TRANSACTIONS

OF THE

INSTITUTION OF ENGINEERS AND SHIPBUILDERS

IN SCOTLAND.

VOLUME XVI.

SIXTEENTH SESSION, 1872-73.

EDITED BY THE SECRETARY.

GLASGOW:
PRINTED FOR THE INSTITUTION BY
WILLIAM MUNRO, 81 VIRGINIA STREET.

1873.

OFFICE-BEARERS

Elected 22nd April, 1873.

SIXTEENTH SESSION, 1872-73.

President.

ROBERT DUNCAN.

Vice-Presidents.

J. L. K. JAMIESON. | H. R. ROBSON. | J. Z. KAY.

Councillors.

GEORGE RUSSELL.
JAMES HOWDEN.
JAMES REID.
JAMES HAMILTON.
DAVID ROWAN.

BENJAMIN CONNER.
JAMES DEAS, C.E.
JAMES LYALL.
EBEN. KEMP.
ANDREW BROWN.

Committees.

Finance.

DAVID ROWAN, *Con.*
J. L. K. JAMIESON.
JAMES DEAS, C.E.
H. R. ROBSON.

Library.

B. CONNER, *Lib. Con.*
GEO. RUSSELL.
J. Z. KAY.

Treasurer.

M. R. COSTELLOE, 12 James Watt Street.

Secretary.

W. J. MILLAR, C.E., 100 Wellington Street.

Sub-Librarian.

R. T. WALKER, Corporation Buildings, 2 Dalhousie Street.

CONTENTS.

SIXTEENTH SESSION, 1872-73.

PAPERS READ.

PLATES.

The responsibility of the statements and opinions given in the following Papers and Discussions rests with the individual authors; the Institution, as a body, merely places them on record.

INSTITUTION OF ENGINEERS & SHIPBUILDERS

IN SCOTLAND.

(INCORPORATED.)

SIXTEENTH SESSION, 1872-73.

Introductory Address. By Mr ROBT. DUNCAN, President.

Read 22nd October, 1872.

GENTLEMEN,—In taking the Chair, to which your Council have done me the honour of appointing me, in room of the President elect of the Institution, Mr Robert Bruce Bell, whom severe illness has compelled to withdraw for a time from active life,—it becomes me publicly, as I have already done privately, to acknowledge my high sense of the honour your Council have conferred on me, and to crave your indulgence and assistance, during my term of office, in my humble endeavours to carry out worthily the aims and objects of this Institution. I believe it to be my duty also, in which I am sure I have your cordial support, to tender from this Chair, the sympathy and good wishes of the members of this Institution, to our esteemed friend, Mr Bell, trusting that he may soon be able to take his place again among us, and happily to occupy this Chair, which he has had unhappily to resign, but which his eminent engineering abilities especially qualify him to adorn.

It has always been a pleasure to the Presidents of this Institution, as it is now to myself, to congratulate its members upon its continued prosperity and success, as *the* Scientific Institution of the most important industries of Scotland. It is very gratifying to know that it has the support of the greater number, if not the whole, of the leading men of these industries in Scotland,

and not a few leading Scotchmen and others in other countries, whose kindly remembrance of Scotland and her institutions, as well as a laudable desire to keep abreast of her progress, makes them our useful and valuable auxiliaries by the way. Our connection also with scientific men and kindred institutions in England, and elsewhere, is a source of profit and pleasure, we trust as great to them as it is to us, as our large, increasing, and most valuable Library can testify; and to the many generous donors who, during the past year, have favoured us by contributions of books, I would beg your kind permission to tender, in name of the Institution, our grateful thanks.

In connection with this subject, I may mention that the Council have had under consideration, the greater usefulness of the Library. It would give pleasure to the Council to see all connected with the Institution taking more interest in the Library, and availing themselves of the opportunity of perusing those valuable works which it contains.

There is another class of our friends who, as members and associates, are useful to Institutions such as this, but who, unfortunately, do not always receive the recognition and encouragement they deserve. I mean that small, hard-working, and ill-paid class, who contribute of the fruit of their experience and practice, in papers original, theoretical, and illustrative, within the proper business of the Institution. We have known it a difficult matter, in our experience, to get up sufficient material in this department of the business of the Institution, to constitute our transactions, a valuable contribution to the scientific and practical literature of the year. I am satisfied that in Scotland, and especially in the busy *West*, this should be a wholly anomalous position. The stimulating influences of our vast mineral resources and industries, and equally extensive commerce, as well as our multifarious manufactures, and our unrivalled position as the first shipbuilding and engineering district in the world, should make the "*Transactions*" of our representative Institution a source of interest and information, somewhat proportioned to our reputation. It appears to me then, that to that small band, who have so far contributed by their ability to the success of this Institution, our thanks are doubly due; for the future, I am disposed to believe that a still more kindly invitation and recognition, rather than dry reception and equally dry discussion, would have a beneficial influence upon our proceedings and their record.

One other matter I would speak of in this connection, as among the fair and legitimate means by which the usefulness of this Institution should be promoted, namely, the application of certain funds belonging to the Institution, and which might belong to it. I have not the slightest desire nor intention to reflect for a moment on the intromissions of the past, but there is one fund in which I have long been interested, of which this Institution might have had the benefit for a considerable time, if it had been reasonably willing to meet the views of its subscribers. "The John Wood Memorial Fund" was set on foot by the members of the Scottish Shipbuilders' Association before its amalgamation with this Institution. Its object was to commemorate the great services of John Wood to the science and art of shipbuilding in Scotland. The desire was, in the first instance, to found a scholarship in connection with one of the Universities in Glasgow; but eventually it was considered that it would be more generally useful, if it could be appropriated to the establishment of a Lectureship on Naval Architecture and Marine Engineering in connection with this Institution. To increase the estimated advantages of this Lectureship, it was suggested that one or more of the Medal Funds of the Institution should be incorporated with it, and the whole applied in a manner set forth very clearly in reports submitted by various committees appointed from time to time to confer with the trustees of that fund. It is matter for regret, that for certain reasons, or feelings, a prejudice existed in the minds of some members of this Institution against the proposed lectures, and the matter was allowed to drop. I think it a very great pity that it was so, because it would in many respects have met the remarks I have just been making, on improving the value of our Transactions; and I believe I am perfectly justified in saying, that it was in no way intended to compete with, neither would it have been permitted to interfere injuriously with, the Civil Engineering Classes in the University under the care of our distinguished member, Professor Rankine. The chief aim and desire of those who advocated its adoption by this Institution, was to foster and assist a taste for the higher studies of the University, among the younger graduates and associates of the Institution. I am fully persuaded that a few such lectures, if possible, under the direction of Dr Rankine himself, along with the regular business of the Institution, would give a value and importance to its Transactions such as they have never hitherto possessed, besides being useful and auxiliary to the University studies on the cognate sciences, in which Dr Rankine has no superior. I have brought this under your notice again in the hope that some definitive action may be taken in the matter before it be too late. Year by year those who knew John Wood best, and subscribed most liberally, are dropping from the scene; and, if it were possible, I feel persuaded that there is no man of this country whom the shipbuilders and engineers of Scotland would do more honour to themselves in thus honouring, "in memoriam," than John Wood, the builder of the "Comet," and the father of all that is best in the style of our ships, and truest in the practical application of science, in the shipbuilding of Great Britain.

Permit me now, as a shipbuilder, to direct your attention for a little to the past progress and present position of our art, commercial and naval.

It is needless, in the time at my disposal, to take you back beyond the last ten years; the interesting transition period in our history, from the building of the *first* wooden steamer to the building of the *last*, and the establishment of the iron age in shipbuilding, is too well known to require special attention here. What has not yet been recorded of it, will be written by-and-bye in the popular history of the earlier half of the nineteenth century. What we have to do with now is the fact that IRON is established, and the fighting, as well as the commercial, fleets of the world being "reconstructed" on principles, proportions, and designs, that would have filled our ancestors of fifty years' ago with astonishment, if not dismay; but such things are, and we accept them with the philosophy of people accustomed to sensations, quite prepared to admit that in shipbuilding and engineering, as in all other departments of modern scientific progress, almost everything under the sun is new.

The merchant shipbuilding of the last ten years has undergone a great change, not only in style, but in construction. The sailing ships, in size and proportions, may be considered steady, if they have not reached their limit. Various causes unite in the ship itself to make a very large sailing ship unprofitable property. The limit may safely be fixed under 2000 tons. Over that, to any part of the world, a steamer will pay, and, as a matter of course, will take the trade.

The enormous expansion of ocean steam lines since the general adoption of the compound engine is wonderful. The opening of the Suez Canal as a short cut to India and China has been an additional stimulus, but it may safely be said that without the compound engine, steam lines round Cape Horn on the one hand, and direct to China on the other, would have been impracticable. The great desideratum now is that the coal resources of the world should be properly developed. The risk which the commerce of the world may be said to run from the action of a few wrong-headed miners and speculative coalmasters in Britain, is too serious to be contemplated with satisfaction, and the economical balance can only be safely adjusted, by encouraging the development of the mineral resources of all other countries with which we have communication. In India and China, superabundant population should make the mining and the mineral cheap. Within the last few years the Chinaman has taken his place in the United States as the most willing and intelligent of labourers, and with a constantly increasing immigration into America of those able-bodied and docile workmen from the far East of the Old World, and Anglo-Saxon, German, and Scandinavian headmen from its far West, a great future is not far distant for the boundless coal and iron resources of America. With India the matter is in our own hands, and with the opening up of South America, China, and Japan by steam, the demand will develop the supplies all in good time.

In our own, and other advancing European countries, it appears to me that the manual labour of coal and iron getting must be more and more supplemented by machinery. The higher the prices paid for labour will compel the adoption of labour-saving implements. Already the agriculture of this country is become more a matter of money and machinery than of men, and the enormous harvest immigrations which we can all remember, have given place to the reaping machine, which cuts steadily and never strikes. So is it with the great steam ships, which, when produced, do their work steadily and well, but unfortunately the labour necessary for their construction is the least to be depended on of all our elements of production. Year by year the production of machinery is becoming more the product of machines, the labourer or tradesman being more an attendant than a workman, his skill more of the head than of the hand. It is not so with the iron ship. The furnace and the punching machine may be said to be the two main tools of the shipbuilder, nearly all else is labour, fitting, depending upon men and not upon machines; while rivetting, almost the most important part of the whole, is in the hands of the lowest and least manageable of our workmen. Can the invention of this age and Institution not do something towards the rivetting of an iron ship?

With the great expansion in ocean steam trade, and the size of ocean steamers, a great change has taken place in the proportions of the ships themselves, and the arrangements of their scantlings for construction. The earliest ocean steamers of 40 feet beam and 30 to 35 feet deep did not much exceed 200 feet long: now, the iron ocean steamer of the same breadth and depth exceeds 400 feet. The change has been comparatively gradual, but nearly all in the same direction; length in proportion to breadth and depth. Draft of water being a fixed basis, not exceeding 20 to 25 feet for the largest merchant ships and principal trading ports, length was the most obvious direction of increase, provided sufficient strength with reasonable weight could be accomplished; and as the *material*, to be efficient, had to be apportioned chiefly to the top and bottom of the ship, large alterations had to be made in its arrangement and distribution; as the ship, to be a profitable carrier on any dimensions, must be a reasonable, and, as nearly as possible a minimum, weight of herself for the weight to be carried. The lead in this rearrangement of scantlings to length and other dimensions was taken by the Liverpool Underwriters' Registry; Lloyd's Registry adhering more to the arrangements for short proportions, which had been in a manner carried forward from the system in practice in the construction of wooden vessels. Eventually the demand for longer and lighter steamers superannuated the older rules of Lloyd's, and within the last three years, the rules of the two societies have been more nearly assimilated, to meet the growing requirements of the times. The transverse framing in both has been greatly reduced, and the longitudinal proportionately increased; the ratio of weight to tonnage, of the largest vessel, of the longest proportions, being as yet, very little in excess of the weight by the shortest measure of ten years ago. Possibly a further extension of length might be safely effected, without much increase of weight, by a still further adjustment of the transverse and longitudinal scantlings. I am not of opinion that it would be advisable to reduce much further the vertical side framing, by carrying the longitudinal system from keel to gunnel, otherwise we should have the top and bottom buckling together like an accordion. We must have sufficient side framing to give rigidity to the plating, and to carry the beams and stringers necessary to the lateral strength of the ship; in the bottom, there is reason for believing that longitudinal floors would be preferable in very long ships; and the present system of skin intercostals, is an approximation that might be carried further, with advantage to the local and distributed strain on the bottom, at the expense of the material in the transverse floors, but without prejudice to their special functions. The great length exposed the weakness of the top, or upper decks, in long ships, to a more marked extent than of the bottom, hence the all but universal adoption of iron decks in large ships over nine beams long.

But here we approach a limit of length which must be arrived at by stages, according to the work the ship is intended to perform. Weight aloft and high freeboard are incompatible with stability and deadweight carrying ability. For a purely cargo ship, the largest displacement and the lowest freeboard, combined with lightness in the ship herself, especially above water, are the essential elements for profit. Therefore, the proportions and form, which combine the minimum of material in construction, according to the best practical distribution for stability, safety, and speed, with the largest carrying capacity in proportion to cost and economy in working, are the practical limits to the size of our purely cargo steamers. My present impression is that the economic limit of the weight of such ships in relation to weight carried, is reached at a length equal to 20 times the draft of water; and thus, if 25 feet draft be considered the deepest workable limit, with say one-third of draft as freeboard; the largest purely cargo ship that it would be advisable to build should not exceed 500 feet long.

In ships which are intended for combined passenger and cargo trades, height of freeboard is essential to the safety and comfort of the passengers; breadth is necessary to stability with the greater height; and as the dead weight capacity requirement is less, in proportion to the gross capacity, by the amount of space or tonnage appropriated to the passengers; the length may be extended in ratio to the extreme depth, without any increase in weight of ships in ratio to gross capacity. To put this in figures again assuming the minimum freeboard at two-thirds the draft, the extreme depth would be about 42 feet, and the length fully 600 feet.

For purely passenger ships again, assuming it possible that the development of ocean travelling, should make it desirable, that the highest speed attainable could be made profitable between the continents by such expresses of the sea, a midship freeboard equal to the draft would give the required security, with 50 feet extreme depth, and with proportionate strength for a length approximating 750 feet.

