# TRANSACTIONS

OF THE

# INSTITUTION OF ENGINEERS IN SCOTLAND

WITH WHICH IS INCORPORATED THE

## SCOTTISH SHIPBUILDERS' ASSOCIATION.

VOLUME X.

TENTH SESSION, 1866-67.

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TENTH SESSION, 1866-67.

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# CONTENTS.

## TENTH SESSION, 1866—67.



### PAPERS AND DISCUSSIONS.

# PLATES.

# MEDALS AWARDED

FOR

# PAPERS READ DURING SESSION 1865-66.

## THE INSTITUTION MEDAL.

To Mr. JAMES ROBERTSON, for his Paper "On Frictional Screw Motions and Applications."

---

## THE MARINE ENGINEERING MEDAL.

To Mr. NATHANIEL BARNABY, Member of Council I.N.A., for his Paper "On the Connection of Iron and Steel Plates in Shipbuilding, especially such as are subject to sudden Tensile Straining."

# INSTITUTION OF ENGINEERS IN SCOTLAND

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## TENTH SESSION 1866-67.

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*Introductory Address.* By Mr. J. G. Lawrie, President.

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*Read 31st October, 1866.*

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Gentlemen,—In resuming business this session we have reason to be encouraged to continued industry by the success which attended our labours last session.

During last session we had papers on the strength of materials that are extensively used by engineers; papers explanatory of certain ingenious mechanical contrivances; papers on the propulsion of ships; papers on the mode of perfecting the action of certain tools and instruments; papers on the strength and construction of ships, both iron and composite; papers on the construction of ships with reference to sea-worthiness; papers on new applications of iron, and on the most efficient mode of using iron in various structures; papers on the policy of certain laws affecting shipping property and those who use it; and besides, papers on various other subjects.

The papers on these subjects, and the discussions which followed were of great value to the engineer. Throughout these papers and discussions the desire plainly was to treat the subjects both practically and scientifically, and to consider them in a way dictated by a knowledge of principles rather than empirically. Several of the subjects of these papers were of singular interest and importance. Of these there is perhaps no subject that better merits the attention of such institutions as this than the construction of ships in respect to sea-worthiness, and we have reason to be gratified with the reception that our views on this subject received in the most influential quarters. Our attention was particularly drawn to this subject by the recent occurrence of disasters at sea, attended with the most lamentable results in the loss of human life; and the views which we persistently advocated to the Government in a contemplated change of the Board of Trade regulations, would certainly have already become law but for the change of Ministry at the time. The delay will, however, we believe, be only temporary.

We trust that by continued perseverance during this and future sessions the proceedings of this Institution will ever be of equal interest and utility; and that an important object of the business of this institution will always be to trace the relation of practical mechanics and scientific principles, and to investigate in what way the operations of the engineer can be advanced by the application of pure science, so that in the performance of the work which he seeks to accomplish his progress may be the result of an intelligent application of Nature's laws.

The progress of scientific engineering has of late years been rapidly extending, and has received during last summer a most signal illustration in that great work, the Atlantic Telegraph Cable. The accomplishment of this work, the construction and the laying of the cable, required a greater breadth of scientific engineering than any other that has, perhaps, ever been performed. The design of the cable required an extensive acquaintance with the principles of that subtle and powerful agent electricity. The construction of the cable required an experience, the result of many years' practical study, at an expense measured by millions sterling; and the task of laying the cable could not have been accomplished at all without the assistance of these powerful machines, steam ships, which involve a knowledge of the principles of steam. Thus, without a knowledge of the principles of electricity, without a knowledge of steam, and without a mechanical ability to carry into effect the requirements of these scientific principles, the electric cable could neither have been made, nor could it ever have been laid across the Atlantic. No engineering work has certainly ever been performed of a higher character, not only in the result sought to be attained, but in the means employed for its attainment. To recapitulate the process and progress through which this great work has been accomplished is unnecessary in this place, as scarcely anything can be added to the copious information on the subject supplied in the public prints. Familiar as we are, however, with the various steps through which this work has passed, and simple as they now appear, no words can express the wonderful nature and the wonderful advantage of the results which this work is destined to confer. Wherever and whenever the action of mankind is based upon information possessed, the means by which distance—the impediment hitherto to the transmission of information—can be eliminated becomes of paramount importance. No man can be engaged in the business and pursuits of life without desiring at times expeditious communication with those at a distance, and by the electric telegraph a correspondence amounting to a conversation is easily effected with an economy of time that it is impossible to calculate. The electric telegraph not only quickens the steps of events by quickening the transmission of information, but introduces at the same time an altogether new and in a sense opposite element in the progress of events, by arresting as it were their passage, which but for the telegraph would have gone out of reach before they could be otherwise utilised. This compound advantage of the telegraph obtains in the whole intercourse of the human family. Events are not only hastened by its means, but, by the more perfect information it gives, other events are crowded forward, for which no motives would otherwise have existed.

The success, both physical and commercial, that has attended the Atlantic cable, puts it now beyond a doubt that all populous places on the globe will very shortly be within almost instant reciprocal communication.

Such is the memorable result attained in this the greatest effort of scientific engineering in modern times. Other recent illustrations, however, are not awanting to show the services rendered by science to the engineer, and of these in the instrument which has recently received so much attention, and which is now popularly called the needle-gun, these services are prominently apparent. The transition in point of utility from the muzzle-loading flint-gun to the breech-loading needle-gun is scarcely less than from the stage coach to the railway train. The stage coach is of no use whatever when within reach of a railway train, nor is the flint-gun of any greater value in comparison with the breech-loading needle-gun. Upon the railway train depends almost the existence of modern commerce, and upon the needle-gun depends to a considerable extent apparently the fate of modern warfare. The effectiveness of the British needle-gun depends upon the efficient breech by which breech-loading is rendered satisfactorily attainable; it depends also upon the construction of the cartridge, which is made to explode by a part of the end being indented; and it depends upon the coating of the cartridge which prevents the fouling of the barrel. In this cartridge no opening in the case is necessary for the explosion to be produced, but simply that a part of the case be indented inwards, and hence the certainty of the explosion when desired. In other cartridges, as in that used in the well-known Prussian needle-gun, the cartridge case requires perforation, which opens the way for the admission of moisture, and introduces uncertainty in the explosion. For the production of this gun—the British needle gun—the services of the scientific engineer are indispensable to elucidate the construction of the barrel, the construction of the bullet, and the construction of the necessary cartridge, without which efficiently constructed the barrel and the bullet, though perfect in themselves, would be wholly a failure. The rude instrument by which a bullet may be thrown by the explosion of gunpowder is a very different one from the British breech-loading needle-gun; in the latter, the rifle barrel is a highly ingenious contrivance to give the bullet a rotation round a longitudinal axis, in order to prevent rotation round any other axis which would cause the bullet to deviate from a direct path, or rather from a perpendicular plane passing through the bore of the barrel. The construction of the bullet, having its centre of gravity properly situated in relation to its figure, is no less essential in order that the bullet may travel in the proper trajectory, with a minimum disturbance from the action of the atmosphere. The construction of the cartridge, by which the explosion being effected without perforation of the case, and without external fire, is of paramount importance, in order that the action of the gun may be independent of the weather or moisture. The coating of the cartridge, which is contrived to prevent the fouling of the barrel by the passage of the bullet or by the explosion, is essential in order that the gun may not become useless in action; and, lastly, the gunpowder—both that which projects the bullet and that which produces the explosion—have all been subjects of scientific investigation, and the results of scientific knowledge.

Another illustration of the services rendered by science to the engineer exists in the modern improved steam-engine. Great as were the advantages derived from the original form of the steam-engine, in which the same vessel performed the duties of steam cylinder and condenser, it is nevertheless an instrument immensely behind the modern engine. The invention of a mechanical prime mover, which should be independent of the action of the wind, and which, not being fettered to situations where falls of water existed, could be placed anywhere and extended indefinitely, possessed plainly advantages wholly unattainable without such a prime mover, and was therefore fitted to produce an entire revolution in operations dependent on the exertion of dynamic force. Beyond the applications falling within the scope of a prime mover, such as the original form of steam-engine, there existed even a wider range to which such a prime mover could not be profitably applied, and which consequently were as entirely shut out from that class of prime movers as if it had not existed. For these, the more perfect instrument in the modern steam-engine is peculiarly adapted. In steam navigation, for example, the improved steam-engine is rapidly becoming indispensable. For that purpose the difference betwixt an engine which uses 4½ lbs. of coal per horse power per hour, and one which performs the same work with 2 lbs., is so great that in many cases while the one is very much what the circumstances and conditions, require, the other is absolutely worthless. With the former the expense of the fuel would alone in many cases be a bar to its use; but when to the expense of the fuel is added the incompatibility of burning 4½ lbs. of coal per horse power, with the requirements for carrying cargo, the application of such a prime mover is wholly out of the question, and brings into prominent contrast the advantages of the latter. And these advantages are most prominently services rendered by science to the engineer. The advantages obtained by expanding the steam, the advantages of surface condensation, and the advantages of moderate superheating, which constitute the improvements of the modern steam-engine, are due altogether to the scientific engineer. No one of the three has been the result of accidental observation, but has been due to elaborate and patient investigation. It is true that the amount of advantage derived from any one or all of these improvements has not yet been by common assent definitely ascertained, the experience of different engineers showing different results, arising, probably, to a large extent from inaccuracy of observation, and also to the different modes by which the advantages are sought to be arrived at. While, however, these different results are being discussed, questioned, and not unfrequently discredited among the doctors, the users of the steam-engine, the public, are plainly in practice answering all doubts by a steadily increasing demand for the improved steam-engines, showing that, although different forms may yield different amounts of advantage, they all, in every practicable form, yield results of sufficient advantage to induce their extended application. The progress made by these improvements points palpably to the time, and at no distant period—within, probably, fifteen or twenty years—when in steam navigation, for every work, except it may be the shortest coasting voyages, the injection condensing steam-engine will be entirely obsolete. On a vast variety of stations the question is not one with a consumption of 4½ lbs. of coal per horse-power of more or less profit, but it is whether there is to be or there is not to be steam navigation at all, and the advantages of steam navigation compared with sail navigation are so tangible and so great as to insure the unremitting attention of engineers to the entire removal of the remaining difficulties in the way of the improved steam-engine. The great ocean race from China, which has received so much notice within the last few weeks, and which reflects so much credit on the shipbuilders of this neighbourhood, whom we are proud to number in our list of members of this Institution, will undoubtedly, in a very few years, lose its prominence, and be eclipsed by a race of far higher speed.

The great and prominent improvement in the steam-engine, as applied more particularly to steam navigation, is the economy of fuel, and without that improvement all the others that have been made would have been worthless, but with that improvement others have been of immense value, as in the change from the paddle wheel to the screw propeller. For many services, the paddle wheel was a most clumsy, inconvenient, and undesirable mode of propulsion. For all services, except, as yet, in shallow water, the screw propeller is nearly all that can be desired.

Recently, however, a method of propelling ships by the reaction of water issuing from turbine water wheels, now commonly called the Ruthven mode of propulsion, has been revived, and has lately been tried in one of her Majesty's ships called the *Waterwitch*. This method of propelling ships is not without advantages peculiarly its own. For example, in many ships, and perhaps in all, the great power which a ship so fitted possesses in discharging an immense quantity of water, the result, it may be, of a leak or injury, is of no inconsiderable importance. Probably, a facility of manœuvring a ship so fitted is another advantage. But there are no good grounds for believing that this mode of propulsion will be more economical in the application of dynamic effect or power, or in fuel, than the screw propeller, nor even that it will be so economical. In a comparison of the two modes of propulsion, there are three elements which fall to be considered:—

1st, The consumption of the power of the machinery due to the friction of the propelling instrument.

2d, The consumption of the power of the machinery due to that part of it which is carried off by the water projected from the ship.

3d, The consumption of the power of the machinery due to the propulsion of the ship, or that is developed in the propulsion of the ship.

To compare minutely the friction in the two methods, it would be necessary to know the surface, in each case, of the propelling instrument; in the one case the surfaces of the screw propeller, and in the other the surfaces of the turbine wheel and the surface of the water passages. Even, however, without these measurements, it is plain that the screw propeller has the advantage to a large extent in this respect. The surface of the propelling instrument itself is manifestly in favour of the screw propeller, and the loss arising from the friction of the water in the water passages with the turbine wheel has no counterpart at all with the screw propeller.

With regard to the consumption of the power of the machinery in that part of it which is carried off by the water that is projected from the ship, it is to be observed that with the screw propeller, if there be a sufficient number of blades, the whole water in the cylinder, of which the diameter is the diameter of the propeller, and the length the speed or space passed through by the ship, is driven off with a certain speed which measures the reactionary power obtained in that way for the propulsion of the ship. If this cylinder be reduced in diameter the water must be driven off with a higher velocity to maintain undiminished the reactionary power derived from that source; and, inasmuch as the power carried off by the water and wasted not being developed in the propulsion of the ship increases as the square of the velocity, plainly the higher the velocity with which the water is projected from the ship the greater the power carried off to waste. Consequently, in this respect the turbine wheel plan, adopted in the *Waterwitch*, in which the discharge orifices are of small dimensions, comparatively, and, therefore, the velocity with which the water is projected necessarily considerable, is inferior to the screw propeller.

With respect to the consumption of the power of the machinery due to the propulsion of the ship, it is to be observed that with the screw propeller the power of propulsion is derived from two sources—the one being the reaction due to the water which is projected backwards from the ship, and the other due to the reaction of the water in having imparted to it the velocity with which it is projected from the ship. For example, suppose the ship be propelled through the water by a propeller working in a solid, as it could be by having for illustration a propeller shaft of great length, then all the power of the machinery, with the exception of that required for friction, would be employed in propelling the ship, and none would be carried off by water being projected backwards from the ship, because none would be so projected. When, however, the propeller works not in a solid but in water, there is plainly reaction obtained for the propulsion of the ship, first from the inertia of the water in having velocity imparted to it, and then there is reaction corresponding to that velocity. The reaction due to the inertia of the water in having velocity imparted to it is measured by the rapidity with which that velocity is imparted, and is represented by a quantity proportioned directly to the velocity, and inversely to the time in which the velocity is imparted, or, in other words, is represented by the expression the velocity divided by the time; and if, therefore, the time during which the velocity is imparted be reduced to one-half, or one-fourth, or one-tenth, or is infinitely reduced, then the reaction obtained from this source is increased twice, or four times, or ten times, or is infinitely increased—that is, if the propeller imparts the velocity to the water with great rapidity, the reaction will be equal to that of the propeller working in a solid. With the turbine wheel the reaction obtained from the inertia of the water in having velocity imparted to it is plainly much inferior to that obtained with the screw propeller.

In all the three elements the screw propeller appears therefore to have the superiority.

1st, In the friction of the rubbing surfaces.

2nd, In the quantity of power carried off to waste by the water projected backwards from the ship.

3d, In the quantity of power which is developed in the propulsion of the ship.

And the extent of superiority depends upon the details of the manner in which the two methods of propulsion are carried out.

The *Waterwitch* has already been submitted to a trial on the Thames, and in the report on the subject which has appeared in the press, the performance has been greatly lauded. The method of propulsion has been lauded, and the machinery by which the method has been carried into effect has, as usual with many of our English friends, been also very considerably trumpeted. The facts, however, stated in the report do not afford the means of correct inferences respecting the result obtained, and the further experiments yet to be made are probably desirable to elicit in actual practice the true character of this method of propulsion.

The illustrations which have been adduced of the progress of scientific engineering could be multiplied to almost any extent. Within the last few years engineering has been rapidly changing character. Formerly engineering was not nearly so much as now a succession of scientific improvements. Then it was enough in a sense to be a hewer of wood and drawer of water and to travel in a beaten path; but now it is far otherwise, engineering being in all directions full of novelties —the dictates of science. The mode of communication between distant places is, we have seen, entirely new, and is the result of laborious, patient, and keen investigation of the occult laws of nature. The mode of conveyance both by land and sea is full of the use of Nature's hidden laws. The material which the engineer employs is rapidly being changed, stone being superseded by iron, and iron in many applications being displaced by steel, produced in a manner entirely new and due to principles far from obvious. Defining an engineer to be an artificer on matter, the scientific nature of his employment is apparent, whether we consider him as a fabricator of machines for transmitting intelligence or for transporting the fruits of the earth; whether he be considered as a fabricator of food in high agriculture, which is now in reality a manufacture; or as a fabricator of coverings to protect us from the inclemencies of the weather in the beautiful materials now constantly produced; or as a fabricator adapting everything around us, beneath us, or over our heads, to the wants and comforts of man. It is no longer sufficient for the engineer to know by rote the successive steps necessary in the various operations which fall to be performed by him, and which, when known, may all be classed under the denomination of hewing wood and drawing water. He must be acquainted with the principles or laws of nature upon which these various operations depend; he must extend the applications of these principles in new developments if he would seek to keep abreast with the progress of modern engineering. It has been frequently alleged, and correctly so, that the task of deciphering Nature's laws, that is, of becoming scientific, is difficult of performance, and that any action taken upon a misapprehension of these laws is attended with disappointment and disaster. No doubt if erroneous steps be rashly made upon a misconception of the laws of Nature, the result will be disappointment and failure; and in proportion to the rareness of the capacity of correctly understanding these laws is the distinction of doing so, and the value of the reward due to success. These difficulties may furnish reasons for diffidence in undertaking the task, but they furnish no reasons for discrediting or undervaluing the labours of the successful explorers, which an inconsiderate view of the matter has not unfrequently encouraged.

To assist each other in deciphering the laws of Nature, to explain their application, to pick up Sir Isaac Newton's pebbles on the seashore, and to be enabled to practice our profession of Engineer with increasing intelligence, is our object in these meetings.

"The search itself rewards the pains,
So though the chemist his great secret miss,
(For neither it in Art or Nature is,)
Yet things well worth his toil he gains,
And does his charge and labour pay,
With good unsought experiments by the way."

## *On an Improved Overhead Traversing Crane, Worked by Power.*

By Mr. Wm. Smith, Eglinton Engine Works.

(SEE PLATES I., II., AND III.)

*Received and Read 31st October, 1866.*

The traversing crane which forms the subject of this paper, was erected at Eglinton Engine Works in this city, about eight months ago, and since that time has been regularly at work. The convenience and saving effected by its use has been so great that the writer has thought a description of the construction and mode of working it might be acceptable to the members of the Institution.

The erecting shop in which the crane is placed, is 200 feet long by 53 feet wide inside the walls, and, although the original intention was to place two cranes in this shop, the rapid manner in which this one does the work, makes it quite unnecessary, unless it might be for the purpose of lifting heavier loads than one crane is capable of doing.

The crane is driven by power by means of an endless cotton cord, $\frac{7}{8}$ths of an inch diameter, extending the whole length of the shop, supported at intervals by guide pulleys, and returned round a pulley at the one end, which is fixed in slides and tightened and adjusted by means of a screw and hand wheel, as shown in Fig. 1, Plate I. The slides and screw are nine feet long, and allow of adjustment until the cord has stretched 18 feet, after which it may require to be cut shorter and spliced over again. This tightening pulley may also be adjusted in some cases by means of a weight instead of a screw.

Fig. 2, Plate I., shows an elevation of the crane resting on the walls of the shop; Fig. 3, Plate II., is a plan; and Fig. 4, an end elevation of the crane. Two wrought-iron girders form the beams of the crane, and are fixed to two cast-iron carriages, each having two wheels for the longitudinal rails. The crab is constructed of two cast-iron cheeks, set on four wheels to move transversely, and carries the chain barrel, gearing, and small platform for the man in charge.

The driving-cord moves at the rate of 1800 feet per minute, and is first taken over a V pulley on the crane 3 feet diameter, marked A in Figs. 2 and 3, and shown in section Plate III. On the same shaft as this pulley, a spur pinion is fixed, driving a spur wheel on the end of the shaft, B. This shaft extends the whole length of the crane, and gives motion to the main driving shaft of the crab, DD, Fig. 3, by means of a small vertical shaft and mitre wheels, marked C, Figs. 2 and 3. When the cord is put in motion, the shaft, B, and the main driving shaft of the crab, DD, are always in gear. From the shaft, DD, all the working parts of the crane are put in motion by means of three hand wheels, E, F, G, Fig. 3. In connection with each hand wheel, a worm moves a short lever which throws a friction clutch in gear for working, reversing, or holding in a neutral position at pleasure.

The hand wheel, E, puts in gear the clutch and spur wheels, which work the chain-barrel, H, for lifting and lowering the load. This barrel is made large, with grooves chased in it at the proper pitch to receive the chain, and to accomplish the whole lift of 20 feet without riding the chain. A fast and slow motion is given to the barrel by means of double spur wheels and pinion, N, Fig. 3, Plate II. A friction strap, K, Figs. 2 and 3, is attached to the mitre wheel, I, of this motion for the purpose of lowering the load. A set of three sheave blocks is also used to assist in reducing the motion of the lift.

The hand wheel, F, puts in gear the clutch and spur wheels, which cause the crab to traverse either way at pleasure on rails fixed on the beams of the crane.

The hand wheel, G, puts in gear the clutch, bevel wheels, and vertical shaft, M, Fig. 3, for driving the shaft, L. This shaft extends the whole length of the crane, and on each end of it a spur pinion is fixed, driving simultaneously one of the carrying wheels at each end of the crane by means of spur wheels, giving motion to the crane either way the whole length of the shop.

The heavy loads, from 2¾ tons up to the maximum load of 15 tons, are raised at the rate of 1 foot 5 inches per minute, giving a leverage of 1270 to 1. With light loads, the speed of lifting is increased to 7 feet 4 inches per minute, giving a leverage of 245 to 1.

The speed at which the crane traverses the shop longitudinally, is 41 feet per minute; and the speed the crab traverses the shop transversely, is 44 feet per minute.

The whole power requisite for working the crane when fully loaded, is transmitted to the counter-shaft upon which the driving-cord pulley is fixed, by a 3½ inch leather belt, working on fast and loose pulleys 18 inches diameter, making 191 revolutions per minute. By means of a belt-lever and two pull-cords, the crane can be put in motion and stopped by the workman on the platform at any point.

On each side of the crane, there is a wooden platform, supported from the wrought-iron girders by cast-iron brackets. A small platform is also connected to the crab, upon which the workman in attendance stands, and from which all the hand wheels for starting and stopping the different motions of the crane are under his control.

The long shafts, B and L, Fig. 3, which extend the whole length of the crane, are each supported at intervals by three tumbler-bearings, and also by a fixed bearing from the cheeks of the crab. Each shaft has also a small groove running the whole of its length for fixing the bevel wheel connecting it with the crab, and at the same time permitting the wheel to slide on the shaft when the crab is traversing.

Plate III. shows plan and sections of two pairs of the friction clutches used on the shaft, DD, for the purpose of starting and stopping the different motions of the crane; one pair is shown in section, and one pair in plan. The two mitre wheels marked Q, are bushed with brass, and are loose upon the shaft, DD; they are also coupled by the mitre wheel, R, which revolves on a stud, and serves for reversing the motion. The two discs, SS, are keyed fast to the shaft, DD, and have fitted and fastened to them the expanding rings, T, which are shown in a neutral position, ready to be acted on by moving the conical block, U, either way, by the lever worm and hand wheel, V. When the conical block, U, is thus moved, it expands the friction ring, T, by means of a short lever, W, and wedge piece, X, and fixes either of the mitre wheels, Q, transmitting the power one way or the other, as required.

One man is quite capable to work and keep the crane in order, effecting a saving in ordinary working of 4 to 5 men daily.

The crane is provided with handles fitted to each end of the shaft, DD, for working it by hand in cases of emergency.

In the subsequent discussion,

Mr. Downie said he approved of the construction of the crane, and thought it was greatly simplified as compared with many of those now in use. It was similar to those at Crewe, designed by Mr. Ramsbottom, but the driving band of those at Crewe, he believed, worked at a much greater velocity. He understood that Messrs. Dubs and Co.'s cranes were a modification of the arrangement of those used at Crewe; but the details of this one were much simpler than either, and, therefore, entitled to much credit—the friction clutches, and the mode of working the various motions were all that could be desired in simplicity and efficiency.

Mr. W. Smith said that the velocity of the driving band of the cranes erected at Crewe by Mr. Ramsbottom, was 5000 feet per minute. High speed in driving bands was sometimes objectionable, and after full consideration of the subject, and his previous experience with such bands, he fixed on 1800 feet per minute as a suitable speed, and the working of the crane justified his choice. The crane was driven by a 3½ inch belt over an 18 inch pulley, and had never refused to raise a weight of 15 tons, and without any noticeable change in the motion. One man worked the crane, and had full control over all the motions, and could do more work with it in one hour than seven men could do in three hours. The rope they had in use had been going for eight months, and only now it gave but slight symptoms of wearing. He believed they would improve on the band the next time they were getting one, as the cotton of which the present one was made had been rather hard. He did not think any thing could beat a cotton band. This one had stretched so as to reduce its diameter about one-eighth, and had only been spliced once. He had no doubt that the weather affected the cotton band; but being in a house it was not liable to much change of temperature. They regulated its length by a screw arrangement at one end of the shop. He believed that a weight would be easier on the cord, and perhaps it would stand longer. It was greased regularly with tallow. The machine merely traversed on rails, no racks being necessary. The friction was quite sufficient to keep it in its place. He had never observed the slightest tendency to slip when lifting. The whole weight of the crane was about 25 tons. He had not found the slightest difficulty with the friction rings of the clutches not biting sufficiently to hold. They were not cut at an angle, but were parallel like piston rings. There would be no difficulty in applying it to ordinary travelling cranes in locomotive shops. It might be necessary to put two shafts across the beams, and to alter the arrangement of the crab. It had been found necessary for the driving pulley on the crane to be of a V shape, as shown in the drawing. The band was only $\frac{7}{8}$ths of an inch in diameter at first, and after eight months' use, it was now about three-quarters. It was but a little clear of the bottom of the V pulley—all the pulleys were highly polished, and worked on steel pins.

Mr. James Milne said it seemed to him a very neat and simple arrangement. He considered the mode of driving much superior to driving by shafting for such a length of shop; the making of a secure coupling, without increasing the diameter of the shafting, being no doubt a practical difficulty.

Mr. Smith remarked that those two shafts across the house made about 113 revolutions per minute.

Mr. W. Johnstone inquired if the simplification of this appliance could be easily adapted to workshop cranes now in use, and said he thought it was a very useful thing, and he would avail himself of an early opportunity to inspect it in operation.

Mr. Jas. Robertson said that he had seen in the Mersey Iron and Steel Works a crane something like that described by Mr. Smith, and did not see any material novelty in the arrangement. It seemed to him that the friction clutches, and, indeed, all the apparatus was well arranged and easily worked.

Mr. Smith said that while the component parts were not new, the whole arrangement and mode of working was new, so far as he was aware.

Mr. Day said that the peculiarity of arrangement in this crane was in having the rope along the length of the shop only. The driving rope of the crane at Crewe goes along the length of the shop, and also across, and then round a driving pulley on the crab. He believed that at the Mersey Iron Works there was a crane which was actuated by a shaft going across the girders, the rope running along, and not having any unnecessary pulleys to interfere with the freedom of the action.

Mr. Downie said that cross shafts were not novel things. In the cranes in Messrs. Mirrlees and Tait's, and Randolph, Elder, and Co.'s, and many others, there were cross shafts such as described.

Mr. Day said the cross shafts were quite common; but they were not driven by a rope. Mr. Ramsbottom's crane had no cross shaft. There the rope passed over one part of the shaft, and then over a set of pulleys on one end of the girder, so that the rope caused an immense amount of friction. The rope they had, had worn only about twelve months.

Mr. W. R. M. Thomson said that in some cases such cranes were carried along by an arrangement of spur and bevel wheels, from the motion of a single longitudinal shaft in fixed bearings, and in others the shafts worked in pendulous bearings. One such crane had been designed and erected by one of the Government Engineers at Woolwich, and it might be a question whether this mode of actuating the transverse shafts, or that by the rope worked out by Mr. Smith, was the best.

Mr. Day was of opinion that at Woolwich Arsenal a pendulum boss was used to support the shaft.

Mr. Clapperton thought there could be no doubt that Mr. Smith's plan was much the best and easiest. It was very cumbersome to pass the traveller over pendulum bosses. It was worthy of notice that one rope was sufficient for all the motions of the crane—it was used for transporting the whole crane from end to end of the shop, traversing the crab across the shop, and hoisting. He thought that was a great advantage. The whole arrangement was worthy of much consideration. It appeared to him to be a new idea, that one simple band should be able to hoist 15 tons, and that under the control of one man. Mr. Smith had great credit by the arrangement.

Mr. Jas. Robertson said that he had seen in Manchester the endless driving rope applied to hoists without being passed round the driven pulley, the driving bite being effected by a pulley placed at the opposite side of the rope, and made to press the rope into the driven pulley. He thought that this method of driving would do well for travelling cranes, as a strong rope could be used, and in this way wrought at a slow speed.

Mr. Smith said if the pulleys attached to his crane were apt to get damp, or to rust, it would be necessary to make them of brass, or of timber; but they have no tendency to become so, as they are inside the house, and are kept quite clear and polished. If much bite were required on the band, it would never do. They must get up the speed of the band, so that a small tensile strain would communicate the power required.

Mr. Day said that an important fact was, that in using a small rope a very small force was employed at a high velocity.

Mr. Brownlee thought that Mr. Smith had made a good selection in choosing cotton for his band. A belt, or hide rope, had been suggested; but with so heavy a material stretching over 200 feet, without supports, the oscillations of such a band would likely operate very injuriously, whereas the lightness and elasticity of a cotton rope rendered it peculiarly suitable, since with such a material those destructive oscillations would in a great measure be avoided.

Mr. J. R. Stewart had found Manila to make an effective band,

and cheaper than cotton. Messrs. Dubs & Co. had used one, five-eighths of an inch in diameter, for a year past, with the greatest satisfaction.

# *On the Comparative Merits of the Rules of Lloyd's and the Liverpool Underwriters, for the Construction of Iron Ships.*

By Mr. John Price.

(SEE PLATES IV. AND V.)

*Read 28th November, 1866.*

1. The object of the following paper is to offer to some extent a reply to a paper read in 1865, before the Scottish Shipbuilders' Association, on a subject, the title of which, in the "printed proceedings," is "Remarks on the difference between Lloyd's and the Liverpool Underwriters' Rules for Iron Ships;" and to the discussion which subsequently took place at an adjourned meeting, of which the title was—"On the comparative merits of the Rules of Lloyd's and the Liverpool Underwriters, for the construction of Iron Ships."

In proceeding, I have considered it unnecessary to criticise the paper, except in reference to the three following propositions, viz.:—

I. Whether the Liverpool scantling has been correctly represented in its relation to Lloyd's?

II. Whether the Liverpool 20 years' vessel is better or worse than a Lloyd's A, vessel considered relatively thereto?

III. Whether the Liverpool 20 years' vessel is better or worse than a Lloyd's A vessel, considered in relation to some standard made common to both?

2. As reference will occasionally be made to Table I., I may here state that the figures in columns 4, 5, 6, 7, 8, 9, and 10, are the areas in

square inches of the parts of the several vessels' scantling indicated by the heading of each column, for one side of each vessel, and that the upper row of figures in each column, against each vessel's name, are the areas by the Liverpool rules, and the lower row of figures are the areas of the same parts by Lloyd's rules; thus, the "bottom plating" of the *James Wishart* is, (col. 5) for one side, by Liverpool rules, 124·19 square inches, and by Lloyd's it is 151·12 square inches. The right hand small space column under each heading shows the difference per cent. between the several areas as provided by the two sets of rules; thus, the difference of *James Wishart's* "bottom plating" (col. 5) is 22 per cent. by Lloyd's over the Liverpool's provisions.

The Sections which will be referred to are those appended of the eight vessels used as subjects for comparison in this paper, Fig. 8, Plate V., of which, shows in detail, the way in which the comparisons have been made.

3. *First*, then, " Whether the Liverpool scantling has been correctly represented in its relation to Lloyd's?"

On page 83, line 13, read—"The requirements of both registries, although on the whole not far from each other, differ in some respects." . . . . (Continue at line 33), "It is not my intention to discuss the differences in those rules." . . . . (Continue at page 84, line 9), "One of the points that falls to be discussed is whether the 20 years' vessel in the Liverpool book is *any better* than the A 1 vessel of Lloyd's book, or *vice versa*. For the purpose of forming an opinion on the subject, I have compared the scantlings of vessels of *the usual proportions and form*, taking dimensions of vessels which have been classed in both books, and find that, in the framing and plating of vessels from 500 to 2000 tons, Lloyd's rules, require on an average from 7 to 10 per cent. more weight of material than the Liverpool rules, while in the inside stringers, keelsons, &c., the Liverpool rules require from 7 to 10 per cent. more weight of material than Lloyd's."

For the purpose of coming to the same conclusion, if practicable, with the author of the paper, I have compared the scantling of vessels of the usual form and proportions, taking the dimensions of vessels which have been classed in both books, and find that in the plating of vessels from 500 to 2000 tons Lloyd's rules (for 1864-5) require an average of 15 per cent.; and in the framing of the same vessel, an average of 1¼ per cent. more material than the Liverpool rules, while the Liverpool rules require in inside stringers, keelsons, &c., an average of 15 per cent. more weight of material than Lloyd's. The way in which the comparisons are made, is shown in the section sheets attached to this paper, and are submitted for investigation.

On page 84, line 20, continue—"For sailing vessels of about 500 tons, the difference is trifling, the Liverpool rules being about 2½ per cent. in excess of Lloyd's." I here refer to the *Sarah Scott*, sailing vessel, Table I., of ordinary proportion and dimensions, and of 520 tons under deck, and by careful comparison, find that Lloyd's requires 5 per cent. more material *at least** than Liverpool rules do for such a vessel, and 10 per cent. more in a 700 tons vessel, such as the *James Wishart*.

In the paper referred to it is stated—"For sailing vessels of 1000 to 1500 tons, the total quantity of iron required by Lloyd's is about 5 per cent. more than the requirements of the Liverpool rules, whilst in vessels of about 2000 tons the quantities are nearly equal for both rules." I would here refer to the *Weathersfield*, Table I., of 988 tons under deck, which yields by comparison an excess of 5 per cent., the *Coimbatore*, 1149 tons under deck, showing an excess of 3½ per cent., and the *Nagpore*, 1444 tons under deck, an excess of 6½ per cent.; these excesses being so exhibited by a comparison of the area of section through the maximum of requirements of both registries at the *middle line* of each vessel, and which may be therefore called the nett excess, that is, without adding thereto the greater reductions allowed by the Liverpool book at the ends of the vessels. I also refer to the case of a vessel of 1950 tons under deck, of exactly similar proportions and form with *Nagpore*, taken to test the remark in reference to the agreement by the two registries as to the scantling required by each for

* About 1 to 1½ per cent. add for Liverpool's reductions at ends over Lloyd's.

such a vessel, and find that Lloyd's yields an excess in demand of 7½ per cent.—the comparison being made through the same line of maximum requirements.

4. Thus far, as to whether, *in the aggregate*, the Liverpool scantling has been correctly stated, I differ from the author of the paper under notice.

5. Considering this point further, as to whether the Liverpool scantling, so far as it has been referred to in detail, has been fairly represented. Read on page 85, line 3, "As before noticed, one of the principal differences in the scantlings of both rules is, that in the Liverpool rules the stringers and outside plating are *thinner* than Lloyd's scale; perhaps they may be thick enough for the strength of the ship when she is new, but we must bear in mind that durability has to be considered as well as strength. We all know that corrosion takes place over all the surface exposed, and is proportionately more injurious to thin than to thick plates; and in the case of stringer-plates, the Liverpool surveyors aver that the broad thin plates are stronger than Lloyd's, which are narrower and thicker, taking the same section in each; but it is certain that there is much more waste on the broad surface than on the narrow."

Here, first, the thickness of shell-plating is considered in relation to durability as endangered by *corrosion*.* I find that vessels of 520, 700, 988, 1149 tons respectively, per Lloyd's rules, are provided with the same thickness of plating, from the top of sheer-strake to ⅞ths the internal depth, as measured from the above point to the top of keel, as that provided by the Liverpool book for similar vessels, and that in a vessel of 360 tons, the same or a less thickness of plating is provided.

This part of the vessel, viewed from a practical point of view, is most liable to corrosive action—*first*, by being most exposed at all times to atmospheric changes, *and* during all voyages to water from without and moisture within, dried and precipitated alternately in more or less quickness of succession, by internal or external heat.

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* Corrosion is, throughout this paper, meant to refer only to *oxidation*, and not to *decomposition*—the result of deleterious matter in solution.

Experience shows that the most deceptive and destructive form of corrosive action is set up on the top sides, resulting in the dry, hard deep-coloured oxide, produced by a rapid succession of intense changes of the conditions under which the surface is placed, and resistive to all but the utmost persuasion of force. For these instances, Lloyd's vessels are only provided in the cases quoted, with the same plating as the Liverpool vessel—on the lower part of the side, on the bilges and bottom, there being no more needed from fear of corrosion, and none assumed to be necessary to meet any other cause, the plating of the Liverpool registry is preserved uniform, and while preserving all other necessary qualities, which will be presently referred to, the work in construction is more uniform in closeness and soundness of rivetted parts; the lightness of the plates also offers facilities for working them better to their places, having them in greater breadths or lengths without entail of extra cost, advantages more largely experienced in heavy vessels; the plates are also less liable to rupture under pressure from stranding, and, by experience, are found to be as valuable and durable in view of wasting from all causes as it is found necessary under such circumstances to use.

6. *Secondly.* The stringers of the Liverpool book are at some length dwelt upon, first, as to their greater breadth; and, secondly, as to their durability.

On the *first* point, I reply—it is well-known that plates placed so as to have strains passing through their width, gain strength to resist such strains as they gain increase of width—just as beams gain in the same way, and in proportion to the square of their depths; thus the *Coimbatore*, built by the author of the paper, having a stringer, per Liverpool rules 34″ × $\frac{9}{16}$″, instead of one 29″ × $\frac{10}{16}$″, would have one-third more strength imparted to act against racking and lateral strains on the upper deck line, a trifle more cross-section, and at least other 4 rivets added in that small compass in view of longitudinal strains.

Under such considerations, in the case thus quoted, I would prefer the broad thin plate referred to. No one will question the statement that the more surface exposed to oxidation, the more oxidation will ensue; but I do not think this point of such a serious nature as to merit pre-eminence. I grant that, in course of time, and equal conditions otherwise, a thin plate will disappear, and a thicker will remain; but does it follow, therefore, that a stringer-plate $34'' \times \frac{9}{16}''$ is so much inferior in fitness for position on the deck of an 1149 tons ship, to one $29'' \times \frac{10}{16}''$, as to cause the rejection of the former for such a purpose? It seems more reasonable to say that it would be preferable to adopt the stringer, giving one-third more lateral strength, one-eighth more longitudinal strength by increase of rivetting, and only offering, against such a course, the reason of an inconsiderable loss of vertical stiffness, and an exposure of one-sixth more surface to the slow and improperly cared-for structures, I might almost say stagnant process of oxidation. In an unpublished report on the *Richard Cobden*, an iron vessel, examined when 20 years' old, I find these words under the head of "external examination" and "internal examination" respectively. "The plating, from the keel to the medium load line, with the exception of one fore-foot keel-plate, was found to be in a very perfect state of preservation, and when pierced was not discovered to have lost any of its original thickness; but from this point (medium load line) upwards, the surfaces of the plating wore a considerable coating of rust, which, on being beaten off, exposed a rough and apparently much wasted surface, and which, when pierced, was found to have lost generally over the whole surface from a little less than one-eighth to fully one-eighth of an inch of its thickness."

"The stringers of the upper and 'tween deck beams were found to be in good order . . . . the plating from the keel to the 'tween deck beams was found to be in very good order."

Such a report on an iron vessel, after 20 years' sea-service, and such a vessel, bottom plating $\frac{8}{16}$, side $\frac{7}{16}$, and topsides $\frac{6}{16}$, with stringers upper deck, $24'' \times \frac{6}{16}''$ or $\frac{7}{16}''$, and lower deck, $24'' \times \frac{6}{16}''$, offers some proof that corrosion or oxidation is of a less active disposition than supposed, and if so, the use of the minimum of scantling in ships' sides and stringers is justifiable and commendable.

7. On page 85, line 19, read—"In the floor-plates, frames, reverse bars, especially in the wake of the boilers, the same diminution occurs in the thickness, so that cases such as these prove that thickness is of much more importance than breadth." It is difficult to see precisely the author's meaning here; he seems to have begun this paragraph, intending to show that in the various parts of scantling enumerated, "the same diminution occurs" in the provisions of the Liverpool book; then possibly recollecting that this was not generally the case, the paragraph is finished with a more direct reference to the loss by oxidation.

In the vessels referred to in Table I., viz., 360, 520, 700, 988, 1149, 1444 tons, the same thickness of frame is provided by both registries, and between the two registries there is only a mean of 1¼ per cent. of difference in sectional area of frame and reverse frame taken together. In the 1950 tons Liverpool vessel there is a difference of one-sixteenth in the thickness of the frames, and also a similar reduction in the reverse bars of all the above vessels, except the two least, the smallest of which has one-sixteenth in excess of what Lloyd's provide; and the 520 tons vessel has an equal thickness. As to thickness of floors, the matter stands thus:—In the 360 tons vessel the floors are equal in middle half of vessel; at the ends the Lloyd's floors are one-sixteenth thinner. In the 520 and 700 tons vessels, the Liverpool floors are one-sixteenth less over middle half of vessel than Lloyd's, but of the same size at the ends. In the 988 and 1149 tons vessels, Lloyd's floors are one-sixteenth heavier than those provided by the Liverpool rules over the middle half of the vessel, and are also one-sixteenth *less* than the Liverpool floors at the ends. In the 1950 tons vessel the same thing occurs, while in the 1444 tons vessel the Lloyds' floors are by two-sixteenths the heaviest over the middle half of vessel, and are of the same thickness as the Liverpool floors over the end quarter lengths of vessel.

From this it appears plain that the Liverpool floors are in no case thinner at the ends; in 360, 900, 1100, and 2000 tons vessels, they are one-sixteenth thicker, and in the case of the 500, 700, and 1444 tons vessels, they are the same thickness as Lloyd's at ends.

In reference to these reductions, oxidation is again pleaded as a bar; but if a bar at the middle, why not at the ends of a vessel where it is patent that there is greater foulness, more dirt, and all that tends to promote oxidation than in the middle of a vessel, which may be cleansed more easily and freely, and which is generally therefore better attended to in this respect than the ends are?

But, induced by these comparisons, I am led to believe that this is not the reason why the floors of Lloyd's are made progressively heavier; but because they, with the other scantlings, are made to progress with tonnage, and as the latter cannot safely be trusted to take care of the *depth* for the reason previously referred to, it is made the custodian of the thickness, and permitted thus to increase it, innocently, all but that it swells the grievance of weight.

8. The floors of the Liverpool book are not only thinner in the middle of the vessels but also shallower—thus in the case of the *Coimbatore*, 1149 tons,

The Liverpool floors would be $22\frac{1}{2}'' \times \frac{9}{16}''$.
The Lloyd's floors would be $24'' \times \frac{10}{16}''$.

One-tenth thinner, and one-fifteenth shallower, the proportions as to reduced strength being as 1 is to ·9 for thickness.

And as 1 is to ·862 for depth.

But this shows the Liverpool floor to be stronger for its thickness than the Lloyd's floor.

Then the length of the floor has to do directly with its strength. Provision is made for practically shortening the floors when, by the Liverpool rules, they exceed 21 in. depth at centre line; *i.e.*, when the vessel in which they are placed exceeds 32 feet in beam. Thus, for example, the *Weathersfield*, though of 34 feet beam, would not, if her tonnage did not exceed 1000 in the gross, have any such provision, as by the Liverpool rules she would have, viz., an intercostal keelson rivetted through the skin, thus supporting the floors vertically against twisting or buckling, and, in effect, shortening the floors by half their length.

The 1000 tons steamer, of which particulars are furnished in Table 1, affords a more striking view of the application of this keelson. In this case the beam is 35 feet, without the intercostal being required by Lloyd's; but by the Liverpool rules it is provided, and stands in the double office of shortening the floor line, and offering additional sectional area to bottom, to meet the extra duty the latter has to perform in a vessel of such extreme proportions.

9. The author of the paper referred to, is, I think, quite right when he alludes to the necessity for extra thickness of floors under the boilers of steamers, beyond probably what either of the Registries provide for.

10. Read page 85, line 26 to 34,—"To take the case of sailing ships of from 1000 to 1200 tons, these sizes being most familiar to our members, who have built vessels to class in both books, the stringer plates have to be made in accordance with the Liverpool rules, broader than for Lloyd's, and although we may submit to the Liverpool surveyors, that by Lloyd's we have as much section of iron as they themselves require, we are told that they do not recognise the section as being sufficient without the breadth, and therefore we are required to make stringers to the maximum thickness of Lloyd's, and the maximum breadth of the Liverpool requirements." Then at page 86, line 1, "There are other items which clash in the same manner, and although by correspondence some of the differences may be modified, it is not satisfactory to be dependent on the caprices of committees or surveyors in matters which might be regulated by a little of the give and take principle."

The paper, the subject of these remarks, was read on the 3rd of April, 1865, at which time the firm with which the author is connected was building a vessel, the specification for which was approved by the Liverpool Committee, December 22, 1864, or say three months before this paper was read.

This vessel is now called the *Coimbatore*, and though the section is shown among the annexed sketches, the scantling is not there.

But, that the author of the paper did not represent correctly the practice of the Liverpool Committee, by the last quoted paragraph, I quote the modifications from the maximum of Liverpool requirements in the case of this vessel to prove. Stringer-plates on upper deck were required 34″ wide, they were passed 32″ wide; lower-deck stringers were required 25″, they were passed 23″ wide; the side-stringer required a bulb $8\frac{1}{2}'' \times \frac{9}{16}''$ between the angles—this bulb was left out; the centre line keelson should have been double $18'' \times \frac{9}{16}''$, they were passed $18'' \times \frac{8}{16}''$, and the top and bottom plates of this keelson were passed each one-sixteenth below the thickness required by rules without any protest as to the prospective ravages to be made by oxidation on the reduced thicknesses.

I might refer to vessels built by other builders to show this to be no exceptional case; but I think the *Coimbatore* will suffice for this point and possibly for others to follow.

The author's firm had, in obtaining acceptance of these modifications, very limited experience of the caprices of surveyors or committees, so far as the Liverpool Committee and staff are concerned. The "give and take" proposal of the author is too indefinite for consideration.

11. Before leaving this question, read page 85, line 35, "Then again, besides making the centre keelson so much heavier than Lloyd's, the Liverpool rules require an extra or additional keelson or stringer, which, I have no doubt, may be necessary for vessels built solely to their rules; but when added to a vessel built with the heavy plating of Lloyd's requirements, must be superfluous strength and weight."

Read also at page 95 of the discussion, line 33, "With regard to what had been said about the additional stringer required by the Liverpool rules. . . . . It had been urged that this side-stringer was necessary to support the vessel against shocks received when lying in a tier, but his experience did not point to a single instance in which an *internal* stringer had been required for such a purpose . . . he could not see that a stringer placed where the Liverpool rules required one was of any value in this respect. He had never found symptoms of weakness in this part of the ship."

The centre line keelson is much heavier than Lloyd's. This is required to be so for the following reasons, with others:—1, Because, as has been shown, the floors are much lighter and weaker at the centre. 2, The keel and garboard-strake flanges are also lighter. 3, The lightness of the bottom plating makes it advisable to add in other ways to the gross sectional area of the bottom. This keelson will receive notice further on.

The use of the "side stringer" has been misunderstood, it seems, by some who took part in the discussion.

Its use may be apparent by the following reasoning in reference to Lloyd's, taking section A, appended for reference.

The *Sarah Scott* is just of the size in which Lloyd's would first require the upper turn bilge keelson, and it may not be necessary to go further in reference to the reason for *its* adoption at this limit than to suppose that the side has reached a limit requiring such lateral stiffening. The distance of this keelson from the top of the hold beam is 7 feet. In other words, the keelson is put in with reference to the wants of the side, and a minimum of 7 feet left unsupported—the depth of lower hold under beams being 10 feet 6 inches. The side is then allowed to be extended till the lower hold from under underside of lower deck becomes 15 feet, before any other such fastening is called for—giving a distance from upper turn keelson to top of hold beam of 11 feet (as in the 1444 tons vessel). All other things, therefore, being equal, this extension of side would be equivalent to a loss of one-fourth the strength, for which the provision made is, by increasing the internal flange of the frames from $3\frac{3}{4}'' \times \frac{7}{16}''$ to $5'' \times \frac{9}{16}''$, and by increase of side plating from $\frac{9}{16}''$ to $\frac{12}{16}''$. The increase made by Liverpool rules upon the scantling required for the small ship is nearly identical, viz., frame flange from $4'' \times \frac{7}{16}''$ to $5'' \times \frac{9}{16}''$, and plating from $\frac{8}{16}''$ to $\frac{10}{16}''$.

Increase by Lloyd's,... $1\frac{1}{4}''$ to width of frame flange.
" " $\frac{3}{16}''$ to thickness of side plating,
" Liverpool, $\frac{2}{16}''$ to " "
" " $1''$ to width of frame flange.

There is, therefore, $\frac{1}{16}''$ of thickness of plating, and $\frac{1}{4}''$ of width of frame flange provided by Lloyd's in excess of the Liverpool provisions. The excess in frame will be required to carry the excess in plating through its work, leaving the increase of one-sixteenth of plating (regarded either as increasing the strength of the side in proportion to increase of thickness of plating over Liverpool provisions, which will be $\frac{1}{8}$th, or in proportion to aggregate increase of the thickness of the side of the vessel, measured through the entire section of frame and plating, which will be $\frac{1}{48}$th of that section)—to add, though only in a trifling degree, to the lateral strength, as compared to the loss sustained; the two standing to each other possibly as ·25 : ·05. That is, Lloyd's offers only about ·05 more strength to the side than Liverpool, and it is on this small consideration that this opinion is based, that the side stringer is less necessary to Lloyd's than to the Liverpool vessel of equal depths and beam arrangements.

There is also to be considered the circumstance that, between the limits where Lloyd's provide for side stiffening, viz., between the introduction of the upper turn keelson and the next introduction of orlop beams, there is a threefold increase of weight to be carried, from 500 to 1500 tons. The side thus has its proportionate increase of duty, as shown by a further comparison of the two vessels, in which the fact will discover itself that the side, though one-fourth weaker, has double duty to do in reference to cargo.

*First, Sarah Scott* has 7 feet of side exposed, and is 28 feet beam. Then, take half the beam $= 14 \times 7 = 98$ cubic feet of cargo say, which the 7 feet side has to sustain.

*Second, Nagpore* has 11 feet side, and is 38 feet beam. Then, half of the beam $= 19 \times 11 = 209$. Thus the proportions of cargo duty stand to each other as 98 : 209; or : 1 : : 2·13; or the 1444 tons vessel has rather more than double cargo duty to do as compared with *Sarah Scott*, the 520 tons vessel; and, other things being equal, only to increase required for extended side, the side requires lateral assistance to meet this double duty.

This, it is proposed, should be the precise office of the Liverpool "side stringer," and with this view it is graduated for depths varying from 21 feet to the depth requiring orlop beams. The vessel of 24 feet depth, or 15 feet lower hold, having had some compensation for extended side bearing some proportion to that side, whereas in Lloyd's vessel nothing beyond the trifling items mentioned, such as 1 inch of frame-flange, and three-sixteenths of plating, till the vessel becomes 15 feet 6 inches under lower deck beams, or 24 feet 6 inches in depth, and then provision of a most excessive character is introduced adding vastly more weight than in the 24 feet Liverpool vessel is used for a similar purpose; while it reduces the lower hold from 15 feet 6 inches to some 8 feet—a less lower hold than at any other smaller capacity—and making the orlop-beamed vessel to have no reasonable reference or relation to the vessel 6 inches shallower, and possibly of the same tonnage, in respect of co-efficient of weight, and capacity in point of strength, for her duties.

12. There is no doubt that this stringer is generally in the neutral part of the ship's side. This is inevitable. It is not designed for other than lateral strains, such as result from working in a rolling sea, lying in tiers or docks, and especially for working in or out of docks. Yet, in vessels of greater depth than those into which it is first introduced, it will be higher above the said axis, and to that degree become available for longitudinal strain. It is also generally of a limited length as compared with the other stringers in the smaller vessels into which it is put, seldom being carried into the ends, and rarely requested to be so treated in the Lloyd's vessels into which it has been introduced.

13. *The second proposition is,* "Whether the Liverpool vessel is better or worse than a Lloyd's ship, considered relatively thereto."

In proceeding to consider this proposition, read at page 84, line 31, —"On this point there will no doubt be different opinions, but for our present purpose (which, at line 9 of same page, is to discuss these very points), we may assume their equality in that respect." I proceed, then, likewise, *assuming* that as the author is incorrect under the first proposition, he may be possibly in error as to this assumption.

Read further at page 89, line 7 of the discussion, "If it was considered the data was sufficiently correct to found a discussion upon, then it appeared to him that they should give their opinion as to whether Lloyd's or the Liverpool rules for building iron vessels was the best;" also, at line 27, by a member, "It was found that in vessels built on Lloyd's rules, there was nothing to complain of. . . . He was of opinion that the latter, in ordinary circumstances, was the better system to go upon, and quite agreed with the views as stated in the paper."

These views are summed up at line 3, page 87, "All he had done was to make a few remarks."

But read further at page 90, line 1, a member, "said he had gone very carefully into Lloyd's and the Liverpool rules, and also into the paper, and he could come to no other conclusion than that the Committee of Lloyd's had acted wisely in adopting tonnage as the standard by which the scantling of ships should be regulated. He had always contended that the form of a vessel should be taken into consideration when determining the amount of material to be used in its construction, and the manner in which that material should be distributed; and seeing that the new measurement tonnage, *when looked at with the principal dimensions,* was a correct idea of a vessel's form, it followed that a table of scantlings, based upon such tonnage, would be more satisfactory for general purposes than a table based upon principal dimensions alone. In confirmation of this statement he need only refer to the valuable paper read by the Chairman in November last, in which it was shown that the tonnage of a vessel $205 \times 34\frac{1}{2} \times 24$ could be made to vary from 934 to 1273 tons. Now, by Lloyd's rules, the fuller ship, which would have the greater amount of work to do, would be required to have heavier scantling than the sharp ship; but by the Liverpool rules, the scantling of both vessels would be alike . . . . . . and he thought that this one illustration would suffice to show that the Liverpool Underwriters were at fault in ignoring tonnage, and basing their scantlings on dimensions alone."

Read again at page 92, line 16, ' As had been shown, the rules showed very different requirements in the plating. The Liverpool rules did not take cognizance of plates beyond five-eighths thick, except for very large ships; *but the amount of internal keelson and stringer made it up in weight*"

"Whether Lloyd's or the Liverpool Underwriters were right in regard to the thickness of the plating required, was a question that only experience could decide. He did not know that they could say much about it, unless they could show that the Liverpool ship was weaker, more expensive, and less durable;" and finally read on same page, at line 11, the author "said although there was 10 per cent. more weight of iron, there was only 2½ per cent. less of carrying capacity."

14. In noticing the above extracts, I beg to call attention to the fallacy under which the author of the paper in question laboured when he "assumed" the equality between Lloyd's and Liverpool Rules, viz., "That though the Liverpool rules are 7 to 10 per cent. lighter in plating, they are also 7 to 10 per cent. heavier in internal stringers, keelsons," &c., "*which made it up.*" Or, in other words, that the Liverpool excesses in internal fastenings over Lloyd's are equal to Lloyd's external skin excesses, and that the two features balance each other; or, that one vessel is as heavy as the other. That this is not the case, refer to Table 1, and find the internal fastenings in the *Weathersfield* (built by a member of this Institution), which by Liverpool rules gives, under Column 9, 153 square inches for one-half areas at mid section; Lloyd's gives 137 square inches, or 12 per cent. *less* than Liverpool. Then find, under Column 4, area of one side of shell

plating by Liverpool rules 319; by Lloyd's rules, 360; or 13 per cent. *more* than Liverpool. Now, it is true that the per centage is nearly equal in each case; but it will be seen at a glance, that the Liverpool excess is only stated in a per centage over 137 square inches, the area of Lloyd's keelsons, while Lloyd's exeess is stated to be 13 per cent. over 319 square inches, the Liverpool shell plating, the difference being as 16 is to 41, or as 1 is to $2\frac{1}{2}$.

15. Or again, take the case of the *Coimbatore.* Column 9, Liverpool internal fastenings on one side of vessel, 166 square inches; Lloyd's internal fastenings on one side of vessel, 139 square inches—difference equal to 19 per cent. in favour of Liverpool keelson. Then the area of one side of the Lloyd's shell for such a vessel is 382 square inches, while that for a Liverpool vessel is 339 square inches—difference $12\frac{1}{12}$ per cent. in favour of Lloyd's. In this case, again, as in the *Weathersfield,* the Liverpool excess is 19 per cent. over 139, while Lloyd's excess is $12\frac{1}{12}$ per cent. over 339; or, as 27 is to 43; or, as 1 is to 1·55. In other words, the Liverpool ship would require from one-half more to fully as much more internal fastening as at present provided, before the statements in the paper or discussion on this point would consist with it.

16. The only expressions in the extracts under notice, which border in any way upon the "opinion" which the author solicited at page 89, line 9, and "supposed" at page 94, line 14, are those above quoted, unless that questionable form of it, at page 95, line 9, be held to have any relation to it. To avoid, however, the "general" view, which is on the whole a hazy medium,

*First,* I presume a specific maximum tonnage was not contended for here, so long as between the limits of the extremes of the supposed cases there is a difference corresponding to that quoted, viz:—in the capacities of the two vessels, whose dimensions are stated above, but whose capacities are, as 934 is to 1273; I therefore will take it that two vessels whose capacities are respectively 900 and 1200, would do quite as well for illustration, where, instead of a difference of 339 tons, there is a difference of 300—enough to test the application of Lloyd's scantling by the tonnage basis, and show how it adapts itself to provide for the carrying of every one of its tons. On referring to Table G, I find a certain provision on the above dimensions for 900 tons and for 1200 tons, no additional fastening or scantling whatever to take up the inflated ends which have been gorged with cargo. There is an intercostal keelson added for the capacity exceeding 1000 tons, but what use is this on a floor whose conditions are not altered from those in the vessel of 900 tons, since it stops short of the ends where inflation has been most practised? Not a fraction is added to top fastening, except $\frac{1}{4}$ inch to breadth of angles, nor to side plating; only the frames and reverse frames have been increased in size, adding their quota to the *weighed ends*, which the $\frac{1}{4}$ in. added to keelson angles and $\frac{1}{2}$ in. to depth of keel are inadequate to support. A vessel built entirely to Lloyd's will permit more than this. One may be built on dimensions for 800 tons, and this form may be inflated, if possible, till it carries 1200 tons, and all that Lloyd's will require, to help the structure to support itself and cargo, will be to add one-sixteenth to the thickness of the shell plating, stringers, floors, frames, reverse frames, and a little more for them to carry in the keelson angles, keel, stem, stern frame, and rudder; but not a rivet more added, not an increase in thickness of a single rivet except at the most neutral part of side, though carrying half more and nearly all the added cargo at *the ends*.

Yet we are told with all conceivable distinctness, which a careful investigation only would warrant:—"Now, by Lloyd's rules, the fuller ship, which would have the greater amount of work to do, would be required to have the heavier scantling."

