	£			£	
Beef	33,595,516	68·7	Beef	15,315,408	31·3
Mutton	20,879,684	78	Mutton	5,887,046	22
*do.	20,879,684	70·3	*do.	8,830,569	29·7
Butter	9,721,380	37·8	Butter	15,960,571	62·2
Cheese	7,403,700	59·8	Cheese	4,970,247	40·2

* This amount, as explained in foregoing contribution, would represent approximately the value of imported mutton, if sold at the price of home-raised mutton; that is to say, the values of home-raised to imported are given on a common basis of price.

DISCUSSION CONTINUED

ON

SEA-BORNE TRAFFIC,

MONDAY, APRIL 23rd, 1900,

AT 58 ROMFORD ROAD, STRATFORD, E.

CHAIRMAN:

MR. A. BOYLE (CHAIRMAN OF COUNCIL).

THE CHAIRMAN: We commence our business this evening by asking Mr. Adamson to reply to the discussion on Part II of his paper on "Sea-borne Traffic," which took place at our last meeting, after which we hope to hear Part III, dealing more especially with the subject of propulsion.

Mr. JAS. ADAMSON: It would be interesting if we could tabulate and compare the cost of carrying goods by land as well as by sea. Time has not admitted of my arranging notes I have culled from various sources to show the running expenses of passenger and goods trains, of haulage by horse-power, by oil, by electric power, etc. The upkeep of the roads—stone as well as iron—is an item of expenditure added to the purchase price of land and property, and the outlay on the making of the road, which the steamship knows not, except—as an approximate equivalent —in respect to harbours, lights, and rivers where Government regulations and vested rights have claims upon the tonnage.

A goods train for an average week's work, allowing the wagons to be fully loaded on both the outward and the homeward run, gives about ·098 lb. of coal per ton carried per mile; this is about three times the coal used by an economical cargo steamer of $9\frac{1}{2}$ knots per hour. The average cost of coal per ton for the railway engines will be about 15s. to 16s., and for the steamer 22s. to 24s., less or more according to the route and the class of coal available; the cost of oil for a week's work on the goods engine is about 3s. 6d. The cost of grease for the wagons I have not, but I apprehend the cost for lubrication in all would be under 20s.; the wages for the driver and fireman about £3 8s. to £3 10s. Summing up these various items of cost we therefore have the following for a week's run: Coals £9; lubricating material £1; wages (including guard) £5. The weather will affect the coal consumption, a strong wind increasing it by about 20 per cent.

The balance sheet of one of our steamship companies shows the following percentages; and in considering the expenses involved in connection with both railway and steamship traffic it behoves us to do what in us lies to reduce the costs in each department, consistent with true economy and regard to upkeep, so that from a national as well as a personal point of view we may maintain our position as the carriers and traders of the world's produce:

Fleet value to coal consumed	=	100 : 13·8
,, ,, ,, cost of upkeep	=	100 : 6·5
,, ,, ,, wages, dues, etc.	=	100 : 49·6
,, ,, ,, head office management	=	100 : 2·24
,, ,, ,, directors' fees	=	100 : ·37
,, ,, ,, insurance	=	100 : 3·9

Apropos of Mr. Lawrie's reference to the interesting researches made with a view to trace the origin of the Phœnicians, and his further comment in drawing a parallel between them and the British, one is reminded of the recently published handbook entitled *British-Israel Truth*, a perusal of which will interest if it does not convince us of our responsibilities and our privileges from the standpoint of the editors. About twenty-four years ago I met a fellow countryman in Japan who was collecting evidences from which to show the identity of the Japanese with the lost tribes of Israel. Since then Japan has moved to the front, and the recently constructed steamers are now regular traders to and from our shores in connection with the *Maru* line.