It would be easy to verify these figures, by any of the usual well-known methods of calculating section in ratio to dimensions and weight; assuming the breadth in every instance at not less than $1\frac{1}{3}$ the extreme depth, or, depth $\frac{3}{4}$ths the beam, as the least desirable for stability with ordinary loading. As no rules are in existence for the scantlings of vessels of such extreme dimensions, and no experience to found on, I am assuming weight in ratio to internal capacity, as not exceeding the proportion ruling in the largest under existing rules. But it would be necessary, and probably not difficult, in these large sizes, to rearrange the sections, so that possibly even greater length might be obtained with the same weight, with safety and advantage. We are carrying out at the present time, since the introduction, or properly speaking the general adoption, of the compound engine, an economy of the most beneficial character, by the adoption of higher pressure and greater expansion. Pressures of 60 to 80 pounds per square inch are now common in sea-going steamers, with a consumption of fuel considerably less than half of the ordinary type of marine engine of ten years ago. It is not beyond the bounds of possibility, that we may have safe working pressures of double or treble these figures, as these are certainly double or treble the assumed safest limits of a comparatively recent time; and with corresponding improvement in coal consumption. Economy and profit are the undoubted measures of dimensions in all legitimate trade structures; but whether we shall soon see ships of double or treble their present size, may naturally be doubted. We certainly have doubled the length of ships within the last thirty years, and I see no reason to doubt that we may double that again within the next generation. Not quite *three years ago*, when I designed the new shipbuilding works at Barrow-in-Furness, ships exceeding 400 feet long were not afloat, with one exception; and when I placed on the plan two ships of 500 feet, receiving their machinery at an 80 ton crane, I thought that I had provided for a considerable future. Since that time, you all know, that ships above 400 feet are becoming common, and some approaching 500 feet are even now in progress on the Clyde and elsewhere. Our 80 ton crane at Barrow is being built to carry 100 tons, and I have been seriously at work upon the plans of ocean steamers 600 feet long. I cannot say that these ships are to be built immediately, but coming events do not cast very long shadows now-a-days, and looking forward one generation, and measuring the future by the past, I think it is not problematical that we shall see steamers of 800 feet long, the ferry boats of two oceans, with America for their central station, and Europe and Asia for their weekly termini.

Leaving the Merchant service to take care of itself, as it is very well able to do, let us look for a little at our Navy. Very much greater changes have taken place in it within the last ten years than even in the merchant service. Little more than ten years ago there was not a shell in existence that would pierce an inch plate, and the Warrior and Black Prince were considered impregnable against the heaviest shot then known, behind their 4½ inches of armour plate; but the struggle had fairly begun between guns and armour, or, more properly, between brains and metal, and inch by inch the battle has been fought, and fairly won by the gun. Shells, as well as solid shot, have been driven through the thickest armour plates yet manufactured, and the "first-rates" of our navy are now reduced to the "Devastation," and her sister ships now building, our whole fleet shrinking and sinking before the gun, till in our "mightiest iron-clad" we have a mastless and not very lively turtle, with little more than its back above smooth water.

Thanks to the "Report of the Committee appointed to examine the designs upon which ships of war have recently been constructed," we know rather more about the condition of our naval affairs than we might otherwise have been privileged to learn. That committee was composed of men in many respects well qualified to judge of the merits of those designs, from the evidence before them; among whom it is the honourable distinction of this Institution to have been represented in two of its leading members, Professor Rankine and Mr Denny: the one of the highest standing on the scientific questions involved, the other equally eminent for practical sagacity on construction. If to these we add Sir William Thomson, Glasgow and the Clyde may fairly claim to have been properly represented. Objection has been taken in some quarters, that the committee have left us no wiser than we were, as to the proper design for a modern ship of war; and, to the value of their labours and report, on the ground that they do not even agree. The first objection appears to me unreasonable on the face of it, from the fact that the deliberations of the committee were expressly restricted, by the terms of their appointment, to the consideration of certain elements in the designs, of ships either built, or under construction. Beyond that, they were forbidden to go, or give an opinion; and it would be manifestly unfair to blame them for not doing, what they were expressly prohibited from doing, however capable. On the second point, it appears to me that it would have been astonishing, if, under the circumstances, they had agreed; and that it is an evidence, not only of the ability of the committee, but of the general merits of all the designs, that only two gentlemen out of sixteen, found it necessary to record a difference of opinion. The witnesses were generally selected for their real or assumed ability to give the best existing information on the points under investigation; and yet, after knowing all that they and the committee can, and cannot, tell us, we cannot help reflecting, that the misfortune which led to the appointment of the commission, was a blessing in disguise; and as practical men we know, that the result is no disgrace to our naval constructors, nor to our science and art, whether of ships or guns, nor to our country compared with any other. It is our own guns against our own ships and machinery, and we have the satisfaction of knowing that no other nation has done, nor can do, better. Very lately we have been rather alarmingly told that Russia, with its model cruisers, its "Peter the Great," and its circular iron-clads, is going altogether beyond us; but the steps from the "Blonde" and the "Devastation" to either one or other, are not long; and the designs, ideas, and experience on which they are built are not Russian; they are common to all intelligent men, naval architects, and artillerists. A floating battery that shall offer the smallest mark above water, and carry armour to withstand the heaviest gun that can be sent afloat, is *all that is wanted*, but not so easily obtained. Fourteen inches is the thickest armour now afloat, and 35-ton guns are also afloat to penetrate it. Our most eminent naval architects assert their readiness to float armour up to 30 inches; and our most eminent artillerists are quite prepared, as soon as the design is in hands, to make a gun to punch it. Certainly armour can be carried to any thickness, with a very large floating body, and a very small citadel in proportion; but what is to become of the floating body, which cannot be wholly submerged without very great risk? and if at all awash, no opponent would waste powder on the armour, when a plunging shot on the easily penetrable hull would end the contest. But, supposing the deck were made impenetrable in this way, then comes the TORPEDO to sink it from below.

The plain fact is, that we could not refuse to build such articles so long as France led us; nor can we now, if Russia and Germany choose to spend their money in this fashion; but as our national policy is the reverse of aggressive, it would be folly in us to be first in such a race. We have the satisfaction of knowing, without much obscurity, the best and the worst that can be done in ships of war; that we have ships equal to the best anywhere else, and are beginning others superior; that we have guns unsurpassed in weight and penetration, and do not mean to stop at that; and beyond that, the experience that has been acquired of the use and power of the torpedo, as an instrument of offence and defence, has demonstrated its value as a coast guard superior to all other modes of coast defence; while its application for the purposes of submarine attack, point not indirectly to a revolution, if not to a revulsion, in the practice of naval warfare, and the feelings with which humanity is likely to regard it. Evidently the tendency of modern warfare on the sea, is not to a chivalrous struggle for mastery or honour, but to a murderous intent on wholesale destruction, alike without glory or safety; a contest in which one or both the combatants must certainly perish. The final result of this style of warfare must be, that men will refuse to go to sea to certain death, and we shall have a repetition of the game of the Crimean and Franco-Prussian war; the weaker, or least prepared, will keep in port within a torpedo reef, and the stronger will chafe in idle impotence outside this belt of certain destruction.

This brings us to a point which is now assuming prominence, or rather more prominence than it has had the chance of occupying within the last ten years, the question of dispensing entirely with armour, and trusting solely to heavy guns and speed. The position assumed by the advocates of the latter system is not a novel one entirely, having been advocated all through the armour period by those who had faith in the power of attack against the inertia of mere defence. Eleven years ago, in a paper I read to this Association, I maintained, that although 1-inch plate was impenetrable by any shell, and 4-inch invulnerable to any shot in existence, it would not continue to be so; that human ingenuity would put shot and shell through the thickest armour that could be floated, and that the last resort, and the only style of ship that would continue to be permanently serviceable, was the flying cruiser, with a few powerful guns, and with speed sufficient to choose its own time, and distance, and style of attack. Within a year or two of that time, the American war developed the low freeboard "Monitor" and the "Alabama;" and the naval architects of this and other countries have continued to ring the changes between these two styles ever since. The gun has now, without doubt, asserted its superiority; and the unarmoured cruiser of 15 knots speed, with a 35-ton gun fit to send a half-ton shot through 18 inches of solid armour plate at half-a-mile distance, is quite as dangerous an opponent to the "Peter the Great" or the "Devastation" with 14 knots speed, and 14-inch armour, as these latter are to her.

Two varieties of these styles have been specially before the public within the last few months, namely, the Russian composite cruiser; and the cellular ironclad, which is in some respects now the favourite in our own country; and you will allow me to draw your attention for a minute to the fact that both of these novelties were very distinctly submitted to this Association in the same vessel by one of our members, nearly *eight years ago.* Mr. Boold's composite cruiser, as sketched by him to illustrate his mode of construction, was 320 feet × 45 feet × 18 feet draft, with deep iron frames to main deck, and with a complete iron inner skin joining an iron deck, making a perfect inner ship upon the iron frames, the outside of which was to be planked with wood and coppered. A 6-inch armour belt covered the engine-room amid-ships. The armament was to be carried in a central cupola with two large upper deck uncovered guns, for bow and stern fire. 500 nominal horse power, which with the best engines of that time were equal to 800 N. H. P. of modern compound engines. Twin screws and full masted for sailing. The Russian "Grand Admiral" is described as 300 feet × 48 feet × 23 feet draft, with an iron inner skin, frames worked outside, planked with wood and coppered. A 6-inch armour belt at the water line. 4 upper deck 8-inch guns amidship, protected by an ironclad barbette; and with two 6-inch guns for bow and stern fire. Engines of 900 H.P., and full rigged for sailing. If the coincidence between the two designs be not very natural, it is at least remarkable. But below the main deck, Mr Boolds has further anticipated, by an age at our present rapid rate of transition, the greatest desideratum of the committee on our ships of war; and almost the only point upon which the committee was unanimous; by making a complete cellular ship, divided into a greater number of compartments than has ever yet been proposed; except that by another remarkable coincidence, Admiral Elliott proposes to make his cells exactly the same size. This principle of extensive sub-division below water is being largely adopted by our present naval constructors, and is deemed by other very competent authorities—"the most substantial improvement of these times." Mr Boolds' cells were 12 feet square, from deck to bottom; each cell a water-tight and air-tight bell, with air-pumps and pipes for ventilation, or the expulsion of water in the event of perforation; the theory being the very simple one, that if the air be not permitted to escape, the water cannot enter; and so long as the deck remains intact, and sufficient pressure is maintained by the air-pumps from the engine, the ship is practically unsinkable, even if a shot were to go in at the water line and out through the bottom. These cells are intended to serve all the purposes of the ships requirements, as tanks, magazines and store rooms, so that no room is practically lost. Going into action, each cell would be hermetically sealed, and a pressure put upon it, equivalent to the draught of water, which would be sufficient to keep each and all free under any ordinary penetration; and the crew would, under any circumstances, have the confidence of a provision for their safety, as unequalled as it is still unique. Above the main deck Mr Boolds has another almost equally unique idea, of confining the effects of explosive missiles to a limited area, by dividing the ship by thick-plated bulkheads, one over each alternate bulkhead of the cellular transverse divisions below. And as the main iron deck is intended to be as nearly as possible on a level with the water, shot striking immediately above this deck, and passing through the other side, would have no more effect on the safety of the ship, than the port-holes in an ordinary bulwark.

If this naval cruiser, thus roughly indicated to this Institution eight years ago, does not embody the best of the leading ideas as to what a modern ship of war should be, then we are deceived in the most recent expression of opinion of the first scientific men, artillerists, naval officers, and naval architects of this country. Mr Boolds made a present of his design to the country, but it was too advanced to be worthy of notice, until it came back to us in some respects appreciated and appropriated by foreigners.

Circular ironclads are also the native product of this district. As floating batteries, they are unsurpassable. Mr Elder's had some pretensions to a form of least resistance, but otherwise the Russian's appear to be unobjectionable "tubs."

Without assumption, it appears to me that, so far as can be seen at present, we have nothing to fear from the naval developments of Continental Europe; and certainly nothing to anticipate in that direction, that a comparatively moderate effort, on the part of our Government and our Naval architects, our Shipbuilders and our Engineers, would not enable us to overtake.

On the motion of Mr BROWNLEE, a hearty vote of thanks was awarded the President for his address.

On the Expansion of Water.

Discussion on paper read by Mr ALEX. MORTON, *on 23rd April, 1872.*

This discussion was concluded on 22nd October, 1872, when—

Mr BROWNLEE said that Mr Morton's formula agreed most remarkably with the best experimental determination which had been made —more closely indeed than any other formula known to him, and was, therefore, useful in making special calculations. He did not, however, recognise any theoretical principle upon which the formula was based.

On Improved Canting-Crowned Anchors.

By Captain THOMSON.

Received and Read 22nd October 1872.

My attention was first directed to the improvement of anchors from finding that canting-crowned anchors were not certain of taking hold in soft or loose bottom. The construction of an anchor which would combine all desirable properties, and get rid of the objectionable ones, has been attempted from time to time by a great number of inventors, and over 100 anchors have been patented with this view. But while they have gained an advantage in one direction, it has been more than counterbalanced by disadvantages in another.

The properties of an anchor may be described under two heads:—

1st. The *indispensable* properties, namely, certainty of *biting* in every description of ground; equal strength in all its parts, and good holding qualities.

2d. The *desirable*, but not indispensable properties, namely, non-liability of entangling the chain, ease of breaking out of the ground, and convenience of stowing.

The fouling of an anchor can, in a great measure, be guarded against, but there is no remedy for its not taking hold.

It will be readily admitted that any anchor which is defective in any of the first properties cannot be a good one, although it may possess all the second properties in the highest degree.

That this is the case, in various degrees, with the jointed anchors now in use, is known to many persons who have had opportunities of using them in various descriptions of ground. The causes of these defects cannot easily be discovered by practical tests with large anchors, on account of the difficulty of getting the various descriptions of ground, and the difficulty of putting them in all the positions they are liable to assume when tumbled about by the vessel.

The theory can be more easily illustrated by small models in pre pared soil, where they can be put into every possible position; and with models of the various anchors of the same weight, their properties can be readily discovered.

When "jointed-crowned" anchors were first introduced, it was believed that the liability to foul had been reduced to its minimum, and it had certainly been reduced, so far as the arms were concerned, "when the anchor was set in the ground;" but the stock remained still as liable to be fouled or broken as ever, and it was soon discovered that the facilities for taking hold of the ground had been considerably reduced. This defect in itself far more than counterbalanced the advantage gained. This refers to the Porter and Trotman style of anchor, the canting of which depends upon the resistance offered to the ground by the "spur" or "togle" on the outside of the arm. In soft and loose ground this togle does not always give the necessary resistance, and the anchor comes home with the under arm against the shank, and the upper one standing up.

A number of anchors have been invented having an arm falling on each side of the shank, and both taking the ground at the same time, thus giving increased holding power with diminished weight. It has been found that their certainty of taking hold of the ground is defective, and various attempts have been made to remedy this defect, with but partial success. This description of anchor requires both arms to meet equal resistance, otherwise first one looses its hold, then the other, and so on. In rocky ground, where an anchor only holds by the bill meeting some irregularity, it is not likely that the two bills will always meet with two irregularities just when required.