17. Lloyd's Table G, shows for a vessel *800 and under 900 Tons.*

| Keels. | Frames. | Rev. Frames. | Plating. | Floors & Stringer | Keelson Angles. |
|---|---|---|---|---|---|
| $7\frac{1}{2}'' \times 3''$ | $\frac{8}{16}'' \times 4\frac{1}{2}'' \times 3''$ | $\frac{7}{16}'' \times 3'' \times 3''$ | $\frac{12}{16}''$ $\frac{11}{16}''$ $\frac{10}{16}''$ $\frac{9}{16}''$ | $\frac{9}{16}''$ | $\frac{8}{16} \times 5'' \times 4''$ |
| Rivets. | $\frac{12}{16}$ | | $\frac{14}{16}$ $\frac{14}{16}$ $\frac{12}{16}$ $\frac{12}{16}$ | $\frac{12}{16}$ | $\frac{12}{16}$ |

*900 and under 1000 Tons.*

| Keels. | Frames. | Rev. Frames. | Plating. | Floors & Stringer | Keelson Angles. |
|---|---|---|---|---|---|
| 8" × 3" | $\frac{8}{16}$" × $4\frac{3}{4}$" × 3" | $\frac{7}{16}$" × $3\frac{1}{4}$" × 3" | $\frac{13}{16}$" $\frac{12}{16}$" $\frac{11}{16}$" $\frac{10}{16}$" | $\frac{10}{16}$" | $\frac{9}{16}$" × 5" × $4\frac{1}{4}$" |
| Rivets. | $\frac{12}{16}$ | | $\frac{14}{16}$ $\frac{14}{16}$ $\frac{14}{16}$ $\frac{12}{16}$ | $\frac{12}{16}$ | $\frac{12}{16}$ |

Add intercostal keelson.

*1000 and under 1200 Tons.*

| | | | | | |
|---|---|---|---|---|---|
| $8\frac{1}{2}$ × 3 | $\frac{9}{16}$ × 5 × 3 | $\frac{8}{16}$ × 3 × $3\frac{1}{2}$ | $\frac{13}{16}$ $\frac{12}{16}$ $\frac{11}{16}$ $\frac{10}{16}$ | $\frac{10}{16}$ | $\frac{9}{16}$ × 5 × $4\frac{1}{2}$ |
| Rivets. | $\frac{12}{16}$ | | $\frac{14}{16}$ $\frac{14}{16}$ $\frac{14}{16}$ $\frac{12}{16}$ | $\frac{12}{16}$ | $\frac{12}{16}$ |

*Addition imparted to the Full Vessel.*

| | | | | | |
|---|---|---|---|---|---|
| 1 × 0 | $\frac{1}{16}$ × $\frac{1}{2}$ × 0 | $\frac{1}{16}$ × 0 × $\frac{1}{2}$ | $\frac{1}{16}$ $\frac{1}{16}$ $\frac{1}{16}$ $\frac{1}{16}$ | $\frac{1}{16}$ | $\frac{11}{16}$ × 0 × $\frac{1}{2}$ |
| Rivets. | 0 | | 0 0 $\frac{1}{16}$ 0 | 0 | 0 |

Thus all the additional fastening provided in such a full vessel is practically *nil*, at upper deck line, for, although there is one-sixteenth increase in thickness of stringers and ties, and stringer angles, and $\frac{1}{2}$" in width of one flange of the latter, there is no addition to the rivets which hold them together. The same remark applies to the bottom; the centre line keelson, though one-sixteenth thicker, has its joints no better secured —the only real addition to bottom line being in the depth of keel, which is increased 1 inch; and in the flanges of the garboard-strakes, which are also increased a like amount in depth, and one-sixteenth in thickness; that those additions are relevant to the above conclusions, or adequate to meet the increased duty, it would be useless to affirm.

18. It will only be necessary to add, that in the same vessels built by Liverpool rules, there would be (see Table 1) to begin with, 10 per cent. less gross weight; taking *James Wishart* as an illustration, she would have $4\frac{3}{4}$ per cent. more area in bottom fastenings, and 3 per cent. more in top fastenings. This would be the case for the lower capacity, and though, as seen from Column 7, Table 1, that there is 5 per

cent. less topside and side plating area in the Liverpool vessel than in Lloyd's vessel, yet, on reference to the section of the vessel, it will be seen that this excess is acquired only from the line of hold beams to the point at which the comparisons terminate, viz., two-thirds the depth, measured from the upper side of upper deck beams, the most neutral part of the vessel.

And, moreover, that though over a considerable part of this distance the plating of the two registries agree, and beyond this, to the point at which the comparisons terminate, there is 5 per cent. against the Liverpool rules; on looking to the rivet table at foot of *James Wishart's* section, it will be seen, *first*, that the excess in the plating is not fastened better together than that part of the plating where there is no excess; and in point of longitudinal strength, it is, therefore, no better than if no excess had been added. *Secondly*, that all the side plating below sheer-strake of Lloyd's, has inferior fastening to that provided by the Liverpool rules, the rivets being by Lloyd's twelve-sixteenths, and by Liverpool rules, thirteen-sixteenths, a difference equal to 16 per cent., without touching the question of the number and arrangement of rivets which will be referred to further on.

The sheer-strake is the same as to size and fastening, and as to *size* of rivets in both cases; but the upper-deck stringer is 30 per cent. wider, offering facilities to increase the rivetting of its butts by nearly a like amount, by making room for two more rows of rivets on each side of butts. There is on this same line a gross gain of 7¾ per cent. of area in longitudinal fastenings in favour of Liverpool over Lloyd's, giving the latter credit for the full area of their diagonals for this purpose.

The sum of these differences, therefore, point to two inferences, *first*, that for the lower capacity in the cases assumed, the Liverpool vessel is provided with a larger amount of longitudinal strength than Lloyd's vessel is provided with. *Second*, that whatever be the limit which practice may assign as the ultimate point to which inflation of a particular form may be carried, it is evident that the Liverpool vessel is more efficiently provided for, in view of the demands likely to be made upon her in such a way

Again, although to meet the demands of such a contemplated increase of capacity, the Liverpool rules make little provision, yet, in this respect, they are not inferior to Lloyd's; for, as has been shown, the only part where real additions are made, is in the line of the keel, and it will be found that in passing from 750 to 1000 tons, the keel of the Liverpool vessel changes from

$$8'' \times 2\frac{1}{4}'' \text{ to } 9'' \times 2\frac{1}{2}''.$$

an increase which, with its effects upon garboard-strake flanges, may fairly act as a set off against that provided by Lloyd's.

19. I now refer to the cases of the *Weathersfield*, of 988 tons, and *Coimbatore*, of 1149 tons, as showing how the Liverpool and Lloyd's Rules provide for the *differences* in dimensions usually found to obtain when such large accessions to tonnage are made; and as this is the direct tendency of the New Measurement Tonnage Act, when the builder is allowed to provide his own "form," which he considers the best to carry the tonnage required by the owner, it may serve to show also, how far the Liverpool practice in regulating scantling combines with this other new practice.

*Weathersfield's* builder's dimensions 205 ft. × $34\frac{1}{2}$ ft. × $21\frac{1}{4}$ ft. = 988 tons register *under deck.*

*Coimbatore's* dimensions by builders, 205 ft. × 35 ft. × $22\frac{1}{2}$ ft. = 1149 tons register *under deck.*

Refer to Table 1, first to Column 8, and find for both tonnages the requirements by both registries for deck stringers, ties and angles to be identical; then in Column 7, find Lloyd's excess of area in side plating exactly the same in each case; but as this last item is subject to the same reduction and remarks as have been made in the case of the *James Wishart*, this excess will not be taken into account; then, in Column 6, find that in the case of *Weathersfield*, Lloyd's requirements for keelsons in the bottom, are 13 per cent. less than the Liverpool requirements; and that in the case of the *Coimbatore*, Lloyd's requirements for keelsons in the bottom are $16\frac{1}{2}$ per cent. less than the Liverpool requirements; then, in Column 5, the area of bottom plating in Lloyd's is in both cases 20 per cent. in excess of Liverpool requirements.

The cases will stand in comparison with each other thus, for Table 2:—

| | Weathersfield's. | | Coimbatore's. | |
|---|---|---|---|---|
| | Liverpool. | Lloyd's. | Liverpool. | Lloyd's. |
| Top fastening, | 1· | 1· | 1· | 1· |
| Bottom keelsons, | 1·135 | 1· | 1·166 | 1· |
| Bottom plating, | 1· | 1·2 | 1. | 1·2 |

Showing that while the Lloyd's scantling has permitted no addition however small to the scantling, the Liverpool rules have entailed an addition of 3 per cent. in bottom keelson area, over that required by Lloyd's; and as will be seen in Column 9, caused—by providing for the increased exigencies of the side, together with increase of bottom fastenings—the gross areas of internal fastenings to rise from 12 per cent. in case of *Weathersfield*, to 19 per cent. in case of *Coimbatore*, over Lloyd's requirements. While I show these cases with some particularity, I do not claim any special importance for the small difference, but intend it to be seen that the difference, small as it is, is in favour of the Liverpool mode of providing scantling.

20. I now remark in reference to, and more fully on, Table 1, as to what it shows, and will merely observe in reference to the first seven vessels upon it, that they were taken as being ordinary vessels, showing the usual diversity of form and proportions, as being classed in both Registers, and well known to have been built. In using the sections I have merely taken the outline and arrangement of fastenings, to show that the latter were only ordinary arrangements, and as affording as good specimens as need be, to which I might put on the scantlings of the two Registries as shown by their Tables for 1864-5.

Refer first to Columns 4, 5, and 7, and find under their various headings of "Gross area shell plating," "Bottom plating," and "Side plating," the following per centages of excess required by Lloyd's over the Liverpool rules for the following six vessels, for Table 3:—

| | Gross Area of Shell Plating. | Areas of Bottom Plating. | Area of Side Plating to two-thirds depth |
|---|---|---|---|
| Sarah Scott, | 15½ per cent. | 24½ per cent. | 6⅛ per cent. |
| James Wishart, | 14¼ ,, | 22 ,, | 5½ ,, |
| Weathersfield, | 13 ,, | 20 ,, | 5 ,, |
| Coimbatore, | 12½ ,, | 20 ,, | 5 ,, |
| Nagpore, | 22¼ ,, | 29½ ,, | 13½ ,, |
| No Name, | 14¼ ,, | 20 ,, | 13½ ,, |
| | Mean of first 4 and 6th = 13.9. | Mean of first 4 and 6th = 21·3. | Mean of first 4 = 5·38. |

This table shows, *first*, a very constant ratio to subsist between the plating of Lloyd's and that of the Liverpool book, so far as the latter goes on increasing the thickness of its plating, as shown by the cases of the first four vessels in Table 3. *Second*, That practically the same thing is obtained by the two methods which govern the said increase of plating, and that is a similar gradual increase. Thus, taking the first four vessels and the sixth, I find a mean of nearly 14 per cent. The highest and lowest individual instances being only 1½ per cent. above and below, proves this to be a fair mean. The reason why the first four vessels in Table 3 are taken is obvious; they represent the limits—*first*, at which the two registries approach each other and, *secondly*, the point at which they part company, where the Liverpool book ceases to increase its plating in thickness.

The 6th vessel is taken to show that the further provision made by the Liverpool book, by requiring two double strakes in the vessel's side, when 1500 tons capacity is attained, practically reaches only the limit of approach to Lloyd's plating previously obtained, while being concentrated for totally distinct purposes; *thirdly*, Table 3 shows further that the nearness of the ratios is not confined to the aggregate plating, but preserves its character when found in "bottom plating, and side plating, separately."

21. Again, refer to Table 1, and find, in no instance, that Lloyd's is in excess of the Liverpool book in respect of bottom or top fastenings, or in the gross of both kinds; but that in most instances there is a decided excess in favour of the Liverpool book as to deck-stringers and ties, and that in every case there is a most decided excess in favour of Liverpool in bottom fastenings.

As in the cases of *James Wishart*, *Weathersfield*, and *Coimbatore* already referred to, so in all the other vessels, not only are the areas equal, or in excess, but the forms of the stringers and ties in the Liverpool vessel give more rivet-holding width, lateral stiffness, and hence, in both directions, additional strength. I will again call attention to Table 1, to show that the mean difference of 21·3 per cent. which Table 3 showed to be the excess of Lloyd's plating over Liverpool vessel's plating in the bottom, is really not to be looked at only through that medium; thus, take from Columns 5 and 6 the areas of bottom plating and keelsons of the two registries, and the sum thereby obtained will show a different result.

TABLE 4.

| | Liverpool. | Lloyd's. |
|---|---|---|
| Coimbatore. | | |
| Bottom plating, Column 5, | 149 | 179 |
| Bottom keelsons, Column 6, | 84 | 72 |
| | 233 | 251 |
| | | 233 |
| | | 18 = $7\frac{3}{4}$ per cent. |

The 20 per cent. of Table 1, under the head of Column 5, nor the 21·3 per cent. of Table 3, do not show, therefore, what it is important to know, that in the bottom of the Liverpool vessel there is within $7\frac{3}{4}$ per cent. of the gross area available for resisting compression (which the bottom has usually to bear), which is to be found in Lloyd's; whether this is sufficient, may be determined if its proportion to upper-deck and topside area of fastening be compared from Table 1, Column 7 and 8, find for—

TABLE 5.

| | Liverpool. |
|---|---|
| Coimbatore. | |
| Side plating to ⅔rds depth, Column 7, | 149 |
| Deck-stringers, ties, and angles, Column 8, | 66 |
| | 215 |

Then the top and bottom halves of the vessel are, respectively, as 233 : 215 the latter the top, or as 1 : 1·08—the difference of ·08, showing a margin in favour of the bottom, for corrosive resistance, if desired for such a purpose. It is not contended here that all *the necessary* section is to be found in the top areas of the Liverpool vessel; but it is contended that with what is possessed in the upper region, there is no need for the 7¾ per cent. to be added to the section over and above what is provided for the bottom of the Liverpool vessel, especially when it is considered that the resistance to compression of iron is nearly, if not quite, that which it offers to tension in such a case. Columns 7 and 8 for *Coimbatore* show for Lloyd's vessel.

TABLE 6.

| | Lloyd's. |
|---|---|
| Side plating to ⅔rds depth, Column 7, | 156 |
| Deck-stringers, ties, and angles, Column 8, | 66 |
| | 222 |

And for Columns 5 and 6, for bottom plating and keelson respectively.

TABLE 7.

| | |
|---|---|
| Bottom plating, Column 5, | 179 |
| Bottom keelsons, Column 6, | 72 |
| | 251 |

thus causing Lloyd's top and bottom to stand as 251 : 222, or as 1· : 1·3.

22. One other point is worthy of notice viz: It has been seen that Lloyd's vessel has 20 per cent. more area in bottom plating, but only

7¾ per cent. more gross area in plating and keelsons combined; it has also been shown that this accession of 7¾ per cent. to Lloyd's gross area is unnecessary; but it still remains to be considered in what advantageous way the 12¼ per cent. of deficiency in bottom plating area is made up in the Liverpool vessel, and whether any distinct advantage has been gained over what would be obtained by the manner in which this area would be distributed by Lloyd's rules:—

*First*, in what way is this 12¼ per cent. made up in the Liverpool vessel? Column 6, Table 1, shows it to be by increasing the keelson areas, to an amount which makes the Liverpool vessel have 16½ per cent. more area of these members than Lloyd's, or in other words, 12¼ per cent. of the Liverpool bottom plating is equal to 16½ per cent. of Lloyd's bottom keelsons.

*Secondly*, is this a better distribution than by Lloyd's provisions? To answer this see how Lloyd's do distribute their excess in bottom plating, it is by increasing the thickness over the Liverpool thickness, from $\frac{10}{16}$ to $\frac{12}{16}$ = $\frac{1}{8}$ increase, or 12·5 per cent. Glance now at the rivet table at foot of *Coimbatore's* section, and it will be found, that the $\frac{12}{16}$ bottom plating is held together at the joints by $\frac{14}{16}$ rivets. Referring now to a reliable rule for what size of rivets are required for such plating, I find that $\frac{12}{16}$ plating requires rivets at least one inch in diameter, and that $\frac{14}{16}$ rivets are only fit for $\frac{10}{16}$ plates, the $\frac{12}{16}$ plating of Lloyd's is only fastened with the rivets which are sufficient for, and which are provided by the Liverpool rules for $\frac{10}{16}$ plating.

Thus then the $\frac{2}{16}$″ excess of thickness by Lloyd's might be shorn from the *Coimbatore's* bottom plating, without impairing the longitudinal tensile strength, and it is shown above that the removal to another place of a certain proportion of such excess still leaves sufficient for compression strains. It follows that this change is not for the worse to the vessel. Again refer to *Coimbatore's* section, and find that by the table at the right of the sheet, on lines 3, 3, 4, 4, 5, 5, 6, 6, the proportions are shown in which the areas of the Liverpool and Lloyd's keelsons are made to stand to each other, thus the *centre keelson* on lines 6, 6, are respectively 26 for Liverpool and 17 for Lloyd's or for the whole keelson in each case 21·43 × 2 = 52·80 sq. in. say 53 sq. in., and 17·15 × 2 = 34·30 say 34½ sq. in.; or more than half as much more area in the Liverpool than in the Lloyd's keelson, and then see under what different conditions the keelsons are now made to stand, by the different forms the keelsons are made to assume; thus, the Liverpool keelson is made with a double centre web, of two plates 18″ × $\frac{9}{16}$″ with top and bottom plate 12″ × 9-16″ and 4 angles (two top and two bottom) 5″ × 3½″ × 9-16″, (See Fig. 11, Plate V.) A portion of this keelson supported between supports 20 feet apart would require 238½ tons to break it taking the whole area as effective.

The Lloyd's keelson is formed with one centre plate 16″ × 13-16″ and 4 angles 5′ × 4½ × 9-16″. (See Fig. 12, Plate V.)

A similar length of this keelson treated as a beam in the same way as the Liverpool keelson, would only sustain 137½ tons before breaking,

by the formula, $w = \dfrac{a\,d\,60}{l}$

$a$ = area gross in square inches; $d$ = depth in feet; $l$ = length in feet; and 60 a constant—being applied in each case; the two keelsons thus standing to each other as to transverse strength as 238½ is to 137½ or as 1: 1·73. The constant however as applied to the Liverpool keelson is too low when the way in which the butts are protected is compared with the Lloyd's keelson, the latter having only the single butt strip over the butt joint, while the former has the centre plates acting as butt straps to each other, and in addition the single covering strap. If therefore the constant 70 be used the Liverpool keelson will be seen to be just twice as strong as the Lloyd's, to resist upward strains, as for instance, when the vessel is at rest on blocks or rocks, &c. At the same time the areas being to each other as 53 : 34½, or as 1: 1·53 the Liverpool keelson is half as strong again for compression and in a much better condition still for tension, by reason of the coverings which can be, and are, thrown over all the butts, making their relative strengths for tension probably nearly as 1 : 1·75.

23. Attention is here called to the gross depth through the centre line keelson in the Liverpool vessel, as compared with Lloyd's vessel, the two standing to each other.

TABLE 8.

| | Liverpool Vessel. | Lloyd's Vessel. |
|---|---|---|
| Centre keelson, | 19 in. deep. | 16 in. deep. |
| Floors, | 22½ ,, | 24 ,, |
| Keel, | 9 ,, | 8½ ,, |
| | 50½ in. | 48½ in. |

Showing, that notwithstanding the reduction of floors, the Liverpool vessel has secured, by redistribution of the excesses added for corrosion by Lloyd's, a greater effective depth at a most important part, where any advantage, however small, is an unquestionable gain.

Attention is also called to the "intercostal," as to the way in which it is secured to the skin of the vessel—the effect being analagous to adding a bottom flange, and so constituting this keelson an additional fore and aft rib, and answering the double purpose of preventing any tendency of the bottom plates to buckle when under compression, from any of the numerous imminent causes.

This point is therefore made out, that by the Liverpool redistribution of that 12½ per cent. of material into keelsons, which is, by Lloyd's rules, added to the thickness of the vessel's bottom, distinct advantages are secured, which are highly important to the vessel; and that very large accessions of strength in all other directions have been made, without sacrifice of strength in any direction; this much for the material or sectional area of iron employed in the above referred to parts of the Liverpool and Lloyd's vessels.

24. Attention is now called to the differences existing between the provisions made by the two registries for holding the various scantling together, which, if the measure of the strength of the weakest part be the measure of the strength of the whole structure, will be the best test left now to apply, and which is really the test that most vitally affects the comparison I am now making.

I revert, again, to the stringer plate in the upper-deck of the *Coimbatore*, which is 34″ × $\frac{9}{16}$″. Now, in proceeding with the comparison which I propose to set up, instead of depending for any force upon any views of my own, I will consult the published results of important, and careful experiments made by Mr. Fairbairn, and the comparison will attempt to show whether, as to number and size of rivets, the Liverpool or Lloyd's rules provide most satisfactorily in these respects.

For the sizes of rivets provided by the two registries for the *Coimbatore*, see the rivet Table, at foot of section.

The rules for spacing the rivets, and thus determining their number by Liverpool is, "4 diameters apart from centre to centre," and by Lloyd's, "not more than 4 diameters, and not less than 3 diameters apart." The application of the Liverpool rule needs no explanation; the Lloyd's rule, however, is not so explicit, and it needs to be said that it is meant to allow the rivets to be placed so that there is a distance between their near sides, equal to at least three times the diameter, and not more than four times the diameter of the rivet; this, by Liverpool expression, would be from 4 to 5 diameters from centre to centre.

Apply these rules, then, to the *Coimbatore's* stringer-plate, which, by the Liverpool rules, would have 10 rows of thirteen-sixteenth rivets, spaced 3¼ inches centre to centre, on each side of the butt. The Lloyd's stringer-plate, 29 in. by ten-sixteenth in. would, by the above provision, have 8 rows of twelve-sixteenth inches, spaced with less than 4, and more than 3 diameters between them; thus, as to number in this stringer, the Liverpool rules provide 10 rows, and Lloyd's rules provide 8 rows; or, in other words, the Liverpool rules provide 20 per cent. more rivets than Lloyd's. See the following Table:—

TABLE 9.

| | Liverpool. No. of Rows. | Lloyd's. No. of Rows. | Per Cen |
|---|---|---|---|
| Sheer-strake, | 10 | 9 | 11 |
| Topside, | 11 | 10 | 10 |
| Side, | 9 | 8 | 12½ |
| Bottom, | 8 | 7 | 14 |
| Mean, | ... | ... | 12¼ |

which shows that, in such a vessel as the *Coimbatore*, taken as built under ordinary circumstances, there would be 12 per cent. more rivets by the Liverpool than by Lloyd's rules.

Then refer to rivet Tables for the diameters, and find that the Liverpool rules provide for the stringers, sheer-strake, and topsides, presumedly the most vulnerable parts of the vessel, because primarily dependent upon the rivets; in each case rivets one-sixteenth in. larger in diameter than Lloyd's rules provide. Fairbairn's Table gives the diameter of rivets for nine-sixteenths in. plates as $\frac{13}{16}''$, for twelve-sixteenths in. plates, rivets $1\frac{1}{8}$th in. diameter, and for ten-sixteenths in. plates, rivets of fifteen-sixteenths in. diameter; and for the distance from centre to centre, he gives 4 times the thickness of the plates in each case. The following Table, therefore, will show how far the two registries approximate to the results of Fairbairn's researches, in their endeavours to apply to iron shipbuilding, the results of experience.

TABLE 10.

| | Diameter of Rivets for 9-16ths in. plates. | Diameter of Rivets for 12-16ths in. plates. | Diameter of Rivets for 10-16ths in. plates. | Distance from centre to centre allowed. |
|---|---|---|---|---|
| Fairbairn, | 13-16ths inch | $1\frac{1}{8}$th in. or 18-16ths in. | 15-16ths in. | 4 thicknesses of the plates. |
| Liverpool, | 13-16ths in. | 15-16ths in. | 14-16ths in. | $5\frac{1}{2}$ do. do. about. |
| Lloyd's, | 12-16ths in. | 14-16ths in. | 12-16ths in. | $5\frac{1}{2}$ to $6\frac{1}{2}$ about. |

It will thus be seen that though the Liverpool rules provide more than Lloyd's in number and diameter of rivets, they do not pass the limits, nor indeed reach them, in some instances, at which the greatest strength is found, but, as has been shown as to number, it will now appear that as to size of rivets, Lloyd's Tables provide considerably less than the Liverpool rules, and are, to a corresponding extent inferior in their provisions; thus we may take it that the value of the rivets may be compared by comparing their areas, the areas are—

| | | | | |
|---|---|---|---|---|
| Rivets, | 12-16ths in., | 13-16ths in., | 14-16ths in., | 15-16ths in. |
| Areas, | ·441 | ·518 | ·601 | ·690 |

From this, it will appear that, as Lloyd's rules provide twelve-sixteenths in. diameter rivets for the stringers, and the Liverpool rules provide thirteen-sixteenths in., the provisions stand to each other as ·44 : to ·51, or as 1 : 1·16; making the Liverpool rivets as to diameter one-sixth stronger, or 16 per cent. better, than the Lloyd's rivets, used for the same purpose. If, therefore, this 16 per cent. be added to the 20 per cent. which the Liverpool rules give over Lloyd's as to number, it will show that the Liverpool stringer is fastened in comparison to the Lloyd's stringer, as 136 : 100; or it may be put, that if Lloyd's stringer was altered to the form and fastening prescribed by the Liverpool book, it would be more than *one-third* stronger *longitudinally* than it is. The same reasoning will apply to the shell plating; in respect to numbers, Liverpool provides 12 per cent. more rivets than Lloyd's, and is therefore, in this respect, nearly one-eighth stronger. Take the case of the sheer-strake of *Coimbatore* there is, by Lloyd's 11 per cent. less rivets as to numbers, see Table 9, and the areas of rivets provided by the two registries, being as ·690 : ·601, or as 1 : 1·15 = one-seventh difference = 14 per cent. This shows this important strake to be 25 per cent. inferior to the Liverpool sheer-strake. The topsides bear the comparison even worse than any other part, for there is 10 per cent. less rivets in number, and their areas are as 441 : 610, or as 1 : 1·36, or nearly of one-third less value which, added to 10 per cent. above, makes the topsides 40 per cent. weaker than those of the Liverpool vessel.

The sum of this inquiry as to rivetting is this:—The upper part of the *Coimbatore*, per Liverpool rules as to stringers and ties, on both decks, has longitudinal strength in it over Lloyd's of 36 per cent.
and as to topsides and sheer-strake, a mean of ... 35 per cent.

71 per cent.

and that, as the gross areas of *stringers and ties*, and *side plating*, are nearly similar from line of upper deck to line of lower deck, there is a mean excess of strength in that portion of the vessel alone, in the Liverpool as compared with the Lloyd's vessel, of 85½ per cent.

This may be subject to a slight reduction, as the areas of the portion of topside plating taken, viz., strakes P. O. and N. are not exactly the same as the stringer areas; instead of being so, they stand to each other in each vessel as 66 : 78 for the Lloyd's vessel, and as 66 : 78 in the Liverpool vessel. There are also certain areas, such as ties and angles, wherein the same high per centage might not obtain. However, to cover all such matters, suppose the 35½ per cent. be reduced to 25 per cent., there is still this difference, that the Liverpool vessel has over a Lloyd's vessel one-fourth more fastening in her upper works.

In the lower part of the side, and in the bottom, as shown by Table 4, there is respectively 12½ and 14 per cent. in favour of the Liverpool rules as to number, and as the diameters of both sets of rules are alike there is only the consideration to add to the above per centage, that Lloyd's rivetting has the additional duty to perform, over and above carrying cargo, of carrying an accession of 15 per cent. to its shell-plating, that in the bottom the rivets have 20 per cent. more area, and in the topside 5 per cent. more area, to unite; and that the whole structure to be held together is at least from 4 to 5 per cent. heavier than the vessel built by the Liverpool rules.

25. It follows, therefore, that in further comparing the two types of vessels, which I purpose doing under the third proposition, the per centages 25 per cent. and a mean of 12½ and 14 = 13 per cent. may be used as a set-off to any advantages which the Lloyd's vessel may develope in the last test to which I intend to put both her and her Liverpool sister.

Before leaving this proposition, however, I think it will appear clear, that the question must be answered affirmatively, as to whether the Liverpool vessel is a better vessel than the Lloyd's, considered relatively thereto.

*First*, In that, her scantling has been determined by length, breadth, and depth, instead of tonnage exclusively.

*Second*, In that, portions of scantling used as plating &c., by Lloyd's are used as keelsons in the Liverpool vessel.

*Third*, In that, the rules determining the size and number of rivets are found to differ.

26. *The third proposition is*, "Whether the Liverpool is the best or worst ship, considered in relation to any standard common to both?" As for instance, in the case of being placed in a position in which the whole of the bottom line is thrown into tension, or in which the whole top line is thrown into tension, and the bottom, as a consequence, put under compression.

Let an ordinary test be applied to each vessel, wherein the whole cross sectional areas are put into the form of a beam girder, having a central web, consisting of the side plating, and also top, bottom, and intermediate flanges, into which are concentrated all the sectional areas of the upper deck line, (in which case two-thirds of sheer-strake is added), the bottom line and the 'tween deck line respectively; and the whole divided vertically by, and proved in relation to, the neutral axis of the section thus constituted. Reference is here made to Figs. 9 and 10, Plate V., on which the form of the *Coimbatore* is drawn, with its equivalent girder section, as determined by the scantlings of the two Registries.

The areas of the different parts will be found to correspond with those on *Coimbatore's* section sheet. Attention is first drawn to the position of the two neutral axes. That of the Liverpool vessel being 15 ft. 4 in. from centre of gravity of upper deck line area, while that of the Lloyd's vessel is 15 ft. 5 in. between the same points—showing only a very slight difference between the moments of area in the two vessels.

The displacement of the vessel in each case is assumed to be 2600 tons, or as reduced to the effective weight upon the centre, by taking 74 per cent. of the deadweight capacity, instead of the whole, and adding thereto half the weight of ship and outfit. Thus:—

Capacity about 1723 tons,* 74 per cent. of which $= 1280 + (850 \div 2) = 1705$ tons at centre.

* Deadweight capacity reckoned at 50 per cent. more than registered tonnage.

Then place Lloyd's vessel on supports, 195 ft. apart, one under each end. The strain thus generated, and acting upon the centre, will be equal to half of the 1705 tons multiplied by the leverage of half the length of the ship, and the product divided by the distance of the neutral axis from the bottom. Thus:—

$$1705 \div 2 = \frac{852\frac{1}{2} \times 97\frac{1}{2}}{7{\cdot}58} = 10{,}965 \text{ tons.}$$

for the Liverpool vessel $$\frac{852\frac{1}{2} \times 97\frac{1}{2}}{7{\cdot}66} = 10{,}851 \text{ tons.}$$

the areas in bottom portions resisting tension in the Lloyd's vessel are 482 square inches for bottom flange, and a proportion of the lower half of centre web due to the distance of its centre of gravity from the neutral axis. This is very nearly one-half of the whole distance between neutral axis and centre of gravity of lower flange; and, therefore one-half of the lower portion of centre web is added; thus—

$$482 \text{ sq. in.} + (134 \text{ sq. in.} \div 2) = 482 + 67 = 549 \text{ sq. in.}$$

in the bottom of the Lloyd's vessel.

$$\text{Then } \frac{10{,}965 \text{ tons}}{549 \text{ sq. in.}} = 19{\cdot}9 \text{ tons per sq. in.}$$

For the Liverpool vessel the areas are—

$$468 \text{ sq. in.} + (139 \text{ sq. in.} \div 2) = 537 \text{ sq. in.}$$

$$\text{Then } \frac{10{,}851}{537} = 20{\cdot}2 \text{ tons per sq. in.}$$

This shows that the resisting powers of Lloyd's bottom to tension—taking the gross area in square inches as a divisor, as above—are superior to those of the Liverpool vessel as 20·2 is to 19·9, or 1½ per cent. more. But if it be borne in mind that it is the rivetting that is now under tension, and that there is a difference in favour of the Liverpool vessel in this item of 14 per cent. over Lloyd's, the above figures will then stand thus:—

Liverpool area as above stated bears, per square inch, 20·2 tons, as ultimate strain, while Lloyd's bears, by 14 per cent. diminished areas 23·0 tons as ultimate strain.

Reversing the positions of the vessels, and supporting them by the centre, we have the strain tending to produce rupture at the centre of Lloyd's vessel, as—

$$\frac{852\frac{1}{2} \times 97\frac{1}{2}}{15\cdot4} = 5393 \text{ tons.}$$

And in the Liverpool vessel, as—

$$\frac{852\frac{1}{2} \times 97\frac{1}{2}}{15\cdot33} = 5415 \text{ tons.}$$

The areas resisting in each case are:—For Lloyd's, top flange 116 sq. in., ¾ths of the topside area (between the two upper flanges), or 91·5 sq. in. and half of 'tween deck flange area, or 34 sq. in., or

$$116 + 91\cdot5 + 27\frac{1}{2} + 34 = 269 \text{ sq. in.}$$

For the Liverpool vessel in the same proportions of the several areas there will be—

$$118 + 91\cdot5 + 26 + 36 = 271\frac{1}{2} \text{ sq. in.}$$

Then for the Lloyd's vessel—

$$\frac{5393 \text{ tons}}{269 \text{ sq. in.}} = 20 \text{ tons per square inch of gross section.}$$

And for the Liverpool vessel—

$$\frac{5415 \text{ tons}}{271\frac{1}{2} \text{ sq. in.}} = 19\cdot9, \text{ say } 20, \text{ tons per square inch of gross section.}$$

27. These results show that the Lloyd and Liverpool vessels offer resistance to the tension, thus thrown upon the upper deck to exactly the same amount, so far as their comparative sectional area settles the point; but here also it must be borne in mind that the strain is thrown upon

the sectional area only in the proportion in which the rivetted joints stand to that area, and without inquiring how far either of these vessels approach to that desirable indentity, it is enough to know for my present purpose, that the Liverpool has at least 25 per cent. more strength in the rivetting than the Lloyd's vessel, and hence the above figures become altered in their mutual relationship, and instead of standing as 20 to 20, they will stand as 20 to 25, in other words the case stands thus—as now situated the vessel is in the worst possible position and its tendency to rupture greatest; by putting the comparison in another way the capacities of the two vessels will be seen thus:—Let the formula $\frac{a\,d\,c}{l}$=W, be applied, and let $a$ represent the area of upper half of the vessels, and C = the comparative values of the rivetting of the two vessels, and stand as 60 for Lloyd's and 75 for Liverpool or 25 per cent. difference, then for the Lloyd's vessel we have

$$\frac{269 \times 23 \times 60}{195} = 1903 \text{ tons breaking strain,}$$

and for the Liverpool vessel $\frac{271\frac{1}{2} \times 23 \times 75}{195} = 2400$ tons strains,

it will therefore be seen that if Lloyd's vessel was situated so as to require only 200 tons more than her own displacement to cause rupture, and thus have only the 13th of her displacement weight as a margin of reserved strength, the Liverpool vessel would be perfectly safe under the same circumstances, having little over $\frac{4}{5}$ of her ultimate strength brought into play.

28. I do not think it necessary to carry this comparison further. The question as to comparative resistance to compression is settled, by the close approximation of the areas, and it is quite clear also, that the $7\frac{3}{4}$ excess in bottom area enjoyed by the Lloyd's vessel would, from the defectiveness of the top fastenings, never be called into use.

I wish however to remark here, that I have left unnoticed the three following matters, viz., *First*, that the Liverpool vessel being about 5 per cent. lighter, would therefore have a difference in her favour of some 40 tons of displacement weight in the foregoing calculations.

*Second*, that throughout I have included the deck diagonals as effective cross sectional area, in the Lloyd's vessel, both for longitudinal and compressive strains. If these were deducted therefrom, the difference would be of course more in favour of the Liverpool vessel.

*Third*, I have only applied the foregoing investigations to one size of vessel, and that unquestionably one which does not put Lloyd's provisions in the most unfavourable light when compared with those of the Liverpool book,

I submit, therefore, that in the foregoing remarks under the three propositions, the following points have been shown.

1. That there was not sufficient data supplied in the paper under notice to enable the members of the Scottish Shipbuilders' Association to express any definite opinion on the question propounded in it, viz., "Whether the Liverpool 20 years, or the Lloyd's Ⓐ 1 vessel was the best."

2. That the data furnished was very incorrect as well as insufficient.

3. That in all general and essential points the Liverpool vessel is the most mechanical and strongest, and in this latter respect the most durable, that she is as durable as Lloyd's in all vital parts viewed in relation to corrosive action, and that in view of the intensity of this action, she is more wisely provided for, than Lloyd's vessel, because of being as well provided against it where it is most imminent, and correspondingly provided against it where it is least active.

4. That she is the lightest, and by the opinion of the author of this paper under notice, as well as by internal evidence, she is the cheapest vessel.

5. That therefore the Liverpool vessel, as compared with Lloyd's, is the best vessel, because she combines the greatest strength with equal durability, with less material and at a less cost.

6. That the Liverpool Rules providing for scantling of ordinary vessels, are more effectual and serviceable than those in use by Lloyd's, and that more provision is made by the Liverpool Rules, in view of inflation of the ends of a vessel, whose dimensions remain unaltered, because there is a much greater resident strength obtained by a better distribution and fastening of the material permitting such almost unavoidable encroachments (upon any system of scantling) with the least risk.

7. That the parts of scantlings which the Liverpool committee require to be added or increased in Lloyd's vessel where the latter are sought to be classed in their register book, when such additions refer to keelsons, ties, stringers, and rivetting, do add a clear and important advantage to such vessel, and that there might be a removal of much useless weight from certain parts of such vessels, without loss of any strength thereby, to make way for the said beneficial additions required by the Liverpool committee.

I reluctantly close this paper, deterred from proceeding further on account of the extent to which I have been led in replying to the paper under review so far as it affects the provisions of the two registries for sailing vessels. In closing, however, I beg respectfully to call attention to Table 1, in which will be found a comparison between the provisions of the two registries for a 20 years and an A steamer of 999 tons register, of 250 ft. by 35 ft. 9 in. by 18 ft. 3 in., and of 7 breadths to length, and just under 14 depths in length, in which the gross scantling of the two registries are identical, taken in connection with comparative end reductions, but between which the greatest disparity exists as to the distribution of the material and the relative advantages thereby secured.

# TABLE I.

Showing comparisons of AREAS of the Scantlings of Iron Vessels shown in Mid-section, Plates IV. and V. Areas are for one side only, including half of keel and middle line keelson in each case.

NOTE.—The small "per cent." column, under each heading, shows the excess of area (per cent.), in those parts which the vessels of one Registry have over vessels of the other—Liverpool figures are the upper rows in all cases.

| Column 1 | 2 | 3 | 4 | | 5 | | 6 | | 7 | | 8 | | 9 | | 10 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Vessels taken for Comparison. | Tons nett Reg. | Registry. | Gross Area of one side Shell. | | Area of Bottom Plating. | | Area of Bottom Keelsons. | | Area of Side Plating to 2-3rd depth. | | Area of Deck Stringers, ties, and angles. | | Gross Areas of Stringers, ties, angles, & keelson | | Gross Areas of Half Mid-section. | |
| | | | Sq. ins. | % | Sq. ins. | % | Sq. in. | % | Sq. ins. | % | Sq. in. | % | Sq. in. | % | Sq. in. | % |
| Orange Grove, | 360 | Liverpool, | 189·99 | | 81·62 | | 34·50 | 62 | 81·12 | 5½ | 41·78 | 35 | 76·28 | 46 | 266·20 | 7⅓ |
| | | Lloyd's, | 195·85 | 3 | 91·55 | 12⅛ | 21·30 | | 74·80 | | 30·98 | | 52·28 | | 248·13 | |
| Sarah Scott, | 520 | Liverpool, | 220·49 | | 92·37 | | 42·62 | 30½ | 96·62 | | 51·25 | 24 | 93·87 | 27 | 313·86 | |
| | | Lloyd's, | 225·03 | 15½ | 114.99 | 24½ | 32·64 | | 102·55 | 6⅛ | 41·27 | | 73·91 | | 328·94 | 5 |
| James Wishart, | 680 | Liverpool, | 27 8·48 | | 124·19 | | 42.62 | 4¾ | 117·73 | | 52·50 | 3 | 95·12 | 3¾ | 373·03 | |
| | | Lloyd's, | 318·22 | 14¼ | 151·12 | 22 | 40·75 | | 124·17 | 5½ | 50·96 | | 91·67 | | 410·19 | 10 |
| Weathersfield, | 988 | Liverpool, | 319·77 | | 140·42 | | 68·18 | 13½ | 136·86 | | 66·37 | 0 | 153·67 | 12 | 473·44 | |
| | | Lloyd's, | 360·48 | 13 | 168·18 | 20 | 60·0 | | 143·49 | 5 | 66·57 | 0 | 137·07 | | 497·55 | 5 |
| Coimbatore, | 1149 | Liverpool, | 339·90 | | 149·79 | | 84·63 | 16½ | 149·49 | | 66·37 | 0 | 166·18 | 19 | 506·08 | |
| | | Lloyd's, | 382 61 | 12⅛ | 179·31 | 20 | 72·57 | | 156·55 | 5 | 66·92 | 0 | 139·49 | | 522 10 | 3⅛* |
| Nagpore, | 1444 | Liverpool, | 381·06 | | 169·09 | | 96·80 | 14½ | 171·35 | 13½ | 80·62 | 3½ | 203·79 | 25½ | 588·85 | + |
| | | Lloyd's, | 466·25 | 22¼ | 218·97 | 29½ | 84·49 | | 194·48 | | 77·99 | | 162·48 | | 628·73 | 6½ |
| No. 6, Section Sheet, | 1950 | Liverpool, | 438·55 | | 193·68 | | 102·30 | 12¾ | 164·87 | 13½ | 131·24 | 0 | 233·54 | 5¼ | 672·09 | |
| | | Lloyd's, | 500·86 | 14¼ | 231·55 | 20 | 91·31 | | 187·06 | | 130·60 | 0 | 221·73 | | 722·59 | 7½ |
| Screw Steamer, | 999 gross. | Liverpool, | 316·3 2 | | 148·59 | | 87·31 | 59 | 127·73 | 3½ | 96·87 | 21¾ | 184·18 | 37 | 500·5 | 2‡ |
| | | Lloyd's, | 356·10 | 12½ | 178· | 19¾ | 54·93 | | 132·11 | | 79·58 | | 134·51 | | 490·61 | |
| Mean of per cent., | | | | 15 | | 22¼ | | 15§ | | 7½ | | | | 15§ | | 6§ |

* 6¼ per cent. without side stringer. + Late side stringer added. ‡ Without reckoning end reductions. § Omitting 1st and 8th.

In the after discussion,

Mr. John Ferguson said that the object of the paper, which had been reviewed by Mr. Price, was to draw attention to the annoyance and expense caused to shipbuilders and shipowners, who constructed vessels to class in both Lloyd's and the Liverpool registries. For example, they had to put in thick stringer plates according to Lloyd's requirements, and broad plates to come up to the Liverpool rules. Certainly they sometimes got the differences modified by correspondence; but that was a disagreeable course, and not always successful. The paper was intended to advocate the doing away with any unnecessary weight of iron, or extra expense. He considered that Mr. Price's conclusions came very near to what he had arrived at, with regard to vessels of from 500 tons up to 1000 or 1500 tons. The small discrepancy of one or two per cent., pointed out by Mr. Price in regard to the 200 tons ship, which in the paper was said to be alike according to both Lloyd's and the Liverpool rules, was not worth mentioning. He maintained that he was right in reference to the 2000 tons ship which he had cited, which showed that the weights were nearly equal when built according to Lloyd's or the Liverpool rules. He did not doubt, however, that Mr. Price was quite correct with regard to the vessel he had taken, as the proportions of dimensions of the one vessel might be very different from the other, while the tonnage might be the same in both cases, and as Lloyd's regulate the scantlings chiefly by the tonnage, while the Liverpool scantlings were chiefly founded on dimensions; but still, after looking over his figures he saw no reason to alter his previous deductions therefrom. There were a great many other points in the paper which might be taken up. For instance, Mr. Price supposed that the floors required to be made thicker at the ends, because they were most subject to corrosion there. Now, he differed entirely from him in that opinion. He thought it was in the middle that corrosion was most injurious; and experience showed that. The same argument would apply to the plating. It was all very well to take such a ship as the *Richard Cobden*, where the floors were high throughout. But let him take an ordinary vessel, and he would find a different result. The firm with which he was connected had repeatedly taken the bottoms out of ships, and found them entirely worn through between the frames near the centre of the ship. Now that cement, &c., was used between the frames, that action might be done away with; but he thought that the fact of the greater wear being in the centre of the vessel was an argument why the bottom plating should be thicker, quite irrespective of the chance of the vessel grounding, which was a very important matter; for he held strongly that it was impolitic to reduce the thickness of bottom plating. Experience showed that vessels rivetted according to Lloyd's rules were not deficient in the number or size of rivets; on the contrary, he believed that by the rivets being too large, or too closely spaced, the vessel was weakened. Mr. Price had endeavoured to show that the Liverpool keelson was superior to Lloyd's. He agreed with him in that opinion; but what the Scottish Shipbuilders' Association objected to, was having to add the heavy keelsons of Liverpool to what they looked upon as the unnecessary weight of plating, floors, &c., of Lloyd's.

Mr. Price, in reply, begged to say, that there is not "one or two per cent." only of difference between his and Mr. Ferguson's weights of the 2000 tons vessel; but on the contrary while Mr. Ferguson says that this vessel by the two registries would be of "nearly equal" weight, he (Mr. Price) shows a difference of 7½ per cent., and when he spoke of corrosion he meant the action that took place on iron between the air and water especially, and not by the presence of any deleterious substance. He did not mean by corrosion the action of any substance or matter which might be held in solution in the bilge water, or the rubbing action of gravel, or stones; but simply the corrosion arising from the affinity of the iron for oxygen. The *Orange Grove*, alluded to by Mr. Ferguson, was one of the vessels built on Lloyd's rules, with a heavy floor. He maintained that if the thick floors would not stand, then nothing worse could be said of the thin floors; and that where deleterious substances existed in the bilge water decomposition could not be prevented, unless some material, such as cement, were used as an intercepting medium. He begged to say, that he had gone altogether out of the sphere of speculation—he had even not quoted his own every day experience,—but had referred to facts brought out in experiments; and therefore he trusted that in the contemplated discussion this principle would not be lost sight of. He would like the future discussion to be somewhat different in that respect from the discussion which took place on the paper referred to.

The PRESIDENT assured Mr. Price that facts only would weigh in the discussion. Mr. Price placed very great stress upon the superiority of the Liverpool Rules in regard to heavy rivets; but he appeared to lose sight of this—that not only the strength of the rivets in the butts must be taken into account, but also the rivets in the longitudinal seams, because the rivets in the butts could not be torn without the seam rivets being torn also, and the united strength of all these rivets being greater than the strength of the plates, Lloyd's people would naturally turn round and say that the size of rivets prescribed by them is ample, and that the thicker plating of their rules gives greater strength to the ship.

Mr. PRICE said he had considered that point, and he quite believed that there was a mistake in supposing that to be the case, when the whole depth of the ship was taken. If a series of strakes were produced, with the butts distributed in the usual way as found in vessels, and the strain caused, or supposed to pass, through the whole depth, they would find that the line of fracture resolved itself into the weakest part of the solid plate and through the butts. It was, therefore, a question as to whether the extra thickness of the Lloyd's plate was equal to the extra strength of the Liverpool butt. He did not think that the Liverpool vessel would suffer by a comparison.

The PRESIDENT said that in the paper Mr. Price stated that he had found in the Liverpool butt 25 per cent. greater strength; but he did not think that therefore the side of the ship was stronger.

Mr. PRICE replied that the only place where he claimed that 25 per cent. without any drawback, was where the butt ran across the whole breadth of the plate, and where all the advantage could be claimed, as in the case of the beam stringer.

The PRESIDENT said that according to the Liverpool rules, the web of the centre keelson was a double plate; and it was assumed that because the butt was covered by a solid plate, there was greater strength. But the solid plate was perforated like a butt-strap for the plate on the opposite side, and therefore he did not think there was the superiority in the Liverpool keelson which Mr. Ferguson had admitted.

Mr. PRICE responded, that the plates forming the keelson were from 10 to 12 feet long, and there were from 5 to 6 feet between the butts themselves. This distance, therefore, enabled them to count three nearly solid plates opposite each butt, without reckoning angles, say the butt of the centre web; there was a solid plate on the top, and also a solid plate on the bottom; then although the second plate forming the web was perforated to accommodate the butt strip also put on there, they had its remaining solid section to take into account. That was the least estimate of the strength at that point, whereas Lloyd's keelson has in wake of its butts only the top and bottom angles, and only a single butt strip on one side of centre web.

Mr. W. M. NEILSON said he believed the object of the paper read by Mr. Ferguson was to try and obviate the difficulty of building ships to class in the two registries—and to get the superfluous expense in adapting a ship to class in both registries done away with. He presumed that if all could agree upon one arrangement or class of details, and put their weight upon it, they would get a compromise between the two registries, which was a thing to be desired.

Mr. PRICE replied that that certainly was not the object in view in the discussion. Mr. Barber said "he had gone very carefully into Lloyd's and the Liverpool rules, and also into Mr. Ferguson's paper, and he could come to no other conclusion than that the committee of Lloyd's register had acted wisely in adopting tonnage as the standard by which the scantlings of iron ships should be regulated." The fact was, that the Association had, during the discussion, left the main issue, and those who will read the paper itself will find other questions propounded in it of an entirely different character.

Mr. Ferguson said the object of his paper was to get the best qualities out of each of the rules, and get them formed into one code of laws. His intention was not to condemn the Liverpool rules, but to get their good keelsons, and any other good points, and combine the excellencies in both registries.

The discussion was then postponed till the January meeting.

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The discussion on Mr. Price's paper was resumed on 30th January, 1867. The following remarks by Mr. George Barber were, in his absence, read:—

After having carefully read Mr. Price's paper, and keeping in mind the results of nearly two more years' experience and daily examination of new and old, sound and damaged iron ships, I see no reason for altering or modifying the opinions which I expressed, and which Mr. Price has referred to.

I am afraid that Mr. Price regarded Mr. Ferguson's paper as an *attack* upon the Liverpool Rules. I can safely say that it was not so regarded by the Shipbuilders' Association before whom it was read, and that it was not discussed in a spirit of enmity or opposition.

I am still of opinion that the *form* of a vessel should be taken into consideration when determining the size, amount, and mode of distribution of material to be used in its construction; that the weight of hull should be proportional to the load displacement; and that, as the new measurement tonnage, when looked at with the principal dimensions, is a correct index both of a vessel's form and of her load displacement, a table of scantlings based on such tonnage must be more satisfactory and efficient for general purposes and practice than one based upon principal dimensions alone. If, on analysing and tabulating the dimensions of the different classes of vessels in the mercantile marine, it be found that certain dimensions or proportions invariably produce a certain tonnage, and, consequently, a certain and universal type or form of vessel, it is immaterial whether the standard for scantling be dimensions or tonnage. It will be a distinction without a difference. But this will not be found to be the case. On the contrary, it is well known that every variety of form, from a parallelopipedon to a prism, may, even in ships and steamers, be contained under the same principal dimensions. Now, it was for the especial purpose of taking cognisance of these varieties of form, as also of including all parts of a ship which might be "gorged with cargo," that the new measurement tonnage was introduced, and Mr. Price is mistaken when he supposes that a vessel of 800 tons may be "inflated *at the ends*" until she becomes a vessel of 1200 tons. The "inflated" vessel would be known and registered by the greater tonnage, which greater tonnage would govern the size and amount of material to be used in her construction.

In speaking of the "vital parts" of a ship, I presume Mr. Price means those parts which, if affected by decay or injury, would most readily impair her efficiency or endanger her existence. I am of opinion that such parts are in most cases *below* and not *above* the waterline. I have not found that the wasting or deterioration of material, either externally or internally, or from corrosion, oxidation, or decomposition, takes place to the extent stated in the upper plating and topsides, or to the same extent in those parts of a vessel as in the floors and plating of the bottom. Partly on this account, and chiefly on account of the greater local strength and security afforded at those parts where the greatest local injuries are most often sustained, I consider that a vessel with the stronger floors and thicker bottom plating, required by Lloyd's, is likely, other things being equal, to prove more serviceable and durable than a vessel with floors and bottom plating which Mr. Price admits are "much lighter and weaker." In coming to this conclusion, I am not unmindful of the extra size and weight of the Liverpool keelson; but the instances on record, and within my own personal knowledge, are many, in which a good substance of garboard strake and good substantial floors have been of more value towards the saving of the ship than any extra weight or increased sectional area of internal stringers and keelsons. The damage sustained by iron ships is in most cases of a *local* nature, and I do not think a single instance can be quoted in which a vessel built in accordance with Lloyd's Rules has proved insufficient or unserviceable from structural defect or inherent weakness. These considerations are not always taken into account, and it often happens that attention is directed not so much to ascertaining what mode of construction will be most serviceable for the ordinary risks of navigation and purposes of commerce, as to ascertaining what amount of force will be necessary to *destroy* a ship if placed in positions in which it is scarcely possible a ship ever will be placed; what distribution of material will be most efficient for resisting strains which most probably will never be brought into operation, and what amount of strength will be necessary to withstand the powers of a combination of destructive elements, against which all the applications of human skill and ingenuity will and ever must be valueless.

I cannot agree with Mr. Price that inferiority of workmanship must be a necessary consequence of the adoption of the thicker plating required by Lloyd's. We know that there can be perfection of workmanship in the connection of thick garboard strakes to thicker keels, and it is, therefore, an unjust reflection upon our shipbuilders to maintain that the "soundness of rivetted parts" is dependent upon the difference between a ten-sixteenth inch and a twelve-sixteenth inch plate.

The assertion that "lighter plates, in greater breadths and lengths," will "be less liable to rupture under pressure from stranding," will not, I think, be borne out by any one who has had experience in the examination of stranded ships.

Mr. Price attaches great value, and lays great stress upon the increased size and number of rivets in Liverpool classed ships. But, while attributing the stated superiority to the closer approximation to Fairbairn's experimental results, he does not bring forward any facts to prove that the rivetting prescribed by Lloyd's has proved insufficient. If it has proved sufficient, any increase in the number or size of perforations ought to be avoided.

Mr. Ferguson being unable to be present,

Mr. Duncan read the following extracts from a letter he had that day received from him:—

"As I am unable to be present at the discussion on Mr. Price's paper, I would like you to take exception to the conclusions that he arrives at in his strictures on my paper, viz., "that there was not sufficient data," &c., and "that the data furnished was very incorrect." I suppose he comes to that conclusion, because the data furnished did not agree with the data which he took.

"He must know very well that a slight deviation in the proportions of length, breadth, or depth, would alter all his carefully got up tables of comparison (the tonnage of the vessel being still the same); and while I admit that he may be quite correct in the deductions from his data, I claim the same admission, as I am at liberty to take any proportions different from his which I can obtain from the sources previously named.

"As the greatest disparity is shown to be in the scantlings of a 2000 tons ship, I have again compared the scantlings of a ship of that size, taking the proportions of the *Agamemnon*, one of the first large ships in the Liverpool registry, and make the difference in weight of iron to be 2½ per cent. instead of 7½ per cent., as Mr. Price makes it from the proportions which he took; and I think it unfair to select a limited number of vessels, and dogmatically to condemn as incorrect, all that does not agree with them. I may state that the data which was furnished in my paper was never intended to show any advantage to the one set of rules or the other, the object being to give the correct differences in so far as I could ascertain them."

Mr. Duncan said it appeared to him that the questions involved in Mr. Ferguson's paper, and the discussion which followed thereon, had been almost entirely lost sight of in Mr. Price's reply. He believed the members of the Scottish Shipbuilders' Association generally, who took part in the discussion on Mr. Ferguson's paper, did so, without any party spirit whatever, on the merits of both registries, and not on the superiority of either.

In discussing scientific and practical subjects, the investigation of which constitutes the aim of such Institutions as theirs, party feeling should have no place. To discover, select, and apply the best of everything for the advantage of their respective trades and professions, appeared to him to be the only aim they should have in view in their meetings and discussions, and whatever tended to party spirit or an assumption of superiority should be discouraged.

In discussing the merits of Lloyd's and the Liverpool Rules, they only assumed the consideration of matters of great relative importance to themselves as shipbuilders and shipowners. To know which was best of any matters they deal in or with, was certainly a legitimate part of their business, and it appeared to him that they would be wanting in their duty to themselves as shipbuilders and shipowners, if they accepted, without question, the dictum of any society on matters of so much importance in shipbuilding as the amount, sizes, and distribution of the scantlings of the material with which they constructed their ships. No society had any right to tell them, or any other society categorically, that they were all wrong, that the affairs *they* regulate have been properly considered and must be accepted as law. He trusted they were still at liberty in this country to have an opinion, and to express it courteously, even on such matters as Lloyd's and the Liverpool regulations for the construction of ships, even although they might differ entirely in their estimate of those regulations from those who frame and administer them.

He had no intention of following Mr. Price into the minutiæ of his criticism on Mr. Ferguson's paper and the discussion thereon, but would content himself with defending himself and those who held with him from Mr. Price's strictures on their part of the discussion.

The sole reason for bringing up and discussing the merits of the two registries was, not to make invidious comparisons to the disadvantage of either, but to endeavour to bring about an assimilation of the scantlings of both, so that a ship built to class in both books should not be more expensive to the owner, nor troublesome to the builder, in arranging compensations, in the one case for tonnage, and in the other for dimensions, than if built to either class singly. This matter Mr. Price had entirely passed over in his desire to establish beyond question the superiority of the Liverpool rules; but it is nevertheless the stand-point of the whole discussion. What they all objected to, he believed, was, that the principles on which the scantlings of the two registries are arranged, are fundamentally different; Lloyd's being apparently based on experience and tonnage, or form; the Liverpool rules, apparently, on theory and dimensions, irrespective of form. The Liverpool regulations he took to be based on the calculations for a ship, being analogous to the calculations for a box beam, or girder, and subject to similar conditions for strains on the square inch of section.

While he did not question the right of Mr. Price, or any of the gentlemen belonging to the Liverpool Association, to hold any opinions, or to endeavour to enforce those opinions by legislation, and while he had no inclination in a party spirit to assume anything for Lloyd's above either, he claimed permission to question the propriety of making extreme dimensions the basis for scantlings of ships irrespective of the form, the load, or the work a ship had to do. In shore-girders the form and the load are always or generally taken into consideration, and determine, more or less approximately, the sectional area of the material of which they are constructed.

The framers of the Liverpool rules, while satisfied of the correctness of the principle of calculation by dimensions, had altogether overlooked the considerations of the form and load; and in determining the greater part, if not the whole, of the longitudinal scantlings, by length and breadth alone, had virtually adopted Builders' Measure as their standard of tonnage, and the fullest possible form as the only form which it is expedient to build under any circumstances. But, (and this was the point on which he differed entirely from the Liverpool regulations,) all ships are not *boxes* of the same uniform type, and those who held with him would be difficult to persuade, that the form and the load were of no moment in determining the scantlings of which any ship should be constructed. He had said in a previous paper, and in the discussion on Mr. Ferguson's paper, Mr. Barber had supported him, and Mr. Price had taken special exception to their statement: that on the same principal dimensions he could increase or diminish the tonnage and displacement, or deadweight load, one-third, without inflating or fining the form beyond that usual for merchant ships; and by Lloyd's rules he received or supplied compensation in proportion.

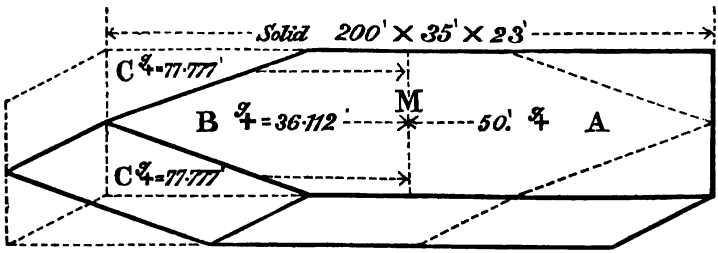
In making that statement he had reference to Lloyd's rules only. By the Liverpool rules it is impossible to increase the tonnage, or real or assumed load, for which provision is made, and strictly speaking therefore, with reference to these rules, he could only say "*diminish*" the tonnage and displacement to the same extent, and receive no consideration for the diminished work, which the reduced form of ship only enables it to do.