I was pleased that Mr. Pollock called our attention to the fact that there are cargo-boats running towed as he described, and it would be interesting if we could get from Mr. Pollock the approximate cost of carriage by that means; all the more so in view of the fact that the farmers of this country are complaining so much of the cost of railway carriage and urging that some means should be found by which they could get their produce into London and other centres of commerce cheaper, or at any rate as cheap as their Continental rivals. With reference to refrigerating machinery I only referred to that in the paper incidentally, as I understand one of our members may shortly give us a paper on that particular subject. Mr. Hawthorn gave us some very interesting figures showing how the economical running of a steamer might be brought about by a higher speed or a lower speed, according to the traffic in which the vessel is engaged, and when the cost of keeping passengers may exceed the cost of coal when a certain speed had been reached. Of course, as Mr. Hawthorn explained, his figures were only relative to show the principle he was advocating. Mr. Lawrie has referred to the competition which we have to encounter from our rivals on the Continent and across the "Herring Pond." Mention was made of the small cost of carriage for bringing meat from Australia and our other Colonies to this country, but although the freight when stated per pound looks very small it really amounts to about £7 a ton weight, which is a very good freight nowadays. Of course a set off against that is the fact that about 20 or 25 per cent. of the stowage capacity of the ship is taken off by the insulation and another large percentage for stowage, so that the £7 per ton has to be considerably reduced when you consider it in relation to the capacity of the steamer; besides which, as a rule, it is only on the homeward voyage that the refrigerating machinery is used. Mr. Ruthven referred to a diagram which he is preparing, with a view of placing before us the coal consumption per ton displacement per mile at different speeds and for different displacements. Mr. Ruthven has been unable to complete his table, but I hope that before this paper is printed we shall have it, as such a diagram will be a valuable addition to our *Transactions*, as showing the limits within which steamers can be driven economically at higher or lower speeds in relation to their displacements. The hint that aluminium might be used more largely in the future has elicited the experience of Mr. Smith that it has been tried and found wanting, so far as its use in sea water is concerned. Mr. Thom and Mr. Atkinson gave us some interesting details about the carriage of cargoes in refrigerating chambers, and referred to the broken stowage and to the fact that water ballast or some other heavy cargo was required to counteract the light weight of the frozen meat brought home. Reference was also made to the chilled meat which has been brought into the market, and which has been preferred to a large extent to frozen meat. Reference was made to the carriage of fruit, and that is a portion of the subject which is particularly interesting. It would be valuable to know at what temperature the different kinds of fruit should be kept, so as to bring them to the market in a fit state for consumption. I have seen the results of some experiments that were made for bringing home some of the finer fruits of India; some have been fairly successful, others have been an utter failure, showing that there is a finely drawn limit at which some of the best fruits can be carried without detriment to their flavour and placed on the home market. There is seldom any demand for taking frozen meat abroad from this country, except for ship use, although there have been instances where frozen meat brought to this country has been again taken out and landed at Port Said and other ports. One thing I do think is a great hardship upon shipowners, when their steamers are used as floating warehouses in port for the storage of the meat, because consignees are not ready to take delivery of the cargoes at once. The meat is discharged bit by bit, so that it is often necessary to keep the refrigerating machinery going for weeks longer than it ought to be running. This, I believe, is being overcome by the enlargement of existing cold stores and the erection of new in various centres.

Mr. W. McLaren (Member) said that before the discussion closed on this section of the paper he would like to mention the petroleum steamers constructed for the carriage of oil in bulk. They had not yet heard anything about this particular trade which was now becoming very prominent. There was one point however in regard to which he thought they might sympathise with shipowners, and that was with reference to quarantine arrangements and regulations at foreign ports. Great delays occurred through these regulations. On the coast of Brazil, for instance, they had sometimes to go some 200 miles to the quarantine station. Delays of this character were most detrimental to the trade, and a feasible way in which individual companies might avoid this loss was to establish direct services to these ports without calling at intermediate places to land passengers and so forth. They should be quite able to provide their ships with sufficient stores to carry them through.

The Chairman: If there are no further remarks, we will close the discussion on Part II, and ask Mr. Adamson to read Part III.

The Chairman: Well, gentlemen, we have now before us a most interesting paper, which goes over a great deal of ground and offers great scope for discussion and the expression of opinions.

Mr. ADAMSON: Seeing that three of our members who hoped to be present have been unable to attend, I have been desired to express a few thoughts suggested by them for special discussion on the subject before us. With regard to the boat fitted with a centre paddle-wheel referred to in the paper, this was an experimental boat, the owner of which was making certain experiments with a view to the preparation of a book dealing with propulsion. It would therefore be premature now to give the results obtained. Another member desired that special attention should be called to the tortuous line which a steamer sometimes makes owing to the steering by the helmsman, and a method that he employed to bring this point home to the steersman in a ship in which he was engaged. A rope was laid on the deck and put in the form of a serpent, and then laid out straight; this object lesson, to enable him to see how many more miles he had caused the ship to run than there was any occasion for, was pointed out to the captain, and by him to the steersman. Another member desired me to call attention to the pitting which he has seen in some bronze blades fitted on steamers running in the Atlantic trade, and he should like to know if other members had had similar experiences. On running his fingers over the surface of the blades in the dark they almost seemed like cast iron, so rough were the surfaces.