The old style of anchor, with a wooden stock, although cumbrous and very liable to entangle the chain, is still preferred by many, on account of its greater certainty of biting, and less liability of the stock getting broken.

Various shapes of palms, set at various angles, have been tried, with the view of getting at that which suit equally well in all grounds.

It will be readily understood that no fixed angle can attain the best results in all grounds, because if "the fluke is set at an acute angle. which is required for entering hard ground, it becomes a plough in soft. In soft ground the greater the angle the better the holding power."

It must, therefore, be evident that no anchor can be constructed with flukes at a fixed angle which will give the best attainable results in all grounds; and to attain this, the arms must be capable of being "set" to suit the nature of the ground. This is provided for in my improvements, and has not hitherto been attempted in any other anchor.

The claims which I make for my anchor are as follows:—

1st. That the stock cannot be fouled by the chain, nor broken.

With regard to this claim, I may state that the breaking of a stock is of such common occurrence that we overlook the fact that an anchor is useless without it; that it is very liable to be fouled by the chain, and frequently gives a great deal of trouble to clear. The strength of anything is the strength of its weakest part. Thus the strength of a common anchor is the strength of the stock, which is easily and frequently broken. If an anchor is useless without the stock, why not have the stock as strong as any other part?

2d. That it readily cants, and takes hold in any ground.

This is the principal aim in this anchor.

3d. That there is no probability of fouling when once set in the ground, and but a remote chance when not set.

4th. That the upper fluke, instead of standing up, as in the old anchor, or lying useless on the shank, is made to come down and take hold of the ground, leaving only a small angular projection above the shank, which the chain easily sweeps over.

5th. That when "catted" and "fished," or taken inboard, there is less liability of the ropes getting foul of it.

6th. That the angle of the flukes can be easily changed to suit the nature of the ground.

7th. That it can be easily taken to pieces, and stowed away.

In my invention I have endeavoured to preserve and improve on the indispensable qualities, while attaining the desirable ones, to a great extent.

Trials have been made with anchors of sufficient size, to show that the claims I make are substantial.

It must be admitted that so long as an anchor must assume the form of a hook to lay hold of the ground it will be impossible to construct an anchor which will not foul under any condition, and the only thing that can be done is to reduce that tendency to its minimum degree.

It is claimed for some anchors that they cannot be fouled, but it is erroneous.

Captain THOMSON then exhibited models of various anchors, and illustrated their properties by experiments.

In the after discussion,

Captain THOMSON said he did not think his form of anchor would be so heavy as the ordinary anchor.

The PRESIDENT said it would be one-third less in length.

Mr WEST said that in the case of this anchor the whole strain was communicated through the stock. The stock then becomes a girder supported at the ends, and the load applied at the middle. The question is, What is the strength of this anchor as compared with others of the same weight?

Captain THOMSON said that the stock was of a curved form, and thus the strain upon it was similar to that on an arch.

Mr WEST said that the efficiency of an arch depended on the sufficiency of the abutments.

Captain THOMSON said that one of his anchors stood a strain of 4¾ tons. The admiralty test being only 1¾ ton. And then the stock did not bend, but collapsed with the lateral pressure communicated through the arms or abutments, which showed that it sustained the strain by being arched on the side opposed to the tension. All the experiments showed that this form of anchor was stronger than the common straight shank anchor.

On the motion of the PRESIDENT, a vote of thanks was awarded Captain Thomson for his paper.

On a New Form of Equilibrium Water Sluice, or Stop Valve.

By Mr F. G. M. Stoney, C.E.

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

Received and read 26th November, 1872.

In bringing before your notice the subject of this paper, I do not propose to occupy your time with anything like a paper upon the construction and working of ordinary sluice valves, as I have no doubt that most gentlemen present are more fully acquainted with the subject than I am; but I hope in attempting to give you a description of my patent equilibrium sluice, to make the subject somewhat interesting, and occupy as little of your valuable time as may be.

There are two kinds of prejudice which it is well to guard against, as they are alike detrimental to the useful development of progress.

The first is the natural prejudice of an inventor in favour of his own notions, which is very likely to confine his ideas to a groove, and prevent his taking a broad view of the question under consideration.

The second is the prejudice of the general public against anything which may be considered as an innovation upon existing forms, and, for certain causes, this prejudice is very likely to influence the makers of standard appliances against an arrangement which might more or less interrupt the harmonious working of an existing system; and this, though it sometimes acts as a safeguard against worthless innovations, frequently prevents the development of a useful idea.

I have every confidence in bringing this subject before the Institution that it will be fairly and freely considered, and that if I am in a groove, I may be kindly helped out of it by the sound judgment of those gentlemen present, who are so well acquainted, theoretically and practically, with the construction and working of valves, and from whose judgment I hope for a sound and valuable opinion of the practical utility of my valve.

Before proceeding to the description, I would wish to state what reasons induced me to seek for any but the ordinary form of valves. I found upon different occasions where it was necessary to open valves speedily and with certainty of their action, that the ordinary valves got stiff and stuck just when it was most urgent that they should work easily.

Again, the subject was brought under my consideration in India, because of the difficulty I saw there in opening or shutting large sluices for irrigation purposes, and it became a fixed principle in my mind that, instead of constructing appliances with screws, gearing, or hydraulic power to overcome the enormous friction on a very large sliding sluice valve, that some means and form should be adopted, so that the pressure due to the head of water should be equilibriated in the first instance, and so do away with work to be done, instead of devising powerful machinery to overcome that work, which, though it may be overcome, yet represents a great deal of power wasted, and a corresponding amount of wear and tear, which might otherwise be avoided, and for this purpose I have designed large equilibrium sluices for irrigation purposes in India, some of them representing an area of 36 square feet, in which the pressure of water is altogether equilibriated.

The valve I now bring before your notice was designed, in the first instance, as an outlet valve for an irrigation tank or reservoir in India, having a depth of water of about 100 feet, and in this case is drawn to suit a 2ft. 6in. pipe. The whole valve is in three main pieces: the valve casing, the hood, and the moving cylindrical valve inside.

Figure 1 (See Plates) represents a longitudinal vertical section through the valve and pipe.

Figure 2 represents a sectional plan of the valve casing, with a portion of the hood.

Figure 3 represents a sectional plan of the open cylindrical valve D.

Figure 4 is a sectional enlargement, showing how the moving valve makes its joints above and below respectively, with a brass guide bush fixed in the upper portion of the casing, and with the brass valve seat attached to the orifice in the diaphragm.

Figure 5 is an enlargement of the head of the screw.

Figure 6 is a transverse section on line P Q, showing the holes through which water communicates with the top of the hood.

On reference to Figure 1 it will be seen that the enlargement of the pipe constituting the main piece or valve casing is divided into a lower chamber A, and an upper chamber B, by means of a sloping diaphragm, projecting upwards from which is a vertical cylindrical orifice C, at least equal to the diameter of the pipe. This orifice communicates with the upper chamber B by allowing the water to flow all round, so as to fill the chamber B from all points of the circle.

The principle upon which my valve is constructed is that of causing the pressures all round on a circle to counterbalance each other, and for the practical carrying out of this idea I close the orifice C by an open cylinder D, which has not any head in it, or any surface exposed to unbalanced pressure.

This open cylindrical valve D, when it is shut down and in watertight contact with the prepared valve seat in the orifice C, allows the water to flow upwards and fill the hood E, which may be at all times full, but prevents the water from flowing through the orifice C into the chamber B. It will be seen that the head of the cylinder D is prepared with a suitably-turned and brass-faced cylindrical recess, upon which is carefully but freely fitted a brass piston ring G, which is capable of shifting its position vertically with regard to the cylinder D.

This piston ring G is slightly coned on its outer vertical surface to suit a like coned portion of the upper part of the brass guide bush fixed in the upper portion of the chamber B, so that when the cylinder D is closed, and makes a watertight joint with the valve seat, the piston ring G will at the same time make a watertight joint with the guide bush, thereby providing against any water escaping from the chamber A or the hood E into the chamber B, either through the lower joint at C or the upper joint at G.

By this arrangement the pressure of water is taken up all round the cylinder D, tending to burst it, but not communicating this strain to any portion of the valve, so as to influence in any way the opening or closing of the cylinder D, and the only portion of this valve which is exposed to unbalanced pressure is a narrow annular area, due to the coning of the valve seat and the piston ring G, but this trifling want of equilibrium disappears when the valve is slightly opened.

It will also be seen from Figure 1 that with the cylinder D is cast a smaller guide cylinder F, which being turned, and passing through a bored chamber in the upper portion of the hood E, forms, in conjunction with the brass guide bush in B, powerful and suitable guides to the steady and true vertical motion of the cylinder D.

This small cylinder F also forms a most convenient means of carrying the brass nut for the lifting screw, and a chamber in which the screw is well protected.

It will be seen from Figure 6 that there are holes bored in the head of the cylinder F, and passing through the flange of the brass nut attached to it, which allow water to communicate with the upper chamber in the hood E, thereby equalising the pressure of the water on the cylinder F.

The head of the lifting screw, as may be seen from the enlargement, Figure 5, may be provided with a coned collar, which being carefully turned and faced on both sides, and working between two similarly coned and faced watertight bushes fixed in the head of the hood forms, as it were, a small valve in itself, which, whether the screw is pressed upwards or downwards, forms a watertight joint, so as to obviate the necessity for packing.

The screw and all working parts of this valve are composed of carefully-finished brass. The cylinder D, as may be seen from Figure 3, need not be turned on its outer surface, excepting where it is prepared on the top of the piston ring G, and below where it is prepared for and finished by a brass coned ring to suit the coned brass valve seat in C; instead of being turned on the remaining portion of its outer surface, it is cast somewhat smaller in diameter than the brass guide bush in the valve casing or chamber B, and the space between them is made up by a suitable number of vertical brass slips attached to cylinder D, and turned on their outer surfaces to fit the guide bush. These slips appear in section on Figure 3.

From the enlargement, Figure 4, which illustrates a portion of the cylinder D shown shut and in conjunction with the section through a portion of the hood and casing, it will be seen how the pressure of the water from the hood causes the piston ring to make a watertight joint with the brass guide bush, at the same time allowing facility for the cylinder D to adjust itself downwards, and find a true joint with the valve seat in C. This arrangement, without the use of any packing, provides an excellent means of compensating for any spring due to the pressure of water, which might take place between the brass guide bush, in the head of the chamber B, and the valve seat in C. It will also be seen from this enlargement, that the upper and outer surface, projecting above the valve casing, forms a convenient guide, by which the hood, being bored to fit it, is kept concentric with the guide bush, and so with the valve seat in C.

It may be easily understood that there is not any unbalanced surface in this valve except the area of a narrow annular surface at the outer margin of the valve, due to the coning, which amounts in this case to a ring ¼-inch wide, having a total area in round figures of 24 square inches.

An ordinary 2ft. 6in. valve would have a surface exposed to pressure of about 855 square inches, which is something more than thirty-five times the area exposed to pressure in my valve. Supposing the head of water to be 100 feet, representing a pressure of 43·3 lbs. on the square inch, my valve would then have, when shut, a total pressure of 1040 lbs., whereas the ordinary 2ft. 6in. valve, under the same head of water, would have a total load of over 37,000 lbs. Supposing my valve to be worked with a screw ¼-inch pitch, or four threads to the inch, and having a simple handle of 18-inch radius, it would require, including the friction of the screw, about 50 lbs. pressure on the handle to start the valve, and after one or two revolutions of the screw, this force would be reduced to about 28 lbs., and this slight amount would only require to be continued while the valve was being lifted through a distance of 9¼ inches, whereas in the ordinary valve provided with a screw of such pitch as would stand the severe pressure on it, and using the same leverage of 18-inch radius, it would require at that point, including the friction of the screw, a force of about 400 lbs. to start the valve. This force would diminish as the valve lifted, but owing to the great pressure at starting, and the distance through which the valve should travel, say about 31½ inches, there would be a large amount of work to be done, which, no doubt, can be done, but is very objectionable, and involves a great deal of wear and tear of the surfaces grinding on each other, under such heavy pressures, and when such valves get scored on their working surfaces, from grit and such like, they become, as it were, dovetailed, and are rendered almost impossible to move.

In my valve there is no such thing, as one surface grinding on the other, under pressure, due to the head of water, and the whole amount of work is so small, and the screw so protected, that I may safely use a brass-lifting screw of sufficiently large body, but with a fine pitch of thread, say four to the inch; by this means, in conjunction with the efficient guides provided, I get a uniform and steady motion of the valve, and also sufficiently slow to prevent damage to the pipes, &c., by opening or shutting too fast.

The total weight of the 2ft. 6in. valve here represented would be about two tons complete; the amount of brass, including the lifting screw, would equal about 300 lbs., and owing to the simple nature of the workmanship on this valve, and the fewness of its parts, and all the work being such as may be performed in the turning lathe, it can be made more cheaply than any valve of its size at present in use.

Figs. 7 and 8 (Plate II.) represent the method in which I propose to arrange this valve as an outlet from deep reservoirs in India.

A cast-iron pipe may be laid in concrete through the embankment, and fitted with my equilibrium valve on its outer end at the foot of the slope. The discharge water may be received in a suitable basin, wherein its velocity is lost, and from whence it may flow quietly over a small weir into an ordinary irrigation channel. On the inner end of the pipe is a cheap and simple clack valve, placed in a suitable cage of timber framing, covered with perforated zinc, and placed on a floor of concrete. The duty of this valve is to allow the equilibrium valve A outside to be cleaned, &c., and to accomplish this it is only necessary to shut down valve B before opening valve A, as the pipe will be full of water, and therefore the valve B may be shut without any water pressure or current acting against it. When the valve B is shut the valve A may be removed and cleaned, and then put back and shut down. There is an inch hole in the clack valve which allows water to leak through when it is shut, and this water is run off by a two or three-inch stop-cock in the casing of the outer valve A, and when the stop-cock is shut the pipe will refill, so that the clack valve B may now be lifted free from pressure or current, and may be conveniently actuated from the head of the embankment by means of a suitable rod (timber, by preference) working through simple guides fixed on standards in the face of the inner slope. This arrangement provides conveniently for any repairs or cleaning to the valve A, and may also serve to relieve the pipe from pressure when desirable.

Besides the ordinary purposes of a stop valve or sluice, this valve may be most conveniently adapted for the purpose of regulating the flow of water into a tank or cistern, so as to maintain a uniform level, which may be simply carried out, as will be seen on reference to Fig. 9 (Plate III.), which shows a modification of the valve, arranged so as to be worked up and down directly by a simple float, which causes it to open or close the orifice as may be required by the level of the water. A valve of this description is more suitable for this purpose than any valve yet made, for two reasons—1st, and chiefly because of the slight power which is required to actuate it under pressure; and 2nd, because of the short distance through which the valve requires to travel between its extreme ranges.