He could not make the ship carry more deadweight than it would swim with, and therefore he was fairly entitled to ask that the utmost displacement load of his intended ship should be taken into consideration in apportioning the scantlings to the work; a consideration which any civil engineer would expect or give for any structure to carry weight on shore. He might be told that the alteration of the form of the ship diminishes the sectional area of the material of the midship section to the diminished load. He said never with the same scantlings; besides which, there is not necessarily any diminution of the mid section to the diminished load, the form of mid section altogether depends on the purpose for which the ship is designed; but if the mid section be diminished, then according to the Liverpool rules the only alteration is in the amount, and not in the scantling, of the bottom plating; the floors, bottom keelsons, and hold stringers being still the same; and the topside plating, deck stringers, and ties from which the tension of the load had been removed, were unaltered in sectional area further than by the altered height of the neutral axis, consequent on the rising of the floor. Now, to treat the Liverpool rules by the principles on which they are based, and consider the ship for the time as a box beam, the effect of this diminution of the load one-third, or any fraction of the maximum, is easily seen by a comparison of the moments of the load. With no alteration of the length, or the section, and supposing the weights to be equally distributed over each body, the moment of stress in each case is exactly proportional to the load on the section, multiplied by the distance of the centre of gravity from the centre of the beam. For example, A is a rectangular solid or box beam of dimensions suitable for a ship similar to those so often quoted in this discussion—say 200 × 35 × 23 with a load displacement of 3000 tons. B is another rectilineal figure inscribed within A, of the same dimensions, but having a load of only 2000 tons, or two-thirds of A, the alteration of the form and load being effected in the manner usual in ships, by cutting off the solids CC from the sides at the extremities, for one-third of the length; then M, the centre of the whole solid, axis of rest or suspension, $g$ the distance of centre of gravity of the respective solids from the axis M. $m$, the moment of stress in foot tons on each is as follows:—

$$\tfrac{1}{2}\,\mathrm{A}g = 1500 \times 50' = 75{,}000 \text{ moment of } \tfrac{1}{2}\,\mathrm{A}.$$

$$\tfrac{1}{2}\,\mathrm{B}g = 1000 \times 36{\cdot}112' = 36{,}112 \quad ,, \quad \tfrac{1}{2}\,\mathrm{B}.$$

$$2\,\mathrm{C}g = 500 \times 77{\cdot}777' = 38{,}888 \quad ,, \quad 2\,\mathrm{C}.$$




Therefore the removal of one-third of the load from the "inflated ends which have been gorged with cargo," is equivalent to a removal of fully half the load from the midship section of the finer form, the comparative moments of A and B being respectively as 75 to 36.

He now repeated, "with all conceivable distinctness," the converse of what he had stated before. Now, by Lloyd's rules, the *finer* vessel, which would have the *lesser* amount of work to do, would be permitted to have the *lighter* scantling in proportion, as any one might see by comparing the scantlings on the 800 and 1200 ton lines, or any variation of the grades one-third. He did not mean to say that Lloyd's scantlings were perfect in proportion to the load, but that the whole amount of material in the ship was nearly so, he had proved in a previous paper. It was possible that the distribution of the material might be amended without adding to the total weight; but while the Liverpool rules admit of no reduction of scantlings even for so important a diminution of the form and load as *one half* of their calculated maximum, Lloyd's rules acknowledge the diminished load by taking tonnage as their standard for scantlings. The extreme cargo load, as Mr. Price had correctly stated, was seldom in excess of once and half the gross register tonnage, to which the weight of the ship was added for the load displacement; but as this also (as he had endeavoured to show in another paper), was, or might be, in direct ratio to the gross register tonnage, it followed that the maximum load on any dimensions, with a given register tonnage, could be easily computed; altogether two and a quarter times the gross tonnage might usually be taken as the gross load; and if the length and the load, as the principal factors in the calculation for strength, could be at all times so easily obtained, he saw no reason why the Liverpool rules might not, without any violation of their own principles of construction take account of the load by the tonnage, and give the ship the benefit of such modification of form and relative scantlings on any dimensions, as science, judgment, or the exigencies of trade might dictate. It might be argued with reason that the actual centre of gravity of the load for each modification of form and the exigencies of loading, even on the same dimensions, cannot be precisely defined in this manner, far less for the proper work of a ship, but granting the worst probable distribution of the stress on the midship section in any case, particularly the worst for the finer forms, that the load be equally distributed over the length, and in proportion to the length, and not to the form, the centre of gravity of each half load, being in the middle of each half length, then the moments of stress in all cases would be as half the load multiplied by one-fourth of the length, expressed by the ordinary formula $m = \frac{1}{8}$ W L, that is, directly proportional to the load, or, as had been shown, its exact equivalent, the tonnage; the calculation was thereby reduced to its lowest terms, tonnage and length; then, given, the same dimensions, the maximum sectional area for those dimensions, and the greatest possible load or tonnage, every reduction of form or tonnage was entitled to a proportional reduction of sectional area.

The formula $S = 2 \sqrt{m}$ appeared to represent, nearly in accordance with practice, the amount of sectional area of metal required for the midship section in proportion to the dimensions and load; and if they tested the scantlings of both registries by this "standard common to both," they might find cases differing considerably in dimensions and tonnage, in which both might be right, while the general application of the standard might show both alike imperfect.

Applying this standard to the figures A and B, taking the moment of load for both, at one-fourth of the length, they had the moment of half A = 75,000, the square root of which is 274, which, multiplied by 2, gives 548 square inches, as half mid sectional area of metal for figure A.

B is also in the same proportion thus—moment of $\frac{1}{2}$ B = 50,000, the square root of which is 224, which, multiplied by 2, gives 448 square inches, as half mid sectional area for figure B.

Now, to test Mr. Price's figures by the same standard, his Table I. contains eight vessels of tonnage respectively, as in the first column of his and the following Table; in the last column of both, are given the gross areas of half mid section, calculated by Mr. Price; the intermediate columns in his (Mr. Duncan's) table show the length, the load, the moment of length and load, and the gross areas of half mid section, computed by the formula $S = 2 \sqrt{m}$.

| No. | Tonnage Register under Deck. | Length. Feet. | Displacement Tons. | $m = \frac{1}{8}$ W, L moment in foot Tons. | $2\sqrt{m}$ Sectional Area of Half Mid Section. Inches. | Liverpool and Lloyd's. Section in Inches. |
|---|---|---|---|---|---|---|
| 1 | 360 | 140 | 810 | 14,175 | 238 | {266 290 |
| 2 | 520 | 150 | 1170 | 21,937 | 296 | {314 329 |
| 3 | 680 | 165 | 1530 | 31,365 | 354 | {373 410 |
| 4 | 988 | 205 | 2250 | 57,000 | 477 | {473 497 |
| 5 | 1149 | 205 | 2600 | 71,500 | 535 | {506 522 |
| 6 | 1444 | 230 | 3250 | 93,400 | 612 | {589 629 |
| 7 | 1950 | 252 | 4400 | 138,600 | 744 | {672 722 |
| SS 8 | 999 | 250 | 2250 | 70,000 | 531 | {500 490 |

The three small vessels were also the broadest in proportion to their length, and the shortest in proportion to their load. The resultants of the moments, therefore, show a smaller relative area of section than is required by either Rules, but this only served to show that short vessels, in relation to their other dimensions, might be built to a lighter grade without having their strength or efficiency impaired. The five large vessels all compared favourably with the standard, both classes retaining nearly their relative and comparative values, but these were all vessels within the ordinary limits for sailing ships, except the last, and in her case only Lloyd's appeared to lose by the comparison.

In the gross section, on the whole, Lloyd's had the excess more nearly corresponding with the calculated section; but Mr. Price maintained that the Liverpool Rules had the advantage in distribution; that also was open to doubt, as mainly a question of thick plating *versus* thin. In six vessels out of eight in Mr. Price's table, the sums of the sectional areas of the bottom plating and keelsons, and also of the two-thirds side with deck stringers, ties, and angles, were respectively greater by Lloyd's than by the Liverpool Rules, so that above and below the neutral axis of the side, Lloyd's distribution was comparatively the stronger. In the bottom, *compression* must first act upon the plating, before it can be felt by the keelsons; the outside layers of the flange being necessarily first to feel the strain. In the topsides, from the neutral axis upwards, *tension* must first act upon the sheer-strake, stringer angles and plates; and even on these the sections respectively do not differ by any appreciable quantity. Mr. Price lays great stress on the breadth of the stringer plate and the additional rivetting. Now, double rivetting, according to Dr. Fairbairn, is equal to the solid plate with ordinary thickness; the extra rivetting therefore is no advantage for longitudinal strength. The breadth of the stringer is a negative benefit for lateral strength where the stringer is not an independent beam, but part of the web of a skeleton beam, of which the breadth of the deck is equivalent to the depth of the beam, and the centre line of the deck its neutral axis, the gunwale angle and the sheer-strake, with the outer edge of the stringer plate, being the components of the flange. Breadth of stringer plate, therefore, so far from increasing the lateral strength of the deck, diminishes it, by dissipating the section over the web towards the neutral axis, where it is not required. The most efficient skeleton beam, as is well known, is not the one in which all the parts are parallel lines; diagonal trussing being theoretically, and much more so practically, recognised as the strongest construction of the kind, especially so is it the case in ships subject to incessant changes in the directions of the strain, not longitudinally only, but laterally, when rolling violently, as is frequently the case; or less commonly, but not uncommonly, when on their beam ends. It appeared to him, therefore, inadvisable, all things considered, in cases where ships are built to class in both registries, to impose the maximum special requirements of both; it is in many cases not much advantage to the ship, and an expensive and questionable benefit to the builders and owners. One illustration from the same table would suffice. The *Weathersfield*, 988 tons under deck, built by himself, to class in both registries, had scantlings, not exactly in accordance with Mr. Price's table, to either registry, or the heavier; but with the benefit of large dimensions and a fine form, was obliged to have for both the scantlings of a 1300 ton ship, and in some respects in excess of the requirements of the ship of 1444 tons.

| | Scantlings. | Gross plating. | Bottom keelsons. | Deck stringers, ties, and angles. | Gross area of stringers, ties, and keelsons. | Gross area half mid sec. | Section to length and load. |
|---|---|---|---|---|---|---|---|
| Weathersfield, 988 Tons Register under Deck. | Liverpool | 319·77 | 68·18 | 66·37 | 153·67 | 473·44 | 477 |
| | Lloyd's | 360·48 | 60·0 | 66·57 | 137·07 | 497·55 | |
| | Actual | 357·25 | 74·4 | 79·12 | 165·5 | 522·75 | |

It would thus be seen that in keelsons, stringers, and gross section, the *Weathersfield* was a fair average of 1300 tons. For actual duty on dimensions and load, with the same breadth, depth, and sectional area, she might have been built 240 feet long, with greater relative strength than the next vessel in the table. That the builders were not favoured by any concessions would be evident. It was possible that they asked consideration for their large dimensions and small tonnage and were refused. He had no desire to bring that special case up now as a "grievance." He was satisfied that law upon law on contrary principles was always objectionable, however impartially and judiciously the administrators might do their duty. He had felt, and did yet feel, as a builder "desiring to provide the form which he considers best to carry the tonnage required by the owner," that with his large dimensions and fine forms for small tonnage, his greater length and breadth for speed and stability, in proportion to load, he lost commercially, when obliged to build to both Rules, where he might save or gain by building *boxes* of small dimensions and large tonnage; but he was satisfied in the meantime that the principles which regulate the design of the best forms, would by and bye regulate their scantlings also.

Mr. Boolds did not think that the object of their meeting together that night was to decide whether the Liverpool Rules were better than Lloyd's, or whether Lloyd's were better than the Liverpool. He thought the discussion was intended to help to discover the best scantling, and to convey to one another the results of their experience, so as to enable them to arrive at some conclusion which might tend to improve the Rules of both registries, and ultimately to benefit the mercantile marine of this country. He would like to read an extract from the paper of Mr. Price—a gentleman whom he esteemed very much. He says:—"Experience shows that the most deceptive and destructive form of corrosive action is set up on the topsides, resulting in the dry, hard, deep-coloured oxide, produced by a rapid succession of intense changes of the conditions under which the surface is placed, and resistive to all but the utmost persuasion of force. For these instances, Lloyd's vessels are only provided in the cases quoted, with the same plating as the Liverpool vessel—on the lower part of the side, on the bilges and bottom, there being no more needed from fear of corrosion, and none assumed to be necessary to meet any other cause, the plating of the Liverpool registry is preserved uniform, and while preserving all other necessary qualities, which will be presently referred to, the work in construction is more uniform in closeness and soundness of rivetted parts; the lightness of the plates also offers facilities for working them better to their places, having them in greater breadths or lengths without entail of extra cost, advantages more largely experienced in heavy vessels; the plates are also less liable to rupture under pressure from stranding, and, by experience, are found to be as valuable and durable in view of wasting from all causes as is found necessary under such circumstances to use." Now, his (Mr Boold's) experience in this matter led him to say, that Mr. Price's assumption was not supported by evidence. From all the knowledge he had had of vessels, the topsides were not the places where the greatest amount of waste took place. He had found in every-day practice, that the parts most subject to waste was between the upper and lower water lines, and in the bottom. He maintained that Lloyd's Rules were right in requiring thicker plating at the bottom than on the topsides; because the vessel had more work to do there, was more subject to accident, and more likely to be injured by corrosion, than in the topsides. Moreover, deleterious deposits were more easily got at on the topsides than on the bottom, and after every voyage she could be scraped and cleaned. In every respect. therefore, the topsides might be made of lighter plating, and he thought it was the bottom at the midship part of the vessel that should be more heavily plated.

Mr. Darling thought that the experience of all who had had to do with steamships, led them to one view of the matter—to increase the thickness of the plating at the bottom rather than at the topsides. In the case of vessels badly loaded, or overloaded, or subject to straining at sea, experience always showed that the butts of the bilge and bottom plating were the first to open and become leaky, and it was quite unusual to see the butts of the topsides strained; indeed, they were found to be much stronger though of diminished substance. He differed from Mr. Price with regard to the plating of a uniform thickness being necessarily the soundest of work, inasmuch as the plating only graduated by one-sixteenth of an inch, and he did not think that that could in any degree prevent the attainment of sound workmanship in rivetting. With respect to the rivets—they were also increased in accordance with the substance of the plating; and he did not think it had been proved that the rivetting was the weakest part of a vessel. It had been said that though the plates were increased one-sixteenth, inasmuch as the rivets were not increased in like proportion, the fabric was said not to be strengthened. This is to assume that the rivets were the weakest part of the butt. Now, experience led him to the opinion that the weakest part of the butt was the plate through the line of rivet holes, as it was found the plates usually tore there, so that if the plating was increased by one-sixteenth of an inch, the structure must be benefitted longitudinally. Also, upon reference to the Liverpool rules for registries, he noticed that fourteen-sixteenth rivets are prescribed for ten-sixteenth and eleven-sixteenth plates, so that if Mr. Price's argument is correct, it would be as well to save the difference of weight of the eleven-sixteenths over the ten-sixteenths. Also, for vessels of excessive proportions, it is recommended "to have one strake above and one strake below the bilge doubled for half the length amidships;" but in very flat floored vessels, he had found the butts in the flat open and leaking, when nothing has been started at the bilges. He was of opinion that it is quite necessary to increase the thickness of bottom plating over that of the sides, and any deviation from this was a mistake.

Mr. PRICE said the Liverpoool Committee did not make any addition to thickness of plating for length merely.

Mr. DARLING said that in the case quoted for illustration, with respect to the Liverpool stringer on deck, it was stated to be five inches broader and one-sixteenth thinner than required for a similar ship by Lloyd's Rules, thereby gaining one-third lateral strength; but he was at a loss to know how by the increase of five inches in breadth, and a decrease of one-sixteenth in thickness, the power to resist lateral pressure was increased by one-third. With respect to deck stringer and ties, he was of opinion that the arrangement of the thicker gunwale plate, assisted by diagonals on the beams placed all fore and aft, ensured a more uniform strength than would be obtained by merely increasing the gunwale plate in width. The beams having a considerable amount of round up, and being supported by iron pillars to each, the effect of so trussing them was to assist in a longitudinal strain both the bottom and the line of deck. Then if the stringer was so much increased in strength by being made broader and thinner, as was asserted by Mr. Price, where was the limit to this alleged increase? There could be none.

Mr. BOOLDS asked whether in Mr. Price's experience he had seen as many topsides as bottoms taken out of ships. He (Mr. Boolds) had seen a great many bottoms taken out, but never a topside; and hence he agreed that the thicker bottom was necessary.

Mr. Price said he knew that the only plates taken out of the *Richard Cobden* were at the far end of the topsides, immediately underneath the forecastle. That was after she was 20 years' old. The experience of Mr. Luke was—"He had examined the *Prince of Wales* and found scarcely any diminution in the thickness of the plates, from wear or corrosion." And the late Mr. Robertson of this port corroborated him. Now, he thought that was quite satisfactory, that for a very long period neither bottom nor topsides deteriorated if they received attention. But the most serious cases had been topsides, and especially in steamers in the wake of the coal-bunkers, which are exposed to the vapour from the bilge water, and also from the coals, which tended to the deterioration of the plates. His experience went in favour of the opinion that the topsides were more quickly deteriorated than the bottom of a vessel. He had never seen the bottom plating of one vessel removed from simple corrosion or rust. He knew that the bottoms of some vessels had been taken out, but these were very few. A vessel was referred to at last meeting which had had her plates very much destroyed; but that was altogether irrespective of thick plating or floors, and it could be met by the use of cement,—a system of preservation to which owners could resort.

Mr. Boolds repeated his question, as to whether Mr. Price would put heavier topsides than bottom on a ship of his own.

The President said that of course Mr. Price would answer that he would put the plates of uniform thickness throughout. He (the President) understood Mr. Boolds to say that he had never seen the topsides of a ship taken out.

Mr. Boolds replied that he had never known the topsides of ships taken out for corrosion or wasting.

The President asked whether Mr. Price had so seen the topside plating of a vessel removed.

Mr. Price said that he had seen an instance of a great amount of corrosion or waste in the coal-bunkers, and extending to the topsides.

The President inquired whether the topsides would have been deteriorated so much had they been painted.

Mr. Darling said that paint and cleanliness were doubtless good preservatives. He had seen topsides badly corroded, but their deterioration had been caused either from bad construction or neglect. In the earlier constructed iron ships, the frame bars or wood stanchions were run through the gunwale plates. Now, with this arrangement it was very difficult to construct tight gunwales, and from continuous leakage at that part, and the 'tween decks being closely ceiled, as was then usual, the leakage was not observed. With respect to the vessel referred to, the *Richard Cobden*, from the extreme fineness of the bottom, it might almost be called a continuation of the topsides from having so great a rise of floor; hence any accumulation of bilge-water had no opportunity to be thrown about. It was the rolling motion of the ship that caused the waste of floors and bottom plating of a vessel at sea. Another cause was chemical action. He knew of a vessel engaged in the sugar trade which had new floors in 1853, and was in dock again the following year, when it was found that her floors were again wasted through, proving that unless the bottom was preserved by cement it quickly gave way. He thought that floors should be made heavier at the centre than in the ends of the vessel. Although cement had done good, yet it had not benefitted the floors, as it only elevated the bilge-water, and brought it nearer to the floor. The principal reason for reducing the floors at the ends of the vessel for a fourth of her length was, the great reduction on the length of the floor itself; also, that the form of the ship was much "fined" from the midship section, and upon taking the ground had not to perform the same work as a midship floor.

Mr. Price said, in reference to what he had been asked, he wished it to be understood that he was of opinion that the corrosive action was more active at the topsides than at the bottom. What had been said about cement only showed that the cement had not been carried up so far as it should be. There was a vessel in Liverpool with a seven-sixteenths bottom. She was 14 years old, and Lloyd's Committee would, by their present tables, require her bottom to be twelve-sixteenths. Now, she had been drilled all over, and she was not found to have sustained any depreciation in the thickness of her plating. When he found a vessel 20 years old all sound in the bottom, but diminished in the topsides as in cases quoted, they would be almost prepared for him advising stronger topsides than bottom.

Mr. Darling said that by reference to the diagram on the wall, it would be observed that the frames of the *Richard Cobden* were turned in a rounded form at the gunwale, and united to the beam, thus leaving the gunwale plate and sheer strake wholly unsupported, either with frame or beam, and the vessel also fitted with a gutter waterway. With such an arrangement he could easily understand that such a gunwale might be very leaky, as the combination was certainly bad, and this might account for how in this instance a greater amount of corrosion and waste had taken place than usual.

The President inquired whether the thinning of the bottoms had been known to cause leakage?

Mr. Price replied that it had not.

Mr. Boolds said it appeared there was no diminution made at the end of a ship in floor plates. Now, he would ask Mr. Price's opinion whether floor plates should be thicker in the end of a ship than in midships, or whether he thought they should be all the same thickness? Mr. Price seemed to think they should be thicker in the ends. His own opinion was, that the strongest plates should be in midships. He believed that Mr. Price's experience would prove that it was not in the end of the vessel where the plates first gave way, but it was the midship floors that were most wasted, such as under the bed of a steam-engine, or coal-bunkers, where they were most apt to waste away. He should like to have that matter explained.

Mr. Price said his views were fully explained in his paper.

Mr. Day said it appeared a great many ships were kept at sea without being painted. In such cases, corrosion would take place both above and below the water-line, and he would like to know whether the external corrosion above was greater than what took place below water. He should be inclined to believe that in such a case the corrosion above water would be by far the more active of the two, and under the condition of bare plates externally, he considered that the external corrosion would be even more rapid than the alleged internal corrosion at the bunkers; under such circumstances, it would be natural to find the plates thinned from the exterior inwards, far more than from the interior outwards. Mr. Price maintained that by far the larger proportion of steam-ships become deteriorated by corrosion of the topsides, and it was evident enough to an eye trained in observing the wear and tear of structures, that a large amount of wear was imposed upon the inner sides of the coal-bunkers. He would therefore wish to ascertain if, after the iron had become rubbed bare, any precaution was taken to prevent corrosion by keeping the iron well painted over with paint. If it was clear that the deterioration by corrosion at these points took place from their being allowed to remain bare, it pointed to a very easy remedy. He also wished to ascertain if the experience of the members of the Institution had been that any corrosion took place at the topsides of the hull, towards either end of the ship beyond the bunkers, and if so, if it was equal in degree to that which took place within the bunkers themselves. He further felt it desirable to ascertain if a similar corrosion took place in corresponding parts of the hulls of sailing vessels in contradistinction to steam-ships; if so, was it as rapid in the former as it appeared to be in the latter.

Mr. Price believed that if any external loss from corrosion took place, it was on the bottom. But he did not admit that there was any estimable corrosion on the bottom, when ships were ordinarily well treated. He could give instances where he believed that, if there was any loss at all it was internal. The topsides of the ship were usually well painted outside, and hence no serious corrosion could take place there.

Mr. Darling said that with regard to external oxidation, his experience showed that there was a greater amount between light and load line than anywhere else, in ships that had been neglected, and oxidation allowed to accumulate. If they referred to any of the men in the habit of getting their living by such work as scraping, he was of opinion that they would as readily undertake to scrape the whole of the bottom as to "beat" or cut off the oxidation in the part referred to, as they would be enabled to do it in less time. Mr. Price says:—"In reference to these reductions, oxidation is again pleaded as a bar; but if a bar at the middle, why not at the ends of a vessel where it is patent that there is greater foulness, more dirt, and all that tends to promote oxidation than in the middle of a vessel, which may be cleansed more easily and freely, and which is generally therefore better attended to in this respect than the ends are." With respect to the greater probability of waste and corrosion at the ends, as still asserted by Mr. Price, the ballast of a ship was usually carried in about two-thirds of her midship length, and he was at a loss to understand where all the extra dirt must have come from in the ends to do all the contemplated damage. The ends of the vessel being so much finer than the midship body, if such an accumulation did take place it could do but little harm, as it never got an opportunity of rolling or being moved as in midships. Just now, he had a vessel under repair where the whole of the midship floors were so much wasted as to require removal, but at the ends they were found to be but little wasted.

Mr. Price said with reference to the form of the vessel, about which Mr. Duncan had asked a question, and to which Mr. Barber had also referred, he thought that in the instances of vessels with fine ends, Lloyd's provisions did not sufficiently keep it in view; and he thought that the Liverpool rules might provide a little more for it. In the late revision of scantling by the Liverpool Registry, vessels over twelve depths had had their main deck stringers reduced in breadth and thickness, so that they had the same proportionate size at the ends as for vessels of shorter dimensions. Mr. Barber also stated that he knew of no instance where Lloyd's vessels were at fault. Nor did he; and he did not think it necessary to show up any case. This was surely an argument in favour of the Liverpool Rules, for if the Lloyd's vessels lasted at present, by making the Liverpool vessels a little lighter they also had the scantling arranged far better and much better fastened; and therefore, the presumption was in favour of the Liverpool ship lasting as well as that of Lloyd's. The *Shipping Gazette*, a day or two back, put the same question. As to what had been said regarding floors, he gave the following statement of the proportions in which the floors of the 360, 550, 700, 998, 1149, 1444, and 1950 vessels stand as to thickness to the thickness due to their depth, taking the proportions of depth and thickness of the smallest as a criterion, viz.:—

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| The floor of the 360 tons vessel is | | | | $17 \times \frac{7}{16}$ | | | |
| ,, | ,, | 550 | ,, | $19 \times \frac{8}{16}$ | proportionate thickness, | | $\frac{8}{16}$ |
| ,, | ,, | 700 | ,, | $21 \times \frac{9}{16}$ | ,, | ,, | $\frac{8\frac{1}{2}}{16}$ |
| ,, | ,, | 998 | ,, | $23 \times \frac{10}{16}$ | ,, | ,, | $\frac{9}{16}$ |
| ,, | ,, | 1149 | ,, | $24 \times \frac{10}{16}$ | ,, | ,, | $\frac{10}{16}$ |
| ,, | ,, | 1444 | ,, | $25 \times \frac{11}{16}$ | ,, | ,, | $\frac{10\frac{1}{2}}{16}$ |
| ,, | ,, | 1950 | ,, | $28 \times \frac{11}{16}$ | ,, | ,, | $\frac{11\frac{1}{2}}{16}$ |

The proportion of thickness to depth is for the

| | | | | |
|---|---|---|---|---|
| $17 \div 7$ | 360 tons vessel = | | 2·42 | 1st. |
| | 550 | ,, | 2·47 | 2d. |
| | 700 | ,, | 2·33 | 3d. |
| | 998 | ,, | 2·30 | 4th. |
| | 1149 | ,, | 2·40 | 5th. |
| | 1444 | ,, | 2·27 | 6th. |
| | 1950 | ,, | 2·54 | 7th. |

$16·73 \div 7 = 2·39$; being mean proportion of thickness to depth, using the thickness in 16ths as a divisor to the depth in inches.

Showing, by the second statement, that the thicknesses assigned by Lloyd's are in the 1st, 2d, and 5th, in exact proportion to their depths, the 7th a little below, and the 3d, 4th, and 6th a trifle above that proportion. This is also borne out by the first statement above. While this shows a proportionate relation between depth and thickness in all the grades, it also shows that the additions to the thickness are demanded by the increased *depth*, and that if there was no margin provided against corrosive action, in the seven-sixteenths floor, there has been none acquired in the heavier ones; but, on the contrary, a small loss on the largest vessel's floor, which is also the deepest floor.

By a like comparison of the Liverpool floors for similar vessels, a similar proportion of thickness to depth in the successive grades will be observed, the mean of the whole of which is 2·63; while the highest and lowest instances show a closer relation to each other than do Lloyd's, proving them to be more consistent or proportionate additions.

The means stand to each other there—

As 2·63 : 2·39 = to a difference of ·23 = 10 % nearly. This represents the difference between the provisions of Lloyd's and the Liverpool Rules in the vessels he had taken, and represents the margin between the two registries which some members had credited Lloyd's with, as enjoyed by that registry, in view of corrosive action; but it must be borne in mind that the Liverpool floor is generally *as* strong, and in cases stronger, taking depth and thickness together for this purpose, as explained at page 8 of his paper, and then it would be found that the Liverpool floor had also a margin in its strength, as compared with Lloyd's, which fully balances the difference in the thickness of the two floors.

One floor is therefore as much liable to loss of strength by any loss by corrosion—acting on both floors alike—as the other, and *vice versa*, one floor (the Liverpool), is at least as valuable for all purposes, except that it has less actual strength at the centre line, as the other (Lloyd's.)

These remarks will apply to the grades above and below those cited in my paper.

The following remarks, based on the practice both of the Liverpool and Lloyd's registries, may be considered pertinent to this question, viz.:—If a $17 \times \frac{7}{16}$ floor can be guaranteed to A or 20 years' grade, as in the case of the *Orange Grove*, with impunity, in the face of corrosive action, then for deeper floors it must only be necessary to add to the thickness in order to preserve its relation to depth for the sake of strength, otherwise the thickness for the grades, equal to the ravages of corrosion, should be stated, if they can be stated, and it should be the minimum for the small vessels, whose floor for strength only would require a less thickness. Can this be done? Who can do more than provide for strength and protect the provision from all insidious agencies that would impair it? This the Liverpool Rules do, as they make cementing imperative, and until Lloyd's take a similar step they will only be contriving vessels in many other respects inferior to the vessels by the Liverpool Rules, but in this not only less durable but unsafe.

Both registries provide for floors of less thickness than the thinnest I have quoted in the paper.

At the limit at which Lloyd's begin to quote in Table G for thicknesses of floors, the thicknesses by both registries agree.

Beyond eleven-sixteenths the Liverpool Rules do not go. Their keelsons are much heavier than Lloyd's, and this limit of floor thickness is just one-sixteenth below the highest limit of Lloyd's.

Now, there was a remark the President made at the last meeting as to the relative efficiency of the two systems of rivets, regarding which he had prepared the drawing (Plate V., fig. 16), to show that what he (Mr. Price) had said was correct.

Fig. 16 is intended to illustrate the lines of probable fracture in the side of such a vessel as the *Coimbatore*. These are indicated by the irregular lines A B C D, which pass first, in the case of B, through solid plating and the seam holes; in the case of A, through the solid plates and the seam and frame rivet holes; and in the cases of C and D, through solid plates in the line of frame rivet holes and the butts of the plating alternately.

| | | | | |
|---|---|---|---|---|
| The areas through the several lines being | | | for A 128·41 | sq. inches. |
| „ | „ | „ | for B 137·39 | „ |
| „ | „ | „ | for C 120·937 | „ |
| „ | „ | „ | for D 121·668 | „ |

which stand as

| B | A | D | C |
|---|---|---|---|
| 1 | ·934 | ·885 | ·880 |

or, in other words, B is the strongest line, and therefore least liable to fracture. C is the weakest line, being 12 per cent. less than B, and therefore, other things being equal, is the most liable to fracture.

D is the next weakest line, being 11½ per cent. less than B, and therefore is liable to fracture next after C; while A is the second strongest, being 6½ per cent. only less than B, and therefore less liable to fracture than the lines C and D.

As the lines C and D pass only alternately through the solid plate and the butts, it follows that whatever advantage is gained in the butts, may fairly be calculated as a clear gain to the Liverpool vessel. This is all the more apparent when it is considered that the plating of this vessel, by both registries, is to within a short distance of the neutral axis, of identical thickness. What has been claimed for the Liverpool advantages gained by superior arrangements as to rivets and rivetting, it will be seen has not been over stated.

In Fig. 16, the rivetting and rivets in the seams are according to Liverpool spacing and diameter. If the Lloyd's arrangement had been adopted in the seams, the lines C and D would be still less than B.

He believed that the days of sailing vessels were numbered, and therefore he had set himself to inquire how many steamers were built on the various classification grades of Lloyd's, which he had tabulated as follows:—

Table (A) showing 1st, The number of *steamers* and amount of their *tonnage*, classed in Lloyd's Register, under the several grades, A A and A in the years 1864 and 1865.

2d, The proportions which the number of vessels and amount of their tonnage, classed under each grade, bear to the whole for *each year*.

3d, The proportions which the totals, under each grade, of steamers and tonnage for both years, bear to the whole for *both years.*

| | | AA | | AB | | AC | | Totals. | |
|---|---|---|---|---|---|---|---|---|---|
| | Year. | Vessels. | Tons. | Vessels. | Tons. | Vessels. | Tons. | Vesls | Tons. |
| Proportions to whole classed in 1864. | 1864 | 17 ·16 = 16℔Ct. | 16,087 ·2 = 20℔Ct. | 73 ·64 = 64℔Ct. | 47,891 ·61= 61℔Ct. | 23 ·2 = 20℔Ct. | 13,948 ·178 = 17¾℔C | 113 | 77,926 |
| Proportions to whole classed in 1865. | 1865 | 22 ·15n 15℔Ct. | 19,397 ·2 = 20℔Ct. | 99 ·67 = 64℔Ct. | 59,791 ·62 = 61 ℔ Ct. | 27 ·18 = 18℔Ct. | 16,929 ·176 = 17¼℔C | 148 | 96,127 |
| Proportion in which the totals under each grade for both years bear to the whole tonnage, &c., for both yrs. | Totals. | 89 ·15 = 15℔Ct. | 35,484 ·2 = 20℔Ct. | 172 ·66 = 66℔Ct. | 107,682 ·61 = 61 ℔ Ct. | 50 ·19 = 19℔Ct. | 30,887 ·177 = 17¾℔C | 261 | 174,058 |

In 1864, there was within a fraction, 4½ times more steam vessels, and 3½ times more tonnage built under AB than under AA, and there was 5⅓ times more tonnage, and 3⅙ times more vessels built under the AB than under the AC grade. At the same time there was one-third more vessels built under the AC than under the AA grade, although the tonnage under the latter grade was one-seventh more than under AC.

In 1865, there was over 4½ times more steam vessels, and over three times more tonnage built under AB than under AA; and there was four times as many vessels, within a fraction, and more than 3½ times as much tonnage built under AB than under AC. At the same time, there were one-fifth more vessels built under AC than under AA, though the tonnage under AA was about one-eighth more than under AC.*

* Of the 196 AB vessels, classed in Lloyd's up to the present time in their register, 172 were built in 1864 and 1865; and of the 65 AC, 50 were built in the same period.

In 1864 and 1865, only about one-fifth of the whole steam tonnage classed in Lloyd's, in each year, was built on AA; while in each year about five-eighths of the whole was AB; and in each year rather more than one-sixth was AC. This shows that for steamers the AB grade is the most used, while the AA and AC are about equally patronised.

AA steamers have topsides and sheer-strake usually equal to the Liverpool 20 years' vessel; while the side and bottom are respectively $\frac{1}{16}''$ and $\frac{2}{16}''$ heavier.

AB steamers have topsides and sheer-strake one-sixteenth less than the Liverpool 20 years' vessel, while the side is of equal thickness and the bottom one-sixteenth thicker.

AC steamers have top-sides and sheer-strake $\frac{2}{16}''$ less than the Liverpool 20 years' vessel; $\frac{1}{16}''$ less thickness of side, and equal thickness of bottom.

The Liverpool 18 years' and 16 years' grades correspond to the two lower Lloyd's grades, with the condition that the Liverpool deck stringer must be taken intact for the 18 years', and reduced one-sixteenth in thickness only for the 16 years'.

Steamships may, therefore, be said to be mostly built to Liverpool Rules as to plating; while as to rivetting and internal fastenings, they are vastly inferior.

The shipping community thus take Liverpool scantling, as far as they can get it under Lloyd's, and at the sacrifice of the elements which Lloyd's do not provide, but which make the Liverpool provisions commendable and perfectly safe.

The following Table B shows farther, that in the two years

| | | |
|---|---|---|
| For *every* vessel of and over . . . . . | 1500 tons | AB, there were 2 AA. |
| For every vessel under 1500 and over . | 1000 ,, | AA, there were 7 AB |
| For every vessel under 1000 and over . | 700 ,, | AA, there were $3\frac{1}{2}$ AB, and $2\frac{1}{4}$ AC. |

| | | |
|---|---|---|
| For every vessel under 700 and over | *500 ,, | AA, there were 5 AB, and $1\frac{1}{2}$ AC. |
| For every vessel under 500 and over | 300 ,, | AA, there were $4\frac{1}{2}$ AB, and 1 AC. |

Table (B) of steam vessels classed in Lloyd's Register in the years 1864 and 1865, showing their tonnage, and capacities, and the number built of each, under the respective grades.

| Year. | Grades of Classification | Tons, 1500 and over | 1,000 and under 1,500 | 700 and under 1,000. | 500 and under 700 | 300 and under 500. | 150 and under 300. | Under 150 Tons. | Total on each grade. |
|---|---|---|---|---|---|---|---|---|---|
| 1864 | AA | 3 | 3 | 4 | 2 | 3 | 1 | 1 | 17 |
| | AB | 1 | 12 | 15 | 19 | 13 | 11 | 2 | 73 |
| | AC | 0 | 0 | 13 | 4 | 4 | 1 | 1 | 23 |
| 1865 | AA | 5 | 0 | 6 | *7 | 4 | 0 | 0 | 22 |
| | AB | 3 | 10 | 19 | 28 | 18 | 14 | 7 | 99 |
| | AC | 0 | 1 | 10 | 9 | 4 | 2 | 1 | 27 |
| Total of both years under each capacity. | | 12 | 26 | 67 | 69 | 46 | 29 | 12 | 261 |
| Total 1864. | | 4 | 15 | 32 | 25 | 20 | 13 | 4 | 113 |
| Total 1865. | | 8 | 11 | 35 | 44 | 62 A | 16 | 8 | 148 |

Of the whole 261 vessels classed, 223, or six-sevenths, are below

* On this grade of tonnage, and that on either side—next highest and lowest—it is not an unusual thing for the AA to be awarded to the AB, on account of the actual gross tonnage turning out less than expected, so nearly are the limits approached.

the 1000 ton grade, the plating for which on A<sub></sub>A does not invariably exceed Liverpool provisions for 20 years; while that for AB and AC generally only corresponds with the Liverpool provisions for 18 and 16 years' grades.

The above also shows that AB grade has by far the largest number of vessels of the sizes suitable for and used in the most important trades.

Table (C) of eighteen iron vessels of over 12 years' old, built to Liverpool dimensions, with thin plating, showing the corresponding proportions required by Lloyd's Ru'es for the same vessels. [Lloyd's scantling (thickness of plating) is on the alternate lines.]

| No. | Age Jan. 1867. | Tons N.M. | Thickness of Plates. | | | | Floors' thickness | Class. | |
|---|---|---|---|---|---|---|---|---|---|
| | | | Sheer. | Sides. | Bottom. | Garboard | | Liverpool's. | Lloyd's. |
| 1 | 13 | 1326 | | 9/16 & 10/16 | 11/16 | 12/16 | 24 × 8/16 | 18 | A 1. |
| | | | | 11/16 & 12/16 | 13/16 | 14/16 | × 11/16 | | |
| 2 | 13 | 1289 | | 8/16 & 10/16 | 11/16 & 13/16 | 14/16 | 24 × 9/16 | 18 | — |
| | | | | 11/16 & 12/16 | 13/16† | 14/16 | × 11/16 | | |
| 3 | 13 | 1393 | | 9/16 | 10/16 | 11/16 & 12/16 | 24 × 8/16 | 18 | — |
| | | | | 11/16 & 12/16 | 13/16 | 14/16 | × 11/16 | | |
| 4 | 19 | 449 | | 6/16 & 8/16 | 8/16† | 9/16 | | 19 | — |
| | | | | 7/16 & 8/16 | 9/16 | 10/16 | | | |
| 5 | 14 | 1015 | | 8/16 | 9/16 & 10/16† | 11/16 | 24 × 8/16 | 18 | — |
| | | | | 10/16 & 11/16 | 12/16 | 13/16 | | | |
| 6 | 23 | 461 | 9/16 | 5/16 & 7/16 | 7/16 & 8/16† | 11/16 | | Annual | |
| | | | 9/16 | 7/16 & 8/16 | 9/16 | 10/16 | | | |
| 7 | 15 | 1019 | | 8/16 | 12/16 | | | | |
| | | | | 10/16 & 11/16 | 12/16 | | | | |
| 8 | 13 | 308 | 9/16‡ | 8/16 | 9/16 | 10/10 | | 19 | A 1 |
| | | | 9/16‡ | 7/16 & 8/16 | 9/16 | 10/16 | | | |
| 9 | 13 | 357 | 9/16‡ | 8/16 | 9/16 | 10/16 | | 20 | 12 |
| | | | 9/16‡ | 7/16 & 8/16 | 9/16 | 10/16 | | | |
| 10 | 14 | 713 | 12/16* | 8/16 | 9/16† | 12/16 | | 20 | 12 |
| | | | 11/16 | 9/16 & 10/16 | 11/16 | 12/16 | | | |
| 11 | 14 | 964* | 8/16 | 7/16 & 8/16 | 8/16† | 13/16 | | 17 | — |
| | | | 12/16 | 10/16 & 11/16 | 12/16 | 13/16 | | | |
| 12 | 14 | 1198* | 9/16 | 8/16 & 10/16 | 12/16 | 14/16 | | 20 | 9 |
| | | | 12/16 | 10/16 & 11/16 | 12/16 | 13/16 | | | |
| 13 | 19 | 330* | | 8/16 | 8/16† | 10/16 | | 10 | 9 rest 6-63. |
| | | | 9/16 | 7/16 & 8/16 | 9/16 | 10/16 | | | |
| 14 | 18 | 1150* | 10/16 | 10/16 | 11/16† | 12/16 | | Annual | — |
| | | | 12/16 | 10/16 & 11/16 | 12/16 | 13/16 | | | |
| 15 | 12 | 1161* | 8/16 | 8/16 | 8/16† | 13/16 | | 14 | 9 |
| | | | 12/16 | 10/16 & 11/16 | 12/16 | 13/16 | | | |
| 16 | 21 | 398 | 8/16 | 7/16 | 9/16 | 9/16 | | 12-65 | — |
| | | | 9/16 | 7/16 & 8/16 | 9/16 | 10/16 | | | |
| 17 | 13 | 380* | 8/16 | 6/16 | 8/16† | 10/16 | | 13 | 6 |
| | | | 9/16 | 7/16 & 8/16 | 9/16 | 10/16 | | | |
| 18 | 14 | 781* | 12/16 | 7/16 & 8/16 | 10/16† | 12/16 | | — | 12 |
| | | | 11/16 | 9/16 & 10/16 | 11/16 | 12/16 | | | |

Sheer-strakes not obtained where omitted.

Floors not obtained with certainty where omitted.

* Refers to special divergence between vessels' *sides* and Lloyd's provisions.
† Refers to special divergence in *floors*. ‡ To identical scantling.

Mr. Duncan and Mr. Ferguson had both stated that he must not be considered infallible in regard to the dimensions he had given, as a little alteration in the length of vessels would make considerable difference. Now, he knew that very well; and therefore, he had taken vessels known to every Clyde shipbuilder. He had taken three vessels built on the Clyde, and three on the East Coast, and had applied the Liverpool rules and compared them with those of Lloyd's, and had found the advantages stated in his paper. He knew that if vessels exactly seven breadths and ten depths be taken, different conclusions would be come to from what he had stated. These were not ordinary, but extreme cases, and if tables of scantling showed any difference at all between ratios of different cases, they would show it there at the extremes. Moreover, as Mr. Ferguson said he had taken ordinary vessels known to have been classed in both books, he (Mr. Price) had taken one of Mr. Ferguson's own vessels, and another built by Mr. Duncan, and compared upon them, the scantlings given by the the two Registries. He contended that it was unjust both to Lloyd's and to the Liverpool Registry to compare them upon vessels at the limits of those provisions, which are never built as *sailing* vessels. He would also say, that if they took a Liverpool ship designed to carry 1000 tons under deck, and Lloyd's ship of 1000 tons gross, including poop, the scantling would be found to differ from the comparisons he had made. The cases must be exactly parallel; 1000 tons in both cases must refer to gross tonnage, inclusive of the margin required for deck-houses, &c., keeping the gross tonnage below the 1000 tons scale. Thus much for the comparison of the two registries; but it should be understood that their scantlings were not designed so much for comparison with each other, as for attaining the same or more important ends by different arrangements—a course, he had no doubt, the Liverpool Committee felt it desirable to take from their extensive experience of iron vessels and their deductions therefrom, in relation to the question involved in the whole subject of the strength and durability of iron ships.

## *On the Employment of Steel in Shipbuilding and Marine Engineering.*

By Mr. George Barber,

*Surveyor to the Board of Trade, London.*

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The employment of steel in shipbuilding, and in the construction of marine engines and boilers, is a subject which is just now occupying considerable attention; and the question having been raised, "Whether practically a girder (*e.g.* the hull of a ship) or steam boilers, or the various parts of a steam engine can, for purposes of safety, be made lighter if made of steel than they can if made of iron?" it has occurred to me that such a subject might be considered with profit, and discussed to good purpose, by the members of this Institution; for I know that many of the members have had experience of the use of steel in shipbuilding, and that many others are able, from practical knowledge, to say whether steel possesses any advantages over iron for marine engines and boilers.

The opinions of practical men respecting the use of steel are very much at variance, and the results of the experiments which have hitherto been conducted have been so widely different from each other as to prevent them being solely relied upon in practice. Some boilers made of steel have, after a certain period of service, been pronounced in better condition than similar boilers, made at the same time, of equal strength of iron, and worked under similar circumstances; and it has been stated that steel boilers, in addition to being in a much better condition, have, during the working, been more free from scale, and have generated more steam, evaporated more water, and consumed less fuel in a given space of time than similar boilers made of iron. Against these statements we have others of a less favourable nature, and we have the fact that steel boilers made by one of the most eminent engineers in the country, had to be taken out of a mail vessel as unserviceable, from defects in the material, after a service of only one year. Then, as to cranks and shafts, while some, and perhaps the majority of engineers, speak highly of steel shafts, others, and also some managers of steam-boat companies, say that, from the results of their own experience, they cannot place such reliance upon shafts made of steel as upon those made of iron. It may be that those who have expressed the latter opinion have not been fortunate in their selection of steel, and that the defects which have prejudiced them against it might have occurred in iron; but, with the improvements which are daily taking place in its manufacture, defects such as have been discovered will soon be remedied, and it is certain that as the advantages of the use of steel become manifest it will be more largely employed in the construction of ships and machinery, though perhaps a longer time may elapse before it is considered a suitable material to be generally adopted for marine boilers.

Our experience and information respecting steel-built ships are very limited; but, in the hope that other members of the Institution will be induced to do the same, I will now state some of the facts which have come under my own observation, the conclusions which I have come to, and the opinions I have formed upon this important subject.

1. I have surveyed and passed for a passenger certificate steam vessels built of steel which have been less in thickness and weight than similar vessels built of iron. These vessels have "River" and "Excursion" Certificates, and the size of the material used in their construction is about one-fourth less than it would have been if they had been built of iron.

2. One of these vessels—the *Samphire*, Dover Mail Packet, of 183 tons net register, and 160 nominal horse-power, whilst on her passage

from Dover to Calais on the night of Wednesday, the 13th December last, came into violent collision with the *Fanny Buck*, an American barque of 585 tons, bound from Rotterdam to Cardiff, in ballast. The *Samphire* was struck by the barque on the port bow, and upon a bulkhead about 33 feet from the stem, and a portion of the vessel of about 12 feet in length, and extending from the gunwale down to the garboard strake and inboard, as far as the thick strakes for the windlass, was completely crushed, broken, and torn away. I examined both vessels shortly after the collision. The stem, thirteen planks of the starboard bow, and some of the timbers and inside stringers of the barque were broken, and pieces of the plating of the steamer were deeply and firmly imbedded in her planks. An examination of the framing and plating of the *Samphire* showed it to be of excellent quality. The beams, which are rolled of I form, $4 \times 4 \times \frac{3}{8}$ (with a waterway stringer-plate $15 \times$ 5-16 and $6 \times 3 \times$ 5-16 angle steel upon the upper flange, and a shelf plate $9 \times$ 5-16 with two $6 \times 4 \times$ 5-16 angle steels under the lower flange) were bent at very sudden curves, but there was no fracture of the skin of the steel. The frames (which are $3 \times 2\frac{1}{2} \times \frac{1}{4}$, and spaced 18 inches apart) had their flanges opened out flat in some parts and crushed quite close in other parts without showing any crack or flaw, and the plating of the hull and bulkheads (5-16" and $\frac{1}{4}$" thick) was twisted and bent into all manner of shapes, but was not *cracked.* The vessel is carvel or flush built, and is double rivetted throughout; and, although the shock of the collision was so sudden and severe, the rivetting all around and in close proximity to the fracture of the hull was quite firm and sound, proving that good workmanship had been combined with good material. The plating of the bottom and sheer strake of this vessel for a length extending ten feet beyond the bulkheads at each end of the engine and boiler space is doubled. On making inquiries I ascertained that the material used in her construction was described in the specification as "steel iron, of the manufacture of Thomas Firth & Sons, of Whittington Works, Sheffield, and guaranteed not to break at a tensile strain of 35 tons per square inch." Another steel-built vessel of 100 tons net register and 50 H.P., and intended for pleasure traffic along the coast, came under my notice in the early part of this summer. On examining this vessel before she was launched I could not help remarking to the builder that the plating of the bottom was unusually irregular and unfair; that the position of every frame could be distinctly seen from the *outside* of the vessel; and that the plating appeared to have buckled or sprung in between the frames, giving an undulating appearance, anything but pleasing to the eye. The rivetting of the bottom was unsatisfactory, and the deck-beams, which were of $5'' \times 2'' \times \frac{1}{4}''$ angle steel, had the same unfair and irregular appearance as the plating of the bottom. The builder and the foreman in charge of the work stated that the framing of the hull was perfectly fair before the plating was commenced, and they attributed the unsatisfactory appearance to the difficulty experienced in working the steel. "It is most troublesome and difficult stuff to work, and buckles and flies in all directions. As soon as we ply it close to one frame it flies off the next; as soon as we get a beam fair in one place it twists in another, and we have had no end of trouble with it." It may be that the unfairness of a bottom and the sharp angular projections at every frame caused by the buckling or springing in of the plates between the frames are not detrimental in point of strength, but it occurred to me at the time that if thin steel plates cannot be worked without twisting and buckling, the frames should be spaced more closely together, so as to give more stiffness to the plating, and also a better chance of having the lines of the bottom fair and pleasing to the eye, though this would to some extent counteract the advantage sought to be gained, in point of lightness, by the substitution of steel for iron. In this case the frames were 20 inches apart and the plating was 3-16 in. thick.

3. I have not passed for "Home Trade" or "Foreign" Service any vessel which has been built wholly of steel.

4. I have seen foreign-going vessels built wholly of steel; but, as these vessels were intended for a special service and were built at a time when rapidity of construction was considered of greater im-

portance than a careful selection of material or excellence of workmanship, the results, which in some cases were far from satisfactory, did not afford a fair criterion for judging of the merits of the material.

5. No legislative enactments nor departmental regulations govern or define the mode of construction or the size, amount, or description of material to be used in the steam and sailing vessels of this country. The supervision exercised by Government over vessels engaged in the passenger trade is general in its character and is directed chiefly to ascertaining that the ship or steamer is suitable and sufficient in every respect for the trade or voyage in which it is to be employed; the surveyors being *wholly* unfettered by detailed rules or regulations, and held *wholly* responsible for all matters to which, by the Acts of Parliament, they are required to direct their attention. The rules issued by the Committee of Lloyd's Register are, however (whether ships are to be classed at Lloyd's or not), taken as a guide by nearly every one engaged in, interested in, or consulted with regard to shipbuilding. But *steel* is not at present recognised in those Rules as a material for shipbuilding, and its use in the construction of any vessel proposed for classification is only permitted after the case has been specially submitted to, and carefully considered by the Committee and Chief Surveyors of Lloyd's Register.

6. In *river* steamers, when a light draught of water and a high rate of speed are indispensable, steel may be advantageously employed, for such vessels have not to sustain the weight and strains, or wear and tear of sea-going ships; and as every part of them may at any time be easily got at and examined, internal and external corrosion may be at once arrested.

7. In *sea-going* vessels the case is different, and I am of opinion that the size of material prescribed by Lloyd's Rules, which have been modified from time to time and are now considered free from objection, should not be diminished until further experience has been gained respecting the efficiency and durability of the material proposed. Steel

may possess superior tenacity, but tenacity is not the only property required. The whole of the material should work well in the fire, should not fail when passed through the rollers, or when receiving at the hands of the workmen the sudden twists and curves required in shipbuilding, and the plating of the hull should be of sufficient substance to withstand the sudden concussion of the waves at the bows and sides, the vibration caused at the stern by the motion of the screw propeller, accidental blows from contact with ice or floating bodies, and the reduction in thickness caused by the friction of the water and by external and internal corrosion. Thin plates of steel may, when new, be of greater strength than thicker plates of iron; but, if corrosion goes on at the same rate upon each, the steel plates will, if allowed to be much thinner, become unserviceable in a much shorter time than those of iron.

8. In shipbuilding, good workmanship is as important as good material. I have found when going through the shipbuilding yards of the Mersey, the Clyde, and the Thames, that much greater care is required on the part of the workmen in fitting, working, countersinking, and rivetting steel plates, frames, and beams than in working those of iron. I have seen steel plates buckle and fly under the hammer and crack during the process of rivetting up. Thin plates of steel will not stand countersinking well; and, if countersunk, there is but little substance left for the body of the rivet. When Low-moor rivets have been used in a steel-built ship they have been sheared off when the vessel has worked in a sea-way; and when steel rivets have been used, the heads have been known to fly off when the vessel has bumped against a pier-head, or been suddenly struck by a barge or heavy floating body. Greater care and closer supervision are likewise necessary in the *selection* of the material. Brittle plates have found and do still sometimes find their way into *iron*-built ships, but the danger from this cause seems to be greater when steel is used. It may happen that steel plates as brittle as cast-iron will, unintentionally, be supplied amongst a quantity which are strong and tough. If one

only of such brittle plates should pass undetected into the hull of a ship (say—under the engine-room, where plates have been known to crack in a steel-built ship when at sea), it might lead to most serious results, and I think it should be made imperative that not only the manufacturers' name, trade-mark, and place of business, but also *the amount of test sustained* should be legibly stamped on every portion of metal supplied for shipbuilding.

9. As great strength and the least possible amount of weight are of importance at the upper part of a ship, steel of suitable manufacture, and having a sectional area of from ·7 to ·75 that of iron prescribed for similar service may be used with advantage for sheer strakes, and for decks, stringers, and tie-plates upon the beams. Its use may also be continued with advantage in the construction of masts and yards, which have to bear a strain in a known direction, and in which lightness and strength are required together; but, having regard to the facts which have come to my own knowledge and under my own observation, I should hesitate to recommend, except under carefully considered regulations, its adoption for the *entire* construction of *sea-going* ships.

10. At the same time I think it is very desirable that experiments should be made with a view of ascertaining whether, for shipbuilding purposes generally, steel of ordinary or special manufacture and of reduced size and weight will, *under every variety of circumstance affecting its use*, be as trustworthy, serviceable, and durable as iron of the size and quality now required by Lloyd's Rules. It is a subject which, even in a pecuniary point of view, should recommend itself to the attention of shipowners; for if the material be of the increased strength stated, *and be in all other respects suitable*, there will follow a great diminution of weight and consequently of displacement. This will render it possible for a small ship to carry the same cargo and go at the same speed as a larger one, or the large ship to carry the same cargo and go at the same speed with a greatly reduced power, and a corresponding reduced weight of machinery and reduced expenditure

of fuel, oil, and tallow; and thus, in either case, not only will the first cost be considerably less, but there will be a constantly recurring reduction in the current expenses. And if steel machinery and boilers should be substituted for iron the advantages will be still greater.

11. The popular error amongst those who have not professionally studied or been practically engaged in shipbuilding, of regarding a ship *exclusively* as a girder, and of supposing that the formula adopted for determining the strength of the latter should be applied *unconditionally* to the construction of the former, has led to much mischief and many serious mistakes in practice. If a ship were to remain always on shore or even in perfectly still water the comparison might hold good, but there can be no possible analogy between a girder or beam *at rest* on shore and a ship in motion in a sea-way. No girder or bridge that has yet been built would stand the test to which a ship of similar proportions and mode of construction would be subjected in a rough sea. The notion that a ship should be of equal strength at top and bottom and be thinned away to the extent proposed at the ends is erroneous and cannot without disadvantage be practically carried out, and we have very recently had melancholy and convincing proof that the strengthening of the upper part of a ship had better be attained by any of the methods known to practical men than by the introduction of box girders or waterways which have been so persistently advocated. The formula used for bodies in *suspension* will not apply to bodies in *flotation*. Here is a simple practical illustration. An outrigger wager skiff 30 feet long, 10 inches broad, 5 inches deep, not much thicker tnan a band-box, and weighing 30 lbs., will carry a man six times its weight with a violent motion through the water, at the rate of 10 miles an hour; but lift the skiff out of the water, suspend it or support it at both ends, and, if the man keeps his seat, it will break in two. In the case of a beam or girder on shore the weight to be sustained is accurately known beforehand, the load is uniformly distributed, and the strains are constant quantities and gradually applied. But, in a ship, the weight carried is a varying quantity, the load is unevenly distributed,

and the strains are not only suddenly applied, but vary in amount and direction every time the ship alters her position, which alteration in position involves also a change in the position of the whole of the material of which the ship is composed. Again, girders and beams are of a recognised and similar form, but the forms of ships have to be adapted to the services on which they are to be employed, and vary according to the tastes and opinions of the owners or builders. A ship, too, in addition to having a form adapted for speed, and having arrangements for cargo, for comfort, and for ventilation, should possess sea-worthy properties, should be able to carry her load with an easy motion even under all varieties of trim, and should have the means of releasing herself speedily from any body of water which may be shipped suddenly upon her decks. None of these conditions are required in a shore girder or beam, and a ship can with no more propriety be called a girder than a girder can be called a ship. Let a girder *be* a girder, and the size and amount of material to be used in its construction with its mode of distribution be made the subject of direct scientific calculation; but let a ship *remain* a ship and its construction be governed by rules based upon scientific investigation *combined with* the carefully considered results of every day experience, and we shall not have to look upon such unserviceable and unprofitable productions as have sometimes come under our notice.

12. I have carefully considered the subject in all its bearings, and have applied to it all the facts relating to steel and steel-built ships which have come within my own knowledge and observation, and I am of opinion that steel of suitable manufacture may be used of less size and weight than iron for the purposes stated in paragraphs numbered 6 and 9 in this paper, and that it may be adopted for the *entire* construction of *sea-going* ships as soon as it has been ascertained by carefully and impartially conducted experiments and well-directed observations, that, with a reduced size and weight, it possesses all the properties, and will efficiently fulfil all the conditions which, under the existing Regulations of Lloyd's, the Admiralty, and the Liverpool

Underwriters are required of the material at present in use. But you have, as Members of your Institution, representatives of cast, puddled, hematite, Firth's, Bessemer, and Mersey steel, and you have also good practical shipbuilders and eminent engineers,—all of whom will, I hope, take up the points to which I have adverted in this paper, and unreservedly state their opinions and experience upon a subject which is really of great importance to the shipowning, shipbuilding, and engineering interests of this country.