Mr. SHOREY: I cannot say that I have had any experience with phosphor bronze blades, but I want to ask one or two questions. These tables have doubtless been got out with a great deal of trouble; but did I understand Mr. Adamson to say that one ship which he referred to was tried with bronze, steel and iron blades—the same ship?

Mr. ADAMSON: Yes.

Mr. SHOREY: Of course on different voyages? What I mean is this, were they run under similar conditions? You may have had very fair weather with bronze blades, and quite the opposite with iron and steel. I certainly agree with the author of the paper that bronze blades should show the best results, but there is one point on which I should like to ask a question. He says: "It is surprising how the blades—especially bronze blades—become coated with sea grass." I should like to know if these bronze blades become more coated than iron or steel. The author has probably had an opportunity of finding that out. Again, speaking of propellers, have we yet arrived at what is the best pitch for a propeller with an engine running at a certain speed—the most economical pitch? Is it more economical to run an engine at a high speed with a fine pitch propeller, or at a slower speed with a coarser pitch?

The CHAIRMAN: We shall be very pleased to hear any remarks that Mr. Roberts may have to offer on the subject. The firm with which Mr. Roberts is connected were among the first, I believe, to use bronze blades.

Mr. W. C. ROBERTS said reference had been made by Mr. Adamson to a vessel with which he was connected. She was not exactly the first steamer to run with bronze blades on her propeller, but she was one of the first to be so fitted, and this occurred nineteen years ago. It was the case of the *Glenogle*. She was fitted with bronze propeller blades of a very peculiar shape. On the backing side the blades were fitted with a form of ribs which were designed to destroy the vacuum that was supposed to form. The arrangement was called a patent, and was treated as a great secret, the blades being cast altogether unknown to the owners, whose representatives simply indented for plain blades. The propeller also revolved in a kind of banjo frame, and there was a 6-in. pipe leading down from the deck of the ship to destroy this vacuum. The object of this arrangement was to increase the speed, but they had not left Glasgow long before it was discovered that a serious mistake had been made. Instead of increasing the speed this patent took three knots an hour off the speed of the ship, so that they had to put into Belfast Lough, where the patent propeller was reduced as far as possible to the form of an ordinary propeller. That was the result of his experience with a patent propeller; and as a rule it was not a very safe thing to "take on" with a patent propeller unless they were fairly certain as to the result. For preventing the pitting of propeller blades his firm had adopted a system which they had found very good, and that was to pin pieces or strips of Muntz's metal on to the cast-iron blades. Two steamers were fitted in this way twelve years ago, and, although they had been running almost constantly, it had not been necessary to touch them since.

Mr. HALLIDAY: Are the surfaces machined before they are brought together?

Mr. ROBERTS: Not at all. The paper is a very excellent one throughout, and ought to give rise to a very interesting discussion, but it requires a little thought before one can venture an opinion on a number of the points raised. I will sketch on the blackboard the plan of the arrangement I have described, to make it more clearly understood. Although it was not a success it may be of interest to members present.

Mr. J. R. RUTHVEN: While we are upon the subject of pitting I may say that at one time I was at a place where we used to cast propeller blades, and I took a great deal of interest in trying to induce the moulders to make a larger number of risers from the tips of the blades, and although I could not follow it all through I believe there was a great improvement in consequence. They got more metal through the moulds, and they got better metal—more dense metal right up to the tips of the blades. I wanted to see if, by giving greater facilities, we could not get all the bad metal to come away, and I believe the system was a success.