It will be seen from the arrows the direction in which the water flows, and the action of the valve will be easily understood by a little inspection of the drawing, which also shows a cage attached to the float, which passing upward outside the valve, carries a ring or disc fitted with a hand-screw. This cage, &c., follows the motion of the float and valve, but by turning down the handscrew against the top of the valve casing, till it lifts up the float and valve, closing the orifice so that the apparatus may be simply converted without the use of an extra spindle or stuffing-box into an ordinary stop valve, which will prevent water flowing into the tank or cistern, when such is desirable, for the purpose of repairing or cleaning.

In the after discussion,

Mr CLAPPERTON asked in what particular was this valve of Mr Stoney different from other equilibrium valves, which were so commonly used? The valve referred to was a common equilibrium valve adjusted in the ordinary way with an annular space of a quarter of an inch to give the pressure to the closing part, whereas in common equilibrium valves less than a quarter of an inch is sufficient. He thought that Mr Stoney was arguing about circular, not slide, valves, when he said, that a quarter of the diameter was quite equal to the area of the outlet or inlet.

Mr STONEY replied that it seemed to him that Mr Clapperton did not yet understand his valve, and the essential difference between it and a common equilibrium valve. If they could make valves discharge large bodies of water as easily as steam, there would be little difficulty. There was a vast difference between his valve and the ordinary equilibrium valve, which was composed of two discs, separated from each other by a spindle. Those valves were very well fitted for a fluid like steam, which was so light. His valve had no discs. It was simply an open cylinder; and if he fitted it with a disc, counter balanced by another disc, the body of water would so forcibly strike against it, that it would shake the valve to pieces. That was the essential difference between his valve and the ordinary equilibrium steam valve.

Mr CLAPPERTON said that Mr Stoney would greatly favour the Institution, if he were to explain how the water coming from either the right or the left side acted so that the valve became in equilibrium.

Mr STONEY said, suppose that the water coming from the pipe from the right flowed upwards from the chamber A, through the orifice C, and filled the hood E; if the cylinder D were shut, no water could flow from the inside chamber or hood to the outside chamber. This valve being shut down, the whole ring is subject to the pressure of water, and it has strength to resist that; there was no surface exposed to pressure upwards or downwards. There was no large disc exposed to the action of water.

Mr KAY said there was one point which he thought must have attracted most of the mechanical engineers, and that was—the stuffing-box. It was proposed to make it water-tight by fitting the flange into a brass disc, but no packing was introduced. Now, he would say that would not withstand the pressure of water without some kind of packing, such as a cup-leather. He was satisfied that by turning and grinding these it would work better; but it was simply a close-fitting disc, and he did not think that it would be so tight as a common stuffing-box, as arranged.

Mr PAGE said that the details of the stuffing-box were of little moment, as any slight defect there could be easily remedied without taking from the merits of Mr Stoney's ingenious valve. The stuffing-box, as represented, he feared would not keep tight under high pressure; but he thought it only fair to state, that with a slight modification, it resembled what had been used, and might be employed with safety under low pressure.

Mr ANDREW LECKIE said he thought the collar was nothing more nor less than a valve. In the coned part being made of cast-iron, he thought that when the valve was in disuse there would be a tendency for it to become fixed on account of the amount of taper which it had. Otherwise he thought that it was very admirably planned for the purpose intended.

D

Mr Stoney said he had to thank the members for the various suggestions made, as to the theoretical and practical advantages and disadvantages of his valve. He must confess that he had no experience as to whether the valve would work well or not; but at the sametime he felt convinced that it would be a very simple matter to make it work. He simply confined himself to the advantages of the valve in its main features; and it was a very small matter of detail whether it was advisable to use a cup leather on the screw or not. He believed that, in making this valve, it would be more suitable to make these collars at an angle of 45 degrees or more, so as to form cone valves on both sides of the screw collar. On this valve the total weight of the moving piece was not more than 7 cwt. If to a valve of such a size as that be added the extreme pressure that will come on it, there will be a load of 1800 lbs. on the screw, so that there was nothing whatsoever in this to prevent it being made sufficiently tight. This valve was designed for irrigation purposes; and, therefore, it was unnecessary to be very careful as to its leaking a little; for leakage in such circumstances was a very small matter. He was glad, however, to have had the opportunity of bringing it under the notice of the Institution, and he would be gratified to carry out their suggestions and make it perfect in every respect, which, he believed, would be easily done. As regarded the coning, and the amount of taper, he believed it was more than was allowed in the ordinary draw valves; but it was found in them that a slight amount of taper facilitated their action very much in lifting, at which time they were most likely to stick, and not when they were closing. He thought the amount of taper shown, which was about one-eighth of an inch, would suit the required purpose, and not wedge.

Mr Clapperton said that while thanking Mr Stoney for the nformation given, he would like to k now the facility with which the valve would equilibriate and adjust itself; and what was the weight of water he had worked it under.

Mr Stoney said that he had not yet worked any valve of this description. He had orders to make them for the Indian Government, which had granted him funds for this purpose two years ago, but circumstances had delayed their introduction.

Mr KAY believed that it was a very good valve, and that after a little improvement it would work very well indeed. He had much pleasure in proposing a vote of thanks to Mr Stoney for his excellent paper.

On Mineral Oil as a Lubricant.

BY MR J. J. COLEMAN, F.C.S.

(SEE PLATE IV.)

Received and Read 26*th November*, 1872.

THE attainment of a good, efficient, lubricating oil for machinery, of constant quality and cheapness, has always been an important and difficult object amongst machinists.

Engineers, from time to time, have fixed upon special oils as being suitable for their purposes. Increased demand for such favourite oils has then frequently caused their prices to advance to far more than can be afforded. A familiar illustration of this fact occurred with lard oil, which being an exceedingly popular lubricant, reached and maintained for a long time a value of £70 per ton; and a still better example is afforded by sperm oil, which attained and kept for a considerable time a value of about 20s. per gallon.

The ever-increasing demand for lubricating oil, owing to extension of works, railways, and engineering operations, renders it more difficult every year to obtain the requisite supplies of oil at a cheap rate.

Olive oil, though comparatively cheap this season, has during the last fifteen years been getting slowly dearer. The average price per ton five years ending 1870 was £57 6s. 11d. per ton, against an average value of £52 18s. 10d. per ton five years ending 1860.

The railway companies who formerly used olive oil have changed of late years to refined rape oil for their locomotives. But rape oil has been advancing in price also, and that notwithstanding the fact that the imports of seed oils five years ending 1870 are *double* what they were five years ending 1860. Being dependent in a great measure also upon the Continent for our supplies of seed oil, international disputes affect the market. During the late Franco-Prussian war the price of refined oil rose nearly 40 per cent., and sophistication became so common that it was no easy matter to buy a pure oil in this country for many months.

The question of what mineral oil is capable of doing for the machinist is therefore an important one, not only on account of the economical aspects of the case alluded to before, but also on account of the fact that material exists in our country for producing an unlimited supply of mineral oil in addition to the yearly quantity of 10,000 tons, estimated as being capable of production by plant actually in existence.

Mineral oil has been hitherto chiefly consumed for the lubrication of spindles, but in bringing this paper before the Institute the writer is specially desirous of calling attention to recent improvements in the manufacture, which give fair promise of its application being successfully extended in new directions.

In the early days of the manufacture mineral oil had the reputation of being repulsive in smell and ugly in colour. These characteristics, however, are now things of the past. That its use requires care, and that experience has required to get at the right way of using it, must be assigned as the cause why some who experimented with it in the early days of its manufacture have not met with the success which others have more recently attained in its varied applications.

It is now more than twenty years since Mr James Young established works for the production of mineral oil from Boghead coal, and it is a curious fact that the primary object for which these works were started was *not* the production of burning oil for lamps. They were established for the purpose of producing a lubricating oil for the supply of cotton spinners at a time when sperm oil was extremely dear. Mr Young's efforts succeeded thoroughly, for the use of mineral oil has extended gradually *for that specific purpose*, so that at present probably 75 per cent. of the cotton mills in the kingdom are run with it. The *now* familiar paraffin lamp oil was formerly waste product, because there was no lamp in existence that would burn it, and it was only after some considerable time that the great paraffin oil industry struggled into existence amidst numerous difficulties, which were destined to be *surmounted* by the indefatigable energy and perseverance of the inventor, and *rewarded* by the creation of one of the most colossal and interesting chemical industries of the age.

It is estimated that the oil works in Scotland distil annually about 800,000 tons shale, producing 25,000,000 gallons crude oil, which when refined, is capable of yielding 10,000,000 gallons burning oil about 10,000 tons lubricating oil, 5800 tons paraffin wax, and 2350 tons sulphate ammonia.

The bottle exhibited contains a sample of the crude oil, and in Table I. is a list of the products which are obtained from it, viz., naptha, a light volatile substance; 2nd, burning oil; 3rd, lubricating oil; 4th, paraffin wax, represented also in the sample bottles before us.

TABLE 1.

	MEAN SP. GR	DISTILLING TEMPERATURE.
NAPTHA, - - -	·750	From 80 to 250 deg. Fah.
B. OIL, - - -	·815	" 250 " 600 "
PARAFFIN WAX, - -	·880	" 600 " 850 "
LUBRICATING OIL, - -	·890	

The refining process consists in separating these products the one from the other, by distillation in large iron stills; but as the different products distil over contaminated with dark, strong-smelling impurities, they are treated also with chemicals until the desired purity is attained. In other words, the separation of the different products of crude oil is effected by distillation, and their individual purification is accomplished by chemical treatment.

If crude oil is placed in an ordinary still, with a condenser attached, and heat is applied, it will boil like any other liquid, and give off vapour, which condenses in the worm of the still to a liquid. As long as there is any naptha in the liquid, which in quantity seldom exceeds 5 per cent., the temperature of the boiling liquid in the still will not exceed 250° Fahr. By the time all the burning oil has passed over, the temperature will not rise higher than 600° Fahr., but during the distillation of the remaining part, which consists of the lubricating oil and paraffin wax mixed together, the temperature of the boiling mass will be between 600° and 850° Fahr.

Thus it will be seen that mineral lubricating oil has quite as high a boiling point as ordinary oils, such as olive oil, rape oil, or fish oils.

It would take too long, and be out of place at this meeting, to describe the various chemical treatments which the oils undergo, but it may be mentioned that the lubricating oil is always finished with a slightly alkaline wash before sending into the market, and that it is in consequence quite impossible to find the slightest trace of acid in the commercial product, whilst it is a well-known fact that both animal and vegetable oils frequently are so acid as to corrode brass.

It will have been observed that the paraffin wax and lubricating oil *distil over together*. The presence of paraffin wax in lubricating oil is no benefit to its lubricating qualities, but rather the reverse, besides which, the presence of the wax makes the oil liable to freeze in cold weather. It is fortunate for the lubricating oil that the high value of the wax always makes it important for the manufacturers to take it all out. This is effected by freezing the oil, which, in warm weather, is accomplished by the beautiful and ingenious mechanism invented by Mr Kirk for the production of artificial cold by the expansion of previously compressed and cooled air, and by which a reduction of temperature to 12° below the freezing point of water is easily attained.

The frozen oil is put into bags and pressed by hydraulic power—the wax is retained inside the bag in scales resembling the scales of a fish, the oil is squeezed out and collected.

The sample exhibited represents well refined commercial mineral lubricating oil, and possesses these qualities:—

1. It is free from unpleasant smell.
2. It boils at over 600° Fah., and therefore contains no dangerous volatile matter.
3. It is quite unalterable in the air, does not absorb oxygen, and gum the bearings of machinery like some other oil which are

liable in warm weather to coat machinery with a leathery substance.

4. It communicates its property of keeping machinery clean to other oils—by preventing their gumming.
5. It will not only refuse to ignite spontaneously when waste is moistened with it and placed in heaps, but it has also the property of preventing other oils producing such results.

Against all these good points is placed one objection, viz.: that it is too thin and limpid; even too thin to be used by itself on spindles.

Sperm oil has always been the favourite oil for spindles, and sperm oil has a particular body or viscosity. Supposing a funnel filled with sperm oil empties itself through a small orifice in five minutes, if filled with pure mineral oil it empties itself at same temperature in nearly three minutes. If filled with lard oil, in seven minutes. Thus the body of sperm oil is *intermediate* between that of mineral oil and that of lard oil; and supposing we make a mixture of equal parts of mineral oil and lard oil, we get at once a product which runs through the apparatus in nearly the *same time as sperm oil.* In fact, sperm oil is just of that body or viscosity which, on the one hand, will prevent adhesion of the metallic surfaces, and on the other hand prevent unnecessary resistance to motion (or glueing, to use a familiar term) in the case of spindles revolving from 2000 or 3000 to 10,000 per minute.

For light machinery like spindles much body is to be avoided; in fact, I have known of a cotton mill being completely stopped by the application of an ordinary-bodied olive oil to the delicate mechanism of the spindle. So far as the writer's observations extend the value then of sperm oil for such purposes is *not* in its possessing a mysterious quality called superior "lubricating power," but merely that it possesses a certain viscosity, which can be exactly imitated by the thickening of mineral oil by suitable heavy-bodied oils.

Inasmuch, however, as the production of mineral oil is so large and the price so reasonable, the question of extending its application to locomotive engines, ordinary shafting, and heavier classes of machinery than spindles, is of great interest. About three years ago my attention was particularly directed to this subject by Mr John Orr Ewing, the Chairman of Young's Company, and my first experiments in this direction were much facilitated by the courtesy of Mr Wheatley, the Locomotive Superintendent of the North British Railway Company, who kindly gave me every assistance in his power.

The first object was to find whether any mixture of mineral oil with ordinary fatty oils, such as rape, olive, castor oil, or neatsfoot oil, would answer the purpose.

A great number of journeys were made with such mixtures—with locomotive engines between Glasgow and Edinburgh, and Carlisle and Edinburgh—the point observed being with each oil to take the temperature of the axle-boxes of the two front wheels of the locomotive, and also the temperature of the atmosphere at the end of the journey, and, if not an express train, at certain points on the road.

The general results of these experiments were unfavourable. Mixtures containing 40 per cent. mineral oil would not do at all. Thirty per cent. produced occasional heating, and 20 per cent. was passable. Except in the important matter of keeping the engine clean, and preventing gumming, which is answered by a very small percentage of mineral oil, the writer could not avoid coming to the conclusion that a *mere mixture of mineral oil with other oils* will not give a resultant having sufficient body for such heavy work as a locomotive.

The question then suggested itself—Cannot mineral oil by chemical means be made heavier in body? and seeing that ordinary oils, like rape, lard, and olive, are compound; that is, composed of fatty acids and glycerine, it seemed to us the question was capable of an affirmative answer.

It was thus, then, that the chemical consideration of the subject evolved the idea of combining the oil with caoutchouc, which, when *used in the way described in our specification*, and for which letters patent were granted, produces a most extraordinary effect in improving the lubricating powers of the oil. With this new product a number of journeys were made between Glasgow and Edinburgh.