In conclusion, I am aware that I have expressed opinions which are opposed to those now commonly entertained by Engineers, but I am. on this account, the more willing to have them submitted to the criticism of the Institution, and to abide by its verdict. Dr Fairbairn, at page 47 of his recent work on Iron Shipbuilding, tells us positively that "the strains in a ship and a monstrous tubular girder are *analogous*," but when Mr. Tate comes to the mathematical investigation of the subject, he tells us candidly, at page 276 of the same work, that "the strains on a ship are *somewhat different* from the strains on an ordinary fixed girder." Here are two opinions of equal value in the same work, and yet it is strange that the former should be readily accepted and constantly, though, perhaps, often inconsiderately repeated, while the latter is left untouched or never acknowledged. Again, in a chapter in the same work, on Composite Shipbuilding, we are told that "the system is not an eligible one, and for sea-going ships is utterly at variance with sound principles of construction;" that "any combination, however well executed, is not calculated to ensure the requisite strength for sea-going vessels subject to severe strains;" that, "on the contrary, *it appears obvious* that a vessel constructed with iron frames and wood sheathing is a decidedly *weak* and unsatisfactory structure;" and that, "for large ships intended to navigate the open sea, the construction cannot be recommended either on the score of economy or safety." These opinions and conclusions are formed upon the results obtained from one miniature experiment which is published in the same chapter. But of what value are either the results of the experiment or the conclusions therefrom when we find that the wood which we may say is the only wood used for composite ships, and which is in every respect the most suitable for the purpose, was altogether *omitted*; that the experiment was conducted upon an inappropriate "platform" imperfectly constructed of "red pine;" that the description and wood-cut illustrative of this experimental platform prove that its mode of construction was not at all in accordance with that of composite ships, or with the ordinary principles and practice observed in shipbuilding; that although we are told in sections 3 and 4 that "red deal or pine is the timber *chiefly* employed," and that "it is probably the *best* timber for sheathing in combination with iron frames" we know that not only is red deal or pine *never* used, but that no shipbuilder would ever dream of planking a composite ship with such *unsuitable* material; that the number of *sea-going* ships of 2130 tons and under built on this principle has increased from three in 1862 to respectively 9, 18, 40, and 40 in the following years; and that the shipowners who have put the principle to the most severe test, and who ought to be the best judges of the value and suitability of the article on which they depend so much for success, have not only not lost confidence in it, but continue to give orders for the same description of vessel? On the 11th September last I made a careful and searching examination in dry dock of the composite clipper *Ariel*, of 853 tons. This ship was one of the nine engaged in the exciting race home from China. She left Foo-chow-foo with the *Taeping*, another composite clipper of 767 tons, on the 30th May; lost sight of her opponent for 70 days; then picked her up off the Lizard; and, with every stitch of canvas set, had a neck-and-neck race with her up the channel, both ships arriving in the Thames on the 7th September, after having accomplished a voyage of upwards of 16,000 miles in 99 days. Without going into the details of an examination which was full of interest, I may state that although the ship must have been subjected in the most intensified degree to all the strains which act with the greatest severity upon ships engaged in such a contest, not one of the results or symptoms which would have been expected from a perusal of the chapter above referred to was discovered, and that the ship and every part of her were as firm, sound, and perfect as on the day she left her builder's hands. I have made this digression for the purpose of showing that the statements, opinions, and conclusions of modern writers must not be accepted or acted upon without having been first carefully considered and tested; that the teachings of modern theory and the results of miniature experiments are of little practical value unless they accord with, and are confirmed by, the facts brought to light in every day practice; and that, so long as shipowners remain alive to their interests and the Committee of Lloyd's Register continue a progressive policy, and an efficient supervision, shipbuilding and its improvement may safely be left in the hands of those engaged in the business, who have a thorough knowledge and experience of the subject, and whose success and reputation wholly depend upon their turning out of hand ships which shall be in every respect sufficient and safe for the legitimate purposes of navigation, and suitable and profitable for the trades or services in which such ships are to be respectively employed.

In the subsequent discussion,

Mr. John Ferguson said he had seen one of the few sailing-ships that had yet been made wholly of steel, while she was undergoing repair. During the hurricane at Calcutta, this ship got a great deal of damage, and paragraphs went the round of the papers praising the material of which she was constructed, and averring that if she had been made of iron she could not have stood the severe strains which she was subjected to. He happened to be in Liverpool after this vessel had returned, and finding that she was in the graving dock at Birkenhead he visited her. Her bulwarks were of steel, and he observed that they had been folded flat down, but not broken. The upper deck beams were very light—he thought not more than three-eighths of an inch thick—and where the ship had been subject to pressure from the other vessels which fouled her they were bent and buckled in many places, but not broken. The 'tween deck beams were in the same condition. He believed that if she had had strong iron beams she would not have buckled so much; but probably she would have broken frames, beams, and plates had they been made of iron. In the stern a great hole had been made; but he believed that her bottom was as fair as any iron ship. The workmen had considerable trouble in getting out the steel rivets to repair her, owing to the hard steel being sore on the tool. He agreed with Mr. Barber that the complaints made against steel ships were to be attributed mainly to the quality of the steel, and that if they could depend on getting good steel, it could be worked almost as easily as iron of the same thickness. He was afraid manufacturers had not yet attained to that proficiency in steel-making which enabled them to make it of a uniform quality. The tonnage of the ship referred to was about 1250 tons, and the thickness of her plates would be about one-fourth less than what was required in iron vessels.

Mr. Downie was also of opinion that if the material was made uniformly good in quality, steel, from its obvious advantages to the shipowners, would be adopted in almost every case, but he did not think its manufacture had advanced so far as to enable the makers always to send it out homogeneous and regular in structure.

The President remarked that John Brown & Co. guaranteed the quality of steel made by them to be regular and uniform.

Mr. Broom said there was no great difficulty in getting it so.

Mr. Hunt asked whether there was not sometimes the difficulty with steel that the rivet holes had to be drilled instead of being punched?

The President said that the rivet holes in the steel plates he had used were punched in the usual way without difficulty.

Mr. Duncan said that the advantage of building vessels of steel was, that for nearly the same money a ship of much smaller dimensions could be made to carry the same cargo, and be sailed at less cost; and therefore she would be a more economical vessel in every respect. He thought that perhaps the fault in steel vessels arose from making the rivets too small. They were made in proportion to the thickness of the steel, but they ought rather to be made in proportion to its tenacity.

The President asked if steel would oxidize in the bottom of a ship faster, or as fast, as iron.

Mr. Duncan believed that Dr. Livingstone had a small boat built of steel. It was very light, and built expressly for exploring the rivers of Africa; but it had not sailed many miles until it was nearly destroyed by oxidation.

Mr. Curle had observed that iron chains of rough quality were less liable to corrode than those of finer quality. From that he would deduce that corrosion proceeds faster in steel than in iron.

Mr. Connor said that no doubt steel axles stood much longer than iron ones. A great deal depended upon annealing the metal properly. If that was properly done, steel would be more regular in quality. Locomotive engine tyres were nearly all made of steel now, and there was no chance of lamination taking place. At first, steel was made too hard, but now it was made softer, and hence it was far more reliable. It was found that steel crank pins were very much better than iron.

Mr. Downie said that steel bearings were found to be better than iron ones if they had been carefully tended at the beginning, when set to work, and till they had, in actual work, got a proper skin upon them. He agreed with Mr. Connor, that the quality of steel very much depended upon the annealing.

The President remarked that Mr. Barber proposed to have the steel tamped, not only with the name of the maker, &c., but also with the strain it would stand. That, he feared, would be unattainable.

Mr. Connor agreed with the President, for steel that stood the greatest tensile strain was found to give way under a less transverse strain.

The President said that Mr. Barber mentioned the case of steel boilers having been taken out of a ship after one year's service. It would be interesting to have the particulars of that case. Two river steamers were furnished with steel boilers on the Clyde, the one had steel rivets, the other Lowmoor, but the steel rivets proved defective. He inquired whether the fact mentioned by Mr. Curle could account for this—that the finer qualities of iron corroded quicker than the coarse.

Mr. Broom did not think that would always be the case.

Mr. Ferguson supposed that if the iron was soft it would corrode faster than if it was hard, even although the hard iron might be inferior in point of strength to the soft.

Mr. Jas. Hamilton said that cast-iron was not so liable to rust as malleable iron; could the impurities in the iron be considered a protection?

Mr. Hunt thought the corrosiveness would depend upon the purity of the metal. A little nickel mixed with iron had been tried to retard corrosion. He was of opinion that the purer the metal was the more quickly it would corrode.

Mr. Watson said that Mr. Husband had made some experiments with steel in marine steam boilers. He had put alternate plates of steel and iron, and after a sea voyage the steel was found to be all pitted over, while the iron plates were quite sound.

Mr. John Todd said that the boiler referred to by Mr. Barber as having been taken out after one year's service was in one of the Dover and Calais mail-boats. It was a tubular boiler, every hole having been drilled and not punched, and was made by Mr. Churchward, of Dover. He had seen the boiler made, tested, and put in the vessel, and he believed that the only fault was a want of heating surface. The ship never had sufficient steam to work her at full power.

Mr. Niven, in answer to the President, said there were some small steamers being built of steel at present at Fairfield Building Yard, Govan. The plates were ⅛ in. thick, and the frames 24 in. apart. They found great difficulty in getting the plates smooth and square.

Mr. Duncan said that he would beg to suggest to the President that he might, with great advantage to the members of the United Institution, and to the subject under discussion, take up and enlarge his remarks on steel for shipbuilding, as given in a paper read to the Scottish Shipbuilders' Association, in February, 1861; and if the Institution considered it advisable to press the consideration of steel for shipbuilding and engineering purposes, he had no doubt that a carefully prepared memorial, submitted by this Institution to Lloyd's

Committee, would meet with the attention a matter of so much importance deserved.

He quite agreed with Mr. Barber in his views on the steel question; but there was another matter treated of by Mr. Barber on which nothing had been said by the meeting, and on which he would beg to support Mr. Barber with a few remarks.

Mr. Barber objects to the common *fashion* of treating a ship exclusively as a *girder;* some engineers will most probably take exception to Mr. Barber's views on this question; but keeping in view the purposes for which ships are constructed, and the work they have to do, the strains to which they are subjected, and the forces with which they have to contend, not merely as floating bodies in a free element, actuated solely by gravity, but as floating bodies driven by the full power of wind and steam against the full force of the sea, he (Mr. Duncan) thought, that with such considerations in view, it would be obvious to most minds, that no calculation based upon the formulæ for the construction of girders for a state of rest on land, could possibly apply to the construction of ships for a state of violent motion on the sea.

He believed Dr. Fairbairn was the originator of the girder idea as applied to ships, and as a recognised authority in engineering, it was fashionable to believe him.

It looked scientific to call a ship a name sufficiently general and comprehensive to need neither definition nor specification, and upon or under which the crudest theories of construction might be safely ventilated, so long as they complied with the girder theories of strength.

Dr. Fairbairn, in his latest work on "Iron Shipbuilding," seems disposed to modify his views and calculations slightly to the views expressed by Dr. Macquorn Rankine on the same subject, in some papers read in 1864, before the British Association, and in which the most severe strains to which a ship afloat is subject are assumed to be when alternately on the top of a wave, or in the hollow between two; in which positions, it is nearly as easy to compute the strains on the section as it is when the vessel is assumed as a fixed girder ashore.

Dr. Fairbairn is evidently out of his element in a ship afloat; he only gives Dr. Rankine a quotative support, and reverts to his favourite girder again, on which he is more at home. He does, however, admit that the girder calculations (that is, the calculations for shore strains,) are of little use in determining the strength of ships for strains when ashore. He says: "It should, however, be borne in mind that although it is possible for a ship to be stranded, with its extremities only supported, yet it is a circumstance which must very rarely happen; and under other circumstances, such as stranded on a lee shore, beaten on rocks or sandbanks, widely different forces come into operation; and the only safeguard in these positions is, increased strength at midships, and a sufficient number of water-tight bulkheads to prevent her filling entirely with water." How much strength is necessary in view of such circumstances we are left to surmise, calculation being evidently at a loss as to the quantity; and no wonder, for there are often circumstances of wind and sea and shore, which Dr. Fairbairn can imagine, in which no amount of additional strength, short of absolute solidity, and not even that, could avail to keep the structure together.

Every naval architect and shipbuilder knows that ships are not constructed to withstand such strains as those; their element is the sea, and for sea strains only is it proper to treat a ship, if it be possible for science to calculate the combined and multiplied strains to which ships afloat are subjected, and from which experience alone has deduced the elaborate structure adequate to the work.

Science, so far as he (Mr. Duncan) was aware, had not yet made the attempt. None of the old writers before the era of iron shipbuilding treat of it other than as matter of fact, and not matter of calculation. Modern authors, since the introduction of iron shipbuilding, have been chary of committing themselves too deeply on this question, except Dr. Fairbairn, who has committed himself pure and simple to the girder; and the simplicity certainly has taken the fancy, and encouraged the presumption of the greater number of his disciples.

Mr. Scott Russell, in his great work which was to have been an

Encyclopædia of Shipbuilding, has totally avoided the question of strains.

Dr. Macquorn Rankine, in his "Treatise on Shipbuilding," which has just been completed, treats this question, as one would expect, from his great scientific knowledge, in a more scientific manner than it has ever been treated before; but his great mathematical and methodical judgment leads him to treat a ship too rigorously as a structure "analagous to a beam," of which the usual variations of position may be considered calculable; and the most severe may be assumed to be, as stated before, when on the crest, or in the hollow of the waves; approximately under the conditions of girder strains. And that, practically, "the best way of insuring that the moment of resistance of the ship shall be sufficient in all positions into which she can roll, is to arrange the material so as to make her moment of resistance to bending in a horizontal plane, at least, as great as her moment of resistance in a vertical plane."

This is perfectly satisfactory, provided the moments of *stress* could be as easily ascertained as the moments of strength or resistance; but in *ships* as totally contra-distinguished from *girders*, this is precisely the point upon which it is impossible to put a definite value by calculation, and thus, decidedly, ships are removed from the category of calculable structures, except in as far as experience has already determined, or may elicit, the scantlings and arrangements suitable for the varieties of sizes, forms, and purposes for which ships are built.

So far as he (Mr. Duncan) had been able to discover, the only writer who has ever really taken a thorough grasp of the subject, and considered it practically, for all the varied strains to which a ship is or can be subjected, and as far as mathematical investigation can be taken as a method of deduction on such a subject, is our respected President, Mr. Lawrie, in the paper already named as read to the Scottish Shipbuilders' Association, in February, 1861, which paper, even in point of time, takes precedence of all the new works quoted.

Mr. Lawrie founds his calculations upon Scoresby's investigations on waves and storms at sea. After calculating the vertical scending and pitching strains for waves of the measured magnitude of 42 feet from crest to hollow, rushing with a velocity of 33 knots an hour, he takes up "another effect due to a gale of wind of a formidable character, and most trying to the strength of ships."

"Scoresby explains that while one system of waves of the dimensions already stated moves in one direction, other systems of the same magnitude move in other directions, and that, at the crossing of these systems, the elevation of the water is that due to wave on the top of wave. The velocity of these waves depends upon the height, and when the velocity of the wind exceeds to a certain extent that due to the height of the wave, the wave is destroyed, and the water, it may be, of the high pinnacles at the crossings, or of the more ordinary wave, is dashed with the utmost violence upon the sides of the ship, producing blows, as if from a mass of ice, and causing a violent tremour or vibration of the entire hull."

"These blows take place not only on every part of the ship, and at every angle depending on the relative directions of the wind, waves, and ship, but occur so as to act in accumulation with other strains, arising from the action of the masts, the altered displacement due to riding the waves, the bending strain lengthwise due to the form of the waves, and other causes."

"When a ship in such circumstances receives a blow from a mass of water, striking the exposed sides with a velocity of 30 to 35 knots an hour, it is well fitted to make the strongest structure stagger."

"It is utterly hopeless to reduce to exact calculation the effects of these blows on any particular ship; but a comparison can be made of their action upon ships of different dimensions, and an estimate formed of the proportional scantlings necessary to resist them."

When a writer approaches such a subject, with so complete an appreciation of the difficulties with which he has to contend, as Mr. Lawrie has done, we may rest assured that no paltry temptations to mere theorising, with a show of science, will induce him to undervalue the results of carefully elicited experience; and, in the same spirit, he (Mr. Duncan) would beg to support Mr. Barber, and to commend reflection to those who are tempted to indulge in generalisation, even on good authority, by treating a ship as a beam or girder, structures with which, practically, a ship has but the remotest possible analogy.

A cannon ball might almost as rationally be treated as a bird when flying through the air, or a horse be treated as a dolphin when swimming in the sea; the horse is a land animal, for which it is designed; and the girder is a structure of *terra firma* also, from which the structure of a ship can no more be deduced than the structure of the dolphin can be predicated from the structure of the horse; the one being designed for, and supported by, its element the sea, and the other being designed for service on the land, and supported by its legs.

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*Note by* Mr. BARBER,—*Received 17th January, 1867.*—With reference to Mr. Todd's statement as to the steel boilers, he must be in error either as to the vessel he has referred to or as to the facts of the case. The boilers in the vessel to which reference has been made proved so defective, from splits and rents in the material in the wake of the furnaces, and other parts, that within twelve months after they were put in it was found necessary to take them out, and they were broken up. The steel shafts in the same vessel also proved so defective, from cracks and flaws, that they had to be removed at the same time as the boilers.

## *On Railway Carriages.*

By Mr. John Page, C.E.

(SEE PLATES VI. AND VII.)

*Received 22nd and read 26th December, 1866.*

### Part I.

As it is desirable, and I think possible, to diminish the resistance that trains of carriages have to overcome, thus reducing the power at present expended in propelling them, and at the same time render railway travelling more safe and comfortable, I hope I may be excused for calling your attention to the subject. I need not refer to the almost universal use of railways by all classes, nor to the vast amount of capital employed in their construction and maintenance, to interest you in the subject, as we are all more or less practically engaged in their construction and the production of plant, or personally interested in their pecuniary results.

Great improvements have been made in the locomotive and in the permanent way,—one improvement has followed another in these departments until a very great state of perfection has been attained; but I think the carriages, with the exception of being enlarged, are very nearly as they were when first introduced.

The wheel base has been increased, offering greater resistance in traversing curves, and it is yet to be proved how far the arrangements introduced, such as curved guides, loose wheels, and long bearings admitting lateral play, have gone to lessen the great strain on the framings, the enormous friction, and loss of effective power, consequent on forcing the wheels along and against the rails instead of permitting them to run freely.

The area of the surface exposed to the atmospheric resistance has also been increased very much. This retarding force, I fear, is neglected, or, if taken into account, has not received that amount of attention which the subject demands.

On referring to old drawings I find the original London and Birmingham first-class carriage, with three compartments to accommodate 18 persons, weighed 3¼ tons. They were 15 feet long, 6 feet 3 inches wide, and 4 feet 9 inches high, with a wheel base of 8 feet. After some time the first-class carriage gradually increased in size; we find it 20 feet long, 7 feet wide, and 5 feet 6 inches high, and fully 5 tons in weight, with a wheel base of 10 feet. But we have now carriages 28 feet long, 8 feet wide, and nearly 7 feet high, weighing about 8 tons, with a wheel base of 15 ft. 6 ins.

The carriages made by the Ashbury Carriage Company are perhaps as perfect as any yet made, not only for the large amount of comfort it affords, but for the taste displayed on the interior fittings and external finish. I would also add my praise of the admirable manner in which the details of construction are carried out, although I cannot agree with the principles on which it is built. It is 25 feet 6 inches long, 7 feet 3 inches wide, and nearly 7 feet high, having a wheel base of 13 feet.

That such increase of size and weight was called for we must admit, being essential to the security and comfort of the public as the speed of travelling increased; but it is most amusing to observe how very closely the first pattern of carriage has been copied and re-copied, without any improvement or alteration in the principle of construction.

Although we sent pattern carriages to be used on the Boston and Providence Line, in the United States, our Transatlantic brethren have, I think, made a decided improvement on our plans; their train of carriages affording more comfort and safety than ours. I think that they are cheaper and injure the road less. I make these remarks, as I have had many opportunities of observing them during a tour extended over three years in the principal States of the Union.

The American carriage (Fig. 1) is usually 30 feet long to accommodate 60 persons; the bodies differ in length, but are generally constructed in this proportion:—At both ends there is a platform of 2 feet 6 inches long, the breadth of the carriage, which makes a 60 passenger carriage, 35 feet long; from these platforms the body is entered at the ends, and from door to door there is a straight passage, on both sides of which there is a row of seats each capable of containing two persons, and so constructed that those using them can sit at all times facing forward, or, by forming themselves into parties of four, sit as in a coach, with a comfortable support to their backs, in either case of such an inclination as to insure as comfortable a lolling position as if seated in a chair. This carriage is used by gentlemen. Ladies sometimes sit in them when accompanied by gentlemen, but should they be unattended or unwell they use the ladies' carriage (Fig. 2), which is beyond doubt the most convenient and comfortable vehicle ever constructed, and reflects great credit indeed on the projector, as it evinced a great anxiety to add to the convenience of the ladies, and so peculiarly adapted is it to their little wants and comforts,—carpeted, furnished with sofas, stoves in cold weather, dressing-room with mirror, and all other conveniences appertaining thereto—that a delicate female can travel with perfect safety much more comfortably than in her own carriage. Night travelling in carriages fitted up with berths is relieved of all its irksomeness, and is thus a saving of time to the man of business. The slave to the "weed" can retire to the smoking carriage; and the invalid gentleman will find his convenience and safety likewise attended to in a carriage usually attached to the train.

The under carriage is composed of what is now well known as the "Bogie," one of which, with four wheels, is placed under the door at each end. (Fig. 4.) The support being thus at the ends, the motion is more pleasant, and there is less tendency to lurch than in an English carriage. The bogie accommodates itself to the curves of the road with ease, and as the wheels in each bogie are as close as they can be to each other, they form with their flanges an unyielding fence of—say, 3 feet 3 inches (when 3 feet wheels are used)—to resist any tendency to get off the track. I am, therefore, of opinion that it is difficult to run an American carriage off the road. I have been in a carriage when the forward bogie left the rails on a very bad part of the Newark and New Jersey Railway, but the hind bogie kept its place, while the forward one was bumping from sleeper to sleeper. I feel assured that an English carriage would have left the road, and have dragged its companions with it over the embankment, as the rails on that spot were in bad repair. I observed an improvement in the construction of the bogie by which accidents resulting from a broken axle were rendered less frequent, if not prevented; and I recollect having had an unexpected opportunity of witnessing its efficacy. An axle broke, and we continued our journey quite unconscious of any danger; it was not known when it took place, but from the appearance of the fracture the axle must have travelled some distance in its broken state.

It is astonishing that more accidents have not happened on the American Railways, as the rails are sometimes laid alongside of the common road, frequently with no other fence but what the nature of the works afford; a few simple contrivances, however, with a little caution, lend a degree of security quite remarkable to an "Old Countryman" accustomed to our well-fenced and well-guarded railways.

To the front of the engine a "cow-catcher" is attached, which is an inclined plane raised in the centre, presenting the appearance of two moulding boards of a plough placed back to back; it lies within a few inches of the rails in front, so that it catches anything lying thereon, and as it gradually inclines down on the side from the centre, it throws the object caught, with violence out of the way of the train. It frequently removes cows from the rails, but if a cow or horse is between the rails, there is a greater difficulty in getting it out of the way; it is then necessary to stop the train. I have seen a pig whipped up and deposited on the side of the road with a speed new to the lazy grunter. I must not forget to mention that the guard of the train can in a moment disengage the carriages from the engine if required. In winter the "cow-catcher" is replaced by a snow-plough.

I have prepared a few drawings of carriages on the American principle, altered in the interior to suit the wants and tastes of the British public.

Fig. 3 is a plan of a post-office carriage. A closet and sofa, with ample space for mail bags, and a large sorting room, are provided. The conductor does not enter the carriage, but walks outside of the inclosed space occupied by the post-office officials.

After the reading of the Paper,

Mr. B. CONNOR said he admitted generally that the American carriages were better than those in this country; but they would not please the people of Scotland. Americans chose to travel in company: Scotchmen did not. The Caledonian Railway Company had tried saloon carriages on some of their branch lines; but they proved a failure so far as the public taste was concerned. The bogie was a necessity of American railways, where the roads were not so good as in this country, and where the curves were more acute. He approved of the passage up the centre of the carriage.

In answer to the President, Mr. CONNOR said the objection to the general introduction of gas into railway carriages was the difficulty of arranging and connecting them. Gas light in itself was cheaper than oil; but he did not know whether or not it was cheaper when the first cost of apparatus was considered.

Mr. DOWNIE thought that the Institution was indebted to Mr. Page for bringing this subject before them, as it included a reduction of engine haulage as well as the increased comfort of the public. The use of the bogie enabled them to have longer carriages, and hence less frictional resistance in axle bearings, &c.; and if, as was proposed, the carriages were made lower, they would offer less resistance to a gale of wind. The safety of travellers would also be more ensured; for with the bogie there was less chance of oscillatory motion than at present.

Mr. CONNOR said that bad coupling up caused oscillation; but that rarely led to an accident.

Mr. DOWNIE said that no doubt there were many matters of detail in connection with this subject to be discussed; but anything likely to increase the strength and safety of railway carriages, or to cheapen the tractive power on railways, was well worthy of their discussion.

Mr. Connor thought that the great point to be first considered, was the amount of stock at present held by railway companies.

Mr. Downie replied that if carriages could be made stronger and cheaper, combined with other advantages, the companies would find it profitable to adopt the new design of carriages, and then they might arrange their plant so as gradually to introduce improved new ones.

Mr. Hamilton said it would be a great convenience if carriages were made lower than at present.

Mr. Downie said the new carriages would do away with the necessity for platforms, as the floor of the carriages would be only 10 or 12 inches from the ground.

Mr. J. Todd remarked that Mr. Curtis had introduced low carriages on the London Bridge and Greenwich line, the floor of which was but two feet from the ground; but after running there for many years, he observed they had been superseded.

Mr. Downie believed that arose from the difficulty of coupling up with other carriages, and other reasons, which would be shown on the plans of these carriages, promised by Mr. Page for our next meeting.

Mr. Todd said that on the North London Railway the engines ran on bogies, but whether the carriages were similarly constructed he could not tell.

Mr. Connor responded that it was a matter of necessity to run on bogies on the North London line; because it was nearly one continuous curve. All the post-office carriages had six wheels, by Government stipulation, the reason being that they are most heavily loaded—much more so than a first-class carriage.

Mr. Todd said that Robert Stephenson had made the first-class carriages on the London and Cambridge Railway with six wheels. He thought they were safer than with only four, and the centre wheels having no flanges. For the safety of passengers he was of opinion all carriages ought to have six wheels.

Mr. Downie said that if six wheels were to be used they must continue to have high carriages, whilst with the proposed arrangement, we had very low carriages, with wheels of large diameter.

The President asked whether, in constructing bogies, Mr. Page intended the axles to go right across?

Mr. Page answered in the affirmative, and said they would be similar to the American bogies.

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## Part II.

A great proportion of the loss of effective power in propelling Railway Trains is due—

1st—To the resistance caused by the use of small wheels.

2nd—To the resistance of the Air; and,

3rd—To the resistance caused by the friction of the wheels against the rails, when brought in contact by the lateral oscillation of the carriages.

I propose in this paper to show the mechanical advantages to be gained by the use of larger wheels, and the possibility of their introduction in carriages much lower than those at present used. These points gained, we have the centre of gravity lowered, less resistance presented to the atmosphere, and, consequently, greater safety guaranteed. I intend also to allude to the errors in the principle of construction of the carriages as they are now built, not with the view of saying anything new, or laying before you more than a brief outline of what has been done or said in the matter, but with a wish to impress on your minds the vast importance of a subject involving the reduction of the working expenses of every Railway, while, at the same time, the comfort and safety of the travelling public would be increased.

Such questions as these were fully discussed during the time the "Battle of the guages" raged, the records of which read *now*, in the light of our experience, present a few useful lessons.

Amongst those who, at that time, advocated "things as they are," I find that an eminent engineer asserted, there was no danger of the carriage overturning; that, from what experience he had of Railways, he believed it would be a most difficult matter to overturn the carriages upon them, even if the object was purposely to do so, and an experiment should be made for the purpose. In lowering the centre of gravity, and in making the wheels larger, he saw no difficulty, and was quite sure, that inasmuch as these alterations have not been made, there is evidence to prove that they are unnecessary. But after all he did see a difficulty, for he proposed to make the carriages omnibus fashion, certainly not an economic arrangement, and certainly not one to be desired. He considered the carriages safe, and said, "as things are safe there cannot be the smallest advantage in making them safer!"

Although I cannot agree with Mr. Brunel in the necessity of increasing the width of guage to obtain greater safety, higher wheels and less resistance to the atmosphere, because these improvements can be attained on the narrow guage, yet I do admire the moral courage shown by him in venturing upon an untrodden path, for all his predecessors were mere imitators, adding or subtracting as their fancy dictated; showing as little variety as we see in canals and in canal boats; and I am not astonished, that this "Arch Innovator," as he was sometimes called, should have considered himself unfairly dealt with, when facts, the results of careful experiments were thus met, particularly so, when those who were interested in perpetuating "things as they are" were brought forward to prove that as things were tolerably well it was useless to seek for better. His pertinent remark *then* is not *now* without its value. He said:—I have the pleasure of being personally acquainted with the gentlemen whose opinions are quoted, and entertain the greatest respect for them; but I should never have thought of consulting them. If before building the Great Western steamship we had written to some of the highly respected and talented gentlemen who command the New York liners, and asked them, if *they* considered there was any danger or inconvenience in the use of sails, and whether they should prefer steam, I think we might have anticipated their answers."

I am not wedded to the plans I intend to lay before you. I do not consider them the best possible, nor do I presume to say it is for the present interest of railway companies to fall in with all that I propose, although they must prospectively look these matters in the face and follow in the march of improvement. I am only anxious that the subject may be fully discussed, and I hope in the remarks which are likely to follow the reading of this paper, that the term "safety" may be used comparatively, as it must be admitted that there is a possibility of danger, arising from various causes, although it is generally supposed that the railway carriages are not easily overturned. Yet we cannot shut out the idea from our minds, that there is, so to speak, a susceptibility of the carriages to be thrown off the rails; and apart from this, we know such does sometimes happen, and that there is really serious cause for being alarmed. I would remind you of the three such accidents which have occurred lately, within a brief period.

The carriages, as they are now made, are perched high over the wheels, and have a tendency to pitch and lurch—two motions neither agreeable nor safe. This tendency was sought to be overcome not by removing the causes, but by adding a contrivance, complex and expensive, called a buffing apparatus. In 1835, Mr. Bergen, of the Dublin and Kingstown Railway, took out a patent for an improvement on the then existing buffer apparatus, which has been superseded by Mr. Booth's improvement. It certainly, when properly used, does go far to impart a steadiness and smoothness of motion at rapid speeds; but I must express my regrets, that such an expedient is necessary to obtain such results.

Curves, under the most favourable circumstances, are highly objectionable, partly arising from the construction of the carriages, which is such as to be rigidly square in all its details; in fact, we may say the wheel moves in a straight groove, or what is equivalent to one, and unless there is some yielding of its parts doing actual violence to them, it is impossible for a carriage to move in any direction but that of a straight line. This evil is magnified by the coupling; for when the coupling is correct and all the carriages are brought tight to their bearings, the train is represented by a strong straight cane, yielding, it is true, to the bends of the road, but such yielding is at the expense of great friction, great straining, and shearing of the rails and wheel flanges.

But curves are unavoidable, and as the carriages are now constructed we are compelled to use the coupling to steady the train; but like the man with the crutch, we acknowledge the assistance it gives, while we regret the necessity which obliges us to use it.

Bad couplings, axles and springs breaking, are admitted to be the proximate causes of many accidents. That such accidents are not more frequent, we are thankful to the ever watchful care of those who have the superintendence of railway plant; but I hold that it would be well, and I think it is possible to reduce the hourly dependence on human watchfulness, which, with Argus eyes, must be ever awake, consequent on our present system; not that I would diminish the attention, care, and watchfulness at present existing, but that I might in a degree lessen the danger resulting from neglect of duty.

I will now allude to the mechanical advantages to be gained by using wheels of larger diameter.

The advocates of the broad guage deemed the most important part of the advantage to be gained by their system, to be the facility with which they could increase the size of the wheels, without raising the bodies of the carriages.

It was proposed to place the body of the carriage between the wheels, and in thus lowering the centre of gravity, it was calculated that greater stability and smoothness of motion would be attained, "as high carriages are more liable to oscillate, and that a very considerable part of the friction was occasioned by the rolling of the carriages, throwing the flanges of the wheels against the rails."

But the idea of bringing down the centre of gravity was not carried out, for in using wheels a little higher than those on the narrow guage, the carriages were actually raised, instead of being lowered, thus presenting a greater resistance to the atmosphere.

The broad guage had many objectors, but they all agreed that it was desirable, if possible, to have larger wheels than those in use. The late Mr. Nicholas Wood, Honorary Member of this Institution, in his report on the Great Western Railway, admits that there is a diminution of friction by increasing the size of the wheels.

Mr. W. Bridges Adams was also a great advocate for high wheels. He, too, proposed to place the body between the wheels. He condemned the present system and proposed in the construction of passenger carriages to abandon the under carriage altogether; to have a body capable of containing, say 12 persons, placed between two wheels, four feet or four feet three inches high, the bodies to be coupled together by jointed iron work, "leaving about 3 inches of space between the bodies in order to allow the axles to accommodate themselves to the line of draught;" he adds, "that with carriages of this description, a whole train might be jointed together without the necessity of buffing springs." It will be seen from the end elevation, Fig. 8, that it is only wide enough to accommodate two persons on each seat; thus his carriage will carry only eight instead of twelve persons.

Mr. Thomas Tredgold remarks, that it seemed quite clear to him, that as far as the friction of the axle is concerned, if you double the radius of the wheel, you reduce the power necessary to move the carriage one-half, and expresses his astonishment, that this truth, although repeatedly published in this country, has been overlooked by many.

To confirm his idea, he instituted a series of interesting experiments. He had a small carriage made with two sets of wheels, one set being 4 inches and the other 8 inches diameter; he used revolving axles of iron 0·55 inches in diameter, working in brass bearings, so that in changing the wheels no change was made in the rubbing surfaces. The wheels were of cast-iron, and the rims turned. The rail was 12 feet long, filed straight and smooth on the upper edges.

In the first experiment, the 4-inch wheels were used, and the carriage was loaded till a weight of 4 lbs. passing over a pulley, and drawing in a line parallel to the rails, produced a regularly accelerated motion on the rails, adjusted so that the first 3 feet were described in 9 seconds, the total weight of carriage and load was 230½ lbs.; so deducting the friction of the pulley from the 4 lbs., it was ascertained that the load was moved by $\frac{1}{59 \cdot 4}$ part of its weight.

The 4-inch wheels were then removed, and the 8-inch ones put on the axles, the pulley being adjusted to render the line of traction parallel to the rails, the moving force of 2 lbs. was applied, and the load increased till the first 3 feet were described in 9 seconds. It was then found to be 219·75 lbs., including the carriage and wheels as before; consequently the load was moved by $\frac{1}{113}$ of its weight.

It thus appears that a load of 230·5 lbs. was drawn by a weight of 4 lbs. with 4-inch wheels, being moved by $\frac{1}{59 \cdot 4}$ part of its weight, and a load 219·75 lbs. was drawn by a weight of 2 lbs. with 8-inch wheels, the load being moved by $\frac{1}{113}$ of its weight. These experiments show that the resistance does not decrease exactly one-half by doubling the size of the wheels; but the difference is not much from that ratio. Mr. Tredgold remarks, that as the experiments were repeated frequently, with as little variation as could be expected, that it may, for rail-roads, be assumed that the power in the same circumstances, as to axles and pressure, is inversely proportional to the diameter of the wheels, or very nearly so.

We will now consider the retarding effects of the air on the motion of the carriages.

I believe that Dr. Lardner was the first person to call particular attention to the fact, that this resistance increases with the square of the velocity; but as far as my reading goes, I think he did not appreciate it to its full value or extent in its effects on railway carriages. His experiments are well known, showing the loss from this cause, and several of them are quite conclusive on the point. In one of them, the half of the front part of a waggon was made to fold down on a hinge joint, so as to expose only half the surface, when required, to the atmospheric resistance; the waggon, being loaded, was started down an incline with the whole of the end surface exposed, and afterwards with the same load and only half the surface of the end exposed.

After minutely detailing the results. Dr. Lardner observes,—"It appears therefore, that with the frontage of 47'·8 square feet this train suffered a greater resistance at 8½ miles an hour, than that which it sustained with the lesser frontage of 23'·8 square feet at 19½ miles an hour.

The general conclusion arrived at by Dr. Lardner, was, that the atmospheric resistance to the passenger trains moving at 30 miles an hour, is equal to 15 lbs. a ton of the gross weight of the train. Taking then an increase at the square of the velocity, we find the resistance to amount to 60 lbs. a ton to a train moving at the rate of 60 miles an hour.

It has been asserted, that the resistance is due to the end of the first carriage only, forgetting that the strong wind, which must be encountered occasionally, at every bend of the road, acts either in the line of motion obliquely, or at right angles to it.

Dr. Lardner did not seem to be quite clear on this point, for he observes, it should also be remembered that the resistance of the air to a train of coaches, does not act exclusively on the front of the first carriage; the carriages of the train are nearly four feet asunder, and the air probably acts more or less on the foremost end of each carriage.

This idea was entertained by Mr. H. Bessemer, who made some ingenious experiments to ascertain the amount of resistance due to the end of each carriage in the train, and as the experiments may be interesting, I will attempt to show the results arrived at.

The model train required five horse power to move it at a velocity of 45 miles an hour. The carriages were constructed on a scale of ⅛ size of those in use on the railways. A spring balance of a good construction was used, and the indications were marked on a card by a pencil tracer.

All arrangements being complete, the train was put in motion, and the speed gradually augmented from the time of starting in each experiment; and when the number of revolutions per minute was attained, which was equal to the number of miles per hour previously determined on for each series of experiments, the speed was gradually diminished till the carriage was brought to a state of rest, when the indications on the card were copied off, and the same experiment twice repeated so as to obtain in all cases the mean of three experiments.

The first series indicated a resistance of 2·1 lbs. per square foot of front surface of carriages at 20 miles an hour; 3·2 lbs. at 25 miles; 4·5 lbs. at 30 miles; 6·1 lbs. at 35 miles; 7·9 at 40 miles, and 10 lbs. at 45 miles an hour.

Having thus ascertained that the pressure was exactly 10 lbs. on the end of the carriage a foot square, a second carriage was placed behind the first, with the space between the buffers left open as is the present practice on railways, the two carriages being put in motion at the selected rate of 45 miles an hour, the resistance indicated as the mean of three experiments was 14·1 lbs.; say 4 lbs. as an addition per superficial foot of the second carriage. A third carriage was connected, the indication was now 18 lbs., showing an addition of 4 lbs. for the third carriage. Three more carriages were successively added, and the result in each case was precisely 4 lbs. per superficial foot. The spring balance indicated a resistance of 30·5 lbs. per square foot of frontage, with a train of six carriages.

This result, the first step in the experiment, having been attained, the plan of reducing the atmospheric resistance by filling up the spaces at the ends of the carriages was next tried; for this purpose, five small hoods of wood made to fit into, and fill up the spaces between the ends of each carriage were prepared.

One of these hoods was placed in between the first and second carriages of the train of six, which then presented externally the appearance of a double carriage, without any space between them for the atmosphere to impinge against. The speed of the train was now increased to 45 miles, and the mean of three experiments showed a diminution of 4 lbs. in the general resistance. A second space was then filled in, and the train brought to the same speed, the result of which was another reduction of 4 lbs. The remainder of the spaces were successively filled up, with like results in each case. The train now presented the appearance of one long carriage, without any break or interval to catch the air, and the experiment clearly demonstrated, that, as the resistance was now reduced to only 10 lbs., being precisely the same as that of a single carriage, in the case of a train of six carriages two-thirds of the atmospheric resistance could be saved by merely filling up the intermediate spaces.

Mr. Bessemer pushed his inquiries further, with a desire to reduce the 10 lbs. resistance, if possible. With this view, he made the front of the train of a wedge form, as is shown in the drawing, and on experiment the resistance was reduced to 6·3 lbs.

Much is due to Mr. Bessemer for his painstaking and interesting experiments, in which he clearly proves the resistance of the air in front of the carriage, as a great retarding force; but I think his mode of cure is a clumsy one. It is to my mind a patching up of what must be admitted to be radically wrong.

Mr. Robert Stephenson has also given much thought and time to this question. In his very able report on the Dalkey and Kingstown Railway, recording the results of his experiments, he says, "there is no alternative but to ascribe the *enormous* loss of power to the resistance of the atmosphere."

In the experiments now brought before you, we have confirmation of two facts:—that at the high rate of travelling on our railways, a great loss is sustained by the resistance of the air, and by the use of small wheels. To meet these evils in the present system, I have prepared drawings to illustrate a mode by which they may be overcome.

The Victoria Carriage is only 9 inches from the rails. No platform is required. Its appearance, considered under the question of safety, is in its favour, and it is hoped that the first impressions will ripen, on more intimate acquaintance, into a conviction of its worth.

This carriage is composed of two first and two second class compartments. It will occupy in a train about 9 feet more than a carriage as now used would, in affording similar accommodation.

Although longer it presents rather less area to the resistance of the air on the side, at the same time the centre of gravity and pressure are brought low, and the angle of stability increased. To show the vast importance gained in these three points, I will trespass a little on your time in alluding to a curious and interesting accident which happened to a train on the Holyhead Railway, during a severe snow storm in the early part of this year.

The wind, whose great retarding force on railways has been so long overlooked, gave us a practical lesson of its power as it rushed down the valleys between the mountains, on the southern side of the line, not far from Bangor, and blew over the Post-office van, only shaking the officials, however, without injuring them. The wind might have struck the carriage, smashing it to pieces, and adding a few to the figures, under the heading of accidents resulting from "causes beyond the control of the Company's servants."

The weight and size of the van not being known, it is impossible to arrive at what force was exerted by the wind in overturning it. But as we have the Ashbury carriage before us, I will take it, and the Victoria carriage, Fig. 5, and compare them under the influence of a strong wind.

I calculate that the Ashbury carriage, weighing with its passengers 11 tons, will require 31½ lbs. per square foot to overturn it, and that the Victoria carriage, carrying the same number of passengers, weighing also about 11 tons, will require a steady pressure of 53 lbs. per square foot to overturn it. This is a great difference in favour of the low carriage.

The talented Editor of Engineering, in alluding to the accident on the Holyhead line, and putting the pressure to overturn the van at 33 lbs. per square foot remarks, "If, however, the wind blew in gusts, as it probably did, a less pressure would suffice to turn the van, as a certain amount of lateral oscillation on the springs would be first set up, and then if one of the gusts happened to coincide with a roll of the van to leeward, the vehicle might be turned over with comparative ease."

The experiments of Mr. Robert Stephenson, Dr. Lardner, and Mr. Bessemer, were confined exclusively to the resistance on the ends of the train. This is entirely got rid of in the new system, as the tender stands higher than the carriage. Thus a surface of about 22 square feet disappears, which in the present system has been proved to offer an enormous resistance at high velocities.

The under carriage is a two wheel bogie, turning on the usual centre. It is connected to the bogie of the next carriage by a sliding iron rod, forming when so coupled a four wheel bogie; but each two wheel bogie has freedom to advance or recede as the buffing apparatus above comes into action, still keeping the faces of the wheels in line with the rails. I am not sure that the coupling of the bogies is necessary, as I have observed two wheel Bissell bogies under engines, and I have every reason to suppose that it will answer as well under a carriage.

The connecting apparatus is simply a buffing and drawing one, and makes no pretensions to steadying the carriage, as it does not require such aid; being hung at the ends and above the centre, there would be no pitching or lurching, and, I may add, no danger of its overturning.

The wheels are 4'-6," but may be higher if thought desirable.

The framing of the carriage is proposed to be formed principally of iron or steel. The whole strength of the body depends on the top; from it downwards, the body is trussed, and can thus be made to carry any weight required.

In consequence of the under part of carriages, such as wheels, axles, springs, &c., failing, a stock of carriages is required to keep up the probable wants of the traffic; on the new system, the bogies will only be required in stock, and an injured one can be replaced by a perfect one in a quarter of an hour.

There is a safety bar, under the flooring, at both ends, which in the event of an axle or spring breaking would come on the rails, and keep the carriage there; in such a case the fall would be only 9 inches. It is drawn from the top, but the drafting rod and buffers may be placed as in Fig. 9, to suit the carriages of the present system.

The Victoria carriage, for the purpose of comparison, is designed in the same proportion as the Ashbury carriage, but I propose a breadth of 9′-6″ for the new carriage, and giving it additional length, so as to carry 16 first class, and 36 second class passengers. Its weight when loaded would not exceed 3¼ tons on each wheel, which is considerably under what is carried by the wheels of some of our locomotives.

I have been examining the defects of the present system of railway carriages, from an engineering point of view, but I have yet to consider it from a sanitary point of view.

The crowded state of our cities sends us longing to the country for repose, and for the pure and invigorating air, and the facilities afforded by our railways induce thousands to reside out of town; but I am informed that in many, many cases, this advantage is dearly bought.

Who, on arriving at the station, can resist the tempting morning paper, the city, home, and foreign news, which, with the leading article of the favourite paper, have all their charms to the inquiring and busy mind; and dull indeed that man must be, who can sit during a run of fifteen or twenty miles, without trying to get a glimpse of the busy outer world, as it is shadowed forth in the daily papers. But it is in thus trying to do so, as the carriage swings from side to side, that the danger lies. In the efforts made to catch each word, and hold it, so to speak, with its neighbour, the paper dances before the eyes; they become dimmed, the head heavy, and the back strained, as the body of the reader endeavours to go with each motion of the carriage; but as the motions are compound ones, the efforts are in vain, and the consequence is, a dulness is felt for an hour or so, after emerging from the station. This slight affection is produced daily, for years, and slowly yet surely undermining the health, we get accustomed to it, and the bad effects, if observed at all, are not traced to their first cause until too late. I regret to say that I can in my limited circle of friends, number a few such cases.

The constant jerking and vibration of the Post-office van must render the labours of the Sorting-Clerk exhausting both to body and mind, particularly as his services are rendered during the night, and the principal part of the time standing. Sir Francis Head, as he sat reclining and ruminating in a corner of what he called a Flying Post-office, remarked, that in consequence of the rapid rate of travelling, the bags which were hanging from thirty pegs on the side of the van had a tremulous motion, which at every jerk of the train was changed for a moment or two into a rolling or pendulous movement, like towels or cloths hanging in a cabin at sea, or the dancing of a hat suspended from the roof of a second class carriage.

Even the most ardent admirer of our present carriages, and the warmest advocate for things as they are, will admit that it would be well to have our carriages lower, without reducing the size of the wheels; and desirable to reduce the unpleasant motion so much complained of, to that of a smooth and uniform motion, Yet I cannot shut out from my mind, that there are difficulties in the way of the change. But I have a hope, as I look at the drawing of the Rocket of 1829, and read the opinions of the men of eminence then, in reference to the locomotive, and to employing it on railways, how it was called a hopeless project; the idea of its ever being able to draw a train of 20 tons at the rate of 12 miles an hour, was ridiculed, and stigmatised as absurd. Yes, I have hope, as I turn to the locomotive of this day, and gaze upon the wonderful improvements which have been made, and are being made on it, that engineers will turn their attention now to the long neglected carriages.

In the after discussion,

Mr. Page being asked to explain how he would attach the brakes to the Victoria Carriage, said:—The well-known brake, which is almost the only power available in retarding the train, has some serious defects. It is described as a screw and lever apparatus, fitted with wooden blocks, to embrace the wheels, on one or both sides. When applied, the action of the springs is stopped, and there is some chance of the wheels getting off the rails; the wheels acting against the rails tear the surface, and the peripheries are ground into a number of flat surfaces which of course increase in number with the stoppages, until it is necessary to turn or grind the tyre to its proper shape. Of course where a number of brakes are employed, the mischief is increased, and it has been asserted that the annual cost of replacing the tyres, only of a brake-van in constant use, is upwards of £20.

The highly-polished surface of the wheel, sliding on the equally polished rail, does not afford the amount of retardation found necessary to stop a train as quickly as is desirable. Friction on the rails, and not on the wheels, is what is required, and to apply the brakeing force direct to the rail, independent of the wheels, is no doubt the most direct mode of proceeding, which, when properly arranged, ought to lessen the risk of the wheels leaving the rails.

A brake on this principle would remove the objection which it appears is now made to the universal use of the steel rails, for the wheel, when acted upon by the brake, does not take sufficient hold of the rail, particularly when the tyre of the wheel is also of steel; and I am informed that the locomotive builders have, in some instances, lately received orders to make the tyres of those wheels to be acted upon by brakes, of iron, such as the wheels of the tender; and it appears also for the same reason that there are some objections to the steel rails in station yards. This seems to me to be a very serious objection, for if at the station, where means are taken to check the speed gradually, the steel rails afford little assistance to the brakes in retarding the train, what will be the result on a line of steel rails should there be a sudden danger of a collision.

It is to be regretted that there should be even the slightest objection to steel rails, as the results of recent experiments show their extraordinary strength and toughness. At the Camden Town Station, where steel and iron rails were laid for about five years next to each other, a practical result has been obtained, showing the positive saving in the use of steel rails, as one of those in the road which had not been turned, was only worn about one-fourth of an inch along its top, while 22 faces of iron rails were completely worn.

It is a well-known fact that steel tyres when acted upon by brake blocks become so very hard, on their bearing surfaces, that it is a most difficult operation to remove the hardened skin which is formed on them, and much ingenuity and money have been expended in overcoming the difficulty experienced in turning or grinding them to a true shape.

An eccentric brake, I think, meets some of the objections to the present machine used for retarding the train, and to show its application, I submit a sketch of one, Plate VII.A, placing it behind the engine, or brake van.

The brake-wheel is made hollow, and filled up with timber, the end grain of which is brought in contact with the rail.

The engine-driver, the first generally to see the danger to a train, can in an instant, by bringing the point D in contact with the rail, cause the break to turn until it arrives at the point B, where it can be held by a paul or catch on the rod; by disengaging the rod, the brake will revolve and return to its former position.

When the point B is on the rail, the hind end of the framing of the engine is slightly raised, and some of the weight taken off the running wheel next to it, which weight is transferred to the brake, making it press as hard on the rail, as may be thought desirable.

On the one axle there are two brakes, one on each side of the engine.

Mr. Downie said that at first he had a difficulty in regard to applying the brake to the train. Those high wheels showed no means of doing so, and he was driven to the opinion that Mr. Page depended upon brakeing the train by means of the engine and tender.

The brake shown, however, he thought might be of use on any of the carriages, but he was afraid it would come rather suddenly into action. He was of opinion that, if the train were running thirty or forty miles an hour, the sudden catch on the rails must give a certain amount of jerk. It seemed very simple, and showed that there was a very large amount of the wearing surface of *end* wood, shown in the drawing as fixed in the periphery of the wheel, of use for brakeing—as much as three-fourths of it. He did not know whether it was applicable to a train going backwards as well as forwards.

Mr. Page said it could be used either way.

Mr. Downie—That seemed to him to remove much of the difficulty of the matter. He thought the arrangement Mr. R. D. Napier had made, of differential leverage, (a model of which was now on the table,) could be applied to brake the whole of the carriages in the train. It was automatic in its action, so that the objection of intense "skidding" at the tender-wheels and brake-vans, thereby cutting up the wheels, &c., and damaging the rails would be obviated, as it could be made use of all through a train of carriages with much lessened intensity, but greater efficiency, owing to the increased rubbing surface presented. It might be under the control of the engine-driver or the guard, and no doubt would be a great saving in the wear and tear of the rolling stock. With regard to the Victoria carriage, he thought that it met an objection made in a former discussion, to the buffing being at the top of the carriage, there would be no difficulty in connecting this kind of carriage with present rolling stock, in the manner shown. He would like to ask Mr. Page about the bogie-frame. He observed it was a single axle bogie, after the plan of Mr. Bissell, which was sketched on the drawing. Mr. Page had introduced Mr. Bissell's arrangement, so as to go round curves without any danger. He thought this would be of great importance in securing safety for those very long carriages. He held that it was necessary in such carriages as they had on the Great Western of Canada, (some of which were sixty feet long,) but they had four-wheeled bogies. He thought there were many things in favour of the new carriage, provided they made its framework strong enough. While they were hung so low as to be easily reached without any platform, they were also sufficiently low to be covered, so to speak, by the ordinary engine and tender from the effects of atmospheric resistance in a very great measure; and it was quite evident that the tractive power required to drag them would thereby be very much reduced, and the power being thus utilised, engines would be able to draw heavier trains, and thus no tonly economy, but more accommodation and of a better kind, would be obtained by using Mr. Page's plan of carriage. He thought that no carriage at present in use on any of the railway lines in this country could compare with it in comfort to the passengers for a long journey.

The President supposed that Mr. Downie's objection to the brake might be met by allowing it to come gradually into action.

Mr. Downie had no doubt that it might be arranged so as to come gradually into use like a wedge-brake.

Mr. Page said it was hung eccentrically, so that the greatest part of the weight of the engine or tender was gradually raised until the brake came to the point B. There is very little danger of its going out of order, as its parts are few, simple, and strong; but he might state that he had been driven to this form, inasmuch as he could not put a brake on the Victoria carriage, but must put it to the engine or tender, or on a brake van.

The President said, that irrespective of being driven to it, if he could bring it into action gradually, it would be an effective brake.

Mr. Page replied that sledge brakes between the wheels had been tried; but even in the centre there was an objection raised to them. In many cases they had to back the train before they could get it out of gear.

Mr. Downie thought Mr. R. D. Napier's differential brake might be applied to a whole train of carriages with great ease, and be perfectly under control. He would put on separate frictional brake-wheels, of 10 or 12 inches diameter, on each axle.

Mr. Page said that Mr. R. D. Napier's plan was most ingenious, and decidedly the best of its kind, although it retained some of the defects of the brakes at present in use. He thought the fine dust from the road would find its way between the working parts of the brake, and perhaps soon wear them away.

Mr. Downie asked whether the cost of the Victoria carriage would bear comparison with that of the carriages at present in use—say the "Ashbury."

Mr. Page had not accurately calculated the cost, but he believed it would not cost more than the "Ashbury." The bottom carriage was done away with in it, and the buffing apparatus was much more simple in the new carriage.

The President said that the new carriage met the difficulty of the railway companies, as it would interlace with other carriages in a train with ease.

## *On the Rate of a Clock or Chronometer as influenced by the mode of Suspension.*

By Professor Sir William Thomson.

(SEE PLATE VIII.)

*Read 27th February, 1867.*

It is well known that the rate of a chronometer, a clock, or a watch may be altered by altering its mode of support. On land, clocks ought to be fixed in as solid a manner as possible, so as to prevent vibration, either by their own action or from extraneous causes, from being communicated to the supports of the pendulum. Even the best astronomical clocks hitherto made are very badly arranged in this respect.

A marine chronometer or watch exhibits in a very striking manner the effects of varying the mode of support. A watch which keeps very good time when carried in the pocket, or laid on a soft pillow, will go at a different rate if laid on a marble slab, or on a hard board. These variations of rate are not due to any imperfections of the balance wheel or mechanism of the watch or chronometer; but arise from reaction due to the motion of the moving parts. A well balanced watch will go equally well whether supported in a vertical or horizontal plane; and a well made watch will, I believe, not be subject to uncertainty of above a quarter of a second per day, if carried about in the pocket all day and put under the pillow at night. This I can testify from experience of a good pocket-watch which I have tried now for nearly two years; indeed, a good pocket-watch, if well treated, is comparable in its performances with the best marine chronometer.

I was very much struck some time ago by a remark made to me by

Mr. Archibald Smith, of Jordan Hill, regarding a demi-chronometer, with detached lever and compensated balance, presented to him by the Admiralty for the voluntary assistance he had given them in working out methods for adjusting the compasses of iron ships. Mr. Smith found that this watch was going well, until one day he observed it had gained 15 seconds, the reason of which he could not explain until he recollected that instead of its having been put under the pillow as usual, it had been hung up in a suspended watch-case.

The question now arises, what is the cause of these variations, and how on dynamic principles are they to be explained. The dynamics of the subject is indeed very simple, and can be easily reduced to a well known general problem.

A simple pendulum when it vibrates through a very small arc, vibrates according to the law of simple harmonic motion. Take a spiral spring, with a heavy weight hanging by it, stretch it a little and let it go, and it vibrates according to the same law. The vibrations of a tuning fork, or any other instrument giving a similar musical sound, are also according to the law of simple harmonic motion. Another case of simple harmonic motion we have when the piston moves to and fro in a cylinder, the head of the piston rod being guided by a cross-head and slides, and the crank and fly-wheel making one revolution for every backward and forward movement of the piston. The balance-wheel of a watch, vibrating to and fro through a certain angle, is approximately a simple harmonic motion. The longer the hair spring is, the more nearly it will approach to simple harmonic motion, and it will keep time the more accurately.

Now, against every change of motion of a body there is a certain reaction, and every motion to and fro of the balance-wheel of a watch or chronometer reacts upon the case of the watch or chronometer; and if the case is so suspended as to be free to vibrate, the motion of the balance-wheel will generate a vibration of the whole, so that we have two motions to consider,—one, that of the balance-wheel, inside the watch; the other that of the whole watch except the balance-wheel. Upon the mode of suspension of the watch or chronometer will depend the nature of the vibration which it takes up and the resultant effect upon the rate The rate is accelerated or retarded according as the vibration of the case is in the opposite direction to that of the balance-wheel, or in the same direction; and the amount, whether of acceleration or retardation, may be as much as a minute an hour, as I hope to demonstrate to you practically.

If a watch or chronometer be allowed extreme freedom to move, it has always a faster rate than when the case is held quite fixed. Mr. Archibald Smith has made experiments on this point upon a pocket watch, with chronometer escapement and compensated balance, and found that the moment of inertia of the frame was $\frac{1}{650}$th of that of the the balance-wheel, from having observed that when hung horizontally by a long thread it had a gaining rate of some 67 seconds in the day.

Observations made by Daniel Bernoulli on the sympathy of vibrations* manifested by the pans hanging from the two ends of a common balance, and the solution by Euler of the particular problem thus presented, seem to have originated the great dynamic problem of the vibrations of stable systems.

When a system of particles displaced from a position of equilibrium experiences in consequence, forces in simple proportion to the displacements of its different parts, its motion may be thoroughly investigated by a generalisation of this problem of Bernoulli and Euler. The solution involves an algebraic equation of the same degree as the number of independent motions which may be given to the system. When the roots of this equation, which are necessarily all real, are all positive, the equilibrium of the system is stable. It is convenient to confine our attention to this case; but it is interesting and important to remark that all the statements we make in reference to it are applicable, by a proper mathematical extension of the language, to cases of unstable equilibrium. Each of the roots of this algebraic equation used in other formulæ belonging to the solution determines a particular proportion of different possible displacements,

* See a Paper "On the Sympathy of Pendulums," by Mr. Archibald Smith, in the Cambridge Mathematical Journal. No. IX. May, 1840.

which, if made simultaneously, will give rise to *corresponding* forces of restitution, according to the following condition. The system, starting from rest in its displaced configuration, will, under the influence of these forces, move so as to diminish the displacements of all its parts in the same proportion. Thus all the displacements will come to zero simultaneously; and therefore the system will move precisely through its configuration of equilibrium. There being no frictional or other resistance, it will oscillate—each displacement varying from maximum positive to maximum negative according to the simple harmonic law; the system passing, twice in each period, through its configuration of equilibrium, and being twice for an instant at rest in the configuration of extreme displacement on either side. This is called a fundamental mode of vibration. There are as many such fundamental modes as the system has of degrees of freedom to move (independent variables). Every possible motion of the system may be resolved into simple harmonic vibrations according to these fundamental modes; or the superposition of simple harmonic vibrations according to the fundamental modes, will give any possible motion of the system. The arbitrary circumstances of displacement and projection by which any possible motion of the system may be instituted are producible by giving proper values to the energies and proper times to the epochs of maximum displacement of the component fundamental modes. The squares of the periodic times of the fundamental modes are the roots of the algebraic equation referred to above. In particular cases, some of these periods may be equal to one another; or all may be commensurable. In general, however, the periodic times of the fundamental modes are all different and incommensurable; and then none of the compound motions—that is to say, no motion except one or other of the fundamental modes—is periodic. The mathematics of the problem, including proofs of these results, will be found in the first volume (now on the point of appearing) of Thomson and Tait's Elements of Natural Philosophy.

The theory is not limited to systems presenting a finite number of independent variables, such as two in the cases we are about to consider more particularly, but is applicable to flexible or elastic bodies and fluids; and to complex systems presenting a finite number of independent variables, on account of solid bodies or material particles, and infinite numbers of variables, due to flexible, elastic, or fluid matter, influenced by them. It includes, for example, the well-known dynamical theory of the vibrations of a stretched cord, of air in an organ pipe, or of water in an open basin of any shape. In the first two of these cases the periods are all sub-multiples of the gravest fundamental modes, whence the explanation of the harmonics of musical cords and of wind instruments; whence also the fact that a stretched cord struck or disturbed in any manner takes a perfectly periodic motion, and gives a true, although not a pure and simple, musical sound, with the peculiar character of the violin, pianoforte, or harp, depending on the way in which the vibration is excited. But the fundamental modes of vibration of an elastic solid—for instance, a stiff metal bar, or a stiff spiral wire (as the "bell" of an American clock), a sheet of metal, or a common bell, are incommensurable. Hence these bodies cannot give any true musical sound other than a pure and simple harmonic note. A large sheet of metal, or a gong, or a drum, when struck, produces an infinite number of discordant notes sounding simultaneously. But in the last-mentioned case, the gravest of the fundamental notes predominates more decidedly than does any one of the fundamental notes in the two other cases; and thus a drum gives a nearer approach to a true musical sound than a sheet of brass or a gong.