Mr. Howie (Member) said he did not agree with Mr. Ruthven when he recommended that in casting propellers the risers should be placed in the way of the blades as well as over the boss. Personally he (Mr. Howie) did not think this necessary. The great difficulty had always been to keep the boss clear of wash and blow-holes. The blades when lifted clear of the mould were generally clean and sound, and no great advantage would be obtained for the added expense of Mr. Ruthven's method. Good, substantial, and heavy risers could always be used to good purpose. In the hands of a careful and experienced moulder there was at present no practical difficulty in the casting of propellers or propeller blades. There was a difficulty, however, in securing the correct pitch in cast-iron propellers at the tips. He spoke of cast-iron only because the propellers which he had checked had been made of that material. This trouble was often seen in the lessening of the pitch by what they might call the warping of the thin part of the blade during the process of cooling. Many reasons had been advanced for this state of things, but it had been found that by increasing the pitch at the tips by about 9 in., of a propeller of 16 ft. in diameter by 16 ft. pitch, they would secure the desired measurements. This was worth doing when it was known that pitches could be incorrect by differences of 12 and 18 in. It seemed to him that these differences would account for the comparisons shown by Mr. Adamson in his able paper between the results of bronze and cast-iron propellers in actual working. Assuming the bronze blade to be a correct pitch and not subject to the same tortive movement in casting, and the cast-iron propeller lessened in pitch, the revolutions were necessarily higher, the slip greater, more steam was used, and, therefore, more fuel wanted. Everything being equal, therefore, they might expect—in spite of the smooth surface given by the bronze material, which could be given to cast-iron by the same process—equal results. Whether it was because of their great ductility resulting in frequent twisting or for other reasons, there seemed lately to be a tendency to increase the thickness and therefore the weight of bronze propellers, so that any gain in this way over cast-iron would be lost. He would like to bear out what Mr. Adamson had said in reference to the re-ending of propeller blades. This work carried out successfully must end in a saving whenever adopted. But it should not be placed in the hands of any or every moulder. The fusing of the old and new parts, to make a good job, could only be obtained by very close attention and careful practice. Re-ended blades which broke a second time broke below the weld, thus showing the great strength of the work. In fusing cast-iron tips to steel the quantity of metal used was very much greater than when fusing cast-iron to cast-iron. With the help of Mr. Adamson, a London firm had carried out work of this kind in large propellers for some years past. The experience related by Mr. Roberts showed how much some of us were groping for knowledge of propellers. The patent which that gentleman described was designed to get rid of the vacuum created by its working. Other inventors seemed to design propellers to set up a vacuum. The late Mr. Mudd had a method during the process of moulding of so altering the bed at the tips as to increase the pitch, say from a uniform one of from 15 or 16 ft. to 21 ft., and doing the same at the roots of the blades, but in the opposite direction, decreasing the pitch by laying on more loam, the laying on and the taking off diverging from the point of the centre of effort. This seemed to have had the same effect as the dropping of a blade off a four-bladed propeller, leaving three to work intermittently. A similar motion was set up with a slight increase of speed. Theoretically it was difficult to form a rule from the experiment, and in practice it was pernicious to both mind and engines.

Mr. HAWTHORN said that during the reading of the paper a thought struck him as to the efficiency of the propeller itself. When was the propeller working most efficiently? What amount of slip was it best for a propeller to have in working? All propellers made a certain amount of slip, and it was not a good working propeller that made no slip. He should also like to ask if any gentleman present had had any experience in working propellers having four blades on the same boss, but with different pitches. He had heard that propellers of this class had been tried on the Continent and seemed to be yielding very good results. He had a very painful recollection of an experience in one steamer with a propeller fitted with cast steel blades. She threw off all four blades, and they were thrown off apparently by centrifugal force during the racing of the engines. The steamer at the time was going across the Atlantic light, and it was some six weeks before she was towed into Falmouth. After the accident she simply took charge of the North Atlantic, and seemed to think it belonged to her. This was the case of a steamer of some 5,000 tons, and it occurred in the year 1880.

Mr. HALLIDAY said that figures were given in the paper which purported to furnish a kind of comparison between ships fitted with propellers that had bronze, steel and iron blades, but Mr. Shorey put the point very nicely when he asked if all the voyages were made at the same time or at different times. Of course that was the whole question. Had there been trials between sister ships—one fitted with bronze blades and the other fitted with steel blades—and had the voyages been made under similar conditions, of course there would be material for a fair comparison. But he did not see how they could make a comparison between results obtained by different ships on different voyages under different conditions. To get over this difficulty of different voyages Sir John Durston had been running two similar vessels on parallel courses from Gibraltar for a distance of 1,000 miles, and under such conditions it was possible to compare what was going on, but when ships, propellers, voyages and conditions were all different it would seem that any reliable material for comparison was an impossibility.