TABLE 2.

EXPERIMENTS MADE WITH LOCOMOTIVE ENGINE, BY MR. J. J. COLEMAN, F.C.S.

GAIN OF TEMPERATURE OF JOURNALS OF ENGINE'S LEADING WHEELS.—DEGREES FAHRENHEIT. (*In Excess of the Atmosphere*).

Date.	REFINED RAPE.	Gain.
1870		
June 22	Glasgow to Edinburgh, - - -	28
„ 22	Edinburgh to Glasgow, - - -	33
„ 22	Glasgow to Edinburgh, - - -	28
„ 23	Do., - - -	30
„ 24	Do., - - -	28
„ 24	Edinburgh to Berwick, - - -	31
„ 24	Berwick to Edinburgh, - - -	25
	AVERAGE GAIN OF TEMPERATURE, -	29
June 9	Edinburgh to Carlisle, - - -	62
„ 13	Do., - - -	66
	AVERAGE GAIN OF TEMPERATURE, -	64

Date.	EWING & COLEMAN'S RAILWAY OIL.	Gain.
1870		
June 28	Glasgow to Edinburgh, - - -	23
„ 28	Edinburgh to Glasgow, - - -	28
„ 28	Glasgow to Edinburgh, - - -	19
„ 29	Do., - - -	21
„ 30	Do., - - -	19
„ 30	Edinburgh to Berwick, - - -	19
„ 30	Berwick to Edinburgh, - - -	18
	AVERAGE GAIN OF TEMPERATURE, -	21
June 9	Carlisle to Edinburgh, - - -	54
„ 13	Do., - - -	55
	AVERAGE GAIN OF TEMPERATURE, -	54½

Table 2 indicates the results obtained, and it will be noticed that the average gain of temperature, which is the difference between the temperature of the air and the axle-box on arrival, is only 21° Fahr. with Ewing & Coleman's oil, against 29° Fahr. when rape oil was used. Further, it was found that on trying similar experiments on the express passenger engine between Carlisle and Edinburgh, the average gain was 64° with rape oil, and 55° with Ewing & Coleman's new oil.

These results were satisfactory, precise, and conclusive to my mind, and were arrived at in June, 1870, by following the engine from the starting in the morning until going into shop at night; and at the same time it is right for me to state to this meeting that such figures as I give are simply the result of my personal and private observation, and gave me that faith in the utility of the invention which has enabled me since to recommend the adoption of the oil in actual practice.

It is of more importance, therefore, to state, that as a practical result of these researches several of the largest railway companies of the United Kingdom are using the oil at the present moment, and that after a practical experience of the working of many hundreds of tons (and I have no doubt shall soon be able to say thousands of tons), it is admitted, without doubt, that there is less tendency to gumming of the machinery than when rape oil is used.

However good a thing may appear experimentally, practical men are cautious in adopting innovations, and the prejudices of the engine-drivers are not the least difficult things to overcome.

Some users of the oil prefer to mix it with other animal or vegetable oils for their large engines, but for the general run of machinery such admixture seems unnecessary.

Quite recently a number of experiments have been made with a three inch shaft revolving 25,000 revolutions per hour and weighted to a minimum of half a ton.

TABLE 3.

FIRST SERIES.—Experiments made with a 3-inch shaft, making 25,000 revolutions per hour. Journal weighted to minimum of half a ton.

		TEMPERATURE GAINED BY JOURNAL. Degrees Fahrenheit (*in Excess of the Atmosphere*).			
		1st Hour.	2nd Hour.	3rd Hour.	4th Hour.
Refined Colza Rape Oil, - -	1st Day,	26	34	39	40
	2nd "	31	39	42	42
	3rd "	28	36	40	42
Natural Lubricating Oil, sold as Don, Globe, or Vulcan Oil,	1st Day,	26	38	43	45
	2nd "	33	41	46	48
Ewing & Coleman's Patent Oil,	1st Day,	16	23	26	33
	2nd "	18	19	25	25
	3rd "	16	16	16	20

SECOND SERIES.—In these experiments the Shaft was run without oil until it reached 150 deg. Fahrenheit by friction; the Oil was then applied by worsted syphons, in the usual way,—the object being to ascertain the cooling powers of the Oil on heated journals.

		DEGREES FAHRENHEIT.			
		1st Hour.	2nd Hour.	3rd Hour.	4th Hour.
Refined Colza Rape Oil, - - -	1st Day,	150	140	132	122
	2nd "	150	130	122	119
	3rd "	150	132	126	120
Mixture of Colza and Olive, - -	1st Day,	150	143	134	122
	2nd "	150	144	132	121
	3rd "	150	141	130	119
Ewing & Coleman's Railway Oil,	1st Day,	150	140	122	106
	2nd "	150	138	119	102
	3rd "	150	139	120	100
Natural Lubricating Oil, - - -	1st Day,	150	168	153	150
Bathville Trinidad Oil, - - -	1st Day,	150	192	*	
	2nd "	150	192		

* It was impossible to proceed further with the Trinidad Oil, as the friction, after reaching 192 deg. Fahrenheit, caused the driving belt to slip. The Journal was, however, fed with Ewing & Coleman's Oil, and the temperature lowered as follows:—1st Hour, 162 deg.; 2nd Hour, 136 deg.; 3d Hour, 124 deg.

In the first series of experiments the shaft was run for three days with each of the following oils, rape oil, don or globe oil, and Ewing & Coleman's new oil. At the end of the fourth hour the rape oil caused the journal to attain on an average 41° of heat, the don or globe oil 46°, and Ewing & Coleman's oil 26°.

Again a second series of experiments were made to ascertain the cooling powers of the oil on heated journals. The same three inch shaft was caused to revolve until the journal was raised to a temperature of 150° and then the same oils were applied. In four hours the rape oil caused the journal to cool down to 120°, the don or globe oil would not allow it to cool at all—the temperature still remaining 150°, whilst our new oil cooled the bearing down to 104° at the end of the fourth hour.

TABLE 4.—VISCOSITY.

	Min.	Sec.
German Refined Rape Oil, ...	8	0
French do. do.	11	0
Lard Oil, ...	7	0
Neatsfoot Oil, ...	8	30
Seal Oil, ...	6	30
Sperm Oil, ...	5	0
Pure Mineral Oil, ...	2	45
EWING & COLEMAN'S PATENT OILS—		
Mineral Oil, Ordinary, ...	8	30
Do. For Railway Use, ...	11	0

The apparatus, invented by myself (See Plate IV.) is used regularly by Young's Paraffin Light and Mineral Oil Company (the sole manufacturers), in testing the body of the oil, and is so arranged that the contents of the inner vessel can be raised to a temperature of 120° by admitting steam to the outer vessel, and then the aperture at the bottom of the inner vessel being opened the length of time required for the vessel to empty itself indicates the body or viscosity of the oil. Table 4 shows the viscosity or body of the various oils in common use, as determined by my apparatus, and it will be noticed that Ewing & Coleman's patent oil is quite equal in body to any of them, and it can, for special purposes, be thickened to any extent, even to the consistency of castor oil. But so long as worsted syphons are used there is a limit as to the body which it is advisable to give the oil. When once the exact body required is ascertained, my apparatus supplies the means of always keeping it to constant standard. Considering, therefore, that in this oil we have the qualities:—*first*, of keeping journals cool, *second*, of body (so that it is prevented from running away to waste), *third*, absolute freedom from any tendency to gum, and *fourth*, cheapness; the writer hopes that the members will excuse him trespassing so much upon their time in bringing before their attention the most important step yet made in introducing refined mineral oil for ordinary shafting and machinery heavier than spindles.

Mr CLAPPERTON asked what proportion did the lubricating power of the oils bear in reference to their viscosity?

Mr COLEMAN said the "viscosity" table *alone* would not give any accurate idea which was the best oil for a specific purpose; but if it were found by experiment that an oil, say sperm oil, would answer the purpose best, then by means of that table they could make another oil of similar viscosity, which, other things being equal, would answer as well.

Mr PAGE moved that the discussion be adjourned until next meeting, as matter treated of in the paper was most important.

Mr KAY then seconded the adjournment of the discussion.

The PRESIDENT hoped that members who took an interest in the subject would come forward prepared to speak upon it at the next meeting.

The discussion on this paper was continued on 24th December, by

Mr JOHN PAGE, who said—The thanks of this Institution were due to Mr Coleman for his talented and instructive paper, particularly for the light he had thrown on the manufacture of mineral oils, which no doubt would help to dispel the prejudices which existed to the use of this much abused, yet very valuable oil. He regretted, however, that although he had praised his oil as having good properties, he had left so much to be drawn from inferences, had not given evidence of how much better and economic it is over other oils in the market, and that he had not given practical examples of its value in work. As, for example, there is no reference in either of the series of experiments to the relative quantity of oil used, and hence the impossibility of arriving at the true economic value of the tests. He objected also to the combination of caoutchouc. From its nature it seemed to him to be rather detrimental than otherwise as a lubricant. As Mr Coleman had ably shown the great importance the oil question had assumed, and the great value of mineral oil, the omission alluded to must be regretted by all taking an interest in the matter; and as he had watched with pleasure the rapid strides its manufacture had made here, under the skill and able hands of Mr Young, Mr Kirk, and Mr Coleman, he would like to see a more practical view of the question taken, that thus the most economic and effective oil might be brought under our notice. With this in view, and to give an idea of what he meant, as to practical results showing commercial value, he had prepared a comparative statement of the results of a series of experiments, giving the lubricating properties of six different oils. In each experiment the exact quantity of oil was used, and the testing machine employed was kept running until the oil was consumed. The results are very favourable to the first in the table, "Engleberts," and are conclusive of its value as a lubricant, for it lasts the longest time without attaining a higher temperature; and from inquiries lately made, he was creditably informed that it maintained the high character the experiments have given it. Mr E. Bainbridge, manager of the Duke of Norfolk's collieries, writes on the 9th inst.:—"The extreme purity of the oil is such that we use it in some of our bearings as it squeezes out, four or five times over, before it disappears. That as a substitute for tallow it is a very economical lubricant for inside of cylinders. That one application of it weekly to bearings is only necessary now, which previously required daily attention. We give the following practical proofs of its economy:—

"1st. Application of lubricant to cylinders and bearings of two winding engines:—

Tallow, at 5d. per lb., ... } Neatsfoot Oil, at 5s. 6d. per gallon, ... }	£1	4	3	a week.
Englebert's Lubricant (solely) at 3s. 9d. per gallon, ...	0	11	3	
	£0	13	0	saving per week,

which is equal to 53 per cent.

"2nd. Application of lubricants to cylinder (84 in.) and bearings of pumping engine:—

Tallow and Neatsfoot, ...	£1	1	0
Englebert's (solely), ...	0	11	3
	£0	9	10 saving per week

equal to 46 per cent."

Mr Bainbridge adds—"I feel confident we are saving 40 per cent. by its application."

It is used on railways also. In experiments made on the North Staffordshire Railway, the chief engineer reported, on a run of 484 miles with a passenger train—

Cost of Rape Oil at 5s. 7½d., or nearly 14d. per 100 miles;
Cost of Englebert's oil at 3s. 4d., or nearly 8½d. per 100 miles.
And on 460 miles with a goods train—

Cost of Rape Oil, 24·02d. per 100 miles.
Cost of Englebert's Oil, 8·69d. „

He could add many more testimonies, with his own experience, to show the value of this oil from a practical point of view, and it is from this mode of looking at the question that it assumes something of importance; but he thought it was at present unnecessary to detain them in so doing, but would read an analysis:—

"6 Gower Street, London.

"I have examined the sample of Englebert's Lubricant sent to me, and find it consists of hydrocarbons, not volatile at a temperature of 600 degrees Fahrenheit, with a very minute proportion (less than one thousandth part) of inorganic matter.

"The specific gravity of the oil was found to be 0·880.

"HENRY MATTHEWS, F.C.S., Analyst."

He would add in conclusion—1st. That it is perpetually free from unpleasant smell. 2nd. It is not volatile at 600 deg. Fahrenheit, and is free from inorganic matter. 3rd. It is unalterable in the air, does not absorb oxygen, and has the rare and important quality of forming a thick enough film on bearing surfaces, to prevent such surfaces sticking, and yet not gum or "coat the machinery with a leathery substance." 4th. It does not ignite spontaneously. It is free from spirit, for he found (and the experiments bear out the assertion) that the lubricant is prepared in such a manner as to almost entirely eliminate the spirit. 6th. It is free from acid. He need not dwell on the injurious effect of acids on brass, nor to the well known fact of their presence in some mineral oils. With these good properties he could add that, not only is it not too thin to be used on spindles, but that it is a fact it is used with success for that purpose. He thought he might say, with safety, from the evidence brought before them, that Englebert's lubricant ranks the nearest of all mineral oils to the purity of quality which characterises the best vegetable and mineral oils.

RESULTS OF EXPERIMENTS ON SIX DIFFERENT OILS.

The oil which lasts the longest time without allowing the bearing of the machine to attain a high temperature, obviously indicates both its durability and antifriction properties.

Name of Oil.	Temperature.	Price.	Hours at Work.	Revolutions. Totals.	Revolutions. Per Hour.
Englebert's, - -	130	3s 9d	123	1,621,780	13,185
Sperm, - -	128	7s 2d	70	917,100	13,101
Don, - - -	128	2s 6d	30	396,000	13,200
Rangoon, - -	135	3s 6d	25	330,000	13,200
Refined Sweet, -	136	4s 2d	16	211,200	13,200
Colza, - - -	128	4s 3d	13	171,600	13,200

Each of these experiments was made with exactly the same quantity of oil, and the testing machine in each case was kept running till the oil was consumed.

Two thermometrical oil testing machines were used in the experiments.

Mr DEAS said he had been making some calculations from the data given, and he found that the first experiment gave 200 revolutions per minute, and the next 218. He found there was a little difference there.

Mr G. RUSSELL asked if the specific gravity of these oils varied much, and if the equal quantities used in the experiments were taken by volume or by weight.

Mr PAGE said it was more by volume that these oils were judged.