An excellent illustration of the general theory is presented by the double pendulum—one pendulum hung from the weight of another—Plate VIII., Fig. 1. If we admit only vibrations in one plane, the system has two degrees of freedom to move. The determinant equation becomes a quadratic with two roots, necessarily unequal. The mathematics need not be given here; but may be advantageously worked out as an exercise by the dynamical student. In the graver fundamental mode the two cords deviate always in the same direction from the vertical; the lower through a greater angle than the upper. In the quicker fundamental mode, the two deviate in opposite directions. The period of the graver fundamental mode is always longer than that of a simple pendulum, of length equal to that of the longer of the two cords; the period of the quicker fundamental mode is always shorter than that of the simple pendulum, equal in length to the shorter cord. If the upper mass is much greater than the one hung from it, and if the two strings be not approximately equal in length, the two fundamental periods differ but little from those of simple pendulums equal in length to the two cords respectively. The diagram—Figs 1 to 5, Plate VIII.—illustrates the circumstances in the cases; first, when the upper cord is considerably longer than the lower; and second, when the lower cord is considerably longer than the upper. In each case OA is the length of the simple pendulum vibrating in the same period as that of the fundamental mode represented.

### Case I.

Figure 2 represents the first or graver fundamental mode; the period of the upper pendulum C P′ being made somewhat graver by the influence of the lower, which, in the course of the vibration, always exerts a force upon it *from* its middle position. Figure 3 represents the second or quicker fundamental mode; the vibration of the upper pendulum being in this instance excessively small in comparison with that of the lower, and forced, by the influence of the latter, to a period much smaller than its own would be if undisturbed.

### Case II.

Figure 4 represents the graver mode; the vibration of the upper pendulum through but a very small arc in comparison with that of the lower, being augmented by the influence of the lower, which, in the course of the vibrations, exerts a force upon it always *from* its middle position. Figure 5 represents the quicker mode; the vibrations of the upper pendulum being made somewhat faster by the influence of the lower, and the lower being influenced so as to vibrate as if it were shortened to the length O A, which is somewhat less than the length C P′.

If P′ consisted of the frame and work of a spring clock, and P′ P were its pendulum, then, in Case I., the vibrations which would be maintained by the actions of the escapement wheel would be that represented by figure 3, and the clock would go faster than if its frame were perfectly fixed. In Case II., the vibrations maintained by the escapement would be those represented by figure 4, and the clock would go somewhat slower than its proper rate. Case I. could never occur in practice, but may be experimentally illustrated by hanging the works of a clock on a light stiff frame, moveable round a horizontal axis. Case II., figure 4, with C P′ much shorter in proportion to P′ P than shown in the diagram, represents the actual circumstances of an ordinary pendulum clock, which, owing to want of perfect rigidity of the frame, must experience a little of the influence of the pendulum in the manner there illustrated, causing the rate of the clock to be somewhat slower than it would be if the support of the pendulum were absolutely fixed. The clock cases of the best astronomical clocks are very ill adapted to give the steadiness necessary for good results; and it is wonderful that their performances are not even worse than they are found to be. The pendulum ought to be hung from a massive stone or metal support, attached to a stone pier, such as those used by astronomers for bearing their optical instruments. There can be no doubt but that the use of this simple precaution, and the making the pendulum many times heavier than has been hitherto used, would render the performances of an astronomical clock, even with a Graham's dead-beat escapement, not merely two or three times better than those of a good watch carried about in the pocket, but ten or twenty times better, which it certainly ought to be in its immensely more advantageous circumstances. A good marine chronometer is probably little less accurate than the best astronomical clocks of the present day. It seems strange that such a very great improvement on Graham's dead-beat escapement as either the chronometer escapement, or the detached lever, constitutes, should not yet have been applied to the astronomical clock. The mercury compensation pendulum, although very bad, cannot probably be blamed for the sudden variations of rate, amounting sometimes to as much as two-tenths of a second a-day, to which the best astronomical clocks at present in use are subject.

If a chronometer is suspended in the manner shown in Fig. 6, I find I can make it go fast or slow as I choose, by shifting the points of support nearer to or farther from the centre. When the upper points of support are very near, the time of vibration of the chronometer as a whole, when turned a little round its vertical axis from the position in which it hangs in equilibrium and let go, is much longer than that of the balance-wheel. When left to itself, with the chronometer going, the reaction of the balance-wheel, through the spring, against the frame, gives rise to a vibration, illustrated by Fig. 3, in which the balance wheel and the rest of the chronometer vibrate round a vertical axis always in opposite directions. The effect of suspension in this instance is to make the watch go faster than when its case is held perfectly fixed, but this effect is smaller the nearer the upper points of support are. The circumstances of the extreme case when they are as close as possible, are best realized by hanging the chronometer by a long single cord, from a fixed point, by means of a sling or two or three cords attached to the chronometer and so adjusted as to keep its face horizontal: thus giving the frame perfect freedom to move round a vertical axis. The permanent effect is then such, that the balance wheel and the rest of the chronometer oscillate in opposite directions through ranges inversely as their moments of inertia. The period of this vibration is the same as that which the balance-wheel would have if the length of the hair-spring were diminished to the same proportion to its whole length that the moment of inertia of the chronometer with the balance-wheel free bears to the sum of this moment of inertia and the moment of inertia of the balance-wheel round its own axis. The period of vibration will be diminished according to square-root of this ratio. Thus, if the moment of inertia of the chronometer is 647 times that of the balance-wheel, the period will be $\sqrt{\frac{647}{648}}$, or less than $\frac{1299}{1300}$ of the proper rate: or the chronometer will gain one second in 1299 or about 67 seconds in the twenty-four hours. This was the result observed by Mr. Smith, from which he inferred the moment of inertia of the pocket chronometer referred to above.

If, on the other hand, the upper points of support are put very wide apart, the vibration maintained is of the same character as that illustrated in figure 4, and the watch goes slower than its proper rate. The farther apart the points of support are the less is this effect, as the circumstances approach more nearly to a perfect fixing of the frame.

If now, commencing with the upper points of support very close together, we gradually increase the distance between them, or, starting with them very wide apart, we gradually diminish the distance, a certain critical arrangement is approached from either direction, and the gaining rate in the former case, or the losing rate in the latter case, is augmented. This critical arrangement is such that the period of vibration of the suspended chronometer, when set to vibrate by an external disturbance, is approximately equal to the period of vibration of the balance-wheel. When the upper points of support are adjusted to produce it, and the chronometer, going, is left to itself, the action of the internal prime mover will bring the whole into a state of vibration, which may be either the first fundamental mode (balance-wheel and frame-work vibrating in the same direction), in which case the chronometer will have a losing rate, or the second fundamental mode (balance-wheel and frame vibrating in opposite directions) in which case the chronometer will have a gaining rate. The gain or loss may amount to as much as one second in sixty or eighty with an ordinary ship chronometer, taken off its gimbals, or a pocket detached lever watch. The amount of the effect will of course be much less for a marine chronometer, not removed from its gimbals, but suspended by cords attached to its outer case, on account of the great addition of moment of inertia due to the outer case. With a marine chronometer, or any watch having a chronometer escapement (Harrison's), or having a duplex escapement, the seconds hand jumps forward once, and one comparatively loud beat is heard, for each period of the balance-wheel; and thus it is easy to see whether the watch, when suspended, is vibrating according to the first fundamental mode (losing), or the second mode (gaining), by noticing in which direction the visible motion is at each beat of the escapement. With either of these kinds of escapement the experiments above described are liable to stop the watch when the upper points of support are adjusted for the critical arrangement. Thus, for instance, if the points of support have first been too close for the critical arrangement, and are gradually separated until the vibration of the frame becomes very large, a great gain of rate is produced; and if the distance is then a little farther increased, the watch will often stop: if then a slight impulse round the vertical axis is given to it to start it, it will commence vibrating according to the first fundamental mode, with a largely losing rate. The other corresponding result is obtained by commencing with the points of support too far asunder for the critical arrangement and bringing them gradually together.

Without exciting independent vibrations of the chronometer or watch as a whole, and counting them, it is easy to perceive whether the circumstances approach the critical condition, by applying the hand to steady the watch, and then observing the phenomena presented when it is left to itself. If the upper points of support are either much too wide apart or much too close together for the critical arrangement, the watch-case will not take any regular harmonic vibration, but will make a slight (perhaps scarcely perceptible) jump once every semi-period or once every period of the balance-wheel, according to the character of the escapement. But if the upper points of support be set approximately to the critical arrangement, and the watch brought to rest and left to itself, it will be seen to commence vibrating through a gradually wider and wider arc until a maximum of vibration is attained. The amplitude of vibration will then diminish, but not to zero; will increase to a second maximum smaller than the first; will diminish to a second minimum not so small as the first minimum; increase to a third maximum smaller than the second; and so on, until, after several of these alternations, a sensibly steady state of vibration, very closely simple harmonic, is attained How nearly the critical arrangement is approximated to, may be judged by counting the number of vibrations executed from starting to the first maximum, from the first maximum to the first minimum, and so on—the numbers being greater the nearer the adjustment is to the critical condition. I made these experiments first on board the *Great Eastern* during her last summer's cruise; and it was curious, as an illustration of the general principle of the superposition of motions, to watch the various phenomena of vibration of the suspended watch presented, quite independently of the swinging due to the rolling of the ship.

When the top points of support are arranged precisely to the critical condition, I find that the watch will, of itself, take sometimes one mode of vibration, sometimes the other. But a very slight deviation in either direction from the critical arrangement suffices to do away with this indifference, and to insure that, when the watch is steady and left to itself, it will take up either always the gaining or always the losing mode of vibration. But even then it may be compelled to take up either mode by properly-timed touches with the finger, and it continues vibrating accordingly when left to itself. Thus, when the top points of support are adjusted, either precisely, or somewhat approximately, to the critical condition, the watch may be made to go either faster or slower than its proper rate, by applying the hand to cause it to take up either mode of vibration at pleasure, and then leaving it to itself. This last experiment ought not, however, to be pushed too far with a valuable chronometer, as the effort to make it take up a mode of vibration opposite to that which it takes up of itself, is liable to make the escapement-wheel trip and run round rapidly, escaping from the control of the balance-wheel and the escapement—this disturbance not being produced by any violent action of the hand, but by very gentle touches properly timed. No such derangement can, I believe, ever take place when the watch is hung in the manner described, and left at rest to take up whatever mode of vibrating it will, and no damage to the most delicate chronometer can result.

The knowledge of those facts may be of advantage—first, in pointing out a simple plan for setting a chronometer without touching the hands; second, in showing how it ought to be supported, in regular use, so that it may go at a uniform rate and keep correct time. It is usual to place ship's chronometers on cushions, at sea, to guard against damage to the works, from tremors of the ship. If the cushion be moderately hard, the chronometer's rate does not (as I have found by trials on board the *Great Eastern*) differ sensibly from what it is when the chronometer is laid on a hard board, the instrument being of course always kept on its gimbals in its heavy outer case. If, however, the cushion is soft enough, the critical condition explained above may be reached or even passed; and great variations of rate in either direction may be produced. Thus, a certain degree of softness in the cushion may make the chronometer lose considerably, and a still softer cushion may make it gain considerably; and cushions softer yet would make the chronometer gain, although not so much. It is possible that an improvement in the practical performance of chronometers at sea, may be attained by fixing the outer case of the instrument to a very heavily weighted base, this base being placed on an ordinary cushion.

At the conclusion of the paper, in answer to questions by the President, Mr. Day, and Mr. Davison,

Sir Wm. Thomson said that the weight of the chronometer would influence the rate at which it would gain or lose by the oscillation, so that it was better to have a massive watch than a light one, as the former was more likely to go well. No doubt, the rate of an ordinary watch-chronometer is very much affected by railway travelling. His own pocket-watch gained from four to eight seconds in journeys to London and back. The railway carriage vibration affected as a prime mover the vibration of the balance wheel, not merely as vibrations induced in the frame by the interior movement would do. If a chronometer case is well weighted, its performance will not be practically injured by the influence which has been described. If it were firmly attached to the middle of a plank four-feet long, with heavy weights fixed near the ends, its rate would be sensibly the same as if its case were absolutely fixed, however this board is supported. To avoid damage from the tremors of the ship, this board should be placed on cushions, and strapped down, or lashed properly, for security.

If a watch be hung on a nail, it depended upon the dimensions of the watch and the time of the balance-wheel whether it will go faster or slower than its proper rate. If, when hung on a nail and set to swing, it vibrated more rapidly than the balance-wheel, then the effect of the hanging would be to induce a slower rate; but if when set to swing it vibrates slower than the balance-wheel, then when left to itself it will go faster than when the case of the watch is held quite fixed. A watch regulated to go correctly when hanging on a nail, (according to a faulty practice, sometimes followed, he believed, in watchmakers' shops) cannot be expected to go at even approximately the same rate as when carried about in ordinary use.

## *On an Improved Screw Steering Apparatus for Ships.*

By Mr. James Skinner.

(see plate ix.)

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*Read 27th March, 1867.*

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Of all the numerous component parts of a vessel, one of the most important and essential is the steering apparatus. On it, to a great extent, depends not only the convenience of handling, but frequently the safety of the ship, and no other part of the fabric is exposed to so much tear and wear, for, be the voyage long or short, stormy or favourable, the steering apparatus is in constant use. It will, therefore, be admitted that any real improvement in this useful machine is a matter of considerable importance, and well worthy of attention.

Among the numerous systems at present in use, the best is undoubtedly the right and left-handed screw, from its steadiness and power; but this is liable to two grave objections,—the first of which is, that the power to move the rudder decreases in proportion as it is moved out of the centre line of the vessel, and, of course, as the rudder is moved out of the centre line and a greater amount of its area is exposed to the action of the water, in that ratio the resistance increases; so that, according to the present arrangements, we have a constantly diminishing power to meet a constantly increasing resistance. Again, as the power diminishes the speed increases, and *vice versa;* and while the rudder is amidships, or nearly so, little power is needed to move it, and, therefore, it might with advantage be moved at a quicker rate, but we find that in the present arrangements it is slower at that point than any other.

That this is the case with regard to the different modes of screw-steering gear at present in use, as well as to nearly all other kinds, will be apparent to any one who considers the matter, and that it is a fault in principle is equally clear.

The improved steering apparatus is shown in Plate IX.

Fig. 1 shows a side elevation.

Fig. 2 shows a plan, the wheel being removed.

Figs. 3, 4, and 5, show the tiller and guide-plate without the framing, screw, or nut. In fig. 4, the rudder is amidships; in fig. 3, it is hard "astarboard;" and in fig. 5, hard "aport."

The tiller is moved by the guides BB.

The defects of the present steering apparatus have been entirely obviated in the new arrangement—in fact, the case is entirely reversed, inasmuch as the power is increased as the rudder is moved over to either side, and the action is quicker when the rudder is amidships and not exposed to the resistance of the water which the vessel passes through. This is brought about by the use of curvilinear guides acting on the tiller, the form of which may be so arranged as to give an increased power to any desirable extent as the rudder is put over to either side.

The second objection to the ordinary screw-steering apparatus already referred to is, that the nuts having to exert their force on one side only, are soon found to wear loose and shake sideways in an unpleasant and injurious manner, and this is also overcome in this apparatus by the longitudinal guides on each side, which take off all strain from the screw and nut except a direct thrust, and so prevent the lateral movement. These guides have a large bearing surface, and they may be made adjustable at any time if required.

In addition to these two chief advantages, the new plan has several others, such as greater simplicity and fewer working parts, dispensing, as it does, with the left-handed screw and nut, only one screw and nut being required. Its compactness is also a prominent feature, as it occupies only about half the space of the ordinary plan, and it may be arranged within a circular casing, of which the rudder-stock is the centre, and it then occupies little more room than a common capstan. This form, although not that shown by the drawing, is that preferred by the inventor.

A working model of the apparatus was exhibited.

In the discussion which followed the reading of the paper,

Mr. Mansel said he thought it a very good arrangement, and that it would be found to work well; he believed it was free from the objection to the right and left screw.

Mr. A. Brown thought that with a screw of large diameter it would make a very good steering gear. There were fewer pieces to keep in repair than in the double right and left handed screw apparatus.

Mr. Downie thought the strain would be very severe on the sliding block to resist the tangential movement of the single tiller-head lever in the groove.

Mr. Brown said he thought it would be better to make it double-handed. It would lessen the strain and increase the power and efficiency of the apparatus.

The President asked whether it had been used in any vessels?

The Secretary stated that he believed it had been fitted into some vessels, but he did not know the results.

Mr. Downie said the question of cost, as compared with other plans, here stepped in. Its compensating power was much in its favour.

The President did not think it would cost more than the right and left handed screw. One objection to it was, that a very little slackness in the block in the groove would allow it to swagger.

Mr. Brownlee said if there was a well-fitted block there, it would not sheer for a long while. It must move in the arc of a circle.

## *On an Improved Steam River Ferry-Boat for Passenger and Cart Traffic.*

By Mr. Julius Drewsen.

(SEE PLATE X.)

*Read 27th March, 1867.*

In these days of invention and application of steam-power to almost every purpose as the best means of superseding manual labour, I have thought that the subject of steam ferry-boats adapted for our River traffic would be one not altogether uninteresting or unfruitful to bring under the notice of this Institution, as I think the time has now come when a revolution in this branch of our passenger accommodation is necessary, from the extensive alterations just made on the breadth of our River, and from the "signs of the times," as manifested by the desire of the community in having boats more in keeping with, and better adapted to supply, the rapidly increasing wants of a vast and extending traffic.

You are doubtless all aware that, for these and other reasons, the Clyde Trustees have for some time been devoting much of their attention to devising means for developing and accommodating their present gigantic passenger and general traffic by means of steam ferry-boats, and for a similar reason, other corporate and private bodies on the River have of late also determined to apply steam, as the most advantageous means of developing their traffic, and of superseding manual propulsion.

From the uniformity of the traffic at the different ferries on the River, as to variety, and I may say quantity, a boat fitted for one would fit all, and, bearing this in mind, I have strictly kept in view what I consider of essential moment in point of economy, viz., the carrying of passengers in the same boat, and at the same time, as horses and carts, and general merchandise. Horse boats as at present used never being fully employed, it is plain that from the speed with which such a boat as that now before you would cross the River when fitted and driven by steam, (2½ minutes,) to carry passengers, and therefore do away with the present very tedious system of conveyance by means of small boats, would be a matter not only of the soundest economy, but, in my humble opinion, the best mode of overcoming the present exceedingly unsatisfactory and irregular, as well as dangerous, mode of conveying passengers.

I have in this design endeavoured to exhibit a boat capable of carrying with ease the whole traffic of any of our River ferries. From a careful study of the traffic done for many years at our principal ferries (Govan, Renfrew, and Erskine,) I have no hesitation in saying that, for a successful boat, the great object to be aimed at is to have one sufficient to carry with ease all the traffic, and at the same time not an inch larger than is absolutely necessary—the conclusion I have come to is, that for a steam ferry-boat to carry four loaded carts, as those of either Govan or Renfrew at present do, would be far too large for our requirements, while that of Erskine would be simply ridiculous, entailing a wanton waste of money in its outfit and maintenance. The former two boats, by hand propulsion, carry, as I have said, four loaded carts, but occupy in crossing on the double journey, from twenty minutes to half-an-hour, depending on the state of weather and tide. Fitted with steam, the boat I propose would carry only two carts, along with fifty passengers in the saloons on each side, but instead of twenty minutes or half-an-hour, as at present, it will perform the double journey in from five to seven minutes, so that a larger boat would only be incurring expense for no end; and by only carrying two carts, the one goes in immediately behind the other, and thus prevents the tedious shifting and arranging necessary before starting. Moreover, it is not more than two or three times in a day that four carts come to the ferries all at once for transmission across, so that two carts may be said to be considerably above the usual number conveyed across at one time. In conformity with this opinion I have fixed the dimensions at 40 feet long by 23 feet broad amidships, tapering gradually to each end to a breadth of 13 feet, while the size of Renfrew ferry-boat is only 36 feet by 18 feet. You will thus see that, although this plan is only fitted to carry two carts, it is a little larger than the present boats; the cause of this, I need hardly mention, is owing to the extra displacement caused by the engine and boilers, with their fittings, and also the space necessary for the passenger saloons on each side.

The chief feature in this design which will readily strike the eye as differing from those of manual propulsion, is its oval form as already mentioned—which will secure for it increased speed, and greater steadiness, and be easier driven than the almost square, flat boats now in use. The bottom I have sloped off at each end, almost to the same gradient as the inclined beaches, to allow it to enter further in; and it is sloped in like manner from each side to the centre, to lessen the effect of the current against it while crossing; letting the water have better clearance than if flat; hence its importance on a river which, like the Clyde, is frequently in flood. The bottom is amply protected from injury by four false keels, 4″ × 3″, and the sides by British oak fenders, 6″ × 6″, running the whole length of the vessel, and affixed to its sides by angle irons.

Referring to the drawings, Plate X., you will see that I have arranged the boat into seven water-tight compartments, by two bulkheads running fore and aft (supporting deck below cart wheels), and by two cross bulkheads at each end. These compartments not only render the boat much safer, but very materially contribute to its strength. Into the side compartment of one side I have placed the boiler, arranged on the multi-tubular system, and capable of bearing a working pressure of 55 lbs., as the best suited for raising steam on the shortest notice, and most economical of fuel; and, from its shape, best adapted for such a boat. The funnel connected with this boiler (the only portion of the machinery above deck) is constructed on the principle of deadening the sound of the exhaust, which blows into it, and also of extinguishing sparks—so ensuring the utmost safety to hay or other inflammable goods while being conveyed across. The approach to the boiler for firing purposes is by a hatch on deck, and for repairs, by a door placed on the inside of the cabins.

The Engines are on the direct-acting diagonal principle; two cylinders, each 9 inches diameter, 18 inch stroke, with reversing quadrants, worked from deck. It works two driving chains, one on each side of the boat, through a wheel and pinion on the Patent Frictional Gearing principle. The two chains I consider necessary, not only as affording additional security from accident over one chain, but in order to steady the vessel on entering the landing berth in windy weather. The engines are likewise placed under deck on the opposite side of the boat from the boiler. The wheel shaft crosses from the inside of one cabin to that of the opposite. Where this shaft pierces the water-tight compartments, it is prevented from interfering with their amenity and usefulness by working through stuffing boxes. On one end of this shaft a friction and chain wheel combined is placed, on the other end only a chain wheel. The chains are conducted to these wheels by a system of leading curves and pulleys as shown in drawings.

I have already mentioned that the driving wheels are driven by Frictional Gearing, which principle I have adopted as the safest. This system will least disturb passengers; and, what is of still more importance, it will not in anywise frighten restive horses while crossing; it will reduce breakage to a minimum; and, from the great tear and wear it stands, will be by far the most economical, and the most applicable for a Steam Ferry Boat.

The Platforms I have made 11 feet long × 13 feet wide, of $\frac{1}{4}$ inch plates turned up at sides, with five stiffening bars of T iron, $3\frac{1}{2}'' + 3'' \times \frac{5}{16}''$, each ending in strong hinges which are bolted on to the hull; they are in addition, lined with tho same size of wood as the deck, and protected on end by the usual iron shield. Instead of these platforms being raised and lowered through the medium of the common long unwieldy poles, which prove such an obstruction in some of the present boats to the inlet of carts loaded with materials requiring much longitudinal space, such as wood and hay—I have placed gibes, which act more directly; the lifting chains are connected to the engine, and can at any time be thrown into motion without stopping, (as can also the driving wheels) by the turning of a handle, placed for that purpose under the easy reach of the man in charge. These gibes are so low that any cart may pass over the top of them, offering no obstruction.

The Carriage Way is so high as easily to allow all machinery to be accommodated under deck; by far the most complete arrangement, in my opinion, as it entirely obviates the plan of placing the boiler in the centre of the space allotted for a cabin on one side, and the engine from interfering in the same manner on the opposite side. It allows for cabin floors to be sunk below the level of the deck; and thus a system of saloons of ample height has been arranged from end to end of the vessel without interruption, and combining the additional great advantage of only raising the top of these saloons a few inches higher than the sides of the present boats, a circumstance of much importance, as the man in charge has thereby a complete view of the river up and down. These saloons are each 24 feet long, six feet nine inches high, and five feet six inches broad at centre; you approach them by a flight of three steps; ample ventilation is provided, and abundance of light from the sides. Objection may be taken to having these saloons at all, but in a stormy day and when the boat is loaded with carts, they would prove of the utmost advantage. They would also prevent the possibility of umbrellas frightening restive horses; and, above all, be a source of comfort to the passengers. On the top of these saloons handles are placed, under command of the master:—viz., one for the throttle valve; one for disconnecting the drawing chains; one for raising and lowering the platforms; and one for reversing the engines.

My views in making this design of boat were to do away entirely with the present use of small boats at those ferries where both horse boats and small passenger boats are used. In short, I combine the requisites for both; and, as at present at Renfrew, and I believe at Govan also, four men are required at a time, whereas, in adopting a steam ferry-boat like this, one only is necessary at once—say two altogether. You have thus gained a clear saving much more than sufficient to clear the interest on the additional outlay of money and the small amount of fuel it would consume (10 cwt. daily). And, in addition, you have a vessel that will last a lifetime, and up to the requirements of the age; and having such, surely it is not too much to suppose that in this, as in almost all undertakings, the superiority of the accommodation and the speed will create an increased traffic.

These designs I have adopted after a course of patient and long study of the various requirements of our ferries, and I venture to hope that you will have no difficulty in observing that I have adopted a plan differing widely in *form* from any now in use, and in arrangement as greatly dissimilar; yet, combining in its construction every convenience for our river traffic, and at the same time securing those additional and important advantages I have already described. In conclusion, I venture to hope that each individual member will, after a careful and unbiassed consideration, suggest any improvements which he may deem necessary to enhance its value.

A neatly made model of the intended ferry-boat was exhibited at the meeting.

After the reading of the paper,

Mr. John M'Donald said it appeared to him that the element of time had been lost sight of in the boat, as respected the crossing of the Clyde.

The President said, Mr. Drewsen estimated that the boat would cross and return in five or seven minutes. He observed that there were means taken for lessening the noise caused by the discharge of the exhausted steam from the cylinder. It appeared to him to combine everything that anybody could desire for comfort and speed in crossing rivers.

Mr. Downie asked whether there was much slack in the chains, and whether it was likely to impede free navigation of the river?

Mr. Brown said there was sufficient slack to allow the chain to drop, so as to prevent any vessel coming in the way. Besides, no steamer drawing much water would go so close to her as to run any risk. The chains fall very quickly at the stern. He asked whether the vessel would not go across quite as straight with one chain as with two?

Mr. Drewsen was of opinion that the two chains were required; and that it would be easier to work the boat with two than with one chain.

Mr. Brown could not give a positive opinion regarding the vessel, as he had not seen the drawings; but he considered the placing of the boiler under deck at one side, and the engine at the other, was a very good arrangement, provided the vessel was not too deep in the centre; but he thought the manner of placing the machinery would distribute the weight pretty well over the structure. His mind was not quite made up in regard to the frictional gearing, about which there was a difference of opinion; but he did not doubt it would be a very good thing if there was no slipping. The arrangement of the platforms was certainly very good. He had no doubt that the saloons would be found very comfortable in stormy wet weather.

The President said that the frictional gearing might be an open question; but did they not think that in this case it was well worthy of a trial?

Mr. Downie did not think there would be the slightest difficulty in regard to the frictional gearing. Fifteen tons, and even heavier weights, were lifted by it every day, by cranes and crab-winches where it was applied, and in conveying such a vessel across a river like the Clyde, where there was little current, there was no heavy strain.

Mr. Drewsen considered it an advantage that the frictional gearing was so much easier to disconnect.

Mr. Brown would like if experiments were made to prove whether one chain or two would suit better for river traffic. At Southampton he had seen boats a little larger than this, and they had generally two chains. The one chain guides and the other drives the vessel. He would also like to know whether condensing or non-condensing engines were better for the purpose.

Mr. Downie could not see much difficulty with regard to the exhausted steam, from non-condensing engines, as it might be put under the water.

Mr. Mansel said it could be directed into the water so as to make no noise at all.

The President was of opinion that owing to the shortness of the passage, the non-condensing engines would be found to be best.

Mr. W. R. Thomson thought that the chains might be considered an obstruction in the river. He was of opinion that the present means of propulsion of the ferry-boats in the higher parts of the river were superior to that of the steam ferry-boat proposed.

Mr. Drewsen said that the chains were found to be no obstruction whatever. They were so heavy that they sunk sharp by either end of the vessel.

## *On the Theory and Practice of the Slide-Valve.*

By Mr. Thomas Adams.

(see plates xi., xii., and xiii.)

*Received 3rd, and read 10th April, 1867.*

The relief of the slide-valve from the load which its construction necessarily imposes upon it, has engaged, and in some instances absorbed for a time, the attention of Engineers. The records of the Patent Office show that upwards of five thousand patents have been taken out for the accomplishment of this object, including amongst them many names of the highest distinction in Engineering. And this forms but a fractional part of the number who have otherwise tried and failed. This is sufficient proof that there must have been some unknown cause, apart from its mere mechanical construction, operating upon the valve to prevent the successful accomplishment of an effect so unanimously desired. That this was so, there is now no longer any reason to doubt; for, upon principles hitherto unknown to Engineers, a slide-valve can be constructed which will work as easily with steam of any pressure on it as with steam off, and be absolutely steam-tight, and bearing on the face of it the impress of simplicity.

With these preliminary remarks, we will proceed to inquire into the power absorbed in working the slide-valve. For that purpose we will select fig. 1, which represents the valve of a goods engine belonging to the North Staffordshire Railway Company, of which Mr. Jas. Johnston is superintendent, and which is a very fair specimen of the most improved proportions applied to the locomotive, viz., outside lap, $1\frac{1}{4}''$, inside lap, nothing; admission port, $1\frac{3}{8}''$; exhaust port, $3\frac{1}{2}''$; inside bar, 1″; outside bar, 2″; length of port, 14½″; width of end bars, 1⅛″; diameter of cylinder, 17″; stroke, 24″; pressure of steam, 140 lbs. per square inch. This engine has no difficulty in taking 70 waggons of goods between Liverpool and Derby. Fig. 1 is a section of the valve in middle position over the ports; fig. 2 is a plan of the same. The outer and inner edges of the valve, by their crossing the outer and inner edges of the ports, determine the distribution of the steam. If, then, we let fall lines *m*, *n*, &c., from each of these edges at right angles to the plane of the valve's motion, and at any convenient distance below describe semi-circles E, &c., equal to the travel of valve, divide these semi-circles into ten equal parts, corresponding to the ten equal divisions on the indicator diagrams. Let the pressure on the back of the valve be represented as positive pressure, and that on the face and in exhaust cavity as negative pressure; measure the horizontal distances from each division to the edge of port or bar, and find what section of surface of valve is exposed to negative pressure. That section, multiplied by the length of port, and by the corresponding pressure on diagram, will give the negative pressure, which, taken for the ten divisions, and their sums added and divided by ten to give their mean, and that sum subtracted from the total positive force, will leave the force available for friction, which, multiplied by the co-efficient of friction, and by the space passed through in feet per minute by the valve, and divided by 33,000, will give the horse power required to work the valve.

Table No. 1 contains the negative forces represented by the larger of the indicator diagrams, Fig. 3. Table No. 2 those of the smaller diagram, corresponding to the ten positions of the valve represented by the ten equal divisions of the semicircle, each division corresponding also with its relative division on the diagram, from which the pressures are all taken. The first column is the number, the second is the sectional breadth, the third is the length in inches, the fourth is the pressure, in pounds per square inch, taken from the diagram, except when the valve is over the extreme end bar, and then the boiler pressure of 140 lbs. is taken. The fifth column is the second, third, and fourth multiplied into each other, which, being done for the four edges of the valve, their sum is taken, and that divided by 10 to give their mean negative force, which, being subtracted from the total positive force, will leave the positive force available for friction. Thus:—

$$\frac{11{,}053 + 5123 + 363 + 24{,}146}{10} = 4068 = \text{negative force.}$$

$$16{\cdot}75 \times 10{\cdot}75 \times 140 = 25{,}208$$

25,200—4068 = 21,140 = positive force available for friction.

$$\frac{21{,}140 \times {\cdot}325 \times 117}{33{,}000} = 24{\cdot}3 \times 2 = 48{\cdot}6 \text{ horsepower} = \text{friction of valves.}$$

21,140 × ·325 = 6870 = pull on valve spindle.

$$\frac{6870 \times {\cdot}15 \times 724}{33{,}000} = 22{\cdot}6 \times 2 = 45{\cdot}2 \text{ horse power} = \text{friction of eccentrics.}$$

$$\frac{227 \times 702 \times 78}{33{,}000} = 376 \times 2 = 752 \text{ horse power of both cylinders.}$$

$$752 - 95{\cdot}5 = \frac{656 \times 100}{752} = 87 \text{ per cent.}$$

100—87 = 13 per cent. equal friction of valves and eccentrics.

This is running in the first notch from full gear. Speed of piston, 702 feet; load drawn, 335 tons.

And of the smaller diagram and Table No. 2:—

$$\frac{8428 + 4110 + 193 + 9{\cdot}510}{10} = 2225 = \text{negative force.}$$

25,200—2225 = 22,975 = positive force available for friction.

$$\frac{22{,}975 \times 35 \times 101}{33{,}000} = 24{\cdot}61 \times 2 = 49{\cdot}22 \text{ horse power} = \text{friction of valves.}$$

22,975 × ·35 = 8041 = pull on valve spindle.

$$\frac{8041 \times {\cdot}15 \times 724}{33{,}000} = 26{\cdot}46 \times 2 = 52{\cdot}92 \text{ horse power} = \text{friction of eccentrics.}$$

$$\frac{227 \times 702 \times 36{\cdot}5}{33{,}000} = 176 \times 2 = 352 \text{ horse power of both cylinders.}$$

$$352 - 102 = \frac{250 \times 100}{352} = 71 \text{ per cent.}$$

100—71 = 29 per cent. = friction of valves and eccentrics, when running in mid-gear. Speed of piston, 702 feet per minute; load drawn, 80 tons.

Thus we see that the combined friction of valves and eccentrics is practically a constant quantity, being in the first notch 95·5 horse power, and in the middle notch 102 horse power, or 6½ horse power more when the cylinders are developing 352 horse power than when they are developing 752 horse power, and hence the absolute necessity of the application of a frictionless slide-valve to engines working a high grade of expansion; and it also shows conclusively, that a decrease in the travel of valve is met by an increase in the power absorbed in working the valve and its appendages. The author is not inclined to speak in definite terms as to the general existence of this high per centage of friction, although in some instances he has got greater advantages than here represented; but there can be no doubt whatever that the co-efficient of friction in actual practice is considerably less than that taken by starting the valve from a state of rest, which latter was the means employed for finding the co-efficients that have entered into the calculation. But it will be remembered that the positive force available for friction, divided by the number of square inches in the bearing surface of valve on cylinder face is the pressure from which the co-efficient is taken. See column 18, table No. 1, bearing surface in square inches, corresponding to 10 positions of valve, which, divided by 10, will give the mean bearing surface. But this valve of the North Staffordshire Railway compares very favourably with others of its class, some of which have 496 lbs. per square inch of bearing surface.

Thus, for table No. 1:— $\frac{21{,}443}{61{\cdot}4} = 350$ lbs. per square inch; and for table No. 2:— $\frac{22,975}{59 \cdot 3} = 390$ lbs. per square inch, which pressure gives co-efficients from a state of rest of ·325 and ·35, the metals being brass on cast-iron, and of the proportion which the valve spindle bears to that of the piston rod. Diameter of piston rod, 2⅝"; area, 5·410□"; diameter of valve spindle, 2¾"; area, 2·405□"; then,

$$5 \cdot 422 - 2 \cdot 405 = \frac{3007 \times 200}{5 \cdot 412} = 55 \cdot 6 \text{ and } 100 - 55 \cdot 6 = 44 \text{ per cent.}$$

the proportion of valve spindle to piston rod.

Figs. 4 and 5 are plan and section of the valve just noticed, after having worked four months. The dotted line shows the original thickness, and the distortions, from a straight line, shows that the pressure has been enough to produce molecular motion of the metal.

It will be seen that the greatest wear is not in the centre of the valve, but inclined towards the bottom by ⅝". The author has observed, that in all cases of valves working vertically, the bottom side wears most. This is in a great measure owing to the combined force of the co-efficient of friction, and the weight of the valve and buckle. A vertical line represents the one, and a horizontal the other force, then the line of the worn cylinder face will be the component of the two forces.

As fair specimens of what Engineers have done in their search for an equilibrium slide-valve, we propose to illustrate the means tried by Sir Daniel Gooch, Bart., when on the Great Western Railway; Waddell, of the Cunard Company, Liverpool; and Napier, and to endeavour to assign to each their relative merits in the case.

Fig. 6 is the valve of Gooch, laid in middle position over the ports, the dimensions of which are:—Admission port, 2"; exhaust, 3½"; outside lap, 1$\frac{1}{16}$"; inside lap, $\frac{1}{32}$"; outside bar, 1⅞"; inside bar, ¾"; length of port, 13"; valve over all, 15 × 11⅛". A is a piston working in a short cylinder, and exposed to the boiler pressure. It is connected to the valve by a link L, working on knife edges. The piston is 12" diameter, and contains 113 squaro inches.

This valve, tested by the rule employed by the author for finding the displacement of steam on the back of valve, reveals the fact that Gooch's piston ought to have been only 9⅞" diameter, and containing 75 square inches; and the difference between 113 and 75, multiplied by 140, the pressure is equal to a force of 5320 lbs. above the balance, showing that the piston was master of the valve, and pulled it clean off, the cylinder face having an excess of force of nearly 2½ tons, and this valve was supposed to be so nearly balanced as to require suspending on knife edges, lest the friction on round pins should have thrown it out of equilibrium.

The rule which appears to have been employed here is, the length multiplied by the breadth, equal to 167 square inches, from which, subtracting the area of the two admission ports, there remains two square inches to hold the valve to the cylinder face, and to overcome the friction of the piston in the cylinder.

Humphrys, of the firm of Humphrys & Tennant, of London, applied the usual packing rings employed by the Admiralty in the high pressure valves of the *Mooltan*, Peninsular and Oriental Company's steam-ship. He displaced the area of the valve less the area of the admission ports. The result was, that these valves did not work on their faces, but on their backs; for, on examining the valves when taken out, a sixteenth of an inch thick of congealed tallow and oil was accumulated on the faces, and this doubtless reveals the truth of the statement in Mr. Murray's paper, read before the Institution of Naval Architects, that engines so fitted by Humphrys worked more economically without than with the high pressure cylinder, and this Engineer fitted up and applied on board this same ship a hydraulic press, to reverse his so-called equilibrium valves. If Mr. Humphrys had desired to hold up those valves to silent derision, he could not have designed better means whereby to display his ingenuity, than the application of the most powerful machine known to Engineers, in order to give motion to a small body so suspended, as to be moved with the least possible amount of force.

The firm of Ravenhill, Salkeld, & Co., applied two 24-inch diameter cylinders, open to the boiler pressure, to reverse the valves of 800

H. P. engines, notwithstanding they were called equilibrium valves, but the combined force of the two cylinders was not equal to the task.

Fig. 7 is a section of Napier's valve, as shown to the author by Mr. John Penn. It displaces steam on the back of the valve, equal to the exhaust cavity. It contains the usual plates, set screws, and gasket packing. This was done by Napier so long as thirty-eight years ago, and had it not been for this system of packing with the laps used in those days, Napier would have had a practically frictionless slide-valve. The packing was the cause of the failure, for the valve itself contains the principle of a frictionless slide-valve. Comparing it with Gooch's valve, the displacement by Gooch is 113, by Napier 65, and by the author 75 square inches; but in some cases, as we will presently see, that by Napier and the author are much nearer to each other.

Fig. 8 is Waddell's, according to his specification, and the tracing, fig. 9 is a half section of the same as applied by R. Napier & Sons, and kindly granted by them for this occasion. P is a plate fixed on the cylinder face, extending to the inner edges of the admission ports, V is the valve, H H are communication holes, and S S are steam spaces; the steam acting on both sides of the valve suspends it in equilibrium by a space equal to the exhaust cavity, exactly Napier's displacement, who did it twenty-four years before Waddell.

Had Waddell stopped here, he would have had a very good valve, where there was space for its application; but, not being satisfied, he wishes to balance the area opposite the admission ports, to do which, he introduces a kind of packing much used by James Watt during the last century; and, in order to balance the difference between the pressure in the steam chest and that in the cylinder—which, with the amount of lap on the valve, is not more than 10 lbs. per square inch—he has to bring to his aid a force by set screws, equal to the length multiplied by the breadth of his packing, and by the total pressure, equal to $1{\cdot}25 \times 40 \times 33 \times 4 = 6600$ lbs. That having been done, it has destroyed a negative force which would have otherwise acted on the extreme end bar equal to an inch, multiplied by the length $= 1 \times 31 \times 2 \times 33 = 2046$ lbs, which, added together, is equal to

8646, and this is the least amount of force with which Waddell's valve can be made steam tight, equal to a force of 183 lbs. per set screw, and to those accustomed to setting up those set screws this will appear a very small amount.

In support of these statements, the author purposes to bring before your notice some experiments made by him in order to determine the forces acting on the valve; and, first, of a perfect equilibrium slide valve.

Mr. Zerah Colburn, of London, has for years past been telling engineers that planes without ports require the same amount of power to move them, whether in a vacuum, in the open air, or in steam of 100 lbs. pressure. The theory is doubtless correct; but as cylinders have ports, and valves cavities, the delicacies of this fine theory are destroyed. In practice, nevertheless, it is fraught with knowledge to engineers seeking for an equilibrium valve, and they ought never to lose sight of it.

Fig. 10.—Let F be the cylinder face, P the admission port, V the valve, with the exhaust valve entirely cut out; D the door of steam chest, P false port in door and opposite true port; C a communication port through valve. The steam will act on the outside of this valve upon equal and opposite areas. The exhaust pressure of a high-pressure engine and the vacuum of a low pressure engine, will act on the inside upon equal and opposite areas. Let the valve move on to open the port, it at the same time opens the false port. Let the valve move on to full port and back again to the point of suppression, during this period, the varying areas exposed to pressure have been equal and opposite. As soon as expansion sets in by the closing of the port, a decrease of pressure within the port is the result; but the communication port C is open between the true and the false port, and during this time the areas have been equal and opposite, and now the steam exhausts from the true port; but it, at the same instant, exhausts from the false port, and as the valve proceeds to full stroke, the areas decrease equally. So, also, during compression on the opposite end, the communication port C maintains the pressures on equal and opposite areas. Having performed a cycle of operations, it will be seen that the pressure cannot touch this valve on any one point without

touching it on an equal and opposite point, under any variation of force, without touching it on an equal and opposite point with the same force, and practically at the same instant of time—and hence a perfect equilibrium valve.

A pair of these valves worked two years and eight months on a pair of oscillating cylinders in a high-pressure boat, built by Smith of London for the Master Shipwright of Woolwich Dock Yard, without any repairs at all.

A pair of those valves was applied to an inside cylinder locomotive on the London and Brighton and on the North London Railways. The valve in this case is made of three wedge shaped pieces, and embraced in the buckle, and forming a parallel block.

The division plate had false ports in either side, and cast hollow to allow steam to pass from one end of the chest to the other. It was dangerous when running with steam, because the heat generated by friction, however small, gradually accumulates, producing an extra expansion of the valve, when seizing takes place, and then the valve spindles break. This also is a perfect equilibrium valve; but worked only a very short time.

The first cost of these valves arising from so many faces being exposed, and from the fineness of the workmanship, is enough to preclude their general adoption. It is, therefore, not the valve best suited to practice, but something that will give and take to irregularities of work and unequal expansion of often times the same metals, and that will have no vegetable packing about it capable of being destroyed by the temperature and pressure.

These valves have been fitted with packing in the same way as Waddell's valve, but these elastic packings would not last a day under the temperatures of the locomotive. It was introduced in the last century to meet the necessities of bad workmanship; but the workmanship of the present day is such, that any two surfaces of metal can be made absolutely steam-tight without the aid of packing. So that, whether for locomotive or marine purposes, the use of elastic vegetable packing ought to be entirely abandoned.

The next valve for consideration is the author's, as applied by Mr. Cowan, superintendent of the Great North of Scotland Railway.

Fig. 11 is a plan and Fig. 12 a section of valve laid over the ports, the exhaust cavity being cut out. The valve is built up so as to receive a ring in the back of it, the ring having a flange on the top of it, which works against the door. It is secured in that position when running without steam by two small springs, the force of which is on the ring and the resistance on the valve, which also prevents the valve from leaving the cylinder face.

The steam in the chest acts on the lower surface of the flange of the ring, pressing it to the door. It also acts between the door and upper surface of the ring (notwithstanding they are scraped surfaces), and being of equal areas, the forces balance each other. The exhaust pressure acts on the top and bottom of the inside of the ring, and on equal and opposite areas, and balance each other, the ring being held in equilibrium.

Fig. 13 is a section as applied by Mr. Cowan with the ordinary exhaust-cavity retained, with two half-inch holes in it to allow the exhaust pressure to act on both sides of the cavity as also on the ring. Mr. Cowan considered that where the steam-chest was deep it was prejudicial to the free flow of the steam to have the cavity cut out, because the steam, at the instant of release, lashes straight across the chest striking the door, and returning at about an angle of 140°, considerably retarded the freedom of the exhaust; an opinion quite consistent with the flow of fluids. He therefore uses the ordinary cavity to guide the steam gradually round from the admission into the exhaust port. Recesses are made in the lap of the valve for the purpose of preventing the destruction of the film on the bars. During long periods of expansion they are filled when over the extreme bar, and again when over the port, but they never exhaust. Mr. Cowan also inserts an ordinary piston-ring in the ring proper for the purpose of making a steam-tight joint, dispensing with hand labour. This he also prefers to scraping the ring into its seat in the valve.

Fig. 14 is a half plan, and shows the method of finding the displacement of steam on the back of the valve. The steam acts on both sides of the valve outside the line of displacement, X Y, on equal and opposite areas, but it also acts on the spaces S S′, which are neither equal nor opposite, S having the pressure on the face and not on the back, while S′ has the pressure on the back and not on the face. It is required that they should balance each other, draw the line *n n*, leaving the spaces *n n* outside equal to the space *m* inside the line of displacement, bisect *n o* in *p*, and draw a line to the opposite angle, one-third that line will be the centre of action of space S, and measures 3·8″ from the centre of valve. Then the area of the triangle, multiplied by the distance of its centre of action from the centre of the valve, which is the leverage with which it acts, will be equal to the area of S′, multiplied by the distance of its centre of action from the centre of the valve, which is the mean fulcrum of the forces, both positive and negative, measured on the line of motion. Thus:—

$$\frac{2{\cdot}8 \times 5}{2} \times 3{\cdot}8 = 26{\cdot}6 = \text{S, and}$$

$$2{\cdot}5 \times 1{\cdot}87 \times 5\,7 = 26{\cdot}6 = \text{S}'.$$

The exhaust pressure acts on the opposite sides of those spaces, but they also balance each other, because they also are multiplied into their leverages.

Various sections of rings were used in experiments to determine the forces acting on their surfaces. The mode of procedure was as follows:—A good strong spring was put under it to keep it up to the door, steam of low pressure was let on, and all was tight, the pressure gradually rises, and at 26 lbs. a blow took place. The higher the pressure the greater was the blow. The ring was then taken out, and ¼″ recessed out of topside, leaving only ½″ to bear against the door when the steam was again let on, and all was tight at and above 26 lbs., but at 49 lbs. pressure a blow began, and the higher the pressure the greater the blow. The ring was again taken out, and another ¼″ recessed out of the top, leaving only ¼″ bearing against the door, the steam being again let on, and it required 78 lbs. of steam to produce a blow. The spring was taken out and weighted to its working deflection, when it was found to be practically equal to the area of the bearing surface multiplied by the pressure.

The experiments which have been made leave no doubt whatever as to the existence of a film of steam adhering to the surface of the metal. The valve, in moving against it, slides over it, and so long as its temperature is maintained, it possesses all the energy of the surrounding steam. It is an elastic fluid possessed of energy; it will therefore perform a given amount of work equal to its equivalent of heat, which it does in supporting the load as the valve moves over it, and when it is destroyed friction takes place.

The author began by displacing the whole of the area on the back of the valve, except an amount on the corners equal to the area of the admission ports. The result of this trial was, that the valve left the cylinder face, and a blow of steam was the consequence. Ten rings of less and less diameter were applied, always bringing the valve away from the cylinder face, until at length it did keep the cylinder and was tight. The valve was taken out and was measured, and the proportions of surface, back and face, are those given by the author's method of displacement. This experiment, like those of the ring, proved conclusively that as you approach the balance of the valve, the action of the film on the bars comes into play, and this force must enter into the calculation for proportioning the opposing surfaces, otherwise no slide-valve can ever approach the state of the balance. These experiments show some of the shoals and quicksands that have deceived engineers, and this film force is the stumbling-block upon which all have been wrecked; for given the relation of surface to pressure and almost any engineer would produce a frictionless slide-valve. Experiments were also made to determine what excess of force on the back of valve was necessary to destroy the interposing film. With steam of 560° temperature it was destroyed with 7 per cent., but with saturated steam of 10 lbs. pressure it required 34 per cent., and the setting in of friction is not uniform, but sudden.

The fulcrum of both positive and negative forces is continually varying when the valve is in motion, the positive traversing about $1\frac{1}{2}$ inches on either side of the centre of the valve, while the negative traverses the whole length of the valve during one revolution, and thus an incessant war is set up between area and leverage. At one time a greater area of negative force prevails, tending to push the valve from the cylinder face, when the positive force acts and prevents it. The valve is incessantly being thrown from the cylinder face, and as incessantly being thrown to it. The molecules of the valve face can never embrace those of the cylinder face in the bonds of friction, but by it the valve is made to float on the fluid skin of the surfaces, and hence the ease with which it is moved.

In the after discussion,

Mr. A. Brown asked whether Mr. Adams' slide-valve would act as well in a large marine engine, with a 40-inch port, as in a locomotive. Would the same principle apply?

Mr. Adams said it would. The application of his valve would not obstruct the passages, and it was the same at any pressure. In his experiments as to friction, he found that the co-efficients were not quite so great with a marine engine as a locomotive. The temperature was the main element which affected the co-efficient of friction.

Mr. D. Rowan said he was a little disappointed to find that there was nothing new to him in Mr. Adams' valve. The fact was, he had been in the habit of making a valve for marine engines, almost identical with Mr. Adams', for the last dozen years or more. He had made them for 70-inch cylinder engines. He had at first adopted the method of cutting out the back of the valve, as the cylinder and valves of marine engines were not subjected to so great a pressure as those of locomotives, he had made the valve of cast-iron. The valves he had made worked very well. His valves were a little different from Mr. Adams', but the design was substantially the same. He had found that the valves in marine engines were generally so very broad, that he could never get them larger than the area of exhaust port. His object had always been, not to relieve the valve of the pressure entirely, but to reduce it as far as possible without relieving the valve from the face. He used to cast a ring upon the back of the valve, which was bored out inside. He used hemp packing in his valve with a gland, and screws to tighten it up. He put a spiral spring, resting upon the back of the valve, to bear the parts up. He bored generally 1 inch, or 1½ inch holes through the back of the valve to admit any steam which might pass the ring into the exhaust passage. It was difficult to get a ring sufficiently large to remove the whole of the pressure, but the principle was identical with Mr. Adams'. See Figs. A, B, and C, Plate XIII.

Mr. Adams asked whether Mr. Rowan's had two rings?

Mr. Rowan replied that it had; but there was no pressure inside the outer ring, the inner ring being simply to compress the packing, instead of which packing he might have used one of Ramsbottom's rings.

Mr. Adams said there had been many plans, and there were also many patents with rings made with flanges, but the proportions were not equal and did not balance each other. If Mr. Rowan's made those proportions equal, it was the first case he had heard of.

Mr. Rowan replied that drawings of his valve might be seen elsewhere. He was not so particular as Mr. Adams in the precise reduction of the pressure, but it suited the purpose to which he applied it—to marine engines—well.

Mr. Adams said that many had attempted this but were unsuccessful. There was no means of finding the exact thing, and therefore there could be no difference between Mr. Rowan's and that of any other manufacturer. The only difference he could observe was the top and the bottom flanges.

The President said that Mr. Adams had pointed out the importance of having the two surfaces exactly equal. Mr. Rowan's plan was the usual form adopted on the Thames for relieving the valve face of pressure.

Mr. Rowan said that he had never seen any but his own. Mr. Penn's was different.

Mr. Adams remarked that nearly a similar thing was applied by

Mr. Maudsley, although he was not right, as he gave an extra force on the flange. Mr. Randolph had assured him that he had the same thing; but he afterwards found that the proportions which he had used of pressing the ring to the door, were as three to one. The result was, that the film of steam behind the surface was entirely destroyed by the extra force. Then many rings have been made by marine engineers, but it was found that the areas were not balanced; and if Mr. Rowan had come upon that, why had he not made it more generally known, because the thing was so plain and useful. All engineers who had now got possession of it were ready to introduce it. It would soon be in use by the British Government, and the American Government had sent a representative here to see it, so that his valve was becoming generally applied, and it was curious if Mr. Rowan had so long been in possession of the same, and it had been so little known.

Mr. Rowan said that if Mr. Adams had the slightest doubt in the matter, he might see the drawings in Cranstonhill Foundry, or at Messrs. Caird & Co.'s, Greenock.

[Subsequent to the discussion, some correspondence took place between Mr. Adams and Mr. Rowan, as to the valve the latter had adopted. In order to remove any doubt, sections of the valves referred to by Mr. Rowan are shown in Figs. A, B, and C, Plate XIII., copied from the original drawings, by the kind permission of Messrs. Caird & Co. and Messrs. J. Aitken & Co.—*Note by Secretary.*]

Mr. A. Gilchrist said that Mr. Adams seemed to throw a slight upon Mr. Waddell's valve. Now, he knew that it was a very good one, and worked admirably. He might mention that they had put Waddell's valve into two steamers with 65-inch cylinders recently, and, after four voyages across the Atlantic, they had been taken out, and there was no appreciable wear observed either on the cylinder faces or valves, and so easily worked that one man at each engine can reverse it at pleasure with ease, and that under a pressure of steam of 28 lbs. and 26 inches of vacuum.

The PRESIDENT said that Mr. Adams had mentioned that his valve was balanced perfectly; but when he said that, he thought it required a qualification, as it would not be the same in all positions.

Mr. ADAMS said it would not be balanced at all times. He had taken it in the middle position; but as soon as it moved from that position there was a deviation, but not very great. The excess was always in the positive direction, so that it kept the valve to the face. Then the force was not sufficient to destroy the film of steam between the surface, and it moved easily. He did not say it was a perfectly-balanced valve. He had given the result of thousands of experiments. He had made seventy-four valves before he discovered the action of the film of steam, and this was the secret of the success of his valve.

Mr. HUNT asked if Mr. Adams found that the proportion of area enclosed by the ring—at which he had arrived by practically trying in succession a number of rings of different sizes—coincided with the rule or method he had given for finding that area.

Mr. ADAMS replied that he had found those areas to be practically the same, but that, in a practical experiment, one did not confine himself to the hundredth part of an inch, and he assumed that rule for general practice.

Mr. HUNT said that in that case the rule might be empirically or accidentally correct, but that the method was obviously incorrectly worked out, even supposing the principles on which it was based to be correct; and he showed, by a reference to the drawing, that if the one-half of the valve was considered, the respective leverages, with the centre of the valve as a fulcrum, were the reverse of those stated in the paper.

Mr. ADAMS said he was aware of that. He had got it to correspond in the worst position of the valve, and, as he had just stated, the negative forces were always less than the positive; but the excess never reached that amount which would destroy the film of steam, and hence the valve moved easily. The valve was designed from practical experience. He made no pretensions to demonstrate it as mathematically correct.

Mr. Hunt said he must repeat that the calculations were incorrectly made, since the leverages were not as stated.

The President supposed it was impossible to make a perfectly-balanced valve; but Mr. Adams intended that the excess of force should never be on the under-side of the valve.

Mr. Brown said that Mr. Adams was no doubt aware that there was no difficulty in getting a valve balanced after it had worked for a day or two. He had seen one which required six men to work it at first, but which wrought easily after the first week. He did not know whether or not the exact proportions had been arrived at, but no difficulty was experienced in making the valves nearly balanced.

Mr. Day thought the meeting had forgotten the question before it. It was now a good deal more than twelve months since Mr. Adams first explained the thing to him; and there was no doubt that what engineers had hitherto done in this matter, was a mere make-shift. It had been used for thirty years on the Thames, and in the Cornish engines, so that it had been a mere cobbling-up to what Mr. Adams had done, except, perhaps, what Mr. Rowan had done, the valve he used being apparently a perfect balance. That was to say, the theoretical film acting on the sides of the ring next the steam-chest door, the balance there appeared to produce a portion of the ease in which the valve worked.

Mr. Adams remarked that the oldest valve of his construction was on the Great Eastern Railway; and after it had worked twelve months, it was taken out, and found to be uninjured on the face. The valve would not wear on the cylinder face; but the top of the ring would wear when running without steam.

Mr. Brownlee asked whether there was any difference between Mr. Adams' ring and Mr. Rowan's? He thought there was this difference, that Mr. Adams had made experiments to determine the exact area, so as to take the friction entirely off the valve. Now, how far this friction was detrimental, while little pressure was left on the valve, he could not say. It seemed to him that very little injury would result though a little pressure was left on the valve

But he would like to know whether it was necessary to be so very accurate as Mr. Adams was in removing all pressure whatever. Was it in any respect detrimental to leave a little extra pressure on the valve?

Mr. Adams said he removed the pressure as far as he could; and he caused the valve to slide on the film of steam between the surfaces with a great deal less power than if the steam was excluded. As he had already stated, he did not entirely balance it at all positions of the stroke. There were two positions in which it was balanced, but in the others it was not. If he were to make the ring less, he could only take the lesser dimensions of the ring into consideration with the reduction of another force acting upon the area of the valve opposite the port during expansion.

Mr. Rowan said the idea which Mr. Adams had acted upon seemed to him to be a patent of Mr. Wilson's, of Patricroft, and which he believed acted very well for land purposes. It was a solid valve of the usual form, which Mr. Rowan sketched upon the board and described.

Mr. Adams replied that there were a great number of patent valves. That of Wilson was a combination of Napier's, displacing the exhaust cavity. It was always difficult to get at the history of a mechanical invention; but it was clear that Napier's displaced the exhaust cavity. Waddell took a position between the two. Wilson's and Napier's were not practicable, neither of which could be applied to any narrow gauge locomotive. He did not know any valve but his own which would stand the test of the locomotive except perhaps Waddell's, without the packing. If he would abandon the packing, he would have a better valve than he has. It was difficult to apply to the modern locomotive, and therefore Waddell's required a new cylinder for the purpose; and any man designing a new thing must make it applicable to present practice, otherwise there will be no market for his invention.

Mr. Hunt asked whether Mr. Adams now cut the ring, as shown in his earlier drawings?

Mr. Adams replied that he did not. Mr. Penn had told him that the cast-iron ring would entirely rust away when the valve was standing still, and would thus prevent water from coming in; but he had not found any corrosion yet, and therefore he had now abandoned the labour of cutting the ring.