Mr. ATKINSON: With regard to the illustration which Mr. Adamson gave of laying a rope on deck, and then drawing it out straight to show the distance saved by steering a straight course, I was thinking he would be a bold engineer to bring the captain down to show him that. It is not always the steersman, however, who is to blame, and with regard to some ships, I think that when they design a ship they ought to design a man to steer her. In nine cases out of ten a ship will not steer without excessive care on the part of the steersman. I have tried it, and I know I could not keep the ship straight. If a ship is full aft it is not an easy matter to steer her.

After a few remarks from Mr. JOHNSTON the discussion was adjourned, and it was suggested that the paper and discussion should be printed and circulated to the members, contributions being invited in writing meantime.

Mr. SHOREY proposed, and Mr. Alderman KIDD seconded, a vote of thanks to the author; and a vote of thanks to the chairman for presiding concluded the meeting.

INSTITUTE OF MARINE ENGINEERS

INCORPORATED.

SESSION 1900-1901.

President: COLONEL JOHN M. DENNY, M.P.

SEA-BORNE TRAFFIC.

CONTRIBUTIONS BY CORRESPONDENCE.

Mr. EDWARD SELBY writes, under date October 2nd, 1900:—Through your kindness I have much enjoyed reading the papers and discussion on "Sea-borne Traffic," which you sent me, and, if you will allow me, I should be glad to inform you that your estimate as to the cost of lubricating material, on an average week's run, for a goods train, is well over the mark, as far as I have been able to ascertain. I do not think that any railway company, or locomotive superintendent, could say with accuracy what oil or grease was used per mile per wagon. It would not, perhaps, be worth the cost of keeping account of such a small item of the total expenditure. On the results of a trial of axleboxes on a colonial railway, the locomotive superintendent said that a wagon ran 20,000 miles, using only six pints of oil. On the other hand, I have seen at least $\frac{1}{4}$ cwt. of grease (value about 6s.) put into the axleboxes of a wagon when running warm in the course of a day. I do not think many experiments in the use of grease in running wagons have been carried out, but in the course of several experiments in the comparison of oil and grease axleboxes which I have been connected with, I concluded, what most people would probably think an axiom—but which all railway companies do not yet seem to have grasped—that it pays far better to spend money on good and efficient lubricating appliances than on more hauling power. I remember a few years ago, while fixing some machinery at a large works, that I could push a wagon along a road by hand, and that another wagon of exactly the same weight and build could only be moved on the same road with a crowbar. The first wagon was fitted with axleboxes efficiently lubricating the journal with oil, and the second wagon had grease axleboxes which did not lubricate the journal at all until it got warm. It does not seem that there is much question why there is so great a difference in the cost of sea-borne and land-borne traffic to read your figures showing percentages from the balance-sheet of a steamboat company. I take it that the 23·69 percentage that you do not account for represents profits to the owners, and I am sure railway directors would be very pleased if their percentages only showed half as well. It is a very important point for the population of this country that the cost of carriage of inland traffic should be kept as low as possible, and in my judgment, one of the most costly factors in railway working, which steamship companies do not have to contend with so much, is the huge capital expenditure that railways are always under. The rapacity of landowners and lawyers add greatly to the cost of carriage, as the railway companies have to look for their repayments to what they can make out of the population of the country, and it is difficult to see why, as railways benefit all classes, one small section of the community should be able to heavily charge the railway companies, and yet benefit by them, while the great majority of the population have no voice in such charges at all. In reading Mr. Ruthven's contribution to your discussion, I began to wish he had gone a little further, and given some reason why a 4,000 ton steamer should take double the coal of a 9,000 ton boat.* If the weight of a railway train is doubled, you can depend on having the coal consumption doubled too, if the engines are the same type, and I should like to know if, in the steamships Mr. Ruthven refers to, the boilers and engines were not of different types, and if the larger boats were not fitted with more economical engines and boilers, which would go far to account for the immense coal saving over the smaller boats. Has there ever been any test of the power absorbed by the friction of the propeller shaft in the bearings and thrust block? With a shaft of large diameter, it seems to me there must be a tremendous amount of power absorbed in the friction of the shaft itself. I should also like to hear if roller bearings have ever been tried for propeller shafts. They could probably be used as easily as they are used in line shafting on land, and if more expensive at first, what is that if coal is saved? In my humble opinion, too, the usual method of lubricating large shafts through an open cup at the top is wrong. The grit can get down there as easily as the oil, and I submit the shafts should be lubricated at the sides, or from underneath, by means of pads or brushes of wool, with wicks attached to syphon up the oil. I do not remember to have ever seen the percentages of expenses of a railway company worked out in the way you have shown with the steamship company, and it would be very interesting if you could get a railway company's balance-sheet analysed in the same way you have done with the steamship company.