Mr COLEMAN had a few remarks to make. In reference to the table of experimental results which had been brought before them, he had to point out, that so far as his experience went, he knew of no testing apparatus in existence which would indicate the adaptability of oil for shafting or journals which differed in size or construction from those of the testing machine itself. There had been a great many attempts made to introduce testing machines; and there had been a great many results given us from those machines; but as he had pointed out in his paper, such deductions were useless; for an oil that would suit light machinery would not suit heavy machinery, and *vice versa.* For instance, an oil that would suit the delicate spindles of a cotton mill, and that would allow freedom of movement in these machines, if applied to the shaft of a steam engine, would be nearly as useless as water, on account of its thinness. After years of study given to these matters, he had come to the conclusion, that, without making experiments with the machinery itself, one could not tell the value of an oil. He had done so by travelling day after day, and week after week with a locomotive engine, and the experiments he had made were all of a practical nature, and had given rise to the views enunciated in the paper he had read before them. He could further prove the position he had taken up by M'Naught's testing apparatus, consisting of two discs, the one revolving on the other. Connected with these discs, was a lever. The upper disc was carried round by the adhesion, and the register upon the lever showed the friction between the two idscs. Now, as tested with that apparatus, which was in use all over Yorkshire and Lancashire, pure mineral was proved to be better than any other oil; but practice in cotton mills shows that a mixture of mineral oil with fatty oil is far better than pure mineral oil. This machine merely shows the viscosity of the oil. There were other apparatus in existence to test such oils, as Bailey's, but its indications were of little value for journals different in size to that of the instrument itself. There was no general mode of testing oils by apparatus, and hence they were obliged to come to the machinery itself, to find out what oil was most suitable; and then by the aid of science and the use of tables, they were able to prepare a substitute for the more expensive oil, such a preparation as would suit as well in working and be very *much cheaper in cost.* In regard to the table exhibited by Mr Page, the price of Engelbert's oil was put down at 3s. 9d. per gallon, or or £45 a ton, which was £2 or £3 dearer than rape oil and quite as dear as lard oil at present prices. Then, if they took his quotation of fine rape oil, it was £50 per ton, although as he had already stated it was selling now at £43. As to the quantity of oil which had been used, and his (Mr Coleman's) not mentioning how much that was in comparison with the quantity of another oil used, he had to observe, that he had pointed out in the paper that the body of the oil could be made of any character that might be suitable for machinery, and the waste of the oil depended upon the body; for in practice three-fourths of the oil was absolutely wasted with the syphon, and the rate of waste was according to the rate of viscosity, and that the viscosity of his patent oil was quite as high as oil ordinarily used in locomotive engines. In reference to the commercial value of his patent oil, it was about 2s. 3d. per gallon, or £27 per ton, which was far lower than any oil mentioned in Mr Page's list. Again, he would remark with reference to what Mr Page had said as to his (Mr Coleman's) not having produced any practical evidence of the oil being useful, that he had delayed bringing the paper before the Institution for a year or two until he should be able to say that they had now hundreds of tons of it in use all over the country; and it was from that very experience of the oil that he had the confidence to bring the paper before them, and to say, that in the present state of knowledge there was the greatest advantage resulting from adopting mineral oils for lubricating any kind of machinery. He was pretty well acquainted with the railways of the country—and there was no greater test for oils than on a railway locomotive—and he knew that on several of the great railways (previous to his invention), the mineral or natural oils had been used, but had been found not to suit; in fact, were positively dangerous, the journals of the axles getting so hot, that they had to wait for hours to cool them. Since, however, his patent process had been introduced, he was able to state that mineral oil, by its means, was used extensively in the United Kingdom. Although the natural American oils had been used in shipbuilding yards, where any roughness was not so objectionable, yet when they have been applied in engines of large power, where a good lubricant was necessary, they had been found wanting. He did not say that Ewing & Coleman's oil had no faults; but as a matter of fact he could state that it was the greatest advance yet made in adapting mineral oil for general use on shafting and ordinary machinery. He would be glad to give any further information on any special points that might be raised in the discussion.

The PRESIDENT regretted that the paper had been so short a time in the hands of the members; but he had no doubt that good would come from its study. He did not think that it would be considered necessary to prolong the discussion; but he was quite sure that the meeting would be ready to acknowledge the trouble Mr Page had taken in the matter, by eliminating certain facts which seemed to put other oils on an equally good footing with Messrs Ewing & Coleman's. He begged to propose a vote of thanks to Mr Coleman for his paper.

NOTE RECEIVED ON 21ST JANUARY, 1873.

Mr COLEMAN begs to communicate to the Institution of Engineers and Shipbuilders a note on his Paper read, November 26th, "On Mineral Oil as a Lubricant."

Two leading Railway Company's have used between them 67,647 gallons of Ewing & Coleman's Patent Oil to end of December, 1872, for lubricating locomotives. This represents a train mileage of above 20,000,000 of miles.

Considering that with a Railway Company, we have the stores manager, on the ground of price in relation to that of other oils to please, and that the locomotive superintendents have hosts of engine drivers under them *daily reporting* as to the efficiency of oil and the quantities used per 100 miles, it is impossible to suppose that large quantities like these can be used if the oil is not economical.

It is further reported as a particular characteristic of the oil, that it keeps engines cleaner than Rape Oil (especially in summer weather, when Rape and other oils rapidly oxidize in a warm atmosphere).

This at once does away with any idea that the peculiar composition of the oil has any tendency to produce clogging or gumming.

Finally, in regard to the experimental results in Table III. it was accidentally omitted to be stated that the oil supplied in each experiment was by a worsted syphon of 5 strands—that it was reported at the time by the mechanic in charge that less of our oil was consumed in each experiment than of the other oils, and that the method of supplying the oil and the size of the syphon were preserved uniform during the whole series of the experiments.

280 Bath Crescent, *21st January, 1873.*

On Street Tramways.

By Mr. JOHN PAGE, C.E.

(SEE PLATES V. AND VI.)

Received and read on 24th December, 1872.

THE prejudice which existed for upwards of ten years against City Tramways being overcome, they are now admitted to be a cheap and comfortable mode of transit, well calculated to systematise and thereby facilitate traffic, and, when fully developed, the difficulties which are always experienced on their first introduction into busy and crowded thoroughfares will soon disappear. They are also admitted to be financially a success. Their economic construction and maintenance must, therefore, be a subject of interest to the capitalist and engineer. With this idea, I propose this evening to inquire into the engineering details of Tramways, considering them under the heads of wooden, composite, and iron systems.

It would be rather difficult to say when the first Tramway was laid, but the records of the early part of the 17th century speak of their use at Newcastle-on-Tyne for the carriage of coal from the pits, with immense benefit and advantage to the coalmasters—a horse being able to draw on them three times as much as he could on a common road.

The Tramway was purely a wooden one, and of the most simple kind. Longitudinal sleepers, which served for rails, were spiked down on rough cross sleepers. These so-called rails soon wore into ruts; and as the expense and trouble were great in tearing up the road, and in the frequent loss of the timber, to renew the rails, a plan was devised of spiking down on the longitudinal sleepers an extra piece of timber, to become an easily removed rail. This so-called invention was considered a wonderful improvement in those days; and the records further state that this description of road was used for a considerable period of time in different parts of the country.

Gradually, however, the purely wooden system fell into disfavour. We now enter upon the composite period, when all wheels were of iron, and a ribbon of iron 5 feet long, 4 inches wide, and 1½ inches thick, with countersunk holes for bolts or spikes, was secured on top of the longitudinal sleepers. This was decidedly a great improvement, as the horse was now enabled by it to take double his previous load. It is amusing now to read of a reason given by the Colebrookdale Company for using iron rails. The manager thought it "in part a well-digested measure of economy in support of their trade," and thought it the best means of stocking their pigs, and, if occasion required it, the pigs could be raised and sent to market.

This rail being perfectly free from raised or sunk obstructions, as represented in Fig. 1 (see Plates), was considered "complete," then, "in design and execution," and a great comfort, it was said, to those on horseback who used the road, as the horse could be turned off without any risk of injury. I may add also that wrought iron is spoken of as being spiked down on the wood.

The next step in advance was the introduction of an upright ledge to the former flat ribbons of cast-iron, which ledge rails were spiked down to cross sleepers, and sometimes to stone blocks. They were strengthened and altered in section to suit the wants of the traffic; but, although many modes were adopted to secure the joints, such as dove-tailed notches, tenons, plugs or lugs cast on, still the road failed at the joints, as the iron crumbled or broke there. I find notices of cast-iron sleepers, convex, concave, and flat on top, diced or chequered on surface, the drawings representing them hollow. In fact, the continuous simple cast-iron sleeper has been shown in so many shapes up to the beginning of the present century that it is very difficult to produce anything new in this way.

Figure No. 2 represents a sleeper rail, used sometime ago at Port-Glasgow.

Figure No. 3 represents a sleeper rail of Ransome, Deas, & Rapier to be "10 or 15 feet long and about 8 to 16 inches broad."

Figure No. 4 represents a sleeper rail of Ransome, Deas, & Rapier, as laid down on the quays here for the Dock Trustees. The sleepers are filled with, and laid on, concrete. They are of cast-iron, chilled on upper surface, are bolted together, and in every way very great care has been taken with them.

Fig. 5 represents a tramrail devised in 1860, to combine "two objects, that is, a way for flange wheels, and a way for ordinary vehicles, the flange wheels of different gauges to run in the grooves, and the plain surface for ordinary carriages.

Fig. 6 represents Ransome, Deas, & Rapier's mode of providing the same accommodation. The former is the better plan.

Mr C. Burn, C.E., published, in 1860, descriptions of different sections of tramway rails. I note a cast-iron one, with dowel and socket or groove cast on ends, to secure the joint; and he remarks that "Mr Maquisten, in his report to the City Council of Montreal, says that cast-iron rails at Boston, except on curves, proved a failure!"

I will state some of the objections that have been made to the cast-iron sleeper rail—1st, that a difficulty exists in maintaining the joints level; 2d, that if the joints could be kept so, the cast-iron will crumble there under the traffic, as shown on plan of sleepers in Figure 7.

As the breadth shown on top of sleeper rail in Figure 4 is more than double what the rails are in our streets, it follows, of course, that double the glossy surface is presented to the horses' feet, thus rendering traffic less safe than what it is. This objection, I think is fatal to its use in cities.

Hollow blocks of cast-iron, 11 by 7 broad on top and 7 deep, have been proposed for tramways. Figure 8 represents "C. Mure's Patent.' The blocks are laid about 2 feet 6 inches apart, with a rail sufficiently strong to support the traffic between the supports. The disadvantages of this system are—1st, that a surface of cast-iron, which soon becomes polished, is presented here and there between the paving stones, and in the case of the points and crossings the polished surfaces are greatly increased, to the evident danger of the horses. The second objection—a serious one—is, that if any rail should get out of order, the street must, on account of the mode of fastening, be opened the entire length of the rail before it can be removed. It is, however, a system of great merit, and is well adapted for a light railway, but would be dangerous in a city.

Although not free from objections, Mr James Livesey's system is an improvement on the one we have been considering. It is represented in Figure 9, and is composed of hollow blocks of about 3½ inches square, with a projection on bottom to increase the base of the road. This base is further increased by mounting the hollow blocks upon wrought-iron base plates, 18 inches by 12 inches wide, as represented in the drawing; but, as in Mr C. Mure's system, if any accident should happen to the road, the street must be opened the entire length of the rail before it can be removed. The rail, you will remark, is in the form of "channel iron." It is of great strength, and is well secured underneath on its dove-tailed side, by a dove-tailed iron key, there are no projections on top beyond the rail.

From the examples of iron systems brought before the public, I will select one more, in which an effort has been made to get over the difficulty of repairs without disturbing the streets. The sleeper is of cast-iron, in section the same as a girder, having a flange, top and bottom, with a thin centre web. On the top flange a rail is secured by a screw, tapped into the sleeper. I wonder if it ever occurred to the proposer of this arrangement how the screw could be taken out after it had been in use for a month.

I now call your attention to the composite system adopted for the Glasgow Tramways. The only new feature that I observe in it is the chair in which the longitudinal sleeper is placed, and its utility is questioned. The portion of the street devoted to the tramway was excavated 17 feet wide and 16¼ inches deep. In this trench bituminous concrete to a depth of 4 inches was laid to form a bed for the cross sleepers. On the cross sleepers the chairs were spiked down; the longitudinal sleepers were secured in the chairs by a wooden pin, and the rails, 60 lb. to the yard, were bolted down to the longitudinal sleepers—the nut, of course, being underneath. It is not unreasonable to suppose that, after a little time, the bolts will require tightening up, particularly at the joints; but this cannot be done without opening the streets; and if a bolt should break, in screwing up, a serious difficulty presents itself, into the details of which it is not necessary to enter, as they will occur to every practical man. This objection was met by altering the cheese-headed bolt of the specification to the one I now exhibit. It has been made with a slit on the top, under the idea that it is possible to screw the rail to the sleeper by an instrument similar to a screw-driver. I ask is it possible to give even one turn to the bolt when its neck is in its place in the rail, particularly when its threads, and the threads of the nut rust, and rust they will in the natural course of things?

We must not forget that the bolt holes will let in water; it will be impossible to keep it out; here is the seat of disease, and rot will surely follow in spite of the wash the outside of the sleepers has received.

From the nature of the system the road is very defective at the points and crossings, the road will sink there, as no bond exists with them and the rails of the main line.

It is a pity that Glasgow, the seat of the iron trade in Scotland, should have adopted such a perishable system, encumbered with so many parts, the failure of one, or they are of little use, must endanger the superstructure of the road. I did hope, that as Glasgow had taken the lead in iron structures, her engineers would have led the way in iron tramways, and not have followed the practice of those who adopted wood as a necessity. At the time they were proposed for the city the use of iron would have effected a saving in the first cost; and as a few good iron systems were offered, I express my regret that one of them had not received a trial. It was admitted that the cost did not enter into the question. The experience of the advocates of the wooden system was pleaded as a reason for its adoption. What did this experience amount to? Positively, that it did not come up to the expectation of its supporters. In a report of Mr Haywood, civil engineer, New York, I find the following:— "From the way the road is supported, which is by frame timber, it is almost impossible, not to say impracticable, to keep the surface of the pavements on a level with the surface of the track." "In the street where I live the track has been taken up several times;" and adds that the difficulties had proved greater than he expected in keeping the road level, and this, he said, you will remember, because the road was supported by timber.

Home authorities also, at an early period, condemned the wooden system. An eminent engineer gave it as his opinion "that for street railways, especially where laid in paved streets, the foundation should be of more durable material than timber, for any disturbance of the rails to repair the foundation impedes not only the traffic on the railway but also the ordinary street traffic, therefore timber should be avoided, and the foundation of the rail composed entirely of iron."

I have said that from the nature of the formation of the road that it will fail at the points and crossings, and at the joints of the rails. I now say they have shown that there is something wrong there, and any person doubting me will soon have an opportunity of testing this statement by taking the cars from George's Cross through Cambridge Street, and by the jolts of the wheel over each joint count the number of rails in the road!

From my experience of engineering work I would be very slow in condemning our tramways for their failure at a few points, as I am very well aware of the difficulties that exist in carrying out the details, even under the most careful supervision, which I know they have received, but I ask how are the repairs to be made. There is no doubt about the matter. The street must be opened up, and as all engineers know the danger that exists in screwing up a bolt with a rusty thread, the danger of breaking the bolt and the difficulty in getting the parts of it out of the timber, I will leave the question in their hands.