Mr. Cowan remarked that it was of no use going into a discussion of the theory of this matter, when they had practice to guide them. He held a very high opinion of Mr. Adams' valve from its practical working. With regard to the theory, he left others to discuss that question; but he might state that he had now the valve working upon ten engines daily—engines, the least pressure of which was 120 lbs., and two of them were 140 lbs., an amount which they would allow was a fair pressure. He began with the valve from a rude sketch made by Mr. Adams; and the first ring that he had put in, was the split ring which Mr. Adams referred to. He made it five-eighths thick; and he put in two springs, which might be seen running transversely in the drawings. When he put the steam-chest door on, when screwed up, it compressed the springs a quarter of an inch, so that though the rings were one-quarter inch, the springs would go up. With a pressure of 84 lbs. upon the one valve, he had run the trial trip up an incline of 1 in 70 with a heavy train, and just before getting to the top, he took the reversing handle, and they worked easily. He had not got over the top of the incline, until the valve had ceased from the pressure of the springs. He disconnected the engine from the tender, and put the reverse handle into mid gear, then swung the engine like a pendulum back and forward, the throttle valve standing fully open; brought back the engine and took out the valves and turned the rings round—they were five-eighths—and put them in again. However, they did not work well. He made a round buckle to correspond. With the round buckle, he found that if the valves were tight, it kept tight as long as the steam was on. But although it was tight when the steam was shut off, when it was put on again the steam ran roaring up the chimney: whether that was from the slide being a little slack he could not say. That was a practical difficulty, but as soon as he went into the oblong buckle, there was no difficulty whatever experienced; and now he had those valves working with pressures of 140 lbs., and they were so tight, that with the steam full on, none escaped. As regarded workmanship, he had put in the valves off the lathe without filing or scraping. The ring was direct off the lathe, and so were the cylinders. He was thorough'y satisfied with the working of this valve, and instead of the two springs running the long way of the ports, he put one spring now running across the ports; and in the engine he turned last out, the cylinder was 16 inches by 24 inches, and the valve 10¼ inches by 16 inches. The spring, with one-fourth of an inch, took six pounds to put it down. The spring was not necessary to keep the valve tight. The use of it was when going into a station, or running down an incline, it made sure that when the steam was put on the next time, the ring was put up against the steam-chest door.

The PRESIDENT remarked, when they ran down hill, Mr. Cowan said that the top of the ring wore. Now, when that cutting began, did it not increase?

Mr. COWAN said they had the difficulty as long as he used the springs; but, as soon as he used another ring, there was no difficulty whatever, and he had the valve face like a mirror. He had engines working under this pressure with valves of cast-iron. He had only got the first two valves he used made of brass, and all since were made of cast-iron. All the rings were of cast-iron, and they worked beautifully. From his experience of twelve months of ten engines working—and he had other four coming forward—he considered Mr. Adams's a perfectly-balanced valve. He could stand outside of the handrail of the engine and shift the valves with steam on, rather easier than with the steam off.

The PRESIDENT said there was a little packing in Mr. Rowan's valve.

Mr. ROWAN said there was simply a packing-ring to prevent the steam from passing—the packing being tightened by screws—but which brought no pressure on the casing door or valve face; it was simply an elastic piston ring.

Mr. Adams stated with regard to what Mr. Rowan had said as to the proportion of the surface of the ring bearing against the door, and the proportion of the flange, that he had determined them for himself by direct experiment. His rings were five-sixteenths of an inch thick in the body, and half an inch broad in the flange, making (if the inside edge of the ring were carried up to the door) three-quarters of an inch bearing against the door. This would so proportion the areas, of a half-inch, equal the underside of flange pressing against the door, against three-quarters of an inch pressing from the door. Now, as the underside of the flange is exposed to a column of steam in the chest, no one doubts its force; but what is new to engineers is, that the three-quarters inch bearing against the door, notwithstanding they are finely surfaced, has got the same relative pressure per square inch of surface, and the three-quarters being greater than the half inch, the result would be that the ring would be pressed from the door and the steam pass as a leak, and hence the necessity of having the surfaces equal since we have the pressures equal. Mr. Rowan had not explained, however, what was the proportion of the size of the rings to the valve.

Mr. Hunt said that a few gentlemen had said that this was entirely a practical question, and that it was unnecessary to go into the theory in the discussion. His former remarks had not a particle of reference to theory. He did not think that any one else who had taken part in the discussion had said a word about theory. He thought Mr. Adams's was undoubtedly the best valve ever produced; and he had simply questioned the correctness of the arithmetical rule for calculating the area, which rule could easily be altered.

Mr. Brown said that perhaps Mr. Cowan could tell them what advantage was got from the use of Mr. Adams's valve in duty performed.

Mr. Cowan replied that that was a point upon which he differed from Mr. Adams. He had come there simply to state the result of his experience, and he did not care who received the honour of discovering the valve; but if Mr. Rowan had used it twelve years ago, it was a pity he had not known of it sooner. He could not get anything like the saving which Mr. Adams supposed by the use of his valve. He did not get above a saving of 11 to 12 per cent.—that was to say, that whereas they used only to be able to take twenty-seven waggons up an incline, now they could take up thirty. But, independent of that, there was a great saving in the link motion, which was rather an expensive thing. Their eccentric straps did not require to be set once for three or four times formerly.

Mr. Russell asked whether this co-efficient of friction was found by experience,—whether the valve was lubricated, and at what pressure?

Mr. Adams replied that the co-efficients which he had were taken by starting the valve from its middle position. Had time permitted, he intended to have made experiments to show the actual pull on the spindle of the valve. He had stated that the co-efficient of friction increased with the temperature. The experiments were made without any lubricant whatever.

The President said that the saving of 10 per cent. was the best indication of the value, so that as a theory they did not require to say much about it.

Mr. Day said that was not the only saving. The valve itself was a great saving.

# *On the Collection, Removal, and Application of Town Sewage, and the Saving of Water.*

By Mr. Thomas Hoey.

(SEE PLATE XIV.)

*Received 11th, and read 24th April, 1867.*

The objects of the following communication are to show:—

1st. An improved construction of water-closet, by the use of which a great amount of the water used by the present water-closet might be saved.

2nd. A method of collecting and removing the sewage.

3rd. A method of manufacturing the sewage into a valuable dry solid manure, capable of easy application to the land.

In the present system of water-closets, no provision is made for regulating and limiting the quantity of water used at each flushing; and, as experience has proved that sewage is in general far too much diluted to allow of its successful application to the land, the first and special consideration in any attempt to reform the existing sewage system, must necessarily have reference to this point.

It has been ascertained by measurement, that the quantity of water passing through an average Bramah water-closet, on being flushed ten times successively—the time of each action being four seconds, and the action being repeated at intervals of two minutes—was a little over nine gallons, giving nine-tenths of a gallon at each flushing, the head of the water being seven feet. But as in ordinary practice the time of action is much more than four seconds, we may safely assume the quantity of water used to be more than double the experimental quantity, which will allow an average of two gallons for each ordinary flushing.

This excessive dilution of the soil by the action of the present water-closet, is often aggravated by a continuous discharge, which, on an average, may amount to upwards of 9000 gallons, by a single water-closet, per day. Until this immense waste is prevented,—until the closet soil is kept separate from the large quantities of water used for other domestic purposes, and from the rain-fall,—it is evident that the profitable utilization of the sewage is commercially impracticable.

This whole waste may be rendered unnecessary and prevented, by the introduction of a meter acting in connection with an intercepting tank, by which the quantity of water used per flushing is limited and accurately measured. In existing water-closets this may be effected by enclosing the water valve within a short piece of lead pipe, flanged at the lower-end for fixing on and jointing to the bottom of the cistern, the top being close, having a small pipe fixed on to its centre of such a height that the top may be on a level with the sides of the cistern, the whole being water-tight, and the wire for lifting the valve passing down this pipe, which also serves as an air-pipe to the meter. By making a very small bore through the top as an inlet into this meter, so that it would require say from two to three minutes to fill, it is evident that when the water valve is lifted, very little more water than that contained at the time in the meter can descend into the service-box. A small India-rubber valve, opening inwards, is attached to a wire passing down through the inlet aperture, the other end being connected with a band of India-rubber, and through it, acted upon by the lever which lifts the water valve; the slip or slack in the wire for lifting the valve, allowing the small India-rubber valve to be drawn up so far as to shut the inlet hole, before the water valve can begin to lift. The subsequent extension of the India-rubber band would permit the water valve to be opened sufficiently far to allow the water to escape from the meter, the elasticity of the band allowing the water valve to shut before the inlet hole is again uncovered.

By this means we should have the expenditure of water accurately measured, and a uniform quantity—which may be fixed at any desired amount—used each time the closet is flushed.

Another essential feature in this supplement to existing water-closets lies in its including the means of perfectly regulating the periods of flushing, so that the process can only be repeated at any fixed interval of time, at which periods it will only discharge the quantity agreed upon; and, although the handle should be held up for any length of time, the discharge will not exceed the given quantity until the handle is again lowered, and the fixed periodic time has elapsed. If the action is repeated before the meter is filled the discharge will be proportionally less. The power of wasting water by a closet so fitted, is necessarily limited to the number of these periodic discharges in a given time, and the quantity discharged each time; it not being possible to fix the working parts of the closet so as to produce a continuous discharge.

This plan of regulating the quantity of water used has been in daily operation for about eight months, using quantities of water varying from one-ninth to one-seventh of a gallon at each flushing, at which latter quantity it is now working; the sanitary results being every way as good as when an unlimited quantity of water was used.

The apparatus is shown in Plate XIV., Fig. 1. A, shows the meter immediately after being discharged; the ordinary water-valve O being shut, and the inlet orifice B opened by the descent of the weight P, which carries the india-rubber disc, for shutting the same, through which the wire C passes, the top end of which is made fast to an india-rubber band R, the top end of which is connected to the lever S by the link *a*. D, the weight on the end of the lever S, the lever being moved by the wire T, acted on by the closet handle. U, the wire for working the plunger G, the bottom end of which, dipping into the cistern H, displaces the acid, which is discharged through the pipe M, into the basin along with the flushing water.

K, a slip loop in the wire U. L, a cross-bar over which the loop J moves, the top end of which loop at the greatest descent resting on the bar L, thus regulating the amount of dip, and consequently of acid discharged. F, the fountain from which the cistern is supplied.

E, service-box as formed in ordinary existing water-closets. On lifting the valve O the water contained in the meter is instantly discharged through the relatively large opening in the valve-seat, a portion of it descending through the pipe N into the basin with the same velocity as when the quantity is unlimited, while a sufficient quantity remains in the box and the pipe to fill the trap-pan.

That so very small a quantity of water as one-seventh of a gallon can flush a water-closet efficiently, may excite surprise, when compared with the large quantities now used for that purpose, but really there is nothing essentially improbable about this proposed limitation. The diameter of the soil-pipe being four inches, its sectional area is little more than twelve square inches, and the depth of the trap not being more than two inches, the entrapped water can only be about 24 cubic inches, that being the amount actually requiring displacement at each flushing of the closet for healthful sanitary action; whereas, with one-seventh of a gallon we have nearly 40 cubic inches, which would displace all the entrapped water, and also an additional quantity to the depth of $1\frac{1}{4}$ inches, which, augmented by the liquid part of the soil, is more than sufficient to clear the trap on the soil pipe every time the closet is flushed. The flushing water being sent into the basin with the same velocity as when an unlimited quantity is used, ensures its being cleansed as thoroughly as by the present mode.

We are thus in a condition to reduce the degree of dilution of the present water-closet soil from one lb. of dry solid matter in one thousand lbs. of water, to one lb. of dry solid matter in $2\frac{7}{8}$ lbs. of water, or to about $\frac{1}{350}$ part of the present dilution of the City Sewage.

This plan of regulating the quantity of water for flushing is equally applicable for preventing waste of water, if the present mode of disposing of the sewage is continued, or if it is used for irrigation. It is only necessary to determine the quantity of water to be used at each flushing, which may be from any fraction of a gallon to any number of gallons, and also the periodic time at which the action of the closet can only be completely repeated, which may be from any fraction of a minute to any number of minutes. If the quantity of water were limited to one gallon per flushing, and the time to ten minutes, all the water that could be wasted with such an arrangement in ten hours, would only amount to sixty gallons, and that requiring an unremitting personal attendance every ten minutes.

Simply and effectually as the limitation and action of the flushing water is accomplished in the manner described, it is quite in vain to attempt, as some persons have done, to test the operation of the smaller quantity of water by the action of an ordinary water-closet, as either the trap pan is not sufficiently lowered, or, if lowered sufficiently, the action is so rapid as to prevent its proper evacuation, or if this is thoroughly effected, the quantity of water admitted into the basin is too great. In short, the complete action must be either undone, imperfectly done, or over done; all of which are equally unsatisfactory.

The practice of excessive flushing, frequently occasions a reaction, which actually produces the evil which excessive flushing is intended to avert. By causing a fall of water in the soil-pipe for a certain period, a current of air is carried through the water in the trapped pipe, and by the action of the falling water is compressed in the soil-pipe, and in the drain in which the soil-pipe terminates, onwards to the drain trap, which, being usually deeper than the one at the closet, is capable of resisting more pressure, and prevents the compressed air escaping in that direction. When the descending current of water is stopped, the compressed air ascending acts on the oscillating water in the trap at the water-closet, and a whiff of impure air is not unfrequently sent through it into the box of the closet. In the drains under the ground floor, a compression of entrapped gas is frequently produced by the same excessive flushing of a closet, by raising the level of the water under the entrapped air, causing an emission of the noxious gas through the joinings of the paved floor.

As any overflow or leakage from the water-closet cistern must not be allowed to enter the soil-pipe, it will be necessary to provide another but much smaller pipe for that purpose, into which all wastage would be discharged. In the event of the water-valve leaking, to prevent the leakage finding its way into the intercepting tank, a small pipe is attached to the lowest part of the descending pipe immediately at its entrance into the basin. This pipe is to be kept open by the action of a stop-cock, which the upward movement of the handle would shut at the time the closet is being flushed, whilst it would, at the same time, lift a conical weight connected by a wire to the lever of the cock, and suspended in a pipe to be kept filled with water. The weight to have an india-rubber or leather flap on its lower end, of such diameter as just to move freely in the pipe, and fixed at the centre to the conical weight; the bending of the flap on rising would afford an easy passage for the water, while, being flat, on descending the motion of the weight would be very slow, and would during its descent, open the cock on the small pipe, thereby allowing all the after leakage to descend through it into the waste pipe.

### DEODORIZATION IN THE CLOSET.

Although with one-sixth or even one-ninth of a gallon of water per flushing, no odour is perceptible; yet, as ultimate deodorization of the soil is absolutely necessary, provision is made in connection with the action of the closet to deliver a quantity of sulphuric acid, or of a solution of sulphate of iron into the basin along with the flushing water. This is accomplished by means of an apparatus (constructed on the same principle as a bird cage fountain) by making a plunger dip into the trough, thereby displacing a quantity of acid equal to the portion of the plunger immersed, the quantity overflowing by a pipe depending on the amount of the plungers immersion, and the acid descending into the basin along with the flushing water.

This sulphuric acid is not to be regarded so much in the character of a deodorizer, as that of an agent for combining with the ammoniacal gases which would otherwise be volatilized while the gas is being generated, and also for fixing it sufficiently when afterwards the resultant salt—sulphate of ammonia—is undergoing the process of dessication by surface evaporation, so successfully employed at St. Rollox in the dessication of certain salts from a state of liquid solution to a state of powdery dryness.

It is not absolutely necessary that the acid should be introduced into the closet in the manner described, except for the purpose of preventing any tendency to the depositing of nitrogenized matters, sometimes found in the basin of water-closets, as it could be used efficiently, and with vastly less trouble, by being introduced directly through the exhausting pipe into the intercepting tank immediately on its being emptied, one operation in that manner sufficing for a whole tenement during an entire week.

A celebrated English farmer, Mr. Harcourt, remarks, that "he obtains the best results by adding one lb. of sulphuric acid to one hundred and fifty lbs. of drainings, and that he has derived, by an expenditure of £1 10s. in sulphuric acid, an increase of hay amounting in value to £9 15s. above that from land treated with an equal quantity of draining without sulphuric acid."

A certain quantity of powdered charcoal should be introduced into the carriage tanks when emptied, for the purpose of absorbing any gases in the soil, which, when the tanks are refilled, may not have been acted upon by the sulphuric acid.

INTERCEPTING TANK.

The intercepting tank is understood to be perfectly water-tight, placed immediately under the lowermost water-closet, the soil-pipe from the closet entering it directly from above. It should be formed of lead, or salt-glazed fire-clay, thus securing the soil against further accession of water, and effectually preventing its entrance into the drains and sewers, and also preventing the diffusion of its noxious fluids to surrounding earthy material. This tank communicates directly, and at all times, with the atmosphere, only through the soil-pipe, which ought, in every instance, to terminate above the roof. There is also a discharge pipe entering from above, and reaching nearly to the bottom of the tank, the other end of this pipe terminating in the street, or any other more suitable locality, the end being so formed as to insure an efficient and readily effected connection between it and one of the exhausted tanks on the carriage; or a soil-pipe can be continued at a proper descending angle from the bottom of the lowest water-closet, to any suitable position for the intercepting tank. The tank should be of such capacity as to contain the soil from all the water-closets in a tenement for one week, allowing four cubic feet of space for each water-closet, equal to about 25% in excess of average requirements. An overflow pipe should be attached either to the tank or to the termination of the discharging pipe, whichever of these may be more adjacent to the common sewer. These intercepting tanks are equally applicable to public urinals.

A portable air-tight intercepting tank could be employed, having a double water-trapped cover to form a perfectly air-tight junction between the bottom of the soil-pipe and the top of the tank. Every facility for removing these tanks should at the same time be afforded, sufficient free space being preserved between the tank and the bottom end of the soil-pipe, and no fixings of any description being employed. The tank on being removed, should have a cap or cover placed over the inlet, dipping into the water luting channel around that orifice, and also an outlet through the bottom, shut by an India-rubber plug opening inwards. These portable tanks not usually containing more than thirteen gallons, would not be an overload for two men, and are chiefly applicable to country residences, or villages having no drains or sewers.

REMOVAL OF SOIL, AND MANUFACTURE OF MANURE.

The intercepting tanks should be emptied once a week, through a pipe proceeding therefrom and terminating in the street, except where the tanks are placed in the street or other accessible place.

The discharge could be effected either by atmospheric pressure or compressed air, and delivered into one of a number of previously exhausted tanks placed upon a carriage, by which it would be conveyed either to a depot in some suitable locality, or to a central station in town, from whence the soil could be discharged by air pressure, through piping, to a general depot, and there received into a reservoir capable of containing one or two days' soil, from 40,000 water-closets. These reservoirs would require to be about 100 feet square, and if for two days' soil, nearly four feet deep. They should be divided longitudinally by partitions into four or more channels, with a cross connection at one end uniting the extreme channels; so that, by having a paddle wheel kept in motion at a narrowed part in the cross-end channel, the entire contents of the reservoir would in turn pass under the churning operation of its rotating blades. During this process, a proper quantity of powdered charcoal or gas coke, reduced to a state of powder, would by a riddling process, be introduced and mixed with the soil in the most equable manner, and absorb any gases not acted upon by the sulphuric acid, so that very little smell, and certainly no gas of vital importance as a fertilizing ingredient, would be allowed to escape.

The soil should remain in these reservoirs until the desired degree of decomposition had been effected, the process being expedited by the application of the waste heat from the evaporating pans to flues under the reservoirs.

The soil, after the process of decomposition is matured, would be gradually transferred to evaporating pans of such length, that by passing the flame and smoke from a furnace over, and in immediate contact with its surface, the liquid part would be rapidly evaporated by the action of the heated gases, their motion carrying off the moisture while being saturated, and probably after imparting—as Mr. Spence of Manchester supposes—the ammonia derived from the coal during the process of combustion to the soil while being desiccated in the evaporating pans, thereby materially increasing its fertilizing powers.

The amount of this highly concentrated dry powder (rivalling the fertilizing power of guano) to be produced from the soil of 40,000 water-closets may be roughly estimated at 15,000 tons per annum, which, at £6 10s. per ton, would, after deducting the cost of production, show an annual profit not greatly under £1 sterling on the soil from each water-closet.

A manure thus produced would be in the proper chemical condition in which the nourishing and stimulating action is immediate on its application to the roots of plants. A manure could also be manufactured from the not completely decomposed soil, which would have the property of a deferred action, depending upon the degree of decomposition the soil had previously undergone before desiccation, the process of decomposition being perfected subsequent to its application to the ground. A manure, the fertilizing action of which would be partly *immediate* and partly *deferred*, and having these qualities in any proportion, could also be manufactured from the same material.

Manures having these various properties are now desired by the intelligent farmer, and from this source only can they be furnished in sufficient quantity and of such quality as to suit his wants.

That this is not a novel manufacture is evidenced by the following quotation from "Elements of Agricultural Chemistry, by Mr. James F. W. Johnston, 1844," who, after describing another process of manufacturing manure, says:—"A better method than that of using gypsum has been lately adopted by Messrs. Turnbull, manure manufacturers in Glasgow. They mix as much sulphuric acid with the urine as is sufficient to combine with and fix the whole of the ammonia which may be produced during the decomposition of the urine. This mixture is then evaporated to dryness, and is sold and applied to the land in a state of dry powder. The present price (1843) of the powder is about eighteen shillings per cwt. Used in this way" (that is, mixed with, and taking the place of not more than one-half of the farm-yard manure usually applied), "at a cost of £2 per acre, Mr. Finnie, of Swanston, informs me it has this year (1843) given him four tons of turnips per imperial acre more than an equal cost of guano."

The only difference between Mr. Turnbull's plan and that proposed here, is using water-closet soil entire instead of urine only.

This mode of treating city water-closet soil appears to be the only available, adequate, and permanent source from which a supply of manure for agricultural purposes can be obtained when the *source* of the present guano supply is exhausted, which is most certainly in the way of being accomplished by a process subject to yearly acceleration. The larger part of the better quality has already disappeared, and the remainder is fast following, under an influence that no human power can avail in averting, demand and supply having no reciprocal relationship in this case of natural and inevitable exhaustion. In fact, every intelligent and enterprising farmer, who has been made aware of this proposed source of manure supply, regards the success of it as the probable advent of an era of agricultural prosperity and progression hitherto unknown in this or any other country.

### ADVANTAGES OF THIS PLAN.

The completion of this plan throughout the city would insure the perfect purification of the entire sewerage, the restoration of the river Clyde to something approaching its original purity, and the profitable utilization of the soil of all existing water-closets, as well as that of all others that its adoption would call into existence, and, besides, would possess the following important advantages, viz.:—

1st, It can scarcely be said to interfere with existing arrangements or apparatus of a sanitary kind.

2nd, It consists of a series of operations almost independent of one another, which could be executed without any regard to local order or sequence.

3rd, It can also be executed in a fragmentary manner, which would afford a cheap means of testing the only part that has not heretofore been in use, and about the working of which people feel some uncertainty, viz., the limited quantity of water for flushing; wherever two closets discharge their soil into the same pipe, one of these may have the meter alone applied to it, without an intercepting tank or deodorizing apparatus.

4th, It may be completely applied at once on the large scale or otherwise, as rendered advisable or necessary by either commercial or sanitary exigencies.

5th, Any portion, however small, can be worked nearly as profitably as a larger section, or even the whole scheme.

By the present system, the sewage, whatever method may be adopted for ultimately receiving and carrying it off, must, in its passage through the sewers, continue to evolve the same pernicious gases as at present, its noxious fluids still permeating to a greater distance both laterally and vertically, and saturating still more thoroughly the surrounding earthy matters with latent poison, the gaseous portion finding its way to the surface at the open gully-holes, or, if these are trapped, through the superincumbent matter in a more or less diluted state.

The outfall plan obviously effects only one-half, and that perhaps the least important, though necessarily the more obvious part of the object contemplated, leaving the less obvious but more constantly pernicious, though preventible evil, rampant as ever, probably even more so—as demonstrated in the partially developed evils of the gigantic and expensive metropolitan system of sewerage—which requires the present waste of water to be continued in all time coming, thus occasioning an absolutely unnecessary loss of at least £40,000 annually.

In our own case, the last announced proposition of the outfall system will cost at least £370,000, but how much more no one as yet can tell, and only disposing of the sewage of 190,000 of the population, or a little over one-third of the whole, equal to about 42,000 households.

Supposing each of these houses to have a water-closet, fitted with a meter, intercepting tank, &c., complete, at a cost of £3 each closet, the entire expenditure would be about £126,000, leaving a balance in favour of this plan of £244,000 on first cost. While costing only about one-third of the proposed outfall sewer plan, it would not be less likely to yield a desirable revenue, as there is no known reason why soil manufactured into manure in the manner indicated should not at least be as remunerative a business on a large as on a small scale

If the only cases that can be founded upon as justifying the hope of a remunerative working of the irrigation system are (1) that of Edinburgh, where the soil of 80,000 of the population has been employed in irrigating 270 acres of land for about forty years successively, has not, in all that time, contributed anything to the city revenue, or (2) that of Croydon, where the soil of a population exceeding 20,000 persons is employed in irrigating 250 acres, yielding a revenue to the town of only £250 annually, or £1 per acre, it seems most extravagant for us to look for any good result. This will be clearly shown by a reference to the following additional cases, viz.:—

(1), Carlisle—revenue to town, nothing; tenants realising nearly £400 per annum.

(2), Malvern—revenue, nothing.

(3), Tavistock—revenue, nothing.

(4), Rugby—revenue to town, £50 per annum.

(5), Watford—revenue to town, £10.

(6), Alnwick—discontinued; for, though the sewage was given free, farmers refused to pay the expense of pumping, because unremunerative.

Besides, it must defy the most fertile imagination to form a conjecture, or the most acutely prescient of our sanitary magnates to foretell the ultimate effects resulting from the permanent existence of 5,000 acres of such a swamp as Craigentinny Meadows, to the windward of such a city as Glasgow, for about three-fourths of every year, and that specially during the warm season, to say nothing of other centres of population in its immediate vicinity. And what is to become of the immense grassy product which might be raised from 5,000 acres of land, which seems to be the only possible or profitable application of the sewage. Mr. Miller, proprietor of the Meadows, being examined before the House of Commons' Committee, 1864, says:—

"200 acres irrigated by gravitation, about 50 by steam-power pumping. These meadows receive the sewage of about 80,000 inhabitants of Edinburgh. The sewage flows constantly night and day. As far as practicable we irrigate night and day. The application of steam-power has not been very profitable. We should otherwise not have ploughed it up for arable purposes. About ten acres a-year have been ploughed up and sewage irrigation discontinued. There is very great difficulty in applying sewage to arable land. I believe that sewage is far more suited to grass than other crop."

### APPLICATION TO COUNTRY AND VILLAGE RESIDENCES.

In consequence of the limited quantity of water necessary for flushing, only a very small cistern is required; it could be filled at stated times by pumping, or even by a hand pail, where it could not be kept filled from a water-butt or by piping. For the same reason the intercepting tank system is peculiarly applicable, no drainage whatever being required; the soil being preserved in a covered water-tight pit, only of sufficient lateral dimensions for the process of emptying; the deodorizing process being effected by the occasional introduction of earth, and the daily introduction of the powdery part of the ashes produced in the house or on the farm through a trap-door in the portable cover, thus at once avoiding the expense and the after nuisance of drains, and securing the entire soil for manuring purposes; or otherwise by having a portable air-tight tank as before described, the soil in that case being afterwards mixed with earth or ashes, or jointly, as circumstances might render necessary.

### WATER SUPPLY AND DISTRIBUTION.

The only possible mode of solving the water supply problem, so as to make it satisfactorily intelligible and conclusive, is to proceed on the basis that a calculation, founded on a lengthened experience of actual consumpt, can alone prove what quantity of water is necessary for a family's ordinary use. This has recently been done in a house consisting of six apartments, occupied by a family of four persons, all adults. By the action of a meter, extending over a period of 104 days, the average consumpt for that time is found to be thirty-seven gallons per day, or 9¼ gallons per head for domestic uses alone, exclusive of bath, water-closet, and wash-house purposes. Such a house and family may be considered a fair average case. But suppose we allow fifty gallons per day for every household as an average domestic consumpt, or fully eleven gallons per individual, then, taking the population of Glasgow, city and suburban, at 510,000 persons, the present requirement for domestic purposes would be nearly six million gallons daily; and supposing the quantity as at present paid for under the public water rate assessment to be nearly one million gallons per day, and adding thereto the seven million gallons now being used daily for trade purposes, the aggregate daily consumpt would not exceed fourteen million gallons for all purposes, amounting to only one-half of our present greatest possible supply of twenty-eight million gallons daily. With an available daily surplus of fourteen million gallons, there could certainly be no valid objection to the appropriation of another seven million gallons daily for trade purposes, thus insuring an addition to the present revenue of £40,000 annually, and this would still leave us with a present surplus of about seven million gallons daily, so that at the end of other thirty years, when the population might possibly be doubled, our available daily supply would only then be fully allocated.*

The prevalent method of putting the means of wasting water, without even an attempt at measurement, into the possession of every one using a common domestic crane for drawing water, is certainly quite unique in practice from a commercial point of view. If we suppose each of the 80,000, or perhaps more, water cranes daily used in Glasgow for domestic purposes to run needlessly for only ten minutes daily—not an extravagant supposition by any means, and that they deliver on an average seven gallons per minute—the

* The above paragraph is quoted from a paper communicated to the Convener of the Committee recently appointed by the Town Council to report on the best mode of dealing with the sewage.

annual loss at £2 per hundred thousand gallons, would be upwards of £40,000, a sum very far short of representing the amount that is wasted, and which might be saved by a better system of domestic distribution.

A considerable saving of water might be effected with the present system of distribution, by simply diminishing the discharging capacity of all cranes, to a delivery of not more than two gallons per minute in any case, those in small houses and all stair cranes, to a delivery of not more than one gallon per minute. By this alteration the possible delivery per crane would be reduced to 600 gallons for ten hours, or to 1440 per twenty-four hours, instead of 10,000 or upwards as at present. When the fact that the time the crane would be allowed to run unnecessarily, would most certainly be about the same in either case, the alteration would insure a saving of at least five-sevenths of the present waste, representing a sum of not less than £28,000 annually from that source, if the ever perplexing sewage difficulty did not persistingly interdict the attempt.

A saving of water, however, could, to a certain extent, be thus accomplished, along with the introduction of the limited flushing and intercepting tank water-closet system, apart altogether from the distribution of water by meter, though by no means so thoroughly and profitably.

## DOMESTIC WATER METER.

The principal feature in the proposed domestic water meter consists in the means employed for registering the time of an uniform discharge by the ordinary swan-neck crane, simply, or in connection with other means of regulating the discharge of water. This uniform discharge implies the necessity of a uniform head pressure which the ordinary water cistern, in every house where there is such, would efficiently supply. The amount discharged is registered by a small piece of clock work, the action of turning on the water allowing the clock to get into motion, while the action of turning it off, stops the motion of the clock; so that, the crane being adjusted to any definite discharge, say, so many gallons per minute, every minute of time the clock has been in motion indicates that the number of gallons has been discharged.

The motion thus acting on the clock work is obtained by fixing a disc, having an eccentric groove on its face, to the key of the crane, into which groove the end of a stud projects, the motion of the crane key turning round the disc, causes the stud to move the rod, into the end of which it is fixed, which motion is ultimately communicated by sundry levers and rods to a loose bell-crank lever, having a weight attached to the vertical arm, so that, when it arrives at a point the least beyond the perpendicular falling over it, it carries along with it a longer and otherwise loose lever; a forked cross-end on the top of which, when the water is being shut off, pushes the pendulum over to the full extent of its ordinary vibration, and holds it there until, by turning on the water, the action of the lever carrying the weight is reversed, and the top end of that lever which held the pendulum is instantly turned over to the opposite side, allowing the pendulum to attain its full vibration, which motion is uninterrupted so long as the discharge continues. Shutting off the water, by reversing the action of the lever and weight, stops the clock's motion, as above described, during the non-discharging period.

To prevent the possibility of inconsiderate waste, shutting off the water is performed by a band of india-rubber acting as a spring, being partially wound round an eccentric pulley fixed on to the crane key, and so formed as nearly to equalize the force of its unequal tension at all points. The same action can also be made to perform the operation of winding up the clock as far as that is necessary.

This meter possesses the special recommendation of not at all interfering with existing water-distribution arrangements. It can be adapted to any mechanical contrivance for that purpose. Its requirements in regard to space are very limited. Its discharge entirely depending on the untrammelled action of the principle of gravitation does not admit of any variation, the indicating apparatus being moved altogether independently of the motion of the water. The simplicity of its action secures it against liability to derangement. Its cost is not such as to prevent its general adoption; where there is a water cistern in a tenement it can be fitted up complete for about twenty shillings.

### CHEMICAL SEWAGE.

In a letter published in *North British Daily Mail*, of 3rd Feb., 1866, the state of the Liffey is thus described:—"There are few or no obnoxious discharges from chemical manufactories, and yet the smell during the warm season is most offensive, and the injury to health incalculable." The Liffey at Dublin being in the offensive condition represented, and that solely in consequence of sewage from dwelling-houses only being discharged into it without, or at least with very little admixture of chemical sewage, are we not justified in inferring that it is chiefly, if not altogether, the soil from our water-closets which has reduced the Clyde to its present notoriously filthy condition; and that, when that source of pollution is intercepted, we will be very near accomplishing, so far as the river is concerned, all that is desirable in a sanitary direction. So that the disposal of the mineralized fluid waste discharged from certain chemical manufactories may really be only a matter of minor importance; the probability being that, in consequence of its very slowly oxidizable properties, by the exclusion of animal and vegetable matters contained in water-closet sewage from the river, it would produce no chemical action, and consequently, no odour whatever.

Its action on the coppering of ships bottoms or the iron plating of vessels, if only mixing with comparatively pure water, need excite little apprehension.

Regarding the sewage from chemical works in which vegetable or animal substances are operated upon—such as distilling, brewing, soap-making, tanning, &c.—the case is entirely different, the sewage from these sources containing elements that render rapid decomposition absolutely certain, and thus the exclusion of all such from the river becomes an unavoidable sanitary necessity.

It is only reasonable to expect that those who produce sewage of a peculiarly objectionable and offensive nature should, at their own expense, make use of every available means to prevent it becoming a nuisance to their fellow-citizens. There can be nothing unjust, under such circumstances, in requiring those persons to pump their sewage into piping at such a pressure as would convey it ten miles down in the direction of the river's course, the piping being laid along Argyle Street and Dumbarton Road, which would be accessible at all times, and could be tapped at any point throughout its course. As this sewage, containing vegetable and animal matter, includes those manurial ingredients in a much more concentrated state than ordinary city sewage, it is more than probable, if this plan of conveying it in piping was adopted, that the farmers on both sides of the road would ultimately use it largely both for fermenting and enriching their dung-heaps or other composts, and probably also in the process of a modified irrigation.

As to the mineralized sewage from St. Rollox works, that it does not necessarily act prejudicially on vegetation, is incontrovertibly established by the fact of grass growing most luxuriantly on the banks of Pinkston Burn, and down to the very surface of the stream, after receiving the mineralized fluid pumped from the mine under the debris of their works, accumulated on the southern side of Pinkston Bog. This sewage, as pumped from the mine, is almost devoid of taste or smell, and is understood to be—not very highly—impregnated with sulphur, which of itself, however, is a very valuable fertilizer, but which, if mixing with sewage containing decomposing vegetable or animal matter in solution, the one would most certainly dissipate that which is most valuable as a manure contained in the other. This fact seems to indicate the advisibility of having two separate systems of piping for conveying the two different species of chemical sewage. Common prudence would, however, suggest the propriety of having a free outfall into the river for the surplus of this sewage, keeping the points of discharge for these antagonistic liquids at least half-a-mile apart. The absolute quantity of this sewage to be disposed of, is so very small when kept clear of all adventitious additions, that its presence in the river would scarcely be appreciable at but a short distance from its entrance.

The mineralized water pumped from the mine at St. Rollox amounts to about 40,000 gallons daily, on an average of nine hours pumping. The quantity oozing per day from the debris, and ultimately descending by Buchanan Street, after deducting the water descending by the railway, and sewage water from Bogside houses, &c., with which it is mixed, is very small, but highly mineralized, being estimated at one-fourth of the quantity pumped from the mine in the same time, being about 67,000 gallons daily, which is double the quantity due to the average rainfall over the entire surface of the mineral refuse.

The amount of liquid which is discharged on special occasions from Pinkston Bog, by the Buchanan Street outlet, is uncertain.

As it is perfectly possible to divert both the sewage from the Bogside houses and the water descending by the railway at a trifling expense into Pinkston Burn, which has now no natural or necessary connection with Pinkston Bog, which, though not now in its state of pristine purity, is by no means in so fœtid a condition as might be expected, after receiving the sewage from Springburn and other places, and the liquid filthiness flowing from the piggeries at Keppoch-hill, all perfectly preventible causes of pollution; the quantity of sewage then to dispose of would be reduced to about 67,000 gallons daily, and said to be of a gradually diminishing degree of saturation.

If the plan of puddling the entire surface of the debris with clay was adopted, it is almost certain that nearly one-half of the sewage would be got rid of at once; an effect which the draining of the bog would most certainly complete.

In the discussion on this paper,

Mr. Hugh H. Maclure said—Mr. Hoey has shown considerable ingenuity and mechanical skill in devising a plan by which water may be economised in the flushing of water-closet basins and soil pipes.

Although I cannot believe in the thorough flushing of these pipes and drains with the very small quantity of one-seventh part of a gallon for each discharge, still I can understand that the object aimed at by Mr. Hoey is in itself good for several reasons. First, the economy of water; and secondly, the benefits to be derived by lessening the quantity of sewage, and possibly modifying the expense of any scheme for the removal and utilization of the sewage of Glasgow.

Mr. Hoey may not be aware that many water-closets have been invented and tried on the self-acting principle, and giving off only a measured quantity of water at each discharge. To my knowledge those closets have been very difficult to keep in working order, and have been almost entirely abandoned. Possibly Mr. Hoey's apparatus may not be so complicated, but plumbers and architects all know that the less complex machinery there are about water-closets, the better for all parties interested, especially for the proprietors.

I do not know the powers of our Corporation Water Act, but to me it is beyond doubt that no plan, however complete in its details, will be carried out unless compulsory powers are given to the authorities, and from the fact of the variety and number of the water-closets in use in Glasgow, it will even then be extremely difficult to carry out any material change in the present system.

I may state from my own experience, that a great waste of water and unnecessary flushing of soil pipes and drains is caused by the vain endeavour to get quit of the disagreeable smell that ascends from the soil pipes and drains when the pan is opened for the discharge of soil and water. The true, but not generally known cause of this, is simply the want of a ventilating tube, attached to the soil pipe, and carried from it right up through the roof into the open air. I believe that little difficulty would be experienced in carrying out this sanitary and water saving measure in existing houses and for new buildings, a few additional feet of three inch piping is all that is required. As to the deodorization as now proposed, it is certainly ingenious in theory, and might be in use as long as the acid chamber held its first charge. I am, however, satisfied that not one person in 1000 would ever be at the expense or trouble of refilling the acid chamber, and, from Mr. Hoey's remarks, I do not think he considers it essential to his plan. With reference to the intercepting soil tanks at bottom of soil pipes, this is simply a repetition of the numerous plans proposed for the hand collection and removal of the night soil that has been brought before the public for the last thirty years, but, owing to the practical difficulties and disagreeable results that arise from any of these plans of collection, and removal of portable vessels or chambers, we have as yet nothing equal or superior for large towns or cities to our present water-closet and drainage system.

At the Congress on the Sewage of Towns, held at Leamington in October last, fully one-half of the papers read were on the theory of the removal of soil by pails or other vessels, and mostly advocating the dry or earth closets, invented and patented in 1838 by Mr. Swinbourne, and now reproduced as Mr. Moulds's earth closets. It seems there is no doubt of the value and suitableness of these appliances for the periodical removal of the night soil, where adopted on a small scale, such as to country villages in lieu of the present open privies; also to schools, poorhouses, and other asylums, where all are under the thorough control of some competent person, and where strict attention would be given to the apparatus employed, and especially in places where there are lots of room for earth, deodorizers, drying sheds, with no scarcity of persons not fully employed at these institutions, who would be induced to take this disagreeable work on hand. Our theorists on the pan-removal system all look with admiring eyes to the Chinese, and point to them as model collectors and manufacturers of manure. We are told, however, "that such is the offensiveness with which the trade is carried on, that the odours of night soil seems to pervade the whole atmosphere." And even in highly civilised Paris, where the separation principle is largely carried out, the odours in that beautiful city are anything but pleasant.

It appears to me that those parties who suggest these sweeping changes in our present water-closet system in their mistaken zeal entirely forget, or do not seem to know how much it would cost to remodel the existing closets and other appliances at present in use; and to attempt the introduction of such plans in large cities like Glasgow where we have already so litttle breathing space, is to me perfectly utopian and impracticable.

Mr. Hoey seems to condemn the principle of intercepting sewers and sewage irrigation. I think if Mr. Hoey would visit the irrigation works at Croydon, Edinburgh, and Carlisle, with an unprejudiced mind, he would see for himself the results of the simplest of all modes of getting quit of our sewage; and I am sure he would alter his opinion. And from Mr. Hoey's concluding remarks as to the treatment of the chemical sewage, he comes round to the belief that, by adopting his suggestions—"the farmers on both sides of the road would ultimately use it for enriching their compost, and probably, also, in the process of a modified irrigation."

The celebrated Dr. Richardson in his paper, read at Leamington, says: "I think there can be no doubt that that town would be most happy, in regard to its health, that should have a proper water supply, a drainage well flushed, and a conduit to take it as it was produced—every particle of sewage clean away into the sea."

And, again, pointing to the irrigation system, he says: "The sewage, if distributed, should be distributed away from a town where there can be no contamination, and in such a way that the ground itself should be one of Mr. Moulds's earth closets on a large scale. In this case we should have a perfect application of the sewage."

The well known Mr. Mechi, of Tiptree Hall, says: "If we consider merely the most available and profitable way of fertilizing the soil, then, I can say, from an experience of eighteen years, that the fluidized condition is much to be preferred to ensure an immediately available result to the husbandman. For all houses and cottages having only out-of-door privies in gardens, there can be no question that earth, or the earth closet, is most convenient and economic, but in towns with an abundant water supply, I must come to the conclusion that the water-closet system must be most effective and convenient."

I think I have said enough to show that Mr. Hoey's plan of collecting the soil in tanks, or house cesspools, is one that will be found most difficult to introduce—unavoidably dirty and disagreeable in its manipulation. We have, happily, in Glasgow, all that Dr. Richardson claims for making a healthy city—abundance of splendid water, good house drainage, and all that we want is proper intercepting sewers, and a means of taking away the sewage into the country and down the river for irrigation or disposal purposes.

Mr. Hoey has indirectly referred to the plan suggested by Mr. J. M. Gale, in the summer of 1865, as the "last announced proposition of the outfall system."

Mr. Hoey seems not to be aware that a plan has been brought before the Lord Provost and Town Council of Glasgow, and is published in a pamphlet (a copy of which he will find in the Library of our Institution), by which the whole of the "sewage of Glasgow and its neighbourhood" may be collected in intercepting sewers through and beyond Glasgow; then in canals, down by circuitous courses, for the ultimate utilization of the sewage to reservoirs at Dalmuir, and he evidently has no knowledge that this can be accomplished for a total cost of £332,031. The plan referred to has also the intention of picking up the sewage of Paisley, with the object of purifying the whole basin of the River Clyde, from Rutherglen to Dalmuir.

Mr. Menzies, who had charge of the sanitary arrangements at Aldershot, in talking of the value of night soil manure at the Leamington Congress, had mentioned that they could not get rid of it there, and that it cost the Government £500 per annum to remove it. It was not manufactured in any manner whatever. Then Mr. Hoey spoke of the limited quantity of water that he proposed for household purposes, and that if it ran only at the rate of about a gallon per minute, this would prevent hot-baths being used, and destroy the usefulness of house-boilers, and lead to many other evils.

Mr. James R. Napier did not see how any objection could be taken to Mr. Hoey's arrangement on account of its complexity. For, *First*, if the object be to save water, Mr. Hoey did it, and could do it, without any mechanism whatsoever, merely by enclosing the discharge-valve of the cistern in a vessel of any size, with a small fixed opening to admit the water to the vessel. The size of this fixed opening determines the greatest amount of water that can possibly be wasted; for it is clear that if the valve of the closet be raised and kept fixed up, no more water will flow into the closet than can get through the small hole in the vessel surrounding the cistern discharge-valve. This may be the 10th, the 100th, the 1000th part of what can at present be so wasted. *Second,* If the object be to make valuable manure of the soil, it is taken for granted that the less water it contains, and the more portable it can be made at the smallest cost, the more valuable it becomes. Mr. Hoey secures this object in the closet by what cannot surely be called complex machinery—an inexpensive piece of elastic gum. While the closet is being flushed, this closes the small opening which, for the first object only, might be always open, and keeps it shut so long as the cistern discharge-valve is open, so that no more water can get into the closet than the exact quantity which it had been determined should be supplied each time the closet is flushed. Thus Mr. Hoey secures one of the essentials for the economical manufacture of manure from the closet soil, and at no inconvenience whatsoever, as far at least as the closet itself is concerned, to the inmates of the house; for, as he purposes afterwards evaporating the water and making a dry manure, it is clear that the less the quantity of water it contains the less will be the quantity of fuel necessary for evaporating it. The so-called deodorising vessel appears to be not essential to the domestic closet, seeing that the object aimed at by its introduction can be as well secured by those interested in the manufacture of the closet soil into manure, putting the necessary quantity of sulphate of iron or other approved substance direct into the collecting-tank described by Mr. Hoey. Thus his closet arrangement is freed from any greater charge of complexity than belongs to the most simple of water-closets. Mr. Napier believed that the most direct and legitimate method of preventing the waste of water was by charging for it either by weight or by measure. Those who wasted it, those who neglected to keep their taps in order, would themselves have to pay the consequences of their own neglect, and not have them paid for by others as at present.

Mr. W. Simons presumed Mr Hoey did not mean his plan applicable to the purification of the River Clyde. He presumed that although the 40,000 water-closets of Glasgow were drained, and otherwise disposed of, the river would not be greatly improved. It was of course suitable to spread the sewage over a tract of country like that round Carlisle, where the value of land was not great; but it came to be a much more serious matter around such a city as Glasgow, where land was so dear. Many schemes had been projected for abolishing the smell of the Clyde; and, on considering the matter with Mr. Brown, he had proposed the following plan, as least expensive, and, he submitted, likely to effect the purpose. Their proposal was to build into the edge of the quays, at the outlet of each *sewer*, a range of gigantic tanks for the purpose of intercepting the sewage. From these tanks there would be flexible pipes, communicating with floating buoys moored in the centre of the river, by means of which the tanks could be tapped every night, and all the solid sewage removed in air-tight steam hopper barges, which would convey the sewage forty miles down the Clyde, where, without stopping the barges, it would be deposited into the open sea; or, if a suitable market offered, it might be deposited into floating depots, and removed from thence by farmers or consumers. By this plan a large portion of the liquid sewage must still be allowed to flow into the river; but he believed the result would be that the objectionable smell from the Clyde would be obviated.

Mr. Hoey said, that although it had been demonstrated by a lengthened experience that one-seventh of a gallon of water is sufficient for each flushing, and also for filling the trap-pan so as to secure a proper luting, there is no reason why persons preferring a larger quantity should not use it. Only, as the additional water used in flushing necessarily involves increased expenditure for plant and labour, and also a proportionate increase of the fuel required for evaporation, when the object is to manufacture the soil into manure, it follows that, in addition to paying for this excess of water as per quantity used, a charge equal to about the cost of two lbs. of coal for every gallon of water so used would be required to cover the increased working expenses, which, if two-sevenths of a gallon were used each flushing, would amount to about one shilling per water-closet annually, thus causing an increase in expenditure of £2000 per annum in treating the soil of the 40,000 water-closets of such a city as Glasgow. The replenishment of the acid-fountain would be accomplished by the introduction—say once a month—of the proper quantity of sulphate of iron in a crystalline state, and then filling up the vessel with water; the outlet at the bottom being shut during the process by the conical part of the plunger filling the corresponding conical seat in the tube in which the plunger is suspended. The discharge of this duty would devolve on persons employed for behoof of those interested in the manure manufacture, at whose expense the acid would be supplied and the labour performed. The modified irrigation alluded to may be seen in full operation all the year round on Mr. Harvey's farms, connected with Hundred Acre Hill Dairy, Glasgow, where for many years no other than liquid manure has been employed in raising crops of all kinds, which would compare favourably with any in the neighbourhood. The liquid manure being applied by three men and three stout lads, by hose and jet, to the entire area of about three hundred acres of land, including at least one application to the entire surface, and from four to six applications to sundry portions, annually. The liquid mainly used being distillery pot-ale, combined with the liquid manure from the cow-sheds. Solid manure, his manager informed me, he never used, except for potatoe crops; but has been in the practice of selling it to the extent of many hundred tons annually. This pot-ale would constitute an important ingredient in the chemical sewage of Glasgow, proposed to be sent along Dumbarton Road through piping, regarding which an eminent manufacturer of manure lately averred that he could realise £2000 per annum out of what passes his establishment were he not otherwise more profitably employed. That such sewage would be used and paid for by farmers is certainly a matter of most reasonable expectation. The water used for wash-house, culinary, and all ordinary domestic purposes, would find an exit as at present by the existing drains and sewers, and would be discharged through these along with the daily average rainfall into the Clyde. Our past experience as to its effects on the river, previous to the wholesale introduction of water-closet soil, abundantly justifies the most assured expectation as to the purity of the river in future by the adoption of the proposed mode of dealing with water-closet soil, more especially as the river is now supplemented by 26 million gallons of additional water daily from Loch Katrine and Gorbals supply.

The President said that, by Mr. Hoey's plan, the whole of the sewage of a large tenement would be discharged into one tank by the different pipes leading from all parts of it. Would there be no difficulty in keeping those pipes clear?

Mr. Hoey replied that, in tenements of flatted houses, the water-closets were usually exactly above each other; and he believed that the use of the seventh part of a gallon of water at each time would be sufficient to keep them clear. But of course more water might be used.

The President asked if it was not objectionable to use water by meter, as tending to induce the use of too little?

Mr. Hoey, in reply, stated that, in the event of such an anomaly, then the difficulty might be easily met by allowing a certain quantity of water per day for domestic use, which would require to be paid for whether used or not.

The President said they could not both effect economy and a saving of water.

Mr. Hoey thought that was quite possible. He had said that people in Glasgow used about 40 gallons each per day. Now he would say a proper proportion would be to allow 4 gallons per pound of rent per day, and any excess to be paid for.

The President asked if Mr. Hoey's plan would cause two sewers to be employed?

Mr. HOEY said he did not interfere with the sewers at all. The present sewers remained exactly as they were at present, and carried off the surface drainage and the ordinary domestic sewage. The water-closet sewage was intercepted and collected in tanks, as explained; and the chemical sewage was intended to be carried direct from where it was made along a separate line of pipes, and be applied to irrigation.

The PRESIDENT said that of course each work must be connected with that pipe. Then the water-closet sewage was to be removed by air-tight carts. Did Mr. Hoey think it would be practicable to bring those carts to the receptacles in a state of vacuum, and then to connect them with a portable pipe, and still to maintain the vacuum?

Mr. HOEY thought so. There was an air-tight pipe and tap to make the connection.

The PRESIDENT said that Mr. Simon's plan would require means of nightly conveying away 28 millions of gallons of sewage, and 10 million gallons of rainfall.

Mr. MACLURE said that the result of calculations showed Mr. Simon's plan to be preposterous, as it would require about 200 vessels to transport the sewage.

Mr. SIMONS replied that ten or twelve vessels of 800 tons would do the whole work, and remove the disgraceful smell.

Mr. MATHESON said that an important element in Mr. Simon's plan was, how he would separate the sewage from the water?

Mr. HOWDEN considered that the chief difficulties in Mr. Hoey's system, would lie in the removal of the soil from the houses in tanks, and in preparing it afterwards for being utilized. The working of Mr. Hoey's water-closet was simple and quite practicable. He had seen similar closets in use, in Manchester, nearly ten years ago, which he believed were still working; they were regularly sold by plumbers. Their use was to prevent the waste of water, and get the soil away. This they did effectually, with the use, apparently, of about a gallon of water each time the closet was used. The apparatus was arranged so that several minutes elapsed before the small cistern that flushed the closet was again filled. An immense quantity of water could be saved in any town by such appliances. In Bristol he understood that the use of water meters, and other apparatus for preventing waste, was very generally enforced, and had reduced the consumpt of water to a remarkable extent. He did not consider the meter described by Mr. Hoey in his paper would prove to be durable. It was a very difficult matter to construct a water meter both simple and durable, and at the same time correct. There were water meters existing that fulfilled these conditions, and which were also very compact. If these were brought into general use in dwelling-houses, the great expenditure of water in Glasgow would be at once reduced. The use of the appliances he had referred to in England was simply to save the water; to reduce the amount of water in closets to such an extent as proposed by Mr. Hoey—to about one-seventh of a gallon—could not, of course, be adopted with our present sewage system, but would be absolutely necessary for the intercepting tank system, as proposed by Mr. Hoey.

Mr. Brown said that if Mr. Hoey's plan were carried out, it would get over the difficulty of Mr. Simons's—the necessity of carrying away so much liquid manure. Their idea, however, was to allow the matter to settle, and, especially in the winter time, only to take away the heaviest part of it. The solid matter of the sewage of Glasgow would not be above 5000 tons, which could be carried away by eight or ten barges, and they meant to allow the liquid part to flow away.

Mr. Maclure remarked that Mr. Brown was labouring under a mistake. The whole sewage of Glasgow was a very thin fluid, and there was really no solid matter whatever, with the exception of what arose from the mud and dirt off the streets and closes.

Mr. Hoey said that it would never do to allow the fluid to run into the river, for in it was the most obnoxious portion of the sewage, and contained the most valuable fertilising ingredients.

The President said, then the liquid might be evaporated.

Mr. Hoey replied that it was done by Mr. Turnbull.

Mr. Page said, of the many kinds of apparatus proposed and used for saving water, there was one, of which he had some experience, which was most efficient and simple—see Fig. 2, Plate XIV. It was merely a cast-iron vessel, connected by a brass union to a lead pipe, direct from the main. On the seat of the water-closet is placed a two-way tap. Its action is as simple as any machine can be. Fig. 3 is a section of the two-way tap, showing the water-way from the main to the vessel; Figs. 2 and 4 show the water-way from the vessel to the water-closet. The water is usually left on the iron vessel, when the closet is not in use. When it is necesssary to flush the closet, the handle of the two-way tap is turned, changing the water-way, as represented in Fig. 4; and the communication having been cut off from the main, the water in the iron vessel can only be discharged into the closet, the quantity can be easily regulated by increasing or diminishing the size of the iron vessel. A glance at Fig. 2 will show that the apparatus works as an air-vessel, and that, according to the pressure on the main, so is the degree of compression of the air in the vessel, and consequently so is the effectual action in flushing the closet. This simple, cheap, and effective apparatus has worked well, and is used without a cistern. I would add, in reference to cisterns, that where they are used, no overflow-pipe should be allowed, and then more attention would be paid to the outlet fittings.

Mr. Hoey, in answer to questions, said it would require ninety-two carts to take away the sewage of Glasgow according to his plan. He could see no insuperable difficulty to keeping the tanks air-tight.

Dr. Fergus thought that the subject which had been discussed admitted of another aspect. Baron Liebig told them that, after scouring the whole world for manure, by and bye they would require to come back to human excrement. His own impression was that Mr. Hoey's plan was an excellent way of utilising sewage, as well as purifying the river. He was of opinion that the water-closets, and also the chemical works, were the cause, to a large extent, of destroying the purity of the river during the last twenty years. He believed, however, that one chief cause of the present polluted state of the Clyde arose from the bar across the river near Dumbarton Castle, the sewage being unable to get away, and so kept continually moving backward and forward up and down the river along with the tide. He thought, therefore, that Mr. Maclure's scheme, to be successful, must include some plan of discharge below Dumbarton Rock. He did not think that there was much strength in Mr. Maclure's argument against Mr. Hoey's plan, that people would not be at the trouble of filling the sulphuric acid chambers. He thought there would be no difficulty in arranging for that simple matter to be attended to. His impression was that the grand point in Mr. Hoey's scheme was the facility with which it might be introduced. In other schemes there was always an enormous initial expense; but Mr. Hoey's might be put to the test for £100 in any tenement of dwellings, time would prove whether it was a practical scheme or not. He did not think that the want of flushing the pipe was any objection to the scheme whatever, because the liquid which passed away was previously deodorised. In the present common sewers the inclination was much less than what was proposed by Mr. Hoey's plan; but nuisances in houses often arose from a very different cause—from the waste pipes getting perforated by small holes, thus admitting to the house the most deadly gases. Aldershot camp had been referred to. Now he was aware that gastric fever had broken out in a camp in consequence of one of the pipes becoming plugged up with fœcal matter; and he believed there was no more common source of gastric fever than smells from sewers. Mr. Hoey's plan would obviate that; and besides, it ought to be remembered that human excreta was rich in all the best ingredients of guano.

The President said the facility with which Mr. Hoey's scheme could be tried at a small expense, was certainly a most important feature of the plan.

*Note by* Mr. T. Hoey—*Received 14th May, 1867.*—In the after-discussion, I said that my belief was, that the ball-cranes for water-closet or other cisterns might be reduced to a delivery, in ten hours, of about double the quantity required per day for the closet, thereby preventing the present excessive waste by leakage.

I stated that Dr. Gardiner assured me that such a closet as that proposed would, in Paris, insure a fortune being made out of it—it being the very thing required to manufacture *poudrette* successfully, they having all the necessary means for doing so, with the drawback of an immense dilution of the soil in water, which it would effectually prevent.

Having visited Craigentinney Meadows several years since, my vivid recollection of its odours inclines me to indorse certain opinions of Dr. B. W. Richardson, which Mr. Maclure has entirely overlooked when quoting from the paper read by that gentleman at the Leamington Congress, and which are to the effect that "the parasite diseases were produced by the transfer of animal organisms from animals to man. They were mainly conveyed to the human subject through animal food. But animals *feed* on *grass* which might be *fertilised* with *sewage*, and *so* the *disease might be transferred from animals to man;*" and as likely by milk, I suppose, as by animal food.

After his enunciating such a theory of disease-transmission, and having smelt Craigentinney, or some such odours, the most inveterately utilitarian sanitary reformer could scarcely be surprised at the conclusions arrived at by Dr. Richardson, who says—"According to our present knowledge, the best mode of applying sewage would be one which avoided the *transference* of these *gases.* That town would be healthiest which had a perfect water-supply, a drainage *well* but not *excessively* flushed, and that carried away every particle of sewage into the sea." The inhabitants of our northern metropolis might benefit by the above advice of Dr. Richardson, to the extent of ridding themselves at once of a profitless nuisance and a long-standing reproach. He further says—"The object of the economist was to remove sewage and save it. This would be compatible with health if the sewage could be perfectly locked up in a town." It would be difficult to give a more condensed and complete description of the intercepting tank system than is contained in that single sentence of Dr. Richardson's regarding the "locking-up of the sewage in a town"—such being the legitimate effect of introducing that system, the entire process being conducted in close vessels.

His recommendation—"that the sewage, if distributed, should be *distributed away from a town*, where there can be no *contamination*"—any person who has ever been within a mile to the leeward of Craigentinney Meadows can easily understand. But as my individual experience in this matter is not of a very recent date, I may perhaps be excused for giving two cases of last year's experience. A gentleman connected with one of our largest engineering establishments in town assured me, that after traversing the shore road from Portobello to Leith, he would never again speak of the Pontine marshes as being the highest representation of olfactory offensiveness.

Further, a gentleman connected with one of our largest chemical works tells me, that while walking from Piershill to Edinburgh, the most offensive odour seemed to saturate the entire atmosphere; and that a quantity of grass, taken from a cart-load which was being conveyed from the Meadows, on the application of a moderate pressure, emitted a liquid smelling strongly of sewage. Such being the sensational effects of 250 acres of fœtid swamp at Craigentinney, how much more terrible would be the effects of twenty times the area of festering semifluid putrefaction, which the execution of Mr. Maclure's plan would call into existence in our case.

In congratulating us on our abundant supply of splendid water, he apparently forgets that we require to pay the not unimportant sum of £90,000 per annum for this supply; and that this *cheap* scheme of his would involve us in an unavoidable—though, under proper arrangements, altogether unnecessary—domestic expenditure, *in all time coming*, of our entire daily surplus supply of 14 million gallons, representing, at £20 per million gallons, the enormous sum of £102,200 annually for the purpose of vainly endeavouring to wash the filthiness out of the present and proposed sewers, which, after all this enormous and costly expenditure of water, would be but very imperfectly accomplished—the sewerage, through its tortuous course, still acting as a gigantic alembic evolving the most noxious gases.

I read Mr. Maclure's pamphlet previous to the publication of my paper; but, at the same time, I must confess that I do not know that his plan can be accomplished at an outlay of £332,031, nor even at double that amount.