Mr. J. R. RUTHVEN (Member of Council): The economy in horse power per ton carried in large vessels, compared with small vessels, has been known for many years; but the exact amount has always been difficult to prove. The figures I gave were from results of a large number of vessels, all of modern type, and each result was from a number of voyages, each voyage about 16,000 miles. The subject is of great interest, and would make a valuable paper, including the data which could be collected in discussion. Brunel and

* Pro rata.

Scott Russell knew the advantages of large ships when they spent so much money to carry out their ideas; and our present shipowners know too.

Roughly speaking, the resistance to propulsion is chiefly due to the amount and quality of the skin surface in contact with the water. This skin friction varies approximately as the square of the size, while the capacity of the vessel varies as the cube of the size; from this it is evident that large ships must be economical compared with small ships. The value of my figures is due to their being taken from actual results of a large number of ships. If harbour accommodation can be provided, and large cargoes collected, the size of vessels, so far as economy of propulsion is concerned, will continue to increase.

Mr. P. W. PARSONS writes, under date Nov. 7th, 1900 :—I must apologise for the long delay in writing you in respect to your paper on sea-borne traffic, part 3, which I have read with great interest. I think the results and figures which you give prove conclusively :—

1. That, other things being equal, a bronze propeller is a distinctly superior propelling instrument to a cast iron or steel propeller.

2. That the best bronze results would be got with the strongest alloy, and the thinnest blade.

If, therefore, an owner decided to avail himself of the advantages of bronze, and wishes to obtain the full benefit to be derived from its use, he should not only select the strongest alloy, but should avail himself of the expert advice of makers of such alloy in determining his sections. This question of sections is a very important one, and the paragraph in your paper, which begins at the bottom of page 33 and continues to the middle of page 34, has a very important bearing on it. Now, as at the end of the paragraph you invite criticism, I have no hesitation in giving you my views.

It is, of course, obvious that a blade may be made either so thin as to spring under working strain, or so stiff as not to spring. The question arises, if it is advisable to make a blade thin enough to spring. I am distinctly of opinion that a blade should be so proportioned that it will not spring. It is quite possible for a blade which has been given too little pitch, to give better results if sufficiently thin to spring slightly to a coarser pitch, but it cannot be so efficient as a blade made with the correct pitch sufficiently stiff not to spring. Any spring in a blade must take place near the point, and an alteration of pitch there must produce a "drunken pitch" on the blade generally, which is not conducive to efficient working. Further, the difference in thickness between a blade which will spring slightly, and one which will be stiff enough not to spring, will be so trifling, that the cleavage resistance would hardly be appreciably affected. Again, the question of fatigue comes in, in a blade made sufficiently thin to spring, and the life of the springing blade would probably be shorter. Also, the amount of the spring being entirely indefinite, in quantity, the form of the blade becomes uncertain and unreliable. In conclusion, I consider any appreciable flexibility in a bronze blade is distinctly disadvantageous. Of course, if a blade springs, it should spring in the direction of a coarser pitch, and that will reduce revolutions. This acoounts for the argument of some who, as you say, claim that a greater efficiency in a bronze blade is shewn in reduced revolutions, only that the reduced revolutions do not indicate improved results, but only an increase of pitch due to springing.

The other side referred to in your paper who argue that flexibility would lead one to expect increased revolutions, do not appear to me to understand the question, as flexibility would tend to reduce revolutions. With a bronze and cast iron propeller identical with each other, except as regards sections, the increase in revolutions of a bronze propeller must, it appears to me, be due to the reduced cleavage resistance of the thinner sections and the reduced skin friction of the finer surface. As regards slip, we find that in replacing a steel propeller with a bronze one, we generally reduce the slip, and of course this tends to reduce revolutions, but to increase the speed, other things being equal, by the difference between the mean slip of each propeller.