To show that I have some reason for doubting the stability of the wooden system, I call your attention to a few facts. The Liverpool tramways are in such a bad state that the Corporation intends to take possession of them, as one of the Aldermen said, "to relay them;" and I add that the "Editor of the Engineer," in a leading article on London Tramways, says,—"They are in several places beginning to show serious weakness and defects at the joints of the rails and at crossings.

The Edinburgh Tramways are not in a better state.

I do not think it necessary to bring before you any more examples of systems or sections of rails—and they are numerous—as all that I am acquainted with have the defects I have pointed out; nor to dwell on the resistance offered by the yielding and unyielding of the track which is formed by alternate bearings; nor to the resistance or concussion caused by bad joints, as we know their destructive action, to the injury of the track and to the plant; but will conclude by explaining, with the assistance of models, a system which I think is free of the faults of its predecessors. In saying so, I admit that as the engineering facts and figures of yesterday may be nowhere in a month, it is very possible the details in my plans may be improved.

The system (see Fig. 11) that I now have the honour to submit to you differs from the composite one in use here in this, that it is entirely composed of iron, it is formed of continuous cast-iron sleepers, say 4 feet 6 inches long; 5 inches wide on bed; 4 inches on top, and 6½ ins. deep, weighing about 90 lbs. to the yard. On the upper surface there are dovetailed seats for wedges about 18 inches apart, and a dovetailed seat for the rail. The wrought-iron rail is in section shaped like the letter L inverted ⌉, the vertical limb of which is rolled with a dovetail to fit the sleeper, so that when it is secured in place with the dovetailed wedges, it cannot rise from its seat. I consider a rail of 18 lbs. to the yard sufficient for city traffic. When an 18-feet rail is used it connects five sleepers together, each rail making joint at 2 feet 3 inches from the joints of the sleepers, which secures the surface of the rail always level on top, and as the bottom joints of the sleepers sit in chairs, the joints are preserved from sinking unequally. A most important feature is a rail or tramway.

The system may be carried out in various ways. A simple one is suggested, which is particularly adapted to the busy leading streets of a city. It would avoid the blocking of weeks of the usual traffic, as is done under the present system, to the loss of the traders and the public generally.

It is proposed simply to cut a narrow trench, say 12 inches wide in the street or road, to a depth of about 13 inches. In this trench a bed of cement or asphalte concrete is laid to a depth of about six inches, and on this concreted surface a thin bed of sand or fine concrete is prepared for the longitudinal cast or wrought-iron sleeper, which, when filled with concrete, are seated at their joints in chairs. A light iron tie rod may be used, but I think it unnecessary.

When a line of rail, or one-half of a track, is laid the length of a street, and the paving restored to its original state, the other line of rail, or remaining half of track, may be commenced and finished; and the second track, if required, may be laid in the same way, without interfering with the business or traffic of even a busy thoroughfare; and if laid with care, it is very probable, from the permanent and imperishable nature of the system, that the superstructure of the track will remain intact for many years. The rail will wear, but it can be removed and renewed in a few minutes by simply withdrawing and driving in the dove-tailed wedges, which secure it in its seat. This, it will be admitted, is a decided improvement on the present wooden and other systems described, which necessitates the disturbance of the streets for frequent renewals and repairs to keep the rails level and in place.

The points and crossings can never be made to keep level in the wooden system, particularly those formed by the castings now being used at the corner of St. Vincent Street, as the timbers are cut away to receive them. I do not object to the castings in themselves, as the same pattern has been used with success by Mr C. Mure, but without timber on his system of light railways; but I object to cutting away the timber in the attempt to bond the crossings with the main line. I also object to the manner in which the curves cross each other, as the timbers are much reduced there, in overlapping each other. The right angle crossing at Argyle Street from Union Street is another example of a difficulty that exists with the timber system. The crossing is in a bad state, and will work into a worse one. I have dwelt on these defective features of the wooden system, that I might add all these faults are got rid of in an iron system. Mine are free of them.

I think, if greater freedom were given in the gauge at the curves, the car would run there with less friction. This can only be done in the wooden and other systems described, by having rails rolled specially for that part of the road. In my system, a slight alteration in the sleeper could be made without expense, giving any amount of freedom required.

Under the very able management of Mr Menzies, the horses, harness, men, and the clean state of the cars, are all that we can desire; and in this department we can boast, as we did of old in reference to our omnibuses, that we have the best public accommodation on our tramways in the kingdom.

In the after discussion,

Mr Lyall said he did not observe that any reference had been made in the paper to the cost of laying the tramway proposed by Mr Page. He thought, if Mr Page could give the meeting some information on this point, and how it compared with the wooden system now being carried out in Glasgow, it might be interesting and valuable. He was not clear on the means Mr Page proposed to adopt for uniting the different lengths of his cast-iron longitudinal sleepers. It seemed to him this was an important point, for unless these connections could be made so as to form with the sleepers a uniform resisting bed for the rails, the same defects which were complained of in the wooden sleepers would at these parts be repeated.

Mr Page said he thought Mr Lyall would be astonished when he informed him, that a respectable firm offered to carry out his system in Glasgow, by which a saving of £20,000 would have been effected on the first 19 miles of the Tramway Company's lines. Iron being now high in price, the saving in first cost was not so great;

—a difference, however, of £750 a mile existed in favour of his system,—yet, with that economy in first cost and in the certainty of a corresponding saving in maintenance from the permanent nature of the materials employed,—he must wait his time, as those were obliged to do, who proposed iron instead of wood for ships; they too were met with the remark,—"Wood has been tried, Iron has not." With regard to Mr Lyall's other question, he might explain that the sleepers rested in chairs at their joints, and were thus prevented from sinking there, and as the joints of the rails were made at the middle of the 4 feet 6 inch sleeper, they, the joints, must be always level as when first laid. In complying with a request of Mr Lyall to give a relative cost of the different systems, he would add, as stated before, that his system is now £750 a mile cheaper than that laid down in Glasgow, and £1500 a mile cheaper than that of Ransome, Deas, & Rapier's system. In reference to the rail shown in No. 8, alluded to by Mr Lyall, he called attention to the web, as being an ingenious arrangement by which extra strength was given to the rail at the point requiring it, with very little additional material.

Mr Deas said that as Mr Page had done him the honour to refer to Ransome, Deas, & Rapier's tramway, he might be allowed to make a few remarks. Fig. 4 was a section of the Clyde Trustees tramways, so far as they had been laid, extending to about a mile. The rails were in five feet lengths, dovetailed and grooved at the ends so as to prevent the lapping. It was laid on a bed of cement concrete, 6 inches thick and 21 inches broad. The portion first put down by the Trustees was experimental, and crossed the General Terminus Quay, and led to one of the cranes on the South Quay. It was put down two years ago, on the condition that if it did not satisfy the Trustees, it would be lifted and removed free of all cost to them. Since it was put down, there had never been a halfpenny of repair put on any part of that tramway. The surface of the rails are chilled in about a quarter of an inch, and are very hard. There was a very heavy traffic constantly passing over this tramway; and hence as it had stood so well, the Trustees were so satisfied with it that they had adopted the same system for their other line of tramway. The section shown was 10 inches broad by 8 inches deep, and was intended for flanged and unflanged vehicle wheels. The groove was wide, so that railway waggons could pass over it. This system of tramway was submitted to the engineers of the Glasgow Tramways, with a section from 4½ inches to 5 inches broad, grooved for the purpose of fitting it to the tramway cars, but they did not feel themselves inclined to adopt either his (Mr Deas') or Mr Page's system. He might explain for Mr Page's information, that the rounding away as shown in the drawing, was not wear, but done intentionally, so as to make a smooth joining. The rails showed no sign of wearing, the chilling having rendered them harder than the hardest steel rails that had been used in tramways. The rail was cast in 5 feet lengths for convenience: the switches were 10 feet long, and they were tied at every 15 feet; but tie-rods he thought were not necessary. The cost of the material for the first 4700 yards was 12s. 6d. per lineal yard of single length, or 25s. per lineal yard of tramway, with iron at 60s. per ton. They had now got an offer from the Anderston Foundry Company of something like 20s. per lineal yard of single length, or 40s. per lineal yard of tramway. No doubt, when iron fell in price, it would be in favour of the iron tramways.

Mr Page had no doubt that cast iron would maintain a tolerably fair road; but he still said that the joints did give way. As stated in his paper, they had been tried in Canada, and the engineer to the Montreal Town Council said that they had all failed there. To get over that difficulty it would be necessary to have the rail to cross the joint of the sleeper.

Mr Deas said that their sleepers were very carefully made by the Anderston Foundry Company, who were famed for making railway chairs. He did not see how, with the tongue and groove, there could be any lipping of the joints. He could confirm what Mr Page had said with regard to the lipping of the tramways from St. George's Cross: there was no doubt the use of timber in tramways was a faulty one. Timber was naturally used where timber was obtained cheap, and iron was not easily had; and he believed that it had been used here without considering how differently they were circumstanced. He was surprised that the creosoting had gone so little into the timber, as was shown by the splinter exhibited by Mr Page. He did not expect that, according to the specification, 9 lbs. or 10 lbs. of it would sink into the cubic foot; but he did think a little more would heve permeated it than was shown in Mr Page's sample.

Mr FAULDS said that if the speed was 20 miles an hour, would not the rigidity of an iron road be an objection?

Mr DEAS said that they wanted solidity in tramways. He understood that it was alleged that the bitumen concrete gave it elasticity. He had failed to see any elasticity in it. He thought that if tramways required elasticity, it should be put in the carriages, and not in the rails.

Mr FAULDS thought that tramways were not suited for a city like Glasgow, where we had such an immense cart and lorrie traffic on our principal streets; and he had no hesitation in saying that the tear and wear on horses and vehicles was increased thirty per cent. on every street where tramways were laid. Tramways, he thought, were well adapted for suburban districts.

Mr PAGE said, that Mr Faulds in speaking of 20 miles an hour on a City Tramway, spoke of what could not exist. The speed would not exceed eight miles an hour, and he had the first authority in the kingdom for saying, that the superstructure of a street cannot be too rigid. That was what road makers were always aiming at. It is not rigidity that is objected to in roads. No road maker pretended to say that there was any elasticity in a paving-stone, nor did he seek to make it spring in its bed; on the contrary, he placed it on as firm a bed as he could form. It was the inequalities of the road that were objected to, and he regretted to find our City Tramways were already imparting to the cars the objectionable jolting of the omnibus, consequent on the inequalities of the road at the joints. The question of elasticity on roads was, he feared, little understood, timber was employed without reflecting that there was a limit to its elasticity; but the surface man well understood this; for after a short time, he pronounced the sleeper *asleep*, and found it permanently so, and then stirred up the ballast to give it what the timber lost; thus the road was always loose. Such a state of things could not be permitted in a city

Mr LYALL asked Mr Page whether the street arrangements now being carried out in this city were to be preferred to that of laying the rails nearer the sides of the streets, and leaving a broad passage for the general traffic in the centre? It appeared to some who had an opportunity of observing the working of our street traffic that the present arrangement in the main thoroughfares of Glasgow encouraged every kind of confusion, and increased the liability to accidents; and when boilers, castings, and forgings, &c., of large size were being moved along, the whole of the passenger traffic would be impeded, and from these would result great delay and additional confusion. It was something fearful to contemplate what the results will be in some of those streets, already crowded with vehicles of every kind, should our flying fire brigade dash along when the largest of the vehicles are prevented leaving the centre of the street to make room for the more urgent comer.

Mr PAGE said that if Mr Lyall saw the tramway rails laid close to the footpath, he would consider it a greater incumbrance. Where would private carriages and other vehicles stand?

Mr LYALL said private carriages had no right to stand opposite shop doors, &c., in the main thoroughfares of busy towns. This had only become a practice by indulgence. With reference to Mr Page's plan of fixing and removing the rail, he thought it would commend itself to all interested in this subject.

Mr CLAPPERTON thought that tradesmen had a right to get their goods delivered at their door. The rails are best where they were.

Mr DEAS said that one of the Glasgow Tramway engineers was present, and he was sure they would all like to hear what he had got to say on the subject.

Mr RANKINE might say that what Mr Page had advocated that night was nothing new to the engineers of the Glasgow, and other tramways, who had considered the matter. Mr Page had failed to prove that his tramways would obviate the objections that had been offered to tramways in general.

Mr PAGE—in reply to Mr Rankine's remarks, that "Mr Page had not shown his system was free of the defects of the systems alluded to in his paper," said that he would be obliged for Mr Rankine's information to again call his attention to the following facts already alluded to in his paper, and which were borne out by the testimony of some of the members present.

1st. That timber is a perishable material, and that the attempts to preserve it, as shown by a sample of the wood used, have proved a failure.

2nd. That the bolt hole in the sleeper is a serious defect, as it admits water to the injury of the timber.

3rd. That repairs cannot be effected on tramways, where the fastenings of the rails are underneath, without disturbing the street, interfering with the traffic, and destroying the bond of the paving.

4th. That the defects of the wooden system are now apparent in London, Edinburgh, Liverpool, and in Glasgow—particularly at the points and crossings, and at the curves, where the timbers are actually cut across; and that there is something wrong at the points is admitted by all using the cars.

These defects, and their consequent results, Mr Page insisted, did not exist in his system, for the following reasons:—

1st. That, as iron was only used, it was, he might say, imperishable.

2nd. That all repairs could be effected without disturbing the streets.

3rd. That in our iron system, all points, crossings, and curves were bonded in the main line, and were as strong as any other part of the road.

He added, he said, with pleasure, that he got very favourable opinions of his system from the leading members of the profession as to its worth, and as to its economy in first cost and maintenance.

Mr Clapperton said that one point brought out by Mr Page's system was the facility with which the rails could be repaired. In the Glasgow system the street had to be lifted to some extent, but under Mr Page's system nothing but the rail was disturbed. He thought that was a point of great interest. As regarded Mr Page's remarks in reference to laying the timber system of tramways, at points and crossings, he saw a great defect in cutting the longitudinal sleepers to receive the cast iron points and crossings. He considered it would be an improvement to have no groove on the rail of the curve of the larger radius.

Mr G. Russell wished to make a remark which applied to nearly all the sections exhibited. It was, that the bearing of the wheel was not directly over the centre of the bearing of the sleeper, but to one side, which would have a tendency to cant the sleeper. In the Glasgow Tramways, the cast-iron chair between the cross sleepers and the longitudinal sleepers would check that tendency.