Mr. Page's "simple plan" partakes of the common imperfection of all its precursors, in want of accuracy of measurement, being an incomplete version of the apparatus patented by Mr. Jordan, of Norwich, about thirty-six years ago, as per specification published in *Jamieson's Mechanical Dictionary*, 1832, and only including an embodiment of Jordan's single elementary idea, and not wrought out at all in its modifications as the patentee has it. From the fact of the contained air being compressed in the charging of these vessels direct from the main, every variation of head pressure must produce a corresponding variation in the quantity of water delivered at each discharge. If the pressure only varies from one atmosphere to two, and supposing the capacity of the vessel to be four hundred cubic inches, with a pressure of one atmosphere, the quantity of water given off at each would be *two hundred* cubic inches; and with two atmospheres the discharge would become *three hundred* cubic inches. These certainly cannot be called accurately measured quantities in the ordinary acceptation of the term, and would render it utterly inapplicable in working out the system I have recommended in Glasgow, as we have a much greater daily variation of pressure than one atmosphere.

In conclusion, I quote one of "Mr. Bardwell's Twelve Reasons against Sewage Irrigation:"—

"*Eleventh.*—Besides the noxious sewage gas, there is also the noxious sewage weed—as at Croydon, for instance—in minute flocculent particles, which develope and multiply themselves with extraordinary rapidity; and where sewage irrigation is practised in meadows it adheres to the blades and stalks of grass. It may be detected by rubbing the plant as close to the root as possible between the finger and the thumb, when it will emit an exceedingly offensive odour. This I showed to the astonishment of the gentlemen in a most eminent solicitor's office the other day. I am told the mortality of cattle around Edinburgh has been greater than in any other part of Scotland; it may reasonably be inferred that this is mainly owing to the stock having been largely supplied with sewage-grown grass, seeing that the like effect has followed in the cow-houses of London, where the animals have been fed with *Croydon grass*. Thus the demand for this grass having ceased—the neighbouring farmers won't use it—the proprietor resorted to the expedient of making it into hay, but with the most lamentable results; for, notwithstanding all the drying and covering with rick-cloths, putrescence was not arrested, but the sewage weed decomposed and fired the stacks, leaving but masses of filth, fit only for manure. A friend of mine took me to Beddington to witness this. The stench of the *debris* was at that time abominable, and fully bore out the *naïve* remark of the proprietor—'I don't like making hay!' So much for 'what is being successfully done at Croydon.'

(Signed) "WILLIAM BARDWELL, C.E."

Mr. Bardwell's conclusions, so thoroughly opposed to the opinions held by Mr. Maclure, would, if founded on indisputable facts, nearly settle the question of sewage irrigation.

Mr Maclure having admitted that he laboured under a *mistake* when writing his remarks on my paper, in *believing* that *portable intercepting tanks* were to be used. Consequently, however valuable his remarks may otherwise be, they do not in any sense apply to the *fixed* intercepting tanks that are proposed to be used, neither can they be applied to the working of the general system, of which these form an integral part, as either being "a repetition of the numerous plans proposed for hand collection and removal of night soil, or as being unavoidably dirty and disagreeable in its manipulation," and therefore require no further notice or refutation on my part.

## *On a Method of Utilising Sewage and Preventing Rivers from being Polluted.*

By Mr. David Allan Graham, C.E., Perth.

(SEE PLATES XV. AND XVI.)

*Communicated through Professor Rankine, and read 8th May, 1867.*

At a considerable distance from the town or city, two or more large tanks, are constructed, into which the sewers—*alternately* if two, and in rotation if more—discharge the sewage. The water separates itself from the soil by means of a filter bed, which surrounds three sides of each tank, and flows into the river by means of a gutter, as shown. After one tank is sufficiently full, the sluice which connects it with the city sewer is shut, and the sluice which connects it with the other tank opened, so that the one is ready for filling while the other is ready for emptying.

A dredger working on a frame, similar to a travelling crane, then discharges the soil into trucks, which run on sunk lines of rail, which traverse the entire length of each tank. A stage runs along one side of the outside of each tank, from which a man sees through the circular windows in the side walls how to direct the various movements of the dredger, &c., or bring the trucks into position with the arrangements for that purpose, the whole being wrought from the outside by means of steam or other power, as may be found convenient. The tanks are covered with a glass roof, or partly glass and partly slate, so that light may use its influence to disinfect the interior; and they are also ventilated by means of a furnace at the base of a stalk, which consumes the foul gases as they are generated in the tanks, fresh air being supplied by means of the draught created by the furnace through holes suitably situated, one on either side of the doors of each tank.

After the dredger has done its work, what remains of the soil is deodorized and disinfected, either with earth, sand, or some chemical, after which men enter, and scrape it into one place by means of the common road scraper.

The sides of the tank are now washed with a jet of water, and water is to be forced through the gravel beds as far as that is practicable, so as to remove any soil that may lodge about them; but if they have been wrought for some time, it may be found necessary to renew the beds and remove the old sand, and wash it and the gravel by means of an apparatus similar to a dash wheel.

During the process of washing the beds, a filter sluice is lowered where the gutters discharge themselves into the river, which prevents the soil in the water from passing into the river. Should there be tides, and the sewer levels be low, it may be found necessary to use a large centrifugal pump during a part of the day; but it could also be used for irrigating land, by throwing the water into a cistern, which would give a head to overcome the friction in the pipes.

Fig. 1 is a ground plan of the tanks; they are about 6 feet deep, and 200 feet long by 40 feet wide. The bottom is paved either with fire-clay or pavement. A series of buttresses, B, surround *three* sides of each tank, 10 feet apart, into which are batted cast-iron frames, F, two between each pair of buttresses. These are placed four feet apart, the one, F 1, flush with the inside of, and forming the sides of the tank. These frames are formed with slides into which perforated squares of fire-clay are slid, the one above the other.

The space, S, between the two frames is filled with fine gravel and sand mixed. The spaces, G, at the back of the frames are filled with fine and rough gravel mixed. These beds may either run into the gutter G, which surrounds *three* sides of the tanks, or may terminate in another cast-iron frame with perforated squares of fire-clay as before, but only 1 foot 6 inches deep; the gutter is also filled with large sized pebbles. But this last arrangement is unnecessary, if the pebbles are laid down larger to the outside than on the inside. The water from the soil in the tanks flows through the beds into the gutter, and from it into the river.

The trucks are brought into position in the following manner:—Between each line of rails (which are sunk to the level of the floor of the tank, so as not to come in contact with the dredger when it is working) a pulley, P, hung on a bracket, is made to slide along in a cast-iron groove, X, between the rails. As the soil is removed by the dredgers, the barrel, B, is wound up, the chain attached to the pulley bracket drags it along the groove, and by this arrangement the waggons can always be brought into any position required. The chain that works on this pulley returns to the door of the tank at the top of the inclined plane, P, dredger. The dredger works on a frame similar to that of a travelling crane, and is driven with an endless cotton rope, R, which is guided on to the pulley by means of two other pulleys, T, a row of columns running up the centre of the tanks support the middle of the crane by means of wheels, W, working on a line of rails placed on them.

Each dredger traverses one-half of the house, and they are brought into any position desired, with a screw working a prong, Z, which embraces the block upon which the buckets work.

The frame is brought into position by means of a drag-chain and winding barrel, O and V, and as it advances a pall falls into a rack, R, and keeps the machine from receding with the drag upon it. The lower part of the dredger frame is supported from the block L, which can be adjusted to suit. The arrangements for effecting these motions are shown in large scale elevations, Fig. 2.

The roof is made of glass, or partly of glass and partly slate, bedded into putty or other cement, so as to keep the gases from escaping by the joints.

The couples shown are T iron, upon which T iron purlins run along, and on the top side of which are screwed pieces of wood, upon which are nailed the zinc or cast-iron T strips upon which the glass or slates are to be bedded.

After the reading of the paper,

Mr. Jas. R. Napier thought that allowing the liquid part of the sewage to run waste, and collecting the solid only, would not be approved by the manufacturers of manure, as the liquid was believed to contain the greater part of that which is valuable, and that also which affects injuriously our rivers.

Mr. W. Smith said that the ideas in the paper were quite new, and that it was unwise to dogmatise on such a subject; but, if the paper had contained the results of practical working of the scheme, it would have been more satisfactory. It certainly was a strong objection to the system proposed, that the liquid part was to be lost; but one could scarcely express an opinion upon it without making calculations which the paper did not give.

Mr. J. Hamilton suggested whether it was not intended to retain the valuable part of the manure in the filtering tank?

The President said he was afraid it would be impossible to abstract it by filtration.

Mr. Howden said he doubted whether it would be practicable to pass per day the 30 million gallons of Glasgow sewage through tanks; and, if tanks enough could be got, he was afraid that the filters would require to be made so wide as to be practically useless. He was afraid the plan would not suit for such a city as Glasgow.

Dr. Fergus was very much of the same opinion. The sewage of all large towns was so liquid that it would not suit. The sewage of Glasgow amounted to at least 24 million gallons a-day, and the rainfall would be nearly as much; so that there were between 40 million and 50 million gallons would require to pass through the tanks. Now, it seemed to him impossible to keep so many filters in perfect order, as would be required for so large an amount of sewage; for every one knew how difficult it was to keep filters clean. Then, undoubtedly, the fœcal matter existed in the liquid, and he could conceive of no method of filtration, by mechanical means, that would retain it. It was possible, perhaps, to have chemical filters, in passing through which the fœcal matter might be fixed and retained; but he did not know that such a plan was workable. In striking contrast to this plan of Mr. Graham's was that brought under notice by Mr. Hoey at a previous meeting, by which the whole valuable matter was retained, and no waste took place, while they would get rid of those vile emanations from the sewers, which polluted the atmosphere, not only of the streets, but of their houses; for it was well known that, on drawing the plug of a water-closet, every square-inch of foul air displaced by the water rushed into the house. He could not see anything about this system to commend it. The subject was a clamant one, and ought to receive careful consideration, so that an end may be put to the great waste now going on of phosphates and other valuable matter in the sewage.

The PRESIDENT asked Dr. Fergus whether there was any such chemical filter as he had referred to, that would retain the valuable part of sewage, and send out the liquid as pure water?

Dr. FERGUS said, if it were passed through charcoal it would be deodorised; but the expense would be so enormous as to make that system utterly impracticable.

The PRESIDENT asked whether it was, in fact, possible to retain by filtration what was held in chemical solution?

Dr. FERGUS said his opinion was, that the fœcal matter was held in mechanical suspension; but, unless they could fix the ammonia and other volatile gases, it would be useless. He thought it might be possible to do so, but at a great cost. It was also against Mr. Graham's system, that the cost of apparatus to give it a trial would be very considerable.

Mr. BROWNLEE said the valuable salts were held in solution by the liquid, and if that was allowed to run off to waste by ordinary filtering, the solid matter remaining would scarcely be worth carrying away. He thought a great recommendation to Mr. Hoey's plan was, that it could be tested at little expense. He thought it was well worthy of a trial.

Mr. DONALD said it appeared to him that the question divided itself into two parts—that the term filtration applied to solid matter, and chemical attraction to substances held in chemical solution. He thought Dr. Fergus had not kept these distinctions properly in view.

Dr. Fergus said that a mechanical filter could only collect matters held in mechanical suspension; and he had not said that such a filter would retain and preserve the valuable part of liquid manure.

## *On the Comparative Strengths of Long and Short Struts.*

By Mr. James MacCallum, C.E.

(SEE PLATES XVII. AND XVIII.)

*Read 8th May, 1867.*

This method of finding the strengths of long struts, is but the geometrical expression of the principle first suggested by Tredgold, applied by Gordon, and elaborated by Rankine, viz., that in a strut, one part of the greatest stress is that due to direct crushing uniformly distributed over the cross section, while the remainder is due to the bending action produced by the strut diverging laterally, thus relieving the crushing force on one side, and intensifying it on the opposite side. The formulæ, to which the application of this principle leads, although not complex, are found irksome in practice, more especially in the *designing* of struts, as the method of trial and error (which has to be used) involves the necessity of making the calculations two or three times over; and, besides, considerable care has to be taken in giving the proper values to the different quantities which enter into the calculations. It was meeting with such trivial difficulties which first suggested the method given below, but perhaps its greatest use is the assistance it gives in forming clear conceptions on the subject of resistance to crushing by bending.

The questions which are here solved graphically (see Plates XVII. and XVIII.) are—

(*a*) *Given* the length, breadth, and sectional area of a long strut, what is the sectional area of a short strut, which would be of the same strength as the given long strut? And the sectional area thus found being multiplied by the crushing strength of the material (as found by experiment, and recorded in tables of strength), will give the crushing strength of the given long column.

(*b*) And conversely, in *designing* a strut of a given length, to withstand a given crushing load: that load divided by the crushing strength of each square inch (as given in tables), will be the sectional area required for a short strut; but what would be the necessary area for the long strut?

These are the questions which are to be answered, and to begin with the case which is perhaps of most frequent occurrence, and which is also the simplest, viz., that of a solid cylindrical wrought-iron rod. For example, let it be required to find the crushing load of a wrought-iron rod 5 feet 3 inches long, and $1\frac{3}{4}$ inches diameter (see fig. 3). Draw $\overline{O\,h} = 1\frac{3}{4}$ inches, at $h$ erect a perpendicular whose length is the length of rod (5 feet 3 inches) to the scale of $\frac{1}{4}$ inch to the foot, and along it make $\overline{O\,h}$ equal to the base; from the point thus found draw $\overline{h\,h'}$ perpendicular to the base, intersecting the latter in the point $h'$; then $\overline{O\,h'}$ (= 1·4 inches) is the diameter of a short rod of equal strength to the given long rod, and consequently its area is $1{\cdot}4 \times 1{\cdot}4 \times {\cdot}7854 =$ 2 sq. inches nearly.

This exemplifies the method of obtaining the strengths of struts whose dimensions are given, but the designing of struts of a given length, and to just withstand a given crushing load, is a somewhat more difficult problem. Let it be required to find the diameter of a cylindrical rod 5 feet 3 inches long, which will just crush with a given load of 32 tons. Assuming the crushing strength of short wrought-iron struts to be 16 tons per sq. inch, the requisite area of short strut would be 2 sq. inches, corresponding to a diameter of 1·4 inches. Draw a straight line half the length of this diameter (see fig. 4); at one of its extremities erect a perpendicular equal to the length of rod drawn to the scale of $\frac{1}{4}$ inch to the foot, draw the hypothenuse of the right angled triangle, and produce it through the vertex to O, making the part so produced equal to half the given diameter of the short rod; along the hypothenuse from O (towards the vertex) lay off $\overline{O\,h'}$ equal to the given diameter of the equivalent short rod; and upon the hypothenuse produced to O describe a semicircle. Lastly, at the point $h'$ erect a perpendicular intersecting the semicircle; the length of the line joining that point with O will be the required diameter of the rod. By the measurement, it is found to be exactly $1\frac{3}{4}$ inches. As there is no bending action at the ends, the diameter there might be 1·4 inches, while the diameter at the middle remained $1\frac{3}{4}$ inches, or perhaps it would be more philosophical to make it rather more than $1\frac{3}{4}$ inches, to compensate for the slight diminution of stiffness caused by turning off the metal at the ends; but, practically speaking, that extra metal adds little to the strength of the rod. The scale to which the length is set off, is rather more than $\frac{1}{4}$ inch to the foot, and is scale B of the accompanying set.

But that part of the greatest stress which is due to bending, is affected by the form of cross section, and hence the necessity for using different scales for every different form of cross section. Thus scale A is suitable for solid, square, or rectangular sections; scale B for circular sections; scale C for thin, hollow, square sections; and scale D for thin, hollow, circular sections. Further, the method of demonstration indicated below, shows that an L iron, say 2 feet long and 3 inches leaf, is just as much weakened by reason of its length as a thin hollow square strut 1 foot long and 3 inches square; hence the scale for the latter can be made use of for the former by simply doubling the length of strut. This shows the use to be made of the factors given on the scales.

The experiments of Mr. Hodgkinson have shown that if a strut be jointed at the ends (as in connecting rods), or otherwise so fixed that it is free to bend, its strength is the same as that of a short strut of half the length, firmly fixed in direction at each end; while a strut fixed in direction at one end only, and jointed at the other (or at all events free to move at that end), is of the same strength as a strut three-fourths of its length and fixed at each end. These scales being suitable for struts fixed at both ends, can be adapted to struts fixed at one end only, by multiplying the length by $\frac{4}{3}$, and to struts jointed at both ends by multiplying by 2. However, in the table on Plate XVII.

the factors made use of are $\frac{3}{2}$ and 2, instead of $\frac{4}{3}$ and 2, for the sake of being on the safe side in a matter that does not admit of hair-splitting accuracy.

When we have to deal with struts of other materials than wrought iron, we have little difficulty in adapting this method to suit our purpose. Experiment has shown that cast-iron and timber struts are weakened by lengthening them somewhere between three or four times as much as wrought-iron is weakened. The proportion adopted by Professor Gordon for cast-iron is 3·35; that adopted by Professor Rankine for dry timber is 3·46.

The examples given in Articles 3 and 4 will sufficiently illustrate the other figures of cross section; but it may be added, that in finding the strengths of every kind of strut (except, perhaps, those of solid, square, or circular sections), whose dimensions are given, fig. 1 will be found the most useful, while, in designing long struts, the whole of the figs. 2, 4, 6, and 8, will be found of use. Fig. 6, although stated to be for solid rectangular sections, will be found useful in designing all irregular sections, such as L iron, H iron, &c., the precaution being taken to increase the thickness of metal in the same ratio that $b'$ has been increased to $b$, and $h'$ to $h$. But as this would often lead to uneven measurements, it has been found better in practice to use fig. 6 as a guide to assist in fixing upon the transverse dimensions, verifying by fig. 1.

In demonstrating these constructions, the formulæ arrived at by Professor Rankine will be assumed. Their demonstration is given in his "Applied Mechanics," and extended in his "Manual of Civil Engineering." For struts fixed at each end, it is shown that

$$\frac{P}{S} = \frac{f}{1 + \frac{l^2}{c r^2}} \quad . \quad . \quad . \quad . \quad . \quad . \qquad (1)$$

when P is the crushing force on the strut of length $l$, least radius of gyration of cross section $r$, and sectional area S. Let $h$ be a dimension of cross section measured perpendicular to the axis of the least radius of gyration, and therefore proportional to $r$ and $b$, a cross sectional dimension measured perpendicular to $h$; $c$ is a constant, peculiar to each material; and $f$ is the resistance to direct crushing of unit area.

And, further, let S′ be the sectional area of a short strut of equal strength to the preceding long strut, $b'$ and $h'$ transverse dimensions of the short strut corresponding to the preceding dimensions of the long strut, then plainly—

$$\frac{P}{S'}=f \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (2)$$

whence $$\frac{S}{S'}=\frac{c\,r^2+l^2}{c\,r^2}=\frac{r^2+a^2\,l^2}{r^2} \quad . \quad . \quad . \quad . \quad . \quad (3)$$

where for brevity $a^2$ is put for $\frac{1}{c}$

Now since $r \propto h$ $\quad r = n\,h \quad$ equation (3) becomes

$$\frac{S}{S'}=\frac{h^2+\frac{a^2}{n^2}\,l^2}{h^2}=\frac{h^2+n_{,}^2\,l^2}{h^2} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (4)$$

where $n'=\frac{a}{n}=\frac{1}{n\sqrt{c}}$ and in the notation used on these scales,

$L = n'\,l$, so that equation (4) may be written:—

$$\frac{S'}{S}=\frac{h^2+L^2}{h^2} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (5)$$

In figs. 3, 4, 5, and 6, $\frac{S}{S'}=\frac{h^2}{h_{,}^2}=\frac{b^2}{b_{,}^2}$, wherefore (from equation 5),

$$\frac{h}{h'}=\frac{b}{b'}=\frac{\sqrt{h^2+L^2}}{h}=\frac{\overline{O\,A}}{h} \quad . \quad . \quad . \quad . \quad . \quad (6)$$

Or O A : O $h$ :: O $h$ : O $h'$
and O A : O $h$ :: O $b$ : O $b'$

which two proportions are easily seen from the similarity of the triangles.

To demonstrate the construction in Fig. 1.

Equation (5) becomes $\frac{S}{S'} = \frac{\overline{O\,A}^2}{\overline{O\,h}^2} = \frac{\overline{O\,A}}{\overline{O\,h}} \cdot \frac{\overline{O\,h}}{\overline{O\,B}} = \frac{\overline{O\,A}}{\overline{O\,B}}$ . . (7)

or $\overline{O\,A} : \overline{O\,B} :: \overline{O\,S} : \overline{O\,S'}$ the demonstration of Fig. 1.

and conversely $\overline{O\,B} : \overline{O\,A} :: \overline{O\,S'} : \overline{O\,S}$ the demonstration of Fig. 2.

The demonstrations of Figs. 7 and 8 are the same as those for Figs. 1 and 2, substituting $b$ for S, $b'$ for S′, $\overline{O\,b}$ for $\overline{O\,S}$, and $\overline{O\,b'}$ for $\overline{O\,S'}$.

To demonstrate Figs. 4 and 6. The solution of equation (6) for $h$ gives—

$$h^2 = h' \left\{\left[L^2 + \left(\frac{h'}{2}\right)^2\right]^{\frac{1}{2}} + \frac{h'}{2}\right\}$$

or $h$ is a mean proportional between $h'$ and $\left[L^2 + \left(\frac{h'}{2}\right)^2\right]^{\frac{1}{2}} + \frac{h'}{2}$

But $AB = \left[L^2 + \left(\frac{h'}{1}\right)^2\right]^{\frac{1}{2}}$ $\qquad \overline{O\,A} = \frac{h'}{2}$

$$\therefore \overline{O\,B} = \left[L^2 + \left(\frac{h'}{2}\right)^2\right]^{\frac{1}{2}} + \frac{h'}{2}$$

and $\overline{O\,h}$ is plainly a mean proportional between $\overline{O\,B}$ and $\overline{O\,h'}$ $\therefore \overline{O\,h} = h$. *Q.E.D.*

Mr. Jas. R. Napier, in the absence of the author and secretary, read the paper. He stated that it was a graphic solution of the formulæ published by Dr. Rankine in his "Applied Mechanics and Useful Rules and Tables," and, in order to make it more useful, Mr. M'Callum had given a table for wrought-iron, cast-iron, and dry-timber. He explained also how the scales were formed by working out the scale for circular sections, showing its near coincidence with the common scale of ¼ inch to the foot. It was a very valuable paper, and one which would be useful in many cases. The scales were drawn to the full size, and might be used with great advantage in discovering the right dimensions of piston-rods, connecting-rods, and other parts of machinery, by taking the dimensions of one that was known to be suitable as the foundation of the calculations.

Mr. J. E. Wilson said he had tried the system, and found it very useful.

Mr. W. Smith said it would be found very useful in bringing out the proportional strengths of machinery.

The President asked whether the effect of vibration was considered? Mr. Napier had pointed out that it took into account the crushing and bending strains.

Mr. Jas. R. Napier did not know at the moment what elements affected vibration. But for connecting-rods it was directly applicable.

Mr. Brownlee thought it would be very useful and convenient in application.

Mr. Howden considered it a very useful thing, as it was so very simple.

## *On an Indicator for ascertaining the Speed of Ships.*

By Mr. Jas. R. Napier.

(SEE PLATE XIX.)

*Read 8th May, 1867.*

The following letter, by Mr. Fleming Jenkin, gives an account of trials made with an instrument I had designed some years before, for getting more reliable information as to the speed and efficiency of ships at sea than trial trips usually give. A description of it will be found in the Proceedings of the Philosophical Society of Glasgow, for 1854.

Mr. Jenkin's letter refers to arrangements I had made, at Mr. Lewis Gordon's request, for ascertaining the speed of a ship belonging to Messrs. Newal & Co., that was about to proceed from the Mersey on a telegraph-laying expedition. As my own instrument is better adapted for high than for low velocities, I thought it possible that some means might be found of using the ordinary water tube for the lower velocities, and so provided two of glass, connected to the ship's side by nozzles, similar to those used in the mercury instrument. The orifice of the one instrument faced the bow, to show velocities due to the height of the water column above the surface of the sea. The orifice of the other faced aft, to show velocities due to the depth of the water column below the surface of the sea. It was supposed that these two water tubes might be so worked as to indicate, with tolerable accuracy, the sea level, and so the greater range of the water scale might be made available. Mr. Jenkin refers to these water instruments in diagrams 2, 3, and 4.

As the Secretary of State in Council for India has sanctioned the application of the Mercury Indicator to some vessels building for the Godavery Navigation Works, it appears to me that the present is a favourable opportunity for letting Mr. Jenkin's opinion of it be known.

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COPY OF MR. JENKIN'S REPORT.

BIRKENHEAD, *2nd September, 1857.*

DEAR SIR,

I am directed by Mr. Lewis Gordon to forward the enclosed tracing of diagrams (Plate XIX.) relating to the log, and also to give some account of the observations on which they are founded.

Diagram No. 1, shows five observations on the height of mercury at various speeds.

Observation No. 5 was much the most satisfactory, as the ship had been going at a constant speed for some time in still water, with the mercury steady.

The curve deduced from this observation, $h=\frac{v^2}{24},$ passes very near Nos. 2, 3, and 4. No. 1, I believe to have been a mistake of the mate who heaved the log. I have little doubt that he was just a knot wrong.

We could run no measured mile, and had to trust to the log for Nos. 1 and 5; to the pilots guess for No. 4; just before log was heaved for No. 1, and to the time a piece of wood took to drift past the ship (taken by stop watch), for Nos. 2 and 3. I feel quite convinced that, once properly graduated, by running the measured mile at various speeds, your mercury log would be infinitely more accurate than any such methods. The mercury was very sensitive, and yet the oscillations were easily reduced to a sixteenth of an inch by the cocks. Shutting the cocks does not affect the mean height of the mercury.

The real heights observed at six knots, being one inch and a-half, is very near the theoretical height for positive and negative pressure, the sum of these giving 1.74 inches.

Diagram No. 2 shows the corresponding heights of difference of level in the two water tubes, the vertical scale being $\frac{1}{8}$ inch = 1 inch, this gives the curve from $h = \frac{v^2}{2G}$.

The heights of water column corroborate the mercury observations very remarkably; this is more distinctly seen in diagram No. 3. It was much easier to observe the respective heights of mercury and water at each small variation of speed, than to ascertain this speed. I, therefore, took a great number of such observations, and having laid down the mercury curve from the formula $h = \frac{v^2}{26}$, pricked the observed height of water opposite that point of the curve which had a vertical ordinate equal to the observed height of mercury. The water curve forms a most beautiful mean amongst these.

Before the ship left the river Mersey, at the turn of the tide, I chalked the level of outside water of the sliding scale, and was thus enabled to measure both positive and negative pressures. The negative is not quite so large as the positive; owing, I believe, to the fact, that the water being checked by the back of the tube does not run past the opening at the full speed of the ship; it appears, however, to follow the same law.

The water gauge is less convenient to observe.

I did not succeed in making the oscillations in the two tubes simultaneous. A second pair of cocks are wanted above the elastic tubing, as it is not very easy to tell when the communication with the sea is cut off, the tubing giving the little oscillation, but with this slight improvement it would answer excellently for slow speeds. For high speeds the mercury leaves nothing to be desired.

The water scale was cut out, to go to Bona in a hurry.

Yours truly,

FLEMING JENKIN.

JAMES R. NAPIER, ESQ.,

*Glasgow.*

# INSTITUTION OF ENGINEERS IN SCOTLAND

WITH WHICH IS INCORPORATED THE

## SCOTTISH SHIPBUILDERS' ASSOCIATION.

TENTH SESSION, 1866-67.

## MINUTES OF PROCEEDINGS.

The First General Meeting of the Tenth Session of the Institution was held in the Hall, 204 George Street, Glasgow, on Wednesday, the 31st October, 1866, at Eight o'clock p.m.,—Mr. J. G. Lawrie, President, in the chair.

The Minutes of Meeting of 23rd May were read, approved of, and signed by the Chairman.

The following candidates for admission to the Institution were elected:—

AS MEMBERS.

Mr. Abraham P. Klein, 9 Mersey Chambers, Liverpool.
Mr. Jonathan Hyslop, Civil and Mining Engineer, Wishaw.
Mr. H. T. Lannigan, 11 West Campbell Street.
Mr. John Todd, Branford Place, Duke Street, Glasgow.

AS A GRADUATE.

Mr. Herbert Groves, at 175 Hope Street.

The following Report of the Council was read, and approved of:—

The Council have pleasure in submitting to the Institution the following Report:—

At a meeting of Council held on the 8th October, 1866, the following Committees were appointed:—

*Finance Committee.*

David M'Call, Treasurer, *Convener.*
James Brownlee.
James Hamilton.
Anthony Inglis.

*Library Committee.*

James R. Napier, *Convener.*
Robert Mansel.
J. G. Lawrie.

*Committee on Institution Buildings.*

J. G. Lawrie, *Convener.*

| | | |
|---|---|---|
| W. M. Neilson. | Benjamin Conner. | James Hamilton. |
| John Downie. | Anthony Inglis. | James R. Napier. |

LIBRARY.

The Council have pleasure in noting the following donations of Books, &c., to the Library of the Institution during the recess:—

*(For List of Donations see Page 259.)*

The Library Committee invite the co-operation of all Members, Associates, and Graduates of the Institution in procuring donations of, and recommending and assisting them in the selection of suitable books. The Committee are at present engaged in having the periodicals and the unbound books bound, and are arranging a new catalogue.

The Council are glad to be able to congratulate the Institution on the continued increase of members, and direct attention to the great importance of introducing additional Members, Associates, and Graduates.

Forms of application can be obtained from the Secretary at any time.

The numbers on the roll at the end of last Session were:—

| Hon. Members. | Members. | Associates. | Graduates. |
|---|---|---|---|
| 10 | 300 | 70 | 15 |

## DECEASED MEMBERS.

It is with regret that we have to record the decease of Mr. Nicholas Wood, Honorary Member; Mr. Benjamin H. Blyth, Mr. George Thomson, Ordinary Members; and Capt. Whyte, Associate.

Nicholas Wood of Hetton Hall, Durham, was elected an Honorary Member of the Institution, 25th November, 1863. He was born at Ryton, Durham, on the 24th April, 1795, and died in London, on the 19th December, 1865.

He held a high position as a Mining Engineer, and was largely consulted by private parties, and frequently by the Government. He commenced his mining experience as Colliery Viewer at Killingworth Colliery, near Newcastle.

Although Mr. Wood's profession was more especially that of a Mining Engineer, we find his name associated with many of the more important questions in engineering progress in general, especially locomotives and railways; and in 1825, he published a practical treatise on rail-roads; in 1829, he was elected a judge in the competition of locomotives on the Liverpool and Manchester Railway.

## PRIZE MEDALS.

The Medals for Papers read during last Session, will fall to be awarded at an early meeting. Members are reminded to be prepared on this point.

For Papers which may be read during the ensuing Session, the following Medals are offered for competition:—

"The Railway Engineering Medal," for communications on Railway Engineering and Practice.

"The Marine Engineering Medal," for communications on subjects on Marine Engineering.

"The Institution Medal," for subjects not comprehended by the Railway or Marine Engineering Medals.

These Medals are offered for competition under the following conditions, as passed at a meeting of the Institution held on 1st March, 1865, viz.:—

"The medals shall be given annually, if the Council be of opinion that Papers of sufficient merit have been read in the respective departments; but if it shall be the opinion of the Council that a Paper of such merit has not been read in any department during any Session, the Council shall submit the question to the decision of the Institution; and in the event of the Institution confirming the opinion of the Council, the Medal shall not be given in that department, and the interest arising from that particular Medal Fund, shall be added to the principal."

## PAPERS.

Communications are invited on the science or practice of all branches of Engineering and Shipbuilding, including the description of works executed; the description and performances of machines and ships; the applications of new inventions; the record of experiments, &c.

Those who have not done so already, and may wish their communications brought before the Institution during the Session, will please to communicate with the Secretary as early as possible, so that suitable arrangements may be made.

The Council hope, during the Session, to bring before the Institution valuable communications on a variety of subjects.

## INSTITUTION BUILDINGS.

During last Session an attempt was made, in conjunction with other societies, to devise a scheme by which all the scientific and art societies might unite and procure a suitable and conveniently situated building for the purpose of meetings, library, reading-rooms, &c. After several meetings on the subject had been held, and much delay, many difficulties appeared in the way of conducting such a scheme to a successful termination. The Council considering the amount of funds at the disposal of the Institution, and the aid by subscription, which they might reasonably reckon upon, from several of the members, thought the Institution might, independently of the other societies, procure a suitable building for their own purposes, and perhaps be able to accommodate some of the other societies as tenants. At a special general meeting of the Institution, held on the 23d May last, a motion was brought forward to empower the Building Committee, previously appointed by the Institution, to lease or purchase suitable premises for the accommodation of the Institution, and to raise subscriptions for that purpose. There being, however, a small attendance at the meeting, it was thought unwise to press the motion to a decision, and the matter now rests in that position.

The Council still think that it is practicable for the Institution to procure a building such as has been contemplated, and that in all probability other societies would take advantage of such accommodation as we could offer them.

In making choice of a building for the purposes of the Institution, it appears to the Council that due regard should be had to the following points:—

First. That the building should be suitable for holding meetings, and have library and reading-rooms, &c., and be situated to the west of Buchanan Street.

Second. That it would be important that the building should not be far removed from the business centre of the town, so that the rooms might be used as a place of call for members of the Institution. This is thought very desirable considering the large numbers of non-resident members to whom such a convenience would be a great boon.

The Council, however, desire in this important matter to have the advice and support of all interested.

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The President delivered his Inaugural Address.

A Paper "On an Improved Overhead Traversing Crane, Worked by Power," by Mr. WM. SMITH, Eglinton Engine Works, was read. A discussion followed, and was terminated.

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The SECOND GENERAL MEETING of the Institution was held in the Hall, 204 George Street, Glasgow, on Wednesday, the 28th November, 1866, at Eight o'clock P.M.,—Mr. J. G. LAWRIE, President, in the chair.

The Minutes of previous Meeting were read, approved of, and signed by the Chairman.

The following candidates for admission to the Institution were elected:—

AS MEMBERS.

Mr. M'TAGGART COWAN, 36 Fort Street, Ayr.

Mr. JAMES STIRLING, Glasgow and South-Western Railway, Kilmarnock.

Mr. JOSEPH RUSSELL, Shipbuilder, Port-Glasgow.

A Paper "On the Comparative Merits of Lloyd's Rules and the Liverpool Underwriters' Rules for the Construction and Classification of Iron Ships," by Mr. JOHN PRICE, Sunderland, was read. The discussion was adjourned till the ordinary General Meeting in January.

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The THIRD GENERAL MEETING of the Institution was held in the Hall, 204 George Street, Glasgow, on Wednesday, the 26th December, 1866, at Eight o'clock P.M.,—Mr. J. G. LAWRIE, President, in the chair.

The Minutes of previous Meeting were read, approved of, and signed by the Chairman.

The following candidates for admission to the Institution were elected:—

AS MEMBERS.

Mr. JAMES B. HANDYSIDE, 92 West Regent Street.
Mr. DANIEL RANKIN, Eagle Foundry, Greenock.
Mr. EDWARD BLACKMORE, Eagle Foundry, Greenock.
Mr. WM. PEARCE, Albert Cottage, Govan.
Mr. JAMES L. CUNLIFF, 8 Walmer Crescent.
Mr. JOHN L. K. JAMIESON, 180 West Regent Street.

AS AN ASSOCIATE.

Mr. JOHN WHYTE, Prince Consort Place, Leith.

AS GRADUATES.

Mr. JAMES HAMILTON, Junr., Royal Crescent.
Mr. JAMES GILCHRIST, 11 Sandyford Place.

A Paper "On the Employment of Steel in Shipbuilding and Marine Engineering," by Mr. George Barber, was read; a discussion followed, and was terminated.

Part I. of a Paper "On Railway Carriages," by Mr. John Page, C.E., was read; a discussion followed, and was adjourned till the reading of Part II. of the Paper.

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The Fourth General Meeting of the Institution was held in the Hall, 204 George Street, Glasgow, on Wednesday, the 30th January, 1867, at Eight o'clock p.m.,—Mr. J. G. Lawrie, President, in the chair.

The Minutes of previous Meeting were read, approved of, and signed by the Chairman.

The following candidates for admission to the Institution were elected:—

AS MEMBERS.

Mr. Duncan Stewart, London Road, Mile-End.
Mr. Albert Castel, 27 Florence Place.

AS A GRADUATE.

Mr. John Savery Carey, 175 Hope Street.

Mr. R. Bruce Bell moved that the Institution should vote a further sum of £25, to be expended in the purchase of books, &c., for the Library. Mr. T. Davison, seconded the motion, which was unanimously agreed to.

The PRESIDENT intimated that the Council proposed that the Institution should hold a Conversazione in the Queen's Rooms, on Friday, the 22nd March next. The meeting unanimously approved of the proposal of the Council.

The adjourned discussion on Mr. PRICE'S Paper "On the Comparative Merits of Lloyd's Rules and the Liverpool Underwriters' Rules for the Construction and Classification of Iron Ships," was resumed and terminated.

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The FIFTH GENERAL MEETING of the Institution was held in the Hall, 204 George Street, Glasgow, on Wednesday, the 27th February, 1867, at Eight o'clock P.M.,—Mr. J. G. LAWRIE, President, in the chair.

The Minutes of previous Meeting were read, approved of, and signed by the Chairman.

The following candidates for admission to the Institution were elected:—

AS MEMBERS.

Mr. ALEXANDER M'KINLAY, Custom House.
Mr. WILLIAM WILSON, 349 Eglinton Street.
Mr. JAMES M'CALLUM, 49 Anderston Quay.
Mr. JOHN F. F. COMMON, Royal Exchange Area.

It was moved by Mr. R. M. COSTELLOE, seconded by Mr. T. DAVISON, and unanimously agreed, that a Committee be appointed to draw up a

Report, and memorialize the Board of Trade in reference to the Bill about to be introduced to Parliament to Amend the Merchant Shipping Act, 1854. The following were appointed Members of Committee:—Messrs. J. G. Lawrie, Geo. Smith, jun., James Allan, John Ferguson, R. Duncan, R. Mansel, R. M. Costelloe, A. Gilchrist, D. Rowan, W. Simons. Mr. Lawrie, convener.

Professor Sir Wm. Thomson delivered a lecture "On the Rate of a Clock or Chronometer, as influenced by the mode of Suspension." The arguments were throughout supported by convincing experiments on chronometers, clocks, and watches.

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The Sixth General Meeting of the Institution was held in the Hall, 204 George Street, Glasgow, on Wednesday, the 27th March, 1867, at Eight o'clock p.m.,—Mr. J. G. Lawrie, President, in the chair.

The Minutes of previous Meeting were read, approved of, and signed by the Chairman.

Mr. James M. Blair, Clydesdale Iron Works, was elected as a Member.

The thanks of the Institution were voted to Mr. C. Randolph, for his valuable donation of books to the Library. *(See Page 265.)*

Messrs. Wm. Ramsay and Alex. Smith were appointed Auditors, to audit the accounts for the current Session.

The President, referring to the death of Mr. William Tod, said—

Since we last met in this place we have to lament the loss of a prominent member of this Institution, Mr. William Tod; the son of a distinguished father of whom this Institution—of whom the city of Glasgow, and indeed the whole kingdom, was justly proud, proved to be a successor not unworthy of his father, the late Mr. David Tod. Such men in this country, and in this age of science and mechanics, are those to whom the material progress of the time is directly due, and who reap that reward of respect which they truly earn and as sincerely receive. In every part of the globe, and on every sea, the mechanical triumphs of the Messrs. Tod are found. Wherever steam navigation is used, the name Tod and M'Gregor is there, familiarly known and as highly valued.

The late Mr. William Tod displayed, at an early age, a promptitude for mechanical pursuits, and was placed as an apprentice in the large works of his father, where he was diligently trained during the usual period of apprenticeship. Having acquired a knowledge of his business, and after having been engaged in the design and construction of various minor works, he was associated with a well-known member of this Institution, Mr. Archibald Gilchrist, in designing and constructing the machinery for the *Simla*, a screw-steamer built for the Peninsular and Oriental Steam Navigation Company; and he acquitted himself most creditably in the duty assigned to him in that work. That vessel, the *Simla*, has proved to be one of the most successful that has ever been built, either before or since, and yet holds an unsurpassed reputation in the numerous fleet of the great company to which she belongs. Mr. Tod was ever open to improvement, whether designed by himself or others. He introduced various improvements of his own in the adaptation of the Marine Steam Engine to the Screw-propeller; and designed a form of machinery for Gun-boats of singular compactness and simplicity, and which proved to be very efficient and economical, while at the same time sufficiently below the water line to be protected from shot. Mr. Tod has the credit also of being one of the first Engineers in the country in later times, to appreciate the advantages of surface condensation, and in consequence was the first to use in this country Sewell's construction of surface-condensers. Surface condensation, in which Mr. William Tod has thus had an early and prominent share, promises to be scarcely less important in steam navigation than the screw-propeller, which Mr. David Tod, his father, was substantially the first to put in practice for sea-going ships; and to place it in the high estimation of those interested in steam navigation, which it has ever since maintained. The name of the Messrs. Tod will ever be associated with the success of the Peninsular and Oriental fleet, with the Inman fleet, and other prominent lines of steamers; but Mr. William Tod did not confine himself to his mechanical avocations. In Photography he was well known to be a proficient student, and latterly he had devoted much of his attention, in conjunction with his eminent friend, Professor Grant, of the University, to the construction of an Observatory for astronomical purposes, on his estate of Ayton, where he spent much of his time in the retirement of a country gentleman.

Mr. Tod's amiable character, his unpretending demeanour, and his generous nature, endeared him to a large circle of friends, who will unite with us most sincerely in lamenting his early death, and the great loss we have suffered.

Part II. of Mr. PAGE's Paper on Railway Carriages was held as read; a discussion followed and was terminated.

A Paper "On an Improved Steam Ferry Boat for Carriage and Passenger Traffic," by Mr. JULIUS DREWSEN, was read; a discussion followed and was terminated. A model of the boat was exhibited.

A Paper on an Improved Steering Apparatus, by Mr. JAS. SKINNER, was read; a discussion followed and was terminated. A model of the apparatus was exhibited.

Mr. R. D. NAPIER exhibited Models of his Patent Frictional Windlass and Clutch, and explained their action to the Meeting.

The SEVENTH GENERAL MEETING was held in the Hall, 204 George Street, on Wednesday, the 10th April, 1867, at Eight o'clock P.M.,—Mr. J. G. LAWRIE, President, in the chair.

A Paper "On the Theory and Practice of the Slide Valve," by Mr. THOMAS ADAMS, was read; a discussion followed and was terminated.

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The ANNUAL GENERAL MEETING of the Institution was held in the Hall, 204 George Street, on Wednesday, the 24th April, 1867, at Eight o'clock P.M.,—Mr. J. G. LAWRIE, President, in the chair.

The Minutes of Meetings of 27th March and 10th April were read approved of, and signed by the Chairman.

The following candidates for admission to the Institution were elected members:—

Mr. T. R. OSWALD, Shipbuilder, Pallion, Sunderland.

Mr. THOMAS ADAMS, Mechanical Engineer, 5 Duke Street, Adelphi, London, W.C.

Mr. ALFRED WHEATLY, Mechanical Engineer, North British Railway, Edinburgh.

The Librarian read his report on the condition of the Library.

The Treasurer presented his Annual Financial Statement, duly certified by the Auditors as correct, which was adopted.

The Election of Office-Bearers for the Eleventh Session then took place.

Mr. J. M. GALE, C.E., was elected President; Mr. WM. SIMONS, Vice-President; Messrs. J. G. LAWRIE, D. ROWAN, E. HUNT, H. H. MACLURE, and T. A. MATHIESON, Councillors. Mr. JAMES HAMILTON was elected Treasurer.

The Office-Bearers for the Eleventh Session will be as follows:—

PRESIDENT.

JAMES M. GALE.

VICE-PRESIDENTS.

W. SIMONS. | W. M. NEILSON. | PROFESSOR W. J. M. RANKINE.

COUNCILLORS.

| | |
|---|---|
| J. G. LAWRIE. | A. INGLIS. |
| D. ROWAN. | J. BROWNLEE. |
| E. HUNT. | JAS. R. NAPIER. |
| H. H. MACLURE. | A. GILCHRIST. |
| T. A. MATHIESON. | JOHN FERGUSON. |

TREASURER.

JAMES HAMILTON, STOBCROSS DOCKYARD.

SECRETARY.

J. P. SMITH, 67 RENFIELD STREET.

The Institution Medal for Papers read Session 1865-66 was awarded to Mr. JAMES ROBERTSON, for his Paper on Frictional Screw Motions and Applications.

The Marine Engineering Medal was awarded to Mr. N. BARNABY, for his Paper on the Connection of Iron and Steel Plates in Shipbuilding.

A Paper, by Mr. THOS. HOEY, "On a Mode of Collecting, Removing, and Applying Town Sewage, and the Saving of Water," was, by the permission of the meeting, held as read. Mr. HOEY explained his plan. A discussion followed and was terminated.

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The NINTH GENERAL MEETING of the Institution was held in the Hall, 204 George Street, Glasgow, on Wednesday, the 8th May, 1867, at Eight o'clock, P.M.—Mr. J. G. Lawrie, President, in the chair.

The Minutes of previous meeting were read, approved of, and signed by the Chairman.

Mr. Thomas Hoey, 84 Buccleuch Street, was elected a Member.

A Paper "On a System of Utilizing Sewage, and Preventing the Pollution of Rivers," by Mr. David Allan Graham, C.E., was read. A discussion followed, and was terminated.

A Paper "On the Comparative Strengths of Long and Short Struts," by Mr. James M'Callum, C.E., was read. A discussion followed and was terminated.

Mr. James R. Napier read a paper on his "Indicator for ascertaining the Speed of Ships," and submitted a report of experiments with it, by Mr. Fleming Jenkin, C.E.

# Dr. TREASURER'S STATEMENT—SESSION 1866-1867. Cr.

**Dr.**

| | | | | | |
|---|---|---|---|---|---|
| 1866. | | | | | |
| | To Balance in Union Bank, | | | | £356 15 4 |
| April, 1866, to April, 1867. | To Subscriptions— | | | | |
| | From 98 Members, | @ 30s., | £147 0 0 | | |
| | „ 6 New do., | @ 50s., | 15 0 0 | | |
| | „ 7 „ do., | @ 40s., | 14 0 0 | | |
| | „ 1 „ do., | @ 30s., | 1 10 0 | | |
| | „ 15 Associates, | @ 20s., | 15 0 0 | | |
| | „ 6 Graduates, | @ 15s., | 4 10 0 | | |
| | „ 1 New do., | @ 20s., | 1 0 0 | | |
| | „ 1 „ do., | @ 15s., | 0 15 0 | | |
| | | | | | £198 15 0 |
| | To Arrears of Subscriptions— | | | | |
| | From 1 Member, | 1863-66, | £4 10 0 | | |
| | „ 10 „ | 1864-66, | 30 0 0 | | |
| | „ 68 „ | 1865-66, | 102 0 0 | | |
| | „ 2 New do., | 1865-66, | 5 0 0 | | |
| | „ 38 Associates, | 1865-66, | 38 0 0 | | |
| | „ 4 New do., | 1865-66, | 6 0 0 | | |
| | | | | | 185 10 0 |
| August 31. | „ Dividend on Preference Stock, London & North-Western Railway, | | | 7 14 9 | |
| 1867. March 2. | „ Do., do., | | | 7 15 0 | |
| | | | | | 15 9 9 |
| | „ Sales of Transactions, | | | | 3 5 6 |
| | | | | | £759 15 7 |

**Cr.**

| | | | |
|---|---|---|---|
| 1866. March, 1866, to March, 1867. | By One Year's Salary to Secretary, | | £100 0 0 |
| June 30. | „ Librarian and Janitor, for Session 1865-66, | £6 10 3 | |
| July 17. | „ Under Janitor, | 1 0 0 | |
| August 1. | „ Rent of Hall, | 15 0 0 | |
| 1867. January 3. | „ Insurance on Books, | 0 7 0 | |
| April 19. | „ Librarian and Janitor, | 5 0 0 | |
| | | | 27 17 3 |
| 1867. August 1. | „ Robert Arthur, engraver, | 0 18 0 | |
| December 17. | „ Reporter attending 10 meetings, | 12 1 6 | |
| | „ Porterage and Postage, delivering Transactions, Session 1865-66, | 7 10 0 | |
| 1867. January, | „ Bell & Bain, printers, | 0 4 6 | |
| January 23. | „ Carriage and Porterage of Books to Library, | 0 4 0 | |
| March 2. | „ Jas. Cairns & Co., stationers, | 6 1 6 | |
| „ 2. | „ William Munro, printer, | 139 8 0 | |
| „ 2. | „ Gardner & Stevenson, | 61 5 0 | |
| | | | 227 12 6 |
| 1866. July 20. | „ J. Smith & Son, Books, &c., | 5 7 0 | |
| December 17. | „ A. Reid, for Vols. XII. and XIII. of the Trans. of N. of E. I. of Mining Engineers, | 2 3 6 | |
| 1867. March 1. | „ Mrs. T. Neil, bookbinder, | 8 12 0 | |
| „ 8. | „ J. Smith & Son, books, &c., | 3 8 0 | |
| „ 21. | „ Jas. MacLehose, for Stoney on Iron Girders, | 0 15 0 | |
| April 4. | „ E. & F. N. Spon, for books, | 1 18 0 | |
| „ | „ Bernard Quaritch, | 13 13 0 | |
| „ | „ Thos. Martin, bookbinder, | 10 1 0 | |
| „ | „ William Mackenzie, for "Shipbuilder," 2 vols., | 6 0 0 | |
| „ | „ Williams & Norgate, for books, | 0 19 6 | |
| | | | 52 17 0 |
| April, 1866, to April, 1867, | „ Postage Stamps, Porterage, Carriage, &c., | | 81 13 0 |
| | „ Commission on Collecting Arrears, | | 8 10 0 |
| | „ Balance in Union Bank, | | 311 5 10 |
| | | | £759 15 7 |

Glasgow, 20*th April*, 1867.—We have examined the foregoing Statement, and compared it with the relative Vouchers, and find the whole correct. The balance in the Union Bank being Three hundred and Eleven pounds Five shillings and Tenpence.

(Signed) ALEX. SMITH, WM. RAMSAY, } *Auditors.*

## PRIZE MEDAL FUND.

Cr. | | | | | | | | | Dr.

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 1866. April 11. | To Balance in Union Bank, | £36 | 2 | 5 | 1867. April 20. | By Balance in Union Bank, | £50 | 2 | 8 |
| Aug. 31. | „ Dividend on Preference Shares London & North-Western Railway, | 7 | 0 | 3 | | | | | |
| 1867. March 2. | „ Do. do., | 7 | 0 | 0 | | | | | |
| | | £50 | 2 | 8 | | | £50 | 2 | 8 |

Glasgow, 20*th April*, 1867.—We have examined the foregoing Statement relative to the Prize Medal Fund, compared it with the Vouchers, and find the same correct. The Balance in Union Bank being Fifty pounds Two shillings and Eightpence.

(Signed) ALEX. SMITH, WM. RAMSAY, } *Auditors.*

## CAPITAL ACCOUNT.

### General Fund.

| | £ | s. | d. |
|---|---|---|---|
| London and North-Western Railway Preference Shares, | £363 | 13 | 5 |
| Cash in Union Bank, | 311 | 5 | 10 |
| | £674 | 19 | 3 |

### Prize Medal Fund.

| | £ | s. | d. |
|---|---|---|---|
| London and North-Western Railway Preference Stock, | £330 | 0 | 0 |
| Cash in Union Bank, | 50 | 2 | 8 |
| | £380 | 2 | 8 |

# LIST OF DONATIONS OF BOOKS, &c.

## RECEIVED DURING THE RECESS.

Proceedings of the Institution of Mechanical Engineers:—Meetings held 1st and 2nd August, Parts 2 and 3, and 2nd November, 1865. From the Institution.

Transactions of the Society of Engineers, 1865. From the Society.

Report to the Special Committee on the Traffic and Improvements in the Public Ways of the City of London. By William Haywood, C.E., 1866. Published by M. Lownds, 148½ Fenchurch Street, E.C., London. From the Author.

On Technological Education and Shipbuilding for Naval and Marine Engineers. By John W. Nystrom, 1865. Published by Henry Carey Baird, 406 Walnut Street, Philadelphia, U.S. From the Author.

On Recent Measures at the Great Pyramid. By Professor C. Piazzi Smyth, F.R.S.E., 1866. Published by the Royal Society of Edinburgh. From the Author.

Minutes of Proceedings of the Institution of Civil Engineers, Vols. 22 and 23. From the Institution, 1862 and 1863.

Library Catalogue of the Institution of Civil Engineers, 1866. From the Institution.

Report of the Mercantile Marine Service Association, Meetings held 13th January, and 30th June, 1865. From the Association.

On the Strength of Cast Iron Pillars, with Tables. By James B. Francis, C.E., 1865. Published by D. Van Nostrand, 192 Broadway, New York. From the Author.

From W. J. M. Rankine, C.E., LL.D.

The following Papers, being communications to various Societies and Periodicals by Professor Rankine, have been presented by him to the Institution:—

On Finding the most economical rates of expansion in Steam Engines.

On the Mechanical Principles of the action of Propellers.

On the Principle of Isorthopic Axes in Statics.

On Heat as the Equivalent of Work.

On some simultaneous observations of Rain-Fall at different points of the same Mountain Range.

On the Elasticity of Carbonic Acid Gas.

On the History of Energetics.

On the Application of Barycentric Perspective to the Transformation of Structures, and on the Expansive Energy of Heated Water.

Abstract of an Investigation on Plane Water Lines.

Abstract of a Paper on the General Law of the Transformation of Energy.

On the Means of Realizing the advantages of the Air Engine.

On the exact Form and Motion of Waves at and near the Surface of Deep Water.

On the Hypothesis of Molecular Vortices, or Centrifugal Theory of Elasticity, and its connection with the Theory of Heat.

On the Dynamical Theory of Heat.

On the Absolute Zero of the Perfect Gas Thermometer, being a note to a Paper on the Mechanical Action of Heat.

On the Mechanical Action of Heat, Section 6.

A review of the Fundamental Principles of the Mechanical Theory of Heat; with remarks on the Thermic Phenomena of Currents of Elastic Fluids, as illustrating those Principles.

Experimental Inquiry on the use of Cylindrical Wheels on Railways, &c.

Note as to Two Events in the History of Steam Navigation.

Note to a Letter on the Conservation of Energy.

Summary of the Properties of Certain Stream Lines.

On the exact Form of Waves near the Surface of Deep Water.

On Axes of Elasticity and Crystalline Forms.

On the Stability of Loose Earth.

On the Mechanical Action of Heat, Note on the Absolute Zero of the Perfect Gas Thermometer, Section 6.

On the Thermodynamic Theory of Steam-Engines with dry saturated Steam, and its application to practice.

Supplement to Paper "On the Thermodynamic Theory of Steam-Engines with dry saturated Steam, and its application to practice.

On a Balanced Rudder for Screw Steamers.

From Mr. John Elder.

Wood Cuts illustrating the Memoir of the late Mr. David Elder. By Mr. Jas. R. Napier.—Vol. IX. of Transactions.

Photographs of the late Mr. David Elder. Frontispiece Vol. IX.

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RECEIVED DURING SESSION 1866-67.

Proceedings of the Institution of Mechanical Engineers, 2 Parts. Meetings held 25th January, and 3rd May, 1866. From the Institution.

Proceedings of the Institution of Mechanical Engineers. Meetings, held 31st July, and 1st August, 1866, Part I. From the Institution.

Proceedings of the Institution of Mechanical Engineers, Part II. Meetings held 31st July, and 1st August, 1866. From the Institution.

Proceedings of the Institution of Mechanical Engineers, Part III. Meetings held 31st July, and 1st August, 1866. From the Institution.

Proceedings of the Birkenhead Literary and Scientific Society, 3 Vols., Sessions 7, 8, and 9, 1863-64, 1864-65, 1865-66. From the Society.

Proceedings of the Institution of Civil Engineers, Vols. 24 and 25, 1864-65, 1865-66. From the Institution.

Report of the Smithsonian Institution, Washington, U.S., 1864. From the Institution.

Two Vols. Transactions of the Society of Engineers. London: Vol. 1, 1860-61-62; Vol. 2, 1863. From the Society.

Transactions of the Royal Scottish Society of Arts, Edinburgh. Part II., Vol. VII. From the Society.

Journal of the Liverpool Polytechnic Society. Meeting held 11th March, 1867. From the Society.

Transactions of the Institution of Naval Architects, Volumes I. to VII., Sessions 1860-61-62-63-64-65-66. From the Institution.

Useful Information for Engineers. By Wm. Fairbairn, C.E., LL.D., &c., Hon. Member of the Institution. From the Author. Publishers —Messrs. Longmans, Green & Co., London, 1866.

Die Potentialfunction und das Potential. By Professor R. Clausius, Zurich, Switzerland, Hon. Member of the Institution, 1867. From the Author.

Account of Experiments on the Flexural and Torsional Rigidity of a Glass Rod leading to the Determination of the Rigidity of Glass. By J. D. Everett, D.C.L., 1866. From the Author; read before the Royal Society.

Reduction of the Observations of the Deep-sunk Thermometers at the Royal Observatory, Greenwich, from 1846 to 1859. By J. D. Everett, D.C.L. From the Author. Extracted from the Greenwich Observations, 1860.

On the Velocity of Steam and other Gases, and the true principles of the Discharge of Fluids. By R. D. Napier, Liverpool, from the Author. Publishers, E. & F. N. Spon, London; 1866.

On the Sewage of Glasgow and Neighbourhood, by Hugh H. Maclure, C.E., from the Author. Pamphlet, 1867.

From George Barber, Esq.,

Photograph of the "*Samphire*," after collision.

From Professor Rankine.

"Note on Mr. Merrifield's New Method of Calculating the Statical Stability of a Ship." By W. J. Macquorn Rankine, C.E., LL.D., F.R.S.

On the phrase "Potential Energy," and on the Definitions of Physical Quantities. By Professor W. J. Macquorn Rankine, C.E., LL.D., F.R.SS.L. and E., &c. Read before the Philosophical Society of Glasgow, 1867.

From Robert Dalglish, Esq., M.P., Glasgow.

Report from the Select Committee on the Thames Embankment Bill: 1862.

Report from the Select Committee on the Sydney Branch Mint: 1862.

Amended Report to the Lords Commissioners of the Admiralty by the Committee on Marine Engines, with replies by the Surveyor of the Navy: 1860.

Report to the Secretary of State for India in Council on the Railways in India, for the year 1861-62. By Juland Danvers, Esq., Government Director of the Indian Railway Companies: 1862.

Report to the Secretary of State for India in Council on the Railways in India, for the year 1862-63. By Juland Danvers, Esq.: 1863.

Report from the Select Committee on Ordnance: 1862.

Report of the Progress of the Ordnance Survey and Topographical Depot to the 31st December, 1862. Published 1863.

Report of the Ordnance Survey of the United Kingdom for 1865-66 Published 1867.

Return to an Address of the Honourable The House of Commons 1826, on the East India (European) Troops: 1862.

General Report of the Commission appointed for Improving the Sanitary Condition of Barracks and Hospitals: 1861.

Report of a Committee appointed by the Secretary of State for War to consider and report as to measures that should be adopted in order to simplify and improve the system under which all Works and Buildings (other than Fortifications) connected with the War Department are constructed, repaired, and maintained, in order to give a more direct responsibility to the persons employed in these duties: 1862.

Report of the Joint Committee appointed by the Lords of the Committee of Privy Council for Trade and the Atlantic Telegraph Company, to Inquire into the Construction of Submarine Telegraph Cables: 1861.

Report of the Commission appointed to consider plans for making a communication between the Embankment at Blackfriars' Bridge, and the Mansion House, and also between the Embankment at Westminster Bridge and the Embankment at Millbank: 1863.

From Professor C. PIAZZI SMYTH, F.R.SS.L. & E. &c., Astronomer-Royal for Scotland, Honorary Member of the Institution.

Photographs of the Great Pyramid. Pamphlet.

Montreal and Pictou Coal Company. Pamphlet, with Map.