The question of the pitch to be given to bronze blades to replace existing steel or cast iron blades, is a very difficult one, and it is impossible to lay down any definite rules, and the proper pitch can only be arrived at after a careful study of various data, such as the slip, the lines of the ship, the average speed in knots, the surface and general design of the propeller, etc., etc. At the same time it is clear from the figures you give, that the correct determination of the pitch of a bronze propeller to replace an existing iron or steel propeller, is of the utmost importance, as without the correct pitch it is impossible to fully realize the advantages to be derived from the use of bronze.

I now pass to paragraph three, page 35, in which you state that in the event of bronze blades becoming distorted, there is an advantage in being able to straighten them on account of the higher elastic limit of the bronze. This first part of the paragraph, I take it, refers to straightening blades cold, as you refer to straightening them hot in the remainder of the paragraph. I should therefore point out that we never straighten a blade cold, unless the bend is of an extremely slight nature, and very small in area. Further, in such case the high elastic limit of the material is distinctly a disadvantage, as it means the application of so much more power to overcome this spring in the material. Again, a material with a high elastic limit, is much more likely to be distressed if forced back cold. For this reason we invariably heat blades to a red heat, when the material is like lead, and can be bent in any direction required, to any extent, resuming its former rigidity and elasticity on cooling. In addition to the advantages which can be gained by the substitution of a bronze propeller of a suitable pitch, for a cast iron or steel propeller, in all other respects similar (except in regard to thickness of sections) there is in almost every case some further advantage to be obtained when ordering a new propeller, by slight modifications in the design, which modifications again require to be very carefully considered with all the procurable data of the performance of the ship with the old propeller.

You do not in your paper compare the efficiency of built up, with solid propellers, so I have not gone into the question, but should be interested to have your views thereon, whenever you have time to send them to me. The statistics given in your paper are, I consider, a most useful contribution to a subject which has not received the attention it deserves.

The Editor of the "Buchan Observer," of January 29th, 1901, writes as follows:—The carriage of products, home and foreign, to market is a subject that has received a large amount of attention, but has never been very satisfactorily solved up to the present date. The producer holds that the rates are too high, and the carrier takes the opposite view.

In these islands, before the days of rapid transit had arrived, every producer had to send his goods to market by the cheapest and speediest means he could command; and personal initiative and effort was the main factor in securing satisfactory returns. Now-a-days circumstances have entirely altered, except in the very remote districts, the products of which, however, exercise but a small influence upon the ruling price. For the markets from all the ends of the earth are now more at the command of the consumer than were those of his own countryside half-a-century ago. The produce of the American States can now more easily, and at a cheaper rate, be placed at the centres of British consumption than can those of the more remote districts of the north of Scotland, for example. The purpose of the paper above referred to went to show the extraordinary advances which had been made in regard to sea-borne traffic up to and after the inauguration of steamships, and its effects upon the British Isles. It is impossible here to refer even to the many arguments brought forward in the course of the discussion regarding the ways and the means by which over-sea traffic is so successfully conducted, but, although not specifically mentioned, one cannot help being reminded of the fact that produce can be carried at a cheaper rate to London or Liverpool from the United States than it can be done from the north of Scotland.

It is well-known that a passenger can travel from this country to the United States, or *vice versa*, at a cost of little more than he need expend in journeying from Wick to London—and that is where the advantage of sea-borne, as compared with land-borne, traffic is experienced, and where the difficulty of the home producer is in getting his produce conveyed to market. Our British Railway Companies have been blamed for their exorbitant carriage rates, but in spite of constant complaints and appeals to them they have failed to evince any very ardent desire to amend their charges, and the balance-sheets they issue periodically do not demonstrate to any pronounced extent that they are making a great deal of money by it either. The solution of the conundrum is probably to be found in the fact of the long distance traversed by ships compared with railway trains, for I have it authoritively stated by a traction engine proprietor, who recently entered into a contract to carry stones from a quarry for a distance of six miles, that, if he were paid at the same ratio per ton for double the distance, he could have retired with a competence in a few years. There's evidently a good deal more in carrying than most of us suppose.

We had really begun to think that three-fourths of the inhabitants of the British Isles were being fed on foreign food—on American flour and beef, Australian mutton, and Dutch butter and cheese. But happily that is not so, and if we were to subsist on somewhat short rations, we could yet feed ourselves irrespective of the foreigner. At least this fact is vouchsafed for by Mr. W. M. Taylor, who made an important contribution to the discussion. Mr. Taylor tackled the subject from a particularly wide stand-point, too wide to be commented upon in a cursory note, but some of the figures he quoted, obviously after elaborate and careful research, are of not a little interest to home folks, especially farmers. While we thought that almost all our wheat came from foreign parts, Mr. Taylor tells us that 33 per cent. of it is grown by British farmers, while 58 per cent. of barley and 70 per cent. of oats have a like origin. Again in the case of meat, 70 per cent. of it is British reared and fed, a fact which evokes from Mr. Taylor the statement that "in a time of stress we should not in this country be left in such desperate straits as the defenders of Mafeking." And so it is satisfactory to know that there is little danger of the "roast beef of old England," nor the brose of the north country running short in time of stress.

Mr. Jas. Adamson: In reply to the questions as to the comparative results tabulated in the closing part of the paper, the figures given are based upon the averages of twelve months' work, over the same courses, except where specially mentioned otherwise. It is well known that the results from sister ships cannot be used as a reliable basis of comparison for determining the different values of what may be fitted in these ships. Sister ships, as a rule, differ much in their results under the same conditions, so that it is impossible to gauge the values of different coals, propellers, or other fittings, without making allowances for known differences, based upon the averages of each steamer, extending over a considerable period. Referring to the cost of land-borne traffic, there was an interesting leading article in the "Glasgow Herald" of September 8th, 1900, where the traffic receipts and costs are given for several of the Scotch railways, and in making the comparison between the corresponding periods of the former year, both the receipts and expenses had so increased that the ratio of increase in expenses brought about a reduction in the percentage paid to shareholders, the expenditure increase being largely due to the rise in the price of coal.

The passenger traffic earnings of the Caledonian Railway were shown to be 43·66d. per train mile, an increase of 2·12d. over the previous year, while the heavy traffic earnings were 78·5d., an increase of 1·96d. over the previous year.

The expenditure side of the account shows the following:—

Maintenance of way, works, and stations ..	5·11d.	per train mile.
Locomotive power, including coal	10·98d.	,, ,,
Traffic expenses	10·27d.	,, ,,

Carriage and wagon repairs, compensation claims, and Parliamentary expenses were not shown per train mile, but the data given appeared to bring these out to 6·17d., or a total of 32·53d.

The Glasgow and South-Western Railway traffic receipts were—

From Passenger traffic	45·63d.	per train mile.
From Goods and Mineral traffic	72·51d.	,, ,,

The expenditure side of the account shows the following:—

Maintenance of way, works, and stations ..	4·92d.	per train mile.
Locomotive power, including coal	11·26d.	,, ,,
Traffic expenses	9·82d.	,, ,,

Carriage and wagon repairs, claims, &c., bring up the total expenditure to 32·38d. per train mile, which brings the debit side of the accounts very similar to one another in these two lines.

Referring to Mr. Selby's comment on the 23·69 per cent. to be accounted for in the earnings of a steamer, the percentages cited are simply based on the ratios between certain charges and the fleet value of the steamers as shown by the balance sheet, and do not admit of being summed up to show the profit on the year's transactions. There are charges on capital invested beyond the fleet value which fall to be met. These reduce the percentage of profit, accruing to the owners and shareholders, to a limit more or less approximating to what may be termed a reasonable profit, or what may be considered a reasonable profit to show.

Roller bearings have not been tried, as far as I am aware, for propeller shafts, but have for intermediate shafts. With what results I cannot say. The use of oil and grease for the propeller shaft has come into more general use of recent years for the stern tube bearings, with, I believe, satisfactory results. The loss by friction between the boiler and the propeller is very great. The experiments carried on by Mr. Froude and others, in order to obtain certain data for guidance in calculating approximately the power absorbed, have been published, in the results, by diagrams and formulæ. Mr. Ruthven has replied to the question regarding large steamers and coal consumption.

One is tempted to pursue the investigations suggested by the foregoing figures, and Mr. Selby's remarks on this subject, but I have already trespassed too far. There are many valuable points which have been suggested in the course of the discussion which may be brought forward again for elaboration.