Mr Clapperton said he thought they would all feel very much obliged to Mr Page for bringing this important question before the Institution. He had never seen a system of such light construction as that of Mr Page's, and he thought it was heavy enough for the purpose intended. He quite approved of the simple mode of securing and disengaging the rails in their places, and he had no doubt it would be very effective and safe. With regard to the chairs in which the ends of the sleepers rested at their joints, he had no hesitation in saying that they assisted the rail to maintain a perfect level on the top. He considered the rail a very fair one for city traffic. Mr Page had made a remark about the section, fig. 4, and said that there would be a difficulty in the horses' feet slipping. This, however, could be partially got over by dicing the top of the sleeper. He was sorry that a portion of the iron system had not been tried to test its merits, alongside of the wooden.

Mr Deas said his system had been designed to accommodate the two traffics, with flanged and plain wheels; and the horses themselves, discovering the advantage, went on of their own accord, and travelled along the whole length of the shed.

Mr Kay had much pleasure in proposing a vote of thanks to Mr Page for his very valuable paper.

The President, in agreeing with the motion of Mr Kay, said there was no doubt the timber system was objectionable, and should be dispensed with wherever possible.

NOTE OF 31ST DECEMBER, 1872.

To meet the objections of Mr Russell "that the weight on the sleeper was not distributed, but was borne on one side, and therefore had a tendency to slightly cant the sleeper," I give a modification of my system shown on Plate VI.

There are two rails, secured in place by two dove-tailed fox wedges.

A projection is rolled on the centre of tyre of wheel, instead of the flange on the side as now used.

(Signed) John Page.

LETTER—MR DOWNIE TO MR PAGE.

Glasgow, *13th January, 1873.*

Dear Sir,—I regret my absence in England on the evening on which your valuable paper on Tramways was under discussion at the Institution of Engineers, as, in addition to expressing my views in favour of the three distinctive features possessed by your iron road in preference to any system having timber for a substructure, I was desirous of saying that were a flat rail without grooves placed on the outside of all curves, the flange of the car wheels mounting on it as they came forward would so far equalise the additional traverse, and cause the cars to turn round the corners of streets more easily, and that, in my opinion, the cars should *always* travel on the *right*-hand line of rails, so as to *meet* the traffic, and enable the drivers of carts and carriages to clear the tracks, thus saving time, and wear and tear of rolling stock by the frequent application of the brake, rendered necessary by the present absurd system of traversing the *left*-hand line of rails, thus overtaking the traffic going in the *same* direction, and attempting to warn them off by a whistle signal seldom heard in a busy thoroughfare above the noise of the vehicles that interrupt the way.

Seeing a remedy so simple and obvious would thus make the "rule of the Tramway" (*always keep to the right*) accommodate itself to "the rule of the road," it is to be hoped the gentlemen in charge of these arrangements will speedily make the change for their own gain and the greater safety of the public. From St. George's Cross to Sauchiehall Street, by Cambridge Street, you may, while sitting in the cars, count every joint and length of rail on the present line of Tramway, with the timber substructures, showing the few months it has been in use under traffic has caused general dislocation, which must daily increase; and it is not saying too much in favour of your *cheaper* and better system to expect that it *could not* get in the same condition as the present track after as many years of similar traffic.—Yours faithfully,

(Signed) JOHN DOWNIE.

On Mining Machinery.

By Mr George Simpson.

(SEE PLATES VII., VIII., AND IX.)

Received and Read on 24th December, 1872.

Mining machinery comprehends a large proportion of the mechanical powers at present in operation throughout the country, but it is quite apparent that there is great room for additional applications, especially such as will supersede manual labour.

In the present brief paper I shall notice two branches—*Winding* and other transit machinery, and, more especially, *coal cutting* machinery.

Winding machinery and gearing have not hitherto occupied a prominent attention in this country, such as they have done in England in consequence of the shafts in Scotland being much shallower; but now when we are beginning to count shafts by hundreds of fathoms, greater attention must be bestowed on this department.

We cannot conveniently much exceed 100 fathoms with hemp ropes, in consequence of dead weight in the shaft causing unequal strains on the rope, and for other reasons unnecessary to enter into this paper.

In adopting wire ropes for deep shafts the difficulty is to overcome the dead weight of the rope when the one cage is at the bottom and the other at the top of the shaft. Various arrangements have been made to overcome this, such as conical drums, but the writer is of opinion that an application such as shown (see Plates VII. and VIII.) might be more suitable. At all events, the weight of the rope in the shaft would be equalized, and their being no pithead frame, overwinding would be prevented.

This arrangement of winding machinery is also applicable for underground haulage, and for transferring the power to coal cutting machinery.

On inquiry as to the number of men now employed in Scotland in hewing coal, I find from information furnished by Mr Ralph Moore, Government Inspector of Mines, that the number of coal hewers in his division may be estimated at 15,000. In the Western Division we may assume a like number. Assuming, therefore, 30,000 as the number of coal hewers in Scotland, their labour may be represented by a steam engine of 1140 horse-power.

Taking the coal cutting machine at present in operation at one of the Espieside Pits at Gartsherrie, which the writer saw in operation a few days ago, where from 1½ to 2 feet per minute is holed, 800 such machines would perform the holeing now done by the colliers referred to. Of course the taking down and filling of the coal and attendance on the machine has still to be provided for; but making allowance for this, it will be seen that at least 70 per cent. of manual labour would be dispensed with, and in [the drawing of the coal a steam engine of from 300 to 400 horse-power, properly applied, would supersede 70 per cent. of the manual labour at present employed in that branch of the mine.

In coal cutting machines in use a considerable drawback consists in the rapidity with which the metallic cutters lose their cutting power. For some time back the writer has been experimenting with tools for boreing and cutting coal.

Cutter No. 1 (see Plate IX.) exhibited was used similar to a morticing tool for cutting the coal. The results for about two to three minutes of the cutter, when driven at from 600 to 800 revolutious per minute, was satisfactory, but a rapid diminution of the cutting power of the tool followed, and latterly it ceased to cut.

The tool became *glazed* or *polished,* not *blunted*—in fact, it had lost its cutting edge somewhat similar to a knife when used in cork cutting.

Even with the best tempered tool, and using water thereon, the same result followed. A miner's pick is affected in the same manner.

I have been the more anxious to point out this in order to elicit the opinions of the members on the subject.

The cutters now used at Espieside form no exception in this respect. This machine is driven by compressed air. The cylinder is seven inches in diameter and 12 inches stroke, worked at the rate of from 120 to 160 strokes per minute. At the former speed the movements of the cutters, which are nine in number, equal 33 feet per minute. The chain which carries the cutters is 10 ft. 6 in. long, and makes fully three revolutions per minute. The breadth of cut is 2 ft. 6 in., and of forward movement $\frac{3}{8}$ of an inch by each cutter, or about 12 in. per minute, producing fully $2\frac{1}{2}$ square feet of holeing per minute, but nearly double this area has been accomplished by this machine, which represents the work of 60 men.

The writer fully intended to have submitted complete details of the machinery necessary to generate the power to drive this machine, but has been unable to obtain satisfactory information on the subject.

Referring to the model now shown (See Plate IX.) it will be seen that the jib of the Espieside machine has been dispensed with, and a wheel substituted, and in place of taking the whole depth of the cut, $2\frac{3}{4}$ inches, as in the machine referred to, the writer proposes to take only one half of the depth of the cut by each cutter—as shown —and to drive the machine by rope power. It may be premature here to enter into a comparison of this power with compressed air power, but more anon.

On making further experiments for the boring and cutting of coal the writer used Cutter No. 2, now exhibited, in which were inserted eight diamonds of the form shown. This tool wrought satisfactorily, but the difficulty of fixing the diamonds operated against its continued use.

No. 3 Cutter was then substituted, having the same number of diamonds fixed between two plates. This tool has been driven for half-an-hour at a time, both in sandstone and coal, at the rate of 1000 revolutions per minute, with satisfactory results.

A complete machine for driving this tool by the application of wire rope power has been constructed by the writer, who will be glad to exhibit it to any of the members.

In place of, as at present, making the carriage which supports the cutting machine occupy wholly the floor or pavement of the mine, the writer is of opinion that the machine might be supported on wheels close to the face on the pavement, and above on the face of the coal.

The PRESIDENT said that the Secretary, with the view of eliciting Dr Rankine's views on this important subject, and knowing that the state of Dr Rankine's health would not permit him to be present, had communicated to him some of the questions raised in Mr Simpson's paper, and had received, in reply, some notes which he would now read.

Professor RANKINE, through the Secretary, expressed his regret that the state of his health prevented his being present at the meeting, in consequence of which the few remarks which he now begged leave to send would be made without the advantage of having previously heard Mr Simpson's paper. He understood that one of the questions to be considered would be that of the comparative economy of compressed air and of wire ropes in transmitting power to places below ground for the driving of coal hewing or other mining machinery. He thought that it was almost, if not quite, impossible to give a decided answer to this question, which should be universally applicable; and that individual cases, or classes of cases, would have to be decided each on its own merits. From ordinary experience of rope haulage on mineral railways, the waste of power may be roughly estimated at about 20 per cent. in a mile. Mr Simpson, no doubt, would be able to give the Institution valuable information on this point. On the other hand, in transmitting power by means of compressed air, there were great and unavoidable losses of power in the air compressing engine, arising mainly from the waste of the heat developed by the compression of the air. Those losses had seldom amounted to less than from 65 to 75 per cent. of the whole power of the compressing engine; and it could be shown that in extreme cases they might even exceed 90 per cent. On the other hand, the part of the loss of power which arose from the friction of the air in the pipe, and which, therefore, increased with the distance to which power had to be transmitted, was comparatively small with well-proportioned pipes, and might, he thought, be reduced to about 10 per cent. per mile.

From these reasonings, it appeared probable that wire ropes were the more economical means of transmitting power for short distances, and compressed air for long distances. He could give no opinion as to the probable value of the distance at which those two means were equally economical; but no doubt the information given by authors so able and experienced as Mr Simpson would greatly contribute towards the answering of this question in a satisfactory manner.

For comparatively early information as to the transmission of power by compressed air, he might refer to two papers which had appeared in the Transactions of the Institution of Mechanical Engineers—one by Mr Charles Randolph in 1856, the other by the late Mr Nicholas Wood in 1858.

There was an advantage peculiar to the use of compressed air which deserved serious consideration. It was the ventilating and cooling effects of the air discharged from the underground machinery. He might mention, in conclusion, that the best economy in compressed air apparatus was obtained by the use of moderate pressures; for with these the heating effect and consequent waste of power were moderate.

It may here be explained that when loss of power is stated at a certain per centage per mile—say, for instance, 20 per cent. per mile—that does not mean 20 per cent. of the whole original power on each mile; but 20 per cent. of the actual power in the first mile—20 per cent. of the power remaining after that reduction in the second mile—20 per cent. of the power remaining after the second mile, in the third mile, and so on.

It may also be explained that the two rough estimates of losses of power already given are based upon ordinary experience with the ordinary apparatus. There is a special form of apparatus in the case of rope traction in which the loss of power per mile, according to public accounts of experiments made in France, is between 1 and 1¼ per cent. only; but in that form of apparatus the rope, which is hung above ground at any required elevation, has large supporting pulleys at intervals of about 500 feet, between which it hangs down in curves with a deep deflection; whereas on mineral railways the usual interval is little more than 20 feet.

On the other hand, the loss of from 65 to 75 per cent., which occurs in air compressing engines, exceeds many times the loss theoretically due to the waste of heat; and we may therefore expect to see it greatly diminished through the gradual improvement of the machinery.

Mr D. ROWAN said that he thought the discussion of this important paper should be postponed till next meeting.

The PRESIDENT said that doubtless the coal question was never of greater importance than at the present moment, and that any means whereby manual labour could be supplemented or supplanted would be hailed by all. He begged to propose a vote of thanks to Professor Rankine for his contribution to the discussion, which would be now adjourned till next meeting.

The discussion on this paper was resumed on the 21st of January, 1873.

Mr GEORGE RUSSELL had two questions to put to Mr Simpson. He found that Mr Simpson assumed that 1140 horse-power was equal to 30,000 men engaged in mining. Now, it seemed to him, that Mr Simpson allowed too many men as equivalent to a horse-power. He would also like to know how the ropes, in Mr Simpson's winding machinery were balanced. From the drawings it did not seem to be an endless rope, as each end seemed attached to the cage.

The PRESIDENT said that perhaps some of the members could give them a reason for the effect referred to by Mr Simpson in his paper, where he says:—

"The tool became *glazed* or *polished*, not *blunted*—in fact, it had lost its cutting edge somewhat similar to a knife when used in cork cutting. Even with the best tempered tool, and using water thereon, the same result followed. A miner's pick is affected in the same manner."

Some gentlemen connected with the subject, and who knew the use and properties of steel, would help them by explaining that point.

Mr MORTON said that Mr Simpson had informed them that his coal-cutting tool made from 600 to 800 revolutions per minute; but it would be of much use to the Institution if he would tell them what depth it cut per minute.

Mr DEAS asked whether the blunting was not due to the great speed at which the tool was driven? It was well known that if they ground a tool on a stone going at a *slow* speed, it would grind the stone, but that at a high speed the stone would grind the tool.

Mr BROWNLEE thought that coal mining by hand might be much better effected than by the present mode, by having a light iron telescopic tube to lengthen or shorten with a screw, so that it could be jammed up tight between the roof and the floor. On this fixed tube a double or right-angled socket would swivel, resting upon a moveable collar fixed at the height required. The pick handle passing through the horizontal socket past the side of the fixed upright tube could be shortened or lengthened towards the face of the coal. The miner would not then require to lie on his side and support the weight of the pick, but would sit in the position of a person pulling an oar, and thereby be able to strike with much greater ease, accuracy, and force.

Mr SIMPSON said with regard to the number of men employed in ordinary hard coal, a collier "holes" on an average about the twelfth of a square foot per minute. The machine did five square feet per minute, and that was how he contrasted it with manual power. The winding rope represented is endless, and of course is completely balanced. It is guided over a pulley at the bottom of the shaft. The depth cut by the diamond tool-cutter was one-eighth of an inch in sandstone, and one-fourth of an inch in coal. It traverses four feet horizontally, the range of the machine. He was still of opinion that to hole coal by percussion was the proper method; but he had been induced to follow out the present arrangement of cutters to test the rope power against compressed air. As to improved manual labour machines he had submitted a plan, such as Mr Brownlee mentioned, to the Joint Meeting of the North of England Engineers with this Institution, in 1871, an account of which was given in the Transactions of that meeting. But he had found that manual labour machine would not meet the present requirements. He might explain that for the driving of a machine such as was shown in Plates VII. and VIII,, a steel wire rope, half-an-inch in diameter, was quite sufficient. The strain on the driving pulley in the machine would not exceed two to three hundredweight. The strain on each cutter holeing $\frac{3}{8}$ of an inch by $2\frac{3}{4}$ inches, in coal may be estimated at little more than one ton. He proposed to drive the pulley referred to, which is 2 ft. diameter, at about 1000 feet per minute. To overcome the friction, and drive the machine with a rope embracing half-a-mile radius from shaft, an engine of