Life and Work at the Great Pyramid, during the months of January, February, March, and April, A.D. 1865; with a discussion of the facts ascertained, by Professor C. Piazzi Smyth, F.R.SS.L. and E. &c., Astronomer-Royal for Scotland. Three Volumes, with illustrations on stone and wood, 1867.

From W. M. NEILSON, Esq.

Engineering Plans by F. Passavant and A. Becher. On Locomotive and Marine Engineering. 2 Vols., Letterpress and Plates.

Three Volumes, Dictionaire des Arts et Manufactures; De L'Agriculture, des Mines, &c. Description des Proceeds, de L'Industre Francaise et Etrangere, par M. C. Laboulaye, Paris, 1861. Vol. I., A to F; Vol. II., G. to Z.; Vol. III., Complément.

From Charles Randolph, Esq.

Set of the Cavendish Society's Publications, viz :—

Chemical Reports and Memoirs, on Atomic Volume; Isomorphism: Endosmosis; The Simultaneous Contrast of Colours; The Latent Heat of Steam at different Pressures; The artificial formation of Alkaloids, and Volcanic Phenomena; Edited by Thomas Graham, V.P. R.S., 1848.

Hand-Book of Chemistry; by Leopold Gmelin. Translated by Henry Watts, B.A., F.C.S; 15 Vols, viz:—

Vol. I. 1848. Cohesion, Adhesion, Affinity, Light, Heat, and Electricity.

Vol. II. 1849. Non-Metallic Elements.

Vol. III. 1849. Metals.

Vol. IV. 1850. Metals (continued).

Vol. V. 1851. Metals (continued).

Vol. VI. 1851. Metals (concluded).

Vol. VII. 1852. Organic Chemistry. Generalities of Organic Chemistry. Organic compounds containing two Atoms of Carbon.

Vol: VIII. 1853. Organic Chemistry. Organic compounds containing two and four Atoms of Carbon.

Vol. IX. 1855. Organic Chemistry. Organic compounds containing four and six Atoms of Carbon.

Vol. X. 1856. Organic Chemistry. Organic compounds containing eight and ten Atoms of Carbon.

Vol. XI. 1857. Organic Chemistry. Organic compounds containing ten and twelve Atoms of Carbon.

Vol. XII. 1858. Organic Chemistry. Organic compounds containing fourteen Atoms of Carbon.

Vol. XIII. 1859. Organic Chemistry. Organic compounds containing sixteen and eighteen Atoms of Carbon.

Vol. XIV. 1860. Organic Chemistry. Organic compounds containing twenty and twenty-two Atoms of Carbon.

Vol. XV. 1862. Organic Chemistry. Organic compounds containing twenty-four Atoms of Carbon.

Vol. XVI. 1864. Organic Chemistry. Organic compounds containing from twenty-four to thirty-four Atoms of Carbon.

Vol. XVII. 1866. Organic Chemistry. Organic compounds containing from thirty-four to forty-six Atoms of Carbon.

Chemical Method, Notation, Classification, and Nomenclature: by Auguste Laurent: Translated by William Odling, M.B., F.C.S., 1854.

Life of the Honourable Henry Cavendish, including abstracts of his more important Scientific Papers, and a critical inquiry into the claims of all the alleged discoveries of the Composition of Water; by George Wilson, M.D., F.R.S.E., 1851.

Memoirs of the Life and Scientific Researches of John Dalton: by William Charles Henry, M.D., F.R.S., 1854.

Physiological Chemistry, by Professor C. G. Lehmann: Translated from the second edition by George E. Day, M.D., F.R.S: 3 Volumes, 1851, 1852, 1854.

From J. P. Joule, LL.D.

The following Papers, being communications to various Societies and Periodicals by J. P. Joule, LL.D., F.R.S., &c., Honorary Member of the Institution, have been presented by him to the Institution.

On the Mechanical Equivalent of Heat: read before the Philosophical Society, 1849.

On the Thermal Effects of Fluids in Motion, Parts I., II., III., and IV.: read before ditto, 1853-54, 1860-62.

Introductory Research on the Induction of Magnetism, by Electrical Currents: read before ditto, 1855.

On some Thermo-Dynamic Properties of Solids: read before ditto, 1858.

On the Thermal Effects of compressing Fluids: read before ditto 1858.

On the Surface Condensation of Steam: read before ditto, 1860.

Notes on the late William Sturgeon, Esq., from the Manchester Courier, December 14, 1850.

Apparatus for Refrigerating and Condensing Steam, &c.

Account of Experiments Demonstrating a limit to the Magnetizability of Iron: from the Philosophical Magazine, 1851.

On the Effects of Magnetism upon the Dimensions of Iron and Steel Bars: from the Philosophical Magazine.

On Voltaic Apparatus: read before the London Electrical Society, March, 1842.

On the Existence of an Equivalent Relation between Heat and the ordinary forms of Mechanical Power, from the Philosophical Magazine, 1845.

Researches on Atomic Volume and Specific Gravity: from the Philosophical Magazine, 1846

On the Theoretical Velocity of Sound: from the Philosophical Magazine, 1847.

On a new method for ascertaining the Specific Heat of Bodies: read before the Literary and Philosophical Society of Manchester, December, 1845.

Note on the Employment of Electrical Currents for ascertaining the Specific Heat of Bodies: read before ditto, July, 1847.

Some Remarks on Heat, and the Constitution of Elastic Fluids: read before the Literary and Philosophical Society of Manchester, October, 1848.

Account of Experiments with a powerful Electro-Magnet: from the Philosophical Magazine, 1852.

On Heat disengaged in Chemical Combinations: from ditto, 1842.

On the Fusion of Metals by Voltaic Electricity: read before the Literary and Philosophical Society of Manchester, March, 1856.

On the Heat absorbed in Chemical Decomposition: from the Philosophical Magazine, August and October, 1856.

On some Peculiarities of the Thunderstorm, which occurred in this neighbourhood (Manchester) on Tuesday, the 1(th July last: by the late William Sturgeon. 1856.

On Lightning and Lightning Conductors: by the late W. Sturgeon.

A Short Account of the Life and Writings of the late Wm. Sturgeon: read before the Literary and Philosophical Society of Manchester, October, 1856.

On a Surface Condenser: read before a meeting of the Institution of Mechanical Engineers, held at Glasgow, 17th September, 1856.

On the Thermal Effects of Fluids in motion; temperature of a body moving slowly through the air: read before the Royal Society, June, 1857.

On the Thermal Effects of Longitudinal Compression of Solids: read before ditto, June, 1857.

Note on Dalton's Determination of the Expansion of Air by Heat: read before the Literary and Philosophical Society of Manchester, November, 1858.

On the Utilization of the Sewage of London and other large towns: read before the Lit. & Phil, Society of Manchester, November, 1858.

On a Method of Testing the Strength of Steam Boilers; read before ditto, 1859.

Experiments on the Total Heat of Steam: read before ditto, 1859.

Experiments on the Passage of Air through Pipes, and apertures in thin plates: read before ditto, 1860.

On the Plurality of Inhabited Worlds: read before the Birkenhead Literary and Scientific Society, November, 1860.

On some Amalgams: reprinted from the Journal of the Chemical Society, July, 1862.

On the Probable Cause of Electric Storms.

Note on the History of the Dynamical Theory of Heat: from the Philosophical Magazine, August, 1862.

On the Dynamical Theory of Heat: from ditto, 1863.

On the Mechanical Equivalent of Heat: read before the British Association, 1863.

On a peculiar kind of Mirage, January, 1863.

Note on the Meteor of February 6th, 1818: read before the Philosophical Society, 1863.

On a new and extremely sensitive Thermometer, March, 1863.

Note on the History of the Dynamical Theory of Heat: from the Philosophical Magazine, 1864.

On Magnetic Needles: read before the Literary and Philosophical Society, November, 1864.

On some Facts in the Science of Heat developed since the time of Watt: read before the Greenock Philosophical Society, January, 1865.

On an Instrument for showing rapidly minute changes of Magnetic Declination: read before the Lit. & Phil. Society, January, 1865.

On a Balance after Professor Thomson's principle: read before ditto, 1866.

On an Apparatus for determining the Horizontal Magnetic Intensity in Absolute Measure: read before ditto, March, 1867.

Note on the Tangent Galvanometer: read before ditto, 1867.

From Sir WILLIAM THOMSON.

The following Papers, being communications to various Societies and Periodicals by Professor Sir WM. THOMSON, Honorary Member of the Institution, have been presented by him to the Institution.

On the Electro-dynamic Qualities of Metals: read before the Royal Society, 1856.

Elements of a Mathematical Theory of Elasticity: read before the Royal Society, 1856.

On the Thermal Effects of Fluids in Motion, parts 3 and 4: read before the Royal Society, 1860.

On the Secular Cooling of the Earth: read before the Royal Society of Edinburgh, 1862.

On the Rigidity of the Earth and Dynamical Problems regarding Elastic Spheroidal Shells and Spheroids of Incompressible Liquid: read before the Royal Society, 1862.

On the Dynamical Theory of Heat: read before the Royal Society of Edinburgh, 1854.

On the Equations of the Motions of Heat Referred to Curvilenear Co-ordinates: Cambridge and Dublin Mathematical Journal, 1843.

On the Principal Axes of a Solid Body, Do., 1846

On a Mechanical Representation of Electric, Magnetic, and Galvanic Forces, Do., 1847.

On Certain Definite Integrals suggested by Problems in the Theory of Electricity, Do., 1847.

Notes on Hydrodynamics, Do., 1847.

Theorems with Reference to the Solution of Certain Partial Differential Equations, Do., 1848.

On the Mathematical Theory of Electricity in Equilibrium, Do.

On the Effect of Pressure in lowering the Freezing Point of Water experimentally demonstrated: read before the Royal Society of Edinburgh, 1850.

On the Theory of Magnetic Induction in Chrystalline and Non-Chrystalline Substances. The Philosophical Magazine, 1851.

On the Mechanical Theory of Electrolysis, Do., 1851.

Applications of the Principle of Mechanical Effect to the Measurement of Electro-Motive Forces, and of Galvanic Resistances, in Absolute Units: Do., 1851.

On the Quantities of Mechanical Energy contained in a Fluid Mass, in different states as to Temperature and Density; and On a Mechanical Theory of Thermo-Electric Currents: read before the Royal Society, 1852.

On the Mechanical action of Radiant Heat or Light; On the Power of Animated Creatures over Matter; On the Sources available to Man for the production of Mechanical Effect: read before Do., 1852.

On the Origin and Transformation of Motive Power: read before the Royal Institution of Great Britain, 1856.

On Practical Methods for rapid Signalling by the Electric Telegraph: read before the Royal Society, 1856.

On the Electro-Dynamic Qualities of Metals; Effects of Magnetization on the Electric Conductivity of Nickel and of Iron, read before Do., 1857.

On the Electric Conductivity of Commercial Copper of various kinds, read before Do., 1857.

On Recent Investigations of M. Le Verrier, on the Motion of Mercury: read before the Philosophical Society of Glasgow, 1859.

On the Variation of the Periodic Times of the Earth and inferior Planets produced by Matter Falling into the Sun: read before Do., 1860.

Report of Committee appointed to prepare a Self-Recording Atmospheric Electrometer for Kew, and Portable Apparatus for observing Atmospheric Electricity. From the Report of the British Association for the Advancement of Science for 1860.

On the Measurement of Electric Resistance. From the Transactions of the Royal Society, 1860.

On the Convective Equilibrium of Temperature in the Atmosphere. From the Second Volume of the Third Series of "Memoirs of the Literary and Philosophical Society of Manchester." Session 1861-62.

On the Sound produced by Electric Discharge. From Ditto, 1863.

On the Protection of Vegetation from destructive Cold every Night: read before the Royal Society of Edinburgh, 1863.

On the Forces concerned in the Laying and Lifting of Deep-Sea Cables: read before Ditto, 1865.

On the Observations and Calculations required to find the Tidal Retardation of the Earth's Rotation. From the Philosophical Magazine, 1866.

On the Elasticity and Vicosity of Metals. From the Transactions of the Royal Society, 1865.

On the Thermal Effects of Fluids in Motion; Temperature of a body Moving Slowly through Air: read before Ditto, 1860.

From St. John Vincent Day, Esq.

Eight Volumes Practical Mechanic's Journal. First Series, Vol. VI., 1853-54; Vol. VIII., 1855-56. Second Series, Vol. I., 1856-1857, Vol. II., 1857-58; Vol. III., 1858-59; Vol. IV., 1859-60; Vol. V., 1860-61; Vol. IX., 1864-65.

Thirteen Parts Practical Mechanic's Journal, containing a record of the Great Exhibition of 1862; from May, 1862, to January, 1863.

The Patentee's Manual, being a Treatise on the Law and Practice of Letters Patent, especially intended for the use of Patentees and Inventors. By James Johnson and J. Henry Johnson. 1866.

Volume VII., Second Series, Practical Mechanic's Journal, from April, 1862, to March, 1863, and Vol. I., Third Series, Practical Mechanic's Journal, from April, 1865, to March, 1866.

## BOOKS PURCHASED DURING SESSION 1865-66.

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The Modern System of Naval Architecture. By J. Scott Russell. Published by Day & Son (Limited), Lincoln's Inn Fields, (W.C.) London, 1865.

Transactions of the Institution of Mining Engineers. Vols. XII. and XIII., 1862-3, 1863-4.

The Young Sea Officer's Sheet Anchor, or a key to the leading of Rigging, and to practical Seamanship. By Darcy Lever. Published by Charles Wilson, 157 Leadenhall Street, London, 1835.

The Illustrated Catalogue of the Industrial Department of the International Exhibition of 1862. 4 Vols. London, 1862.

Reports of the Juries of the Exhibition of 1851. London, 1851.

Official Descriptive & Illustrated Catalogue of the Great Exhibition of 1851. London, 1851. 4 Vols.

A Record of Modern Engineering. By William Humber, 1864. Published by Lockwood & Co., 7 Stationers' Hall Court, London.

Vicat on Cements.

Theorie Mechanique par Horn.

Lives of Boulton & Watt. By Samuel Smiles, 1865. Published by John Murray, Albemarle Street, London.

A Record of the Progress of Modern Engineering. Edited by William Humber, 1865. Published by Lockwood & Co., 7 Stationers' Hall Court, London.

A Method of comparing the Lines and Draughting vessels propelled by sail or steam, including a chapter on laying off on the mould loft floor, by Samuel M. Pook, *plates*, ro. 8vo, cloth, New York, 1866.

Marrett's (P. R.) Yachts and Yacht Building: 10 large folding plates, 8vo, cloth. Publishers, E. & F. N. Spon. London, 1865.

Rennie on Harbours.

Theory of Strains in Girders and similar Structures. By B. B. Stoney. Vol. I. London, 8vo. Publishers, Messrs. Longmans, Green & Co.

Navigation a Vapeur Transoceanienne per Eugene Flachat. 3 Vols.

Commissioners' Report on Telegraphy.

"Shipbuilding," Theoretical and Practical, By Watts, Rankine, Barnes, and Napier, Glasgow, 1866, two Vols.

# LIST

OF

# HONORARY MEMBERS, MEMBERS, ASSOCIATES, AND GRADUATES

OF THE

# INSTITUTION OF ENGINEERS IN SCOTLAND

WITH WHICH IS INCORPORATED THE

# SCOTTISH SHIPBUILDERS' ASSOCIATION,

*At the Termination of the Tenth Session, April, 1867.*

---

## HONORARY MEMBERS.

James Prescott Joule, LL.D., F.R.S., Thorncliff, Old Trafford, Manchester.

Charles Piazzi Smyth, F.R.SS.L. & E., Astronomer-Royal for Scotland, 1 Hillside Crescent, Edinburgh.

William Fairbairn, C.E., LL.D., F.R.S., F.G.S., Manchester.

Sir William Thomson, A.M., LL.D., F.R.SS.L. & E., Professor of Natural Philosophy in the University of Glasgow.

Professor R. Clausius, Zürich, Switzerland.

General Arthur Morin, Conservatoire Impérial des Arts et Mètiers á Paris.

Joseph Whitworth, C.E., Manchester.

Archibald Smith, M.A., F.R.S., Jordanhill, Glasgow.

Lewis D. B. Gordon, C.E., Château de Bossy, près Céligny, Canton de Vaud, Switzerland.

## MEMBERS.

| | | |
|---|---|---|
| Thomas | Adams, | 5 Duke Street, Adelphi, London, W.C. |
| James | Aitken, jun., | Shipbuilder, Whiteinch |
| William | Aiton, | Engineer and Contractor, Partick |
| Walter | Alexander, | 1 Avondale Place, Paisley Road, Glasgow |
| William | Alexander, | 23 India Street, Glasgow |
| Alexander | Allan, | Bridge Street, Worcester |
| James | Allan, | 70 Great Clyde Street, Glasgow |
| Thomas | Allan, | Springbank Foundry, Garscube Road, Glasgow |
| Stephen | Alley, | 17 North Claremont Street, Glasgow |
| James B. | Alliot, | The Park, Nottingham |
| Robert | Angus, | Blair Works, Dalry |
| David | Auld, | 23 Duncan Street, Calton, Glasgow |
| James | Baird, C.E., | Glengarnock Ironworks, Kilbirnie, Ayrshire |
| George | Barber, | 5 East India Avenue, London, E.C. |
| Andrew | Barclay, | Kilmarnock |
| Hugh | Bartholomew, | 122 Old Dalmarnock Road, Glasgow |
| William | Beardmore, | The Forge, Parkhead, Glasgow |
| David | Bell, | 8 Arthur Place, Govan |
| R. B. | Bell, C.E., | 203 St. Vincent Street, Glasgow |
| James | Bennie, | 69 Bath Street, Glasgow |
| Joseph | Birnie, | Shipbuilder, Montrose |
| Neil | Black, | Neptune Street, Liverpool |
| Edward | Blackmore, | Eagle Foundry, Greenock |
| Robert | Blackwood, C.E., | Kilmarnock |
| Thomas | Blackwood, | Shipbuilder, Port-Glasgow |
| James | Blair, | 18 Scotland Street, Glasgow |
| James M. | Blair, | Clydesdale Ironworks, Portman Street, Glasgow |

| | | |
|---|---|---|
| H. J. | Boolds, | Lloyd's Surveyor, Greenock |
| Walter | Brock, | At Lancefield Foundry, Glasgow |
| James | Brown, | 247 Bath Street, Glasgow |
| Andrew | Brown, | London Works, Renfrew |
| Richard | Brown, | 37 West Nile Street, Glasgow |
| James | Brownlee, | 173 St. George's Road, Glasgow |
| James C. | Bunten, | Anderston Foundry, Glasgow |
| Amedee | Buquet, C.E., | 31 Rue du Marché, Neuilly, Seine, Paris |
| Andrew | Burns, | Cessnock Road, Govan |
| | | |
| James T. | Caird, | Greenock |
| Duncan | Cameron, | 88 M'Neil Street, Glasgow |
| James | Campbell, | Messrs. M'Dowall & Co's., Johnstone |
| Peter | Carmichael, | Dens Works, Dundee |
| John | Carrick, | 5 Park Quadrant, Glasgow. |
| Robert | Cassels, | 166 St. Vincent Street, Glasgow |
| Albert | Castel, | 27 Florence Place, Glasgow |
| William | Clapperton, | Walkinshaw Foundry, Johnstone |
| Daniel K. | Clark, C.E., | 11 Adam Street, Adelphi, London |
| H. M. F. Van | Cleef, | The Hague, Holland |
| James | Clinkskill, | 3 Rose Street, Garnethill, Glasgow |
| John F. F. | Common, | Exchange Area, Glasgow |
| Charles | Connell, | 54 St. Vincent Crescent, Glasgow |
| Benjamin | Conner, | 17 Scott Street, Garnethill, Glasgow |
| Robert | Cook, | 100 Commerce Street, Glasgow |
| James | Copeland, | 16 Pultney Street, Glasgow |
| William R. | Copeland, | 97 West Regent Street, Glasgow |
| M. R. | Costelloe, | Custom House, Glasgow |
| M'Taggart | Cowan, C.E., | 36 Fort Street, Ayr |
| William | Cowan, | Great North of Scotland Railway, Aberdeen |
| Archibald | Craig, | Gateside, Paisley |
| James L. | Cunliff, | 8 Walmer Crescent, Glasgow |
| John | Cunningham, | M.E., Glengarnock Ironworks |
| Robert | Curle, | Stobcross Dockyard, Glasgow |

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|---|---|---|
| Alfred | Darling, | 75 Jamaica Street, Glasgow |
| Thomas | Davison, | 248 Bath Street, Glasgow |
| St. J. V. | Day, C.E., | 166 Buchanan Street, Glasgow |
| Peter | Denny, | Helenslee, Dumbarton |
| A. C. H. | Dekke, | Shipbuilder, Bergen, Norway |
| James | Donald, | Abbey Works, Paisley |
| John | Donald, | 42 Cadogan Street, Glasgow |
| Robert | Douglas, | Dunniker Foundry, Kirkcaldy |
| John | Downie, | 13 Clarendon Place, Glasgow |
| Julius | Drewsen, | 20 Minerva Street, Glasgow |
| Henry | Dubs, | 2 Wellesley Place, Glasgow |
| Andrew | Duncan, C.E., | 16 Robertson Street, Glasgow |
| Robert | Duncan, | Shipbuilder, Port-Glasgow |
| George B. | Edington, | 7 Buckingham Terrace, Glasgow |
| John | Elder, | 12 Centre Street, Glasgow |
| Mortimer | Evans, C.E., | 97 West Regent Street, Glasgow |
| Robert | Faulds, | 6 Parson Street, Glasgow |
| James | Ferguson, | Auchinheath, Lesmahagow |
| John | Ferguson, | Shipbuilder, Whiteinch |
| Samuel | Fernie, | Bloomsgrove Works, Nottingham |
| William | Ferrie, | Monkland Ironworks, Calderbank |
| J. R. | Forman, C.E., | 133 West Regent Street, Glasgow |
| William | Forrest, | 9 Canal Street, Glasgow |
| Robert | Forrest, jun., | Ardeer Ironworks, Stevenston, Ayrshire |
| Alexander | Fullarton, | Vulcan Works, Paisley |
| John B. | Fyfe, | Canal House, Ardrishaig |
| James M. | Gale, C.E., | 23 Miller Street, Glasgow |
| Andrew | Galloway, | 16 Clyde Place, Glasgow |
| John | Galloway, | Kilmarnock |
| William | Galloway, M.E., | Barleith and Dollars Collieries, Kilmarnock. |
| Archibald | Gilchrist, | 11 Sandyford Place, Glasgow |

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|---|---|---|
| David C. | Glen, | Greenhead Engine Works, Glasgow |
| Robert D. | Glen, | At Messrs. R. Napier & Sons, Govan |
| James | Goodwin, | Ardrossan |
| Gilbert S. | Goodwin, | Alexandria Buildings, Jane Street, Liverpool |
| Henry | Gourlay, | Dundee Foundry, Dundee |
| Edwin | Graham, | Pallion, High Yard, Sunderland |
| George | Graham, C.E., | Caledonian Railway, Glasgow |
| Archibald, | Gray, | Middleton, near Dalry |
| James | Gray, | New Cumnock, Ayrshire |
| Matthew | Gray, | Ashton, Gourock |
| Thomas C. | Gregory, C.E., | 62 St. Vincent Street |
| James | Greig, | Sea View Cottage, Links Street, Aberdeen |
| Charles | Gunn, | 146 West George Street, Glasgow |
| David | Guthrie, C.E., | 23 Miller Street, Glasgow |
| | | |
| James | Hall, | Shipbuilder, Aberdeen |
| William | Hall, | Shipbuilder, Aberdeen |
| James B. | Handyside, | 92 West Regent Street, Glasgow |
| James | Hamilton, | 15 Royal Crescent, Glasgow |
| John | Hamilton, | Shipbuilder, Port-Glasgow |
| George | Harvey, | 42 M'Neil Street, Glasgow |
| John | Hastie, | Deerpark Engine Works, Greenock |
| Peter | Hedderwick, | 1 Buckingham Road, Govan |
| James M'L. | Henderson, | Renfrew |
| John | Hendrie, | Kirkwood, Coatbridge |
| Laurence | Hill, | Shipbuilder, Port-Glasgow |
| Thomas | Hoey, | 84 Buccleuch Street, Glasgow |
| Thomas R. | Horton, | 15 Scotia Street, Glasgow |
| James | Howden, | 128 West Street, Glasgow |
| Edmund | Hunt, | 87 St. Vincent Street, Glasgow |
| James | Hunter, | Coltness Ironworks, by Motherwell |
| John | Hunter, | Dalmellington Ironworks, near Ayr |
| Jonathan | Hyslop, C. & M.E., | Wishaw |

| | | |
|---|---|---|
| Anthony | Inglis | 64 Warroch Street, Glasgow |
| John | Inglis, | 64 Warroch Street, Glasgow |
| John | Inglis, jun., | 64 Warroch Street, Glasgow |
| William | Inglis, | 97 Bridge Street, Manchester |
| John L. K. | Jamieson, | 180 West Regent Street, Glasgow |
| George W. | Jeffrey, | The Ironworks, Hartlepool |
| Ronald | Johnstone, C.E., | 176 West George Street, Glasgow |
| William | Johnstone, C.E., | 14 Bridge Street, Glasgow |
| John | Jordon | Shipping Surveyor, Liverpool |
| Paul | Karchow, | 105 Koquicker Street, Berlin, Prussia |
| Angus | Kennedy, C.E., | 99 Bath Street |
| Thomas | Kennedy, | Kilmarnock |
| John | Key, | Engineer and Shipbuilder, Kirkcaldy |
| David | Kinghorn, | 1 Buckingham Road, Govan |
| Alexander C. | Kirk, | Cranstonhill Foundry, Glasgow |
| David | Kirkaldy, | The Grove, Southwark Street, London, S.E. |
| Abraham P. | Klein, | 9 Mersey Chambers, Liverpool |
| David | Laidlaw, | 147 East Milton Street, Glasgow |
| Robert | Laidlaw, | 147 East Milton Street, Glasgow |
| H. T. | Lannigan, | 11 West Campbell Street, Glasgow |
| George | Lander, C.E., | 67 Renfield Street, Glasgow |
| James G. | Lawrie, | 241 West George Street, Glasgow |
| C. R. | Lawson, | 13 Whitevale, Glasgow |
| James G. | Leadbetter, | 13 Gordon Street, Glasgow |
| Andrew | Leckie, | At Messrs. Cald & Co's., Aberdeen |
| Daniel | Le Visconte, | Shipbuilder, Jersey |
| Robert | Leys, | 9 Constitution Street, Aberdeen |
| H. C. | Lobintz, | Renfrew |
| D. C. | Love, | At Messrs. Barr & Shearer's, Ardrossan |
| George | Low, | St. Peter's Ironworks, Ipswich |
| John L. | Lumsden, | At Messrs. Randolph, Eider & Co's., Govan |
| James | Lyall, | Underwriters' Room, Exchange, Glasgow. |

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|---|---|---|
| John | M'Andrew, | 27 North St. Mungo Street, Glasgow |
| John | M'Ausland, | Engineer, Dumbarton |
| David | M'Call, C.E., | 133 West Regent Street, Glasgow |
| James | MacCallum, C.E., | 35 Loraine Place, Newcastle-upon-Tyne |
| Hugh | M'Coll, | Abden Yard, Kinghorn, Fife |
| Thomas | M'Culloch, | Vulcan Foundry, Kilmarnock |
| James | M'Dermont, | Winton Buildings, Ayr |
| John | M'Donald, | 137 West George Street, Glasgow |
| Walter | M'Farlane, | 46 Washington Street, Glasgow |
| Andrew | M'Geachan, | At Messrs. Blackwood & Gordon's, Port-Glasgow |
| James | M'Gregor, | Beechwood, Partick |
| Josiah | M'Gregor, | Calcutta |
| Neil | M'Haffie, | 8 Broad Street, Mile-end, Glasgow |
| James | M'Ilwham, | Anderston Foundry, Glasgow |
| John | MacKenzie, | Dundyvan, Coatbridge |
| Alexander | M'Kinlay, | Shipwright Surveyor, Custom House Glasgow |
| Robert | M'Laren, | Eglinton Iron Works, Glasgow |
| Robert | M'Lea, | Shipbuilder, Rothesay |
| Andrew | M'Lean, | Stobcross Dockyard, Glasgow |
| James | M'Leish, | 48 St. Enoch Square, Glasgow |
| Walter | M'Lellan, | 127 Trongate, Glasgow |
| Hugh H. | MacLure, C.E., | 65 Sauchiehall Street, Glasgow |
| John | M'Michael, | 55 Drygate, Glasgow |
| John | M'Millan, | Shipbuilder, Dumbarton |
| William | M'Millan, | 289 Dumbarton Road, Glasgow |
| William | M'Millan, jun., | 289 Dumbarton Road, Glasgow |
| John | M'Nab, | Dumbreck Priory, Paisley Road, Glasgow |
| William | Macnab, | Shaws Water Foundry, Greenock |
| Andrew | M'Onie, | 1 Scotland Street, Tradeston, Glasgow |
| Murdoch | M'Pherson, | St. Petersburg, Russia |
| Robert | Mansel, | Shipbuilder, Whiteinch |

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|---|---|---|
| Thomas A. | Matheson, | East Campbell Street, Glasgow |
| George | Menzies, | Shipbuilder, Leith |
| Robert | Menzies, | Shipbuilder, Leith |
| Andrew | Miller, | 1 Buckingham Road, Govan |
| Daniel | Miller, C.E., | 203 St. Vincent Street, Glasgow |
| James | Miller, | Kelvin Forge, Partick |
| James | Milne, C.E., | 16 Windsor Terrace, St. George's Road, Glasgow |
| Robert | Milne, | At 12 Centre Street, Glasgow |
| James B. | Mirrlees, | 45 Scotland Street, Tradeston, Glasgow |
| John M. | Mitchell, | 113 St. Vincent Street, Glasgow |
| John | Moffat, C.E., | Ardrossan |
| William | Moore, C.E., | 49 West George Street, Glasgow |
| Ralph | Moore, C.E., | 7 Queen Square, Glasgow |
| David | More, | 33 Montrose Street, Glasgow |
| Peter | Morrison, C.E., | Shaws Water Works, Greenock |
| Hugh | Morton, | Shipbuilder, Leith |
| Hugh | Muir, | 12 Walworth Terrace, Glasgow |
| Matthew A. | Muir, | Anderston Foundry, Glasgow |
| James | Murdoch, | Lancefield Forge, Glasgow |
| Francis | Napier, | Sydney, Australia |
| James R. | Napier, | 22 Blythswood Square, Glasgow |
| John | Napier, | Lancefield Foundry, Glasgow |
| John D. | Napier, | Kilmun House, Holt Hill, Birkenhead |
| Robert | Napier, | West Shandon, by Helensburgh |
| G. M. | Neilson, | 102 Hyde Park Street, Glasgow |
| Walter | Neilson, | 172 West George Street, Glasgow |
| Walter M. | Neilson, | Hydepark Locomotive Works, Springburn |
| William | Neilson, | Mossend Ironworks, Bellshill |
| Benjamin | Nicholson, | Shipbuilder, Annan |
| Hugh | Niven, | Victoria Cottage, Govan |
| John | Norman, | 16 Pultney Street, Glasgow |

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|---|---|---|
| John W. | Ormiston, | Shotts Ironworks, Motherwell |
| T. R. | Oswald, | Shipbuilder, Pallion, Sunderland |
| John | Page, C.E., | 39 Arlington Street, Glasgow |
| John | Paton, | Railway Foundry, Normanton |
| R. F. | Pearce, | 75 St. Vincent Street, Glasgow |
| William | Pearce, | Albert Cottage, Govan |
| Robert | Porter, | 252 Argyle Street, Glasgow |
| Dundas S. | Porteous, | Engineer, Paisley |
| John | Price, | 42 Villiers Street, Sunderland |
| William | Ramsay, | 49 West George Street, Glasgow |
| Charles | Randolph, | 12 Centre Street, Glasgow |
| Daniel | Rankin, | Eagle Foundry, Greenock |
| James | Rankine, | Shipbuilder, Dumbarton |
| W. J. Macquorn | Rankine, C.E., LL.D., | 59 St. Vincent Street, Glasgow |
| John | Reid, | Shipbuilder, Port-Glasgow |
| William | Reid, | 353 Bath Crescent, Glasgow |
| Joseph | Ritchie, | 2 White Lion Court, London |
| James | Robertson, | 147 East Milton Street, Glasgow |
| John | Robertson, | 49 Anderston Quay, Glasgow |
| William | Robertson, C.E., | 123 St. Vincent Street, Glasgow |
| William | Robertson, | Shipping Surveyor, Pollokshields |
| Hazelton R. | Robson, | 21 Derby Terrace, Glasgow |
| Neil | Robson, | 127 St. Vincent Street, Glasgow |
| Robert | Robson, | 18 Park Terrace, Glasgow |
| James | Rodger, | 5 Park Gardens, Glasgow |
| Richard G. | Ross, | Greenhead Engine Works, Glasgow |
| David | Rowan, | 217 Elliot Street, Glasgow |
| John M. | Rowan, | 120 East Milton Street, Glasgow |
| George | Russell, | 7 Exchange Place, Glasgow |
| James | Russell, | Engineer, Motherwell |
| Thomas | Russell, | Aberdeen Ironworks, Aberdeen |
| Joseph | Russell, | Shipbuilder, Port-Glasgow |

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|---|---|---|
| John | Scott, yngst., | Greenock |
| Thomas B. | Seath, | Shipbuilder, Rutherglen |
| Thomas | Shanks, | Johnstone, |
| James | Shearer, | Shipbuilder, Ardrossan |
| Thomas | Sherriff, | 354 Duke Street, Glasgow |
| William | Simons, | London Works, Renfrew |
| Alexander | Simpson, C.E., | 175 Hope Street, Glasgow |
| George | Simpson, C.E., | 86 West Regent Street, Glasgow |
| Robert | Simpson, | Shipbuilder, Dundee |
| Adolf | Sjoberg, | care of E. Hunt, 87 St. Vincent Street, Glasgow |
| Alexander | Smith, | 57 Cook Street, Glasgow |
| David | Smith, C.E., | 37 West George Street, Glasgow |
| David A. | Smith, | 13 Park Terrace, Glasgow |
| George | Smith, | Sun Foundry, Glasgow |
| George | Smith, jun., | 208 Argyle Street, Glasgow |
| Hugh | Smith, | 2 Havelock Terrace, Paisley Road, Glasgow |
| James | Smith, jun., | 54 St. Vincent Street, Glasgow |
| John | Smith, | Engineer, Firhill Road, Glasgow |
| William | Smith, | 57 Cook Street, Glasgow |
| John | Sneddon, M.E., | 149 West George Street, Glasgow |
| John F. | Spencer, | The Engine Works, South Dock, Sunderland |
| Robert | Steele, jun., | Shipbuilder, Greenock |
| William | Steele, | Shipbuilder, Greenock |
| John | Stephen, | Shipbuilder, Kelvinhaugh, Glasgow |
| Andrew M. | Stewart, | Founder, Irvine |
| David Y. | Stewart, | St. Rollox, Glasgow |
| Duncan | Stewart, | London Road Ironworks, Glasgow |
| James | Stirling, | Glasgow and South-Western Railway, Kilmarnock |
| Patrick | Stirling, | The Great Northern Railway, Doncaster |
| A. Morton | Strathern, C.E., | Johnstone |
| Edward | Strong, | Locomotive Superintendent, Government Railway, Colombo, Ceylon |

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|---|---|---|
| Peter | Sturrock, C.E., Kilmarnock | |
| Captain O. | Suenson, | Copenhagen, Denmark |
| William | Tait, | Scotland Street Iron Works, Glasgow |
| W. R. M. | Thomson, | 146 Holland Street, Glasgow |
| Thomas C. | Thorburn, | Town Surveyor's Office, Birkenhead |
| David | Tod, | Meadowside Works, Partick |
| William | Tod, | Meadowside Works, Partick |
| John | Todd, | Branford Place, Duke Street, Glasgow |
| John | Tulloch, | Engineer, Dumbarton |
| George | Urie, | 101 Commerce Street, Glasgow |
| W. W. | Urquhart, | Blackness Foundry, Dundee |
| Matthew | Waddell, | Cleland, near Motherwell |
| William | Wallace, | Messrs. Allan & Co., Boundry Street, Liverpool. |
| W. R. | Watson, C E., | 1 Royal Bank Place, Glasgow |
| John | Watson, | 9 James Watt Street, Glasgow |
| William | Weems, | Engineer, Johnstone |
| William | Weir, | Eglinton Ironworks, Kilwinning |
| Alfred | Wheatly, | North British Railway, Edinburgh |
| Alexander | Whitelaw, | Gartsherrie House, Coatbridge |
| Isaac | Whitesmith, | 29 Govan Street, Glasgow |
| John | Weild, | Underwriters' Rooms, Exchange, Glasgow |
| John | Wilkie, | 33 Renfield Street, Glasgow |
| Alexander H. | Wilson, | Messrs. Hall & Son's, Aberdeen |
| James E. | Wilson, | 100 Clyde Street, Anderston, Glasgow |
| Peter | Wilson, C.E., | 96 Stirling Road, Glasgow |
| Robert | Wilson, | Abbey Works, Paisley |
| William | Wilson, | 325 Eglinton Street, Glasgow |
| Thomas | Wingate, jun., | Whiteinch |
| Francis | Wise, | Chandos Chambers, Adelphi, London |
| Robert | Young | Forth and Clyde Railway, Balloch |
| John | Yule, | 111 Rutherglen Loan, Glasgow |

## ASSOCIATES.

| | | |
|---|---|---|
| Thomas | Aitken, | 9 Dock Place, Leith |
| James | Allan, sen., | Bothwell Street, Glasgow |
| Andrew | Armour, | 184 Dumbarton Road, Glasgow |
| Thomas | Barclay, | 497 St. Vincent Street, Glasgow |
| T. S. | Begbie, | 4 Mansion House Place, London |
| John | Black, | 27 Lancefield Quay, Glasgow |
| Capt. Alex. | Blackwood, | Leith |
| William | Bragge, | Atlas Works, Sheffield |
| John | Broadfoot, | 28 Lancefield Quay, Glasgow |
| Capt. James | Brown, | 51 St. Vincent Crescent, Glasgow |
| Sir John | Brown, | Atlas Works, Sheffield |
| John | Bryce, | 7 Jackson Street, Glasgow |
| George S. | Buchanan, | 95 Candleriggs Street, Glasgow |
| William | Calder, | Sailmaker, Leith |
| Mungo | Campbell, | 7 Victoria Place, Glasgow |
| John | Dobie, | Shipbuilder, Govan |
| Robert | Duncan, | Ironfounder, Partick |
| Arch. Orr | Ewing, | 2 West Regent Street, Glasgow |
| Captain R. | Ewing, | Carry Cottage, Govan |
| Alexander | Ferguson, | 5 East Breast, Greenock |
| Peter | Ferguson, | 34 Jamaica Street, Glasgow |
| Robert | Gardner, | 2 West Regent Street, Glasgow |
| Allan | Gilmour, | 19 Union Street, Glasgow |
| James | Haddow, | 54 West Regent Lane, Glasgow |
| William | Hall, | Bellevue, Irvine |
| John | Hannan, | 75 Robertson Street, Glasgow |

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|---|---|---|
| Captain D. | Harrison, | 104 North Hanover Street, Glasgow |
| George T. | Hendry, | 8 Dixon Street, Glasgow |
| Capt. David | Henderson, | 52 St. Enoch Square, Glasgow |
| John | Kerr, | 2 West Quay, Greenock |
| Anderson | Kirkwood, | 12 High Windsor Terrace, Glasgow |
| William | Letham, | West Quay, Greenock |
| John Jex | Long, | 12 Whitevale, Glasgow |
| John | M'Alister, | Greenbank Sailwork, Mavisbank, Glasgow |
| James | M'Intyre, | 33 Oswald Street, Glasgow |
| James | M'Intyre, | 47 Queen Street, Glasgow |
| George | Miller, | 1 Wellesley Place, Glasgow |
| James | Miller, | 5 Fitzroy Place, Glasgow |
| John | Milne, | Aberdeen, Leith, and Clyde Shipping Co., Aberdeen |
| John | Morgan, | Springfield House, Bishopbriggs |
| James S. | Napier, | 13 Berkeley Terrace, Glasgow |
| R. S. | Newal, | Ferndene, Gateshead |
| John | Phillips, | 17 Anderston Quay, Glasgow |
| John | Rattray, | 94 Renfield Street, Glasgow |
| Capt. Thos. | Small, | 15 Berkeley Terrace, Glasgow |
| John | Smith, | Aberdeen Steam Navigation Co., Aberdeen |
| John R. | Stewart, | 55 Anderston Quay, Glasgow |
| Alexander | Tolmie, | 166 Buchanan Street, Glasgow |
| Malcolm M'N. | Walker, | 38 Clyde Place, Glasgow |
| H. J. | Watson, | 102 Bath Street, Glasgow |
| James | Watson, | 102 Bath Street, Glasgow |
| John H. | Watt, | 70 Great Clyde Street, Glasgow |
| Thomas | Westhorp, | West India Road, London |

| | | |
|---|---|---|
| Thomas | Whyte, | 9 Brighton Terrace, Govan |
| John | Whyte, | Prince Consort Place, Leith |
| James | Young, | Limefield, West Calder |
| William | Young, | 419½ Argyle Street, Glasgow |

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## GRADUATES.

| | | |
|---|---|---|
| W. M. | Alston, | 8 Granby Terrace, Glasgow |
| John S. | Carey, | At 175 Hope Street, Glasgow |
| Constancio | Costa, | 92 South Portland Street, Glasgow |
| John A. | Crain, | 155 Sauchiehall Street, Glasgow |
| C. H. L. | Fitzwilliams, | Lancefield Foundry, Glasgow |
| J. F. I. | Ghewy, | 82 South Portland Street, Glasgow |
| James | Gilchrist, | 11 Sandyford Place, Glasgow |
| Herbert | Groves, | At 175 Hope Street, Glasgow |
| James | Hamilton, jun., | 15 Royal Crescent, Glasgow |
| Charles B. | King, | 175 Hope Street, Glasgow |
| H. Coke | Powell, | The Engine Works, South Dock, Sunderland |
| Thomas | Roberts, | At Messrs. T. Shanks and Co's., Johnstone |
| W. W. B. | Rodger, | 133 West Regent Street, Glasgow |
| Alexander | Ross, | 2 Grafton Place, Glasgow |
| Alexander | Russell, | 133 West Regent Street, Glasgow |
| Thomas | Shaw, | 133 West Regent Street, Glasgow |
| W. C. T. | Sloan, | 35 Elmbank Place, Glasgow |
| Cornelius | Thompson, | 194 King Street, Aberdeen |

# REGULATIONS

OF THE

# INSTITUTION OF ENGINEERS IN SCOTLAND

WITH WHICH IS INCORPORATED THE

# SCOTTISH SHIPBUILDERS' ASSOCIATION.

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As Amended at Special General Meetings of the Institution, 12th January, 1864, 1st March, 1865, and 28th March, 1866.

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## Section I.—OBJECT.

1. The Institution of Engineers in Scotland shall devote itself to the encouragement and advancement of Engineering Science and Practice; being established to facilitate the exchange of information and ideas amongst its Members, and to place on record the results of experience elicited in discussion. **Object of the Institution.**

## Section II.—CONSTITUTION.

2. The Institution of Engineers in Scotland shall consist of Members, Associates, Graduates, and Honorary Members. **Constitution.**

3. Members shall be Mechanical Engineers, Civil Engineers, Mining Engineers, Military Engineers, Shipbuilders, and Founders. **Who may be Members.**

4. Associates shall be such persons, not included in the classes enumerated in the preceding regulation, as **Who may be Associates.**

the Council and Institution shall consider qualified by knowledge bearing on Engineering Science or Practice.

Who may be Graduates.

5. GRADUATES shall be persons engaged in study or employment to qualify themselves for the profession of Engineers.

Who may be Hon. Members.

6. HONORARY MEMBERS shall be such distinguished persons as the Council and Institution shall appoint.

Number of Hon. Members.

7. The number of Honorary Members shall be limited to twelve.

## SECTION III.—MANAGEMENT AND OFFICE-BEARERS.

Council, Management by.

8. The direction and management of the affairs of the Institution shall be confided to a Council, subject to the control of the General Meetings.

Constitution of Council—Five a quorum.

9. The Council shall consist of a President, three Vice-Presidents, ten Councillors, and a Treasurer; all of whom shall be Members, but not Associates, Graduates, nor Honorary Members. Five Members of Council shall constitute a Quorum.

Secretary how appointed and paid.

10. There shall be a Secretary, appointed by the Council, who shall receive such salary as the Institution shall fix, but who shall not be a Member of the Institution.

## SECTION IV.—DUTIES OF OFFICE-BEARERS.

Office-bearers shall transact the business of the Session for which they are elected.

11. The Office-bearers shall assume office immediately after the close of the Session in which they are elected; they shall hold Meetings, and make arrangements respecting papers and other matters for carrying on the business of the Session for which they are elected; and they shall, any or all of them, give their services as long after such Session as may be necessary to complete matters connected therewith.

12. The President shall take the chair at all Meetings at which he is present; he shall conduct and keep order in the proceedings of the Institution; state and put questions, and, if necessary, ascertain the sense of the Meetings upon matters before them; he may sum up, at the termination of discussions, the opinions given, and declare what appears to be the sense of the speakers, to which he may add his own opinion; and he shall carry into effect the Regulations of the Institution. He shall be a Member, *ex officio* of all Committees of Council. **Duties of President.**

13. The Vice-Presidents shall take part in the Council proceedings; and they shall in rotation take the chair in the absence of the President, and perform the duties enumerated in the preceding regulation. **Duties of Vice-Presidents.**

14. The Councillors shall take part in the Council proceedings, and aid the other Members thereof with their co-operation and advice. **Duties of Councillors.**

15. The Treasurer shall take part in the Council proceedings; he shall take charge of the property of the Institution, except books, papers, drawings, models, and specimens of materials; receive all payments due to the Institution, and pay into one of the Glasgow Banks, in the joint names of the President, one of the Vice-Presidents, and himself, the cash in his hands whenever it amounts to Ten Pounds; he shall pay all sums due by the Institution, but not without an order signed by two Members of a Committee of the Council nominated to examine the accounts; he shall keep an account of all his intromissions in the General Cash Book of the Institution, which shall upon all occasions be open to inspection by the Council, and which shall be balanced annually, up to the last Meeting of each Session; and he shall produce at such Meetings the Cash Book and Annual Balance Sheet, or Financial Statement, together with an **Duties of Treasurer.**

Inventory of all the Property possessed by the Institution, and a Register of the names of the Members, Associates, and Graduates of the Institution, such Register being arranged so as to distinguish all persons whose contributions are in arrear.

Duties of Secretary.

16. The Secretary shall take minutes of the proceedings at all the Meetings of the Institution and Council, and enter them in proper books provided for the purpose; write the correspondence of the Institution and Council; read minutes and notices at Meetings; report discussions; collect subscriptions; perform whatever other duties are indicated in the Regulations of the Institution as appertaining to his department; and, if desired by the Council, prepare and revise papers for reading and publication, and read papers and communications at the Meetings.

## Section V.—AUDIT OF ACCOUNTS.

Auditors and duties.

17. Two Auditors, who shall be Members of the Institution, but not Office-bearers, shall be chosen at an Ordinary Meeting preceding the Annual General Meeting of each Session, to examine the accounts and statements produced by the Treasurer; and the Annual Financial Statement, with their Audit, shall be printed in the notice calling the Annual General Meeting, and shall be read at that Meeting.

## Section VI.—MEETINGS AND PROCEEDINGS.

Ordinary General Meetings every four weeks dur- the Session.

18. The Institution shall hold Ordinary Meetings for reading papers, and for discussing matters connected with the objects of the Institution; and such Meetings shall take place regularly, at least once in every four weeks during each Session; the Sessions to commence

in each month of October, and continue until the month of April next following.

19. At every Ordinary Meeting of the Institution the Secretary shall first read the minutes of the preceding meeting, which, on approval, shall then be signed by the Chairman. The Secretary shall next read any notices which may have to be brought before the Meeting; after which any Candidates for admission shall be balloted for, and any new Members shall be admitted. Any business of the Institution shall then be disposed of, after which notices of motion may be given. The paper or papers for the evening shall then be read. The business of every Ordinary Meeting of the Institution shall commence as soon after Eight o'Clock in the Evening as Ten Members are present. **Ordinary Meetings —order of business.**

20. Any of the Ordinary Meetings of the Institution may be adjourned by a vote of the Members present. **Ordinary Meetings may be adjourned.**

21. Extraordinary or Special Meetings may be called by the Council when they consider it proper or necessary, and must be called by them on receipt of a requisition from any five Members, specifying the business to be brought before such Meeting. **Special Meetings may be called by the Council, or on requisition by five Members.**

22. The Secretary shall issue notices of Meetings to all the Members, Associates, Graduates, and Honorary Members of the Institution, at least four days before each Ordinary or Adjourned Meeting of the Institution; such notices mentioning the papers to be read and business to be brought forward at the Meeting. Similar notices shall be issued of the Annual General Meeting, and of all Extraordinary or Special Meetings of the Institution, at least four days before they are to take place. **Notice of Meetings to be sent at least four days before.**

23. The Council shall meet one hour before each Meeting of the Institution, and on other occasions when **Meetings of Council.**

the President shall deem it necessary, being summoned by circulars stating the business so far as known.

Questions before Meetings how decided.

24. Any question of a personal nature before a Meeting of the Institution or Council shall be decided by ballot; all other questions shall be decided by a show of hands, or by any convenient system of open voting; the Chairman to have a second or casting vote when necessary. None but Members or Associates shall take part in any voting or balloting.

Members, &c., may introduce strangers.

25. Each Member, Associate, Graduate, and Honorary Member, shall have power to admit one stranger to each Meeting of the Institution, who shall sign his name in a book kept for the purpose; but who shall not take any part in the discussions, unless requested to do so by the Chairman of the Meeting.

Nature of papers to be read.

26. All papers read at the Meetings of the Institution must relate to Engineering Science or Practice, and must be approved of by the Council before being read.

Proceedings to be published.

27. The papers read, and the discussions held during each Session, or such portion of them as the Council shall select, shall be printed and published as soon as possible, and shall be edited by the Secretary, in accordance with instructions from the Council. Each paper shall have prefixed to it the date at which it shall have been received by the Secretary.

Explanatory notes after reading of papers may be published.

28. Explanatory notes communicated after the reading or discussing of papers may be printed in the Transactions, if the Council see fit, but not without having prefixed the dates at which they shall have been received by the Secretary.

Copyright of papers shall be the property of the Institution.

29. The copyright of any paper read at a Meeting of the Institution, with its illustrations, shall be the exclusive property of the Institution, unless the publication thereof by the Institution is delayed beyond the

commencement of the Session immediately following that during which it is read; in which case the copyright shall revert to the author of the Paper. The Council shall have power, however, to make any arrangement they think proper with an author on first accepting his paper.

30. The printed Transactions of each Session of the Institution shall be distributed gratuitously as soon as ready to those who shall have been Members, Associates, Graduates, or Honorary Members of the Institution during such Session, and they shall be sold to the public at such prices as the Council shall fix. Authors of papers shall be entitled to twelve separate copies of their papers as printed in the Transactions.

**Members, &c., to receive copies of Transactions—authors 12 copies of their papers.**

## Section VII.—ELECTION OF NEW MEMBERS AND OFFICE-BEARERS.

31. Every Candidate for admission as a Member, Associate, or Graduate of the Institution shall sign an application for admission, and obtain the recommendation of at least three Members; such application and recommendation being according to a prescribed form contained in the Council Minutes. If the Council approve of the application and recommendation, the name of the Candidate shall be inserted in the notice calling the first ensuing Ordinary Meeting of the Institution; and the Candidate shall be balloted for at that Meeting, and shall be admitted if three-fifths of the votes are favourable.

**Candidates how recommended and elected.**

32. The granting of Honorary Membership to any person shall be proposed by the Council, and notice thereof shall be given by the Secretary at an Ordinary Meeting of the Institution. The person shall be

**Honorary Members, how elected.**

balloted for at the following Ordinary Meeting of the Institution, and shall be admitted if four-fifths of the votes are favourable.

Members, &c., formally admitted.

33. New Members, Associates, Graduates, and Honorary Members shall be formally admitted by the President at the first Meeting at which they are present after being elected, when they shall sign their names in the Roll-Book of the Institution, and receive a copy of the Regulations.

Rejected candidates not to be noticed in Minutes—wish of Hon. Members to be obtained before being balloted for.

34. If any person proposed for admission into the Institution is rejected on being balloted for, no notice shall be taken of the proposal in the minutes of the General Meetings; and it shall be ascertained from any person proposed to be made an Honorary Member, before he is balloted for, whether he will accept the honour, no notice being taken of the proposal in the minutes unless he is elected. No candidate for admission shall be balloted for a second time within twelve months.

Office-bearers to be elected by ballot.

35. The Office-bearers required in order to supply vacancies (except the Secretary) shall be severally elected by ballot at an Annual General Meeting, such Meeting being the last Ordinary Meeting held in each month of April.

Term of office.

36. The Members of Council shall each hold his office for not more than two years; and every retiring Office-bearer shall be ineligible to the office from which he retires until after being a year out of it; excepting the Treasurer, who may be re-elected any number of times without interval.

Order in which Presidents and Vice-Presidents shall retire.

37. Of the three Vice-Presidents, two shall retire the year the President continues in office, but only one the year the President retires; and of the ten Councillors, five shall retire each year, the other five retaining

office without re-election. The retiring Members shall be those who have been longest in the offices; or, in case of one or more having to be selected from two or more who are equal in this respect, then the selection shall fall on the one or more having the fewest votes when originally elected.

38. A vacancy occurring during any Session, in consequence of the resignation or death of any Office-bearer, shall be filled up by the Council, until the next Annual General Meeting for electing Office-bearers.

**Vacancies occurring during the Session to be filled up by the Council.**

## Section VIII.—CONTRIBUTIONS OF MEMBERS TO THE INSTITUTION.

39. The Subscriptions noted in the following Table shall be payable on election and at the first Meeting of each Session, by every Member, Associate, and Graduate respectively:—

**Annual Subscriptions payable.**

| | Member. | | Associate. | | Graduate | |
|---|---|---|---|---|---|---|
| | £ | s. | £ | s. | £ | s. |
| If Elected in October or November, | 2 | 10 | 2 | 0 | 1 | 0 |
| If Elected in December or January, | 2 | 0 | 1 | 10 | 0 | 15 |
| If Elected during the remainder of the Session,...................... | 1 | 10 | 1 | 5 | 0 | 10 |
| And every October thereafter,........ | 1 | 10 | 1 | 0 | 0 | 15 |

40. Honorary Members shall pay no contributions.

41. No Member nor Associate whose contribution is in arrear shall be entitled to vote.

**Members, &c., not entitled to vote if in arrear.**

42. Any Member, Associate, or Graduate, whose contribution is more than one year in arrear, may be removed by a vote at a Meeting of the Institution.

**Members, &c., in arrear may be removed by vote of the Institution.**

43. Any Member, Associate, or Graduate retiring

from the Institution shall continue to be liable for annual contributions until he shall have given formal notice of his retirement to the Secretary at or before the first Meeting of a Session.

## Section IX.—REGULATIONS AND BY-LAWS.

Alterations on Regulations.

44. Any proposition for adding to or altering the Regulations may be laid before the Council, who may bring it before the Institution if they think fit, being bound to do so should it be accompanied by a requisition from any five Members of the Institution.

Alterations on Regulations to be made at Special General Meetings.

45. No alteration of, or addition to, the Regulations shall be made except at a Special General Meeting of the Institution, called for the purpose by the Council, by a circular, giving at least four days' notice, and detailing the alteration or addition proposed to be made.

Notice of motions must be given.

46. Motions not relating to the Regulations may be made at any Meeting of the Institution, but not without notice of each such motion having been either inserted in the notice calling the Meeting, or given in writing and read at the Meeting next preceding.

By-Laws — power of Council to make or alter.

47. The Council shall have power to make or alter By-Laws and minor ordinances, in accordance with the spirit, intention, and meaning of the Regulations of the Institution, whenever it shall, in their opinion, appear to be necessary for the good order and government of the Institution.

## Section X.—MEDALS.

48. The Council shall have power to offer annually a Medal for the best paper on any subject not comprehended by the Marine and Railway Engineering Medals, such additional Medal to be called the Institu-

tion Medal, and to be paid for out of the funds of the Institution until a special fund be obtained.

**When Medals are to be given.**

49. The Medals shall be given annually, if the Council be of opinion that papers of sufficient merit have been read in the respective departments; but if it shall be the opinion of the Council that a paper of such merit has not been read in any department during any Session, the Council shall submit the question to the decision of the Institution; and in the event of the Institution confirming the opinion of the Council, the Medal shall not be given in that department; and the interest arising from that particular Medal Fund shall be added to the principal.

## SECTION XI.—MANAGEMENT OF THE LIBRARY.

**Appointment of Library Committee.**

50. The Council at their first Meeting each Session shall appoint three of their number to form a Library Committee, one of the three to be Librarian and Convener of the Committee.

**Powers of Library Committee.**

51. The Library Committee, subject to the sanction of the Council, shall expend in Books and Library expenses the sums placed at their disposal, make By-Laws for the management of the Library, and appoint Assistants.

**Library Committee shall report periodically.**

52. The Library Committee shall report periodically to the Council, detailing the state of the Library affairs.

**Duties of Library Committee, and Annual Report.**

53. The Library Committee shall take charge of all the Books, Papers, Drawings, Models, and Specimens of Materials belonging to the Institution; and they shall annually make an examination of the property under their charge, and report to the Council at the Meeting next preceding the day of the Annual General Meeting.

## LIBRARY BY-LAWS AS TO USE OF BOOKS.

SANCTIONED BY THE COUNCIL, 31ST DECEMBER, 1862, AND AMENDED, 12TH JANUARY, 1864.

When Library is to be open.

1. Except when closed by special order of the Council, the Library shall be open for consulting, borrowing, and returning books, every lawful day except Saturday, from 10 A.M. until 4 P.M., and from 6 P.M. until 8 P.M.; and on Saturdays from 10 A.M. until 2 P.M.

Who may borrow books.

2. Books shall not be lent to any persons except Members, Associates, or Graduates of the Institution; but a person entitled to borrow books may send a messenger with a signed order.

Books for consultation only.

3. The books marked with an asterisk in the Catalogue shall be kept for consultation in the Library only, and shall not be lent.

Register of books lent to be kept.

4. The Librarian, or Assistant Librarian, shall keep a register, in which he shall enter the titles of the book or books lent, the date of lending, the name of the borrower, and the date of the return of the book or books to the Library.

Borrower to sign for books.

5. The borrower of the book or books, or, in his absence, the bearer of his order, shall sign his initials to the entry of such borrowing in the Librarian's Register.

Librarian to certify return of books.

6. The Librarian or Assistant Librarian shall sign his initials to the date of the return of the book or books.

Books damaged to be entered in Register. Intimation to Library

7. Should books be returned in a damaged condition, the Librarian or Assistant Librarian shall immediately make an entry of the fact in the Register, and report

the same to the Library Committee without delay; and he shall give notice in writing of such entry, and report to the person from whom he last received the book, within three clear days of the receipt of the book, exclusive of the day of receiving the book, and the day of giving such notice.

Committee, and notice to last borrower.

8. No person shall be entitled to borrow, or have in his possession at one time, more than two complete works belonging to the Library, or two volumes of any periodical.

Number of books which may be borrowed at one time.

9. No borrower shall retain a book longer than thirteen clear days, exclusive of the days of borrowing and returning, under a penalty of twopence per volume for each day in excess; and written notice shall be sent to the borrower one day after the time has expired; but neither the sending nor the omission to send such notice shall relieve the borrower from the obligation to pay the fine and return the book. In no case shall any book be kept longer than twenty clear days.

Time books may be retained—Fines, &c.

10. In the event of two or more persons applying for the same book at the same time, the applicants shall draw lots for priority.

Lots to be drawn when two may apply for the same book.

11. The foregoing rules may be amended at any time by authority of the Council.

Rules may be altered by authority of Council.

# INDEX



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W. MUNRO, PRINTER, 27 UNION STREET, GLASGOW.

*PLATE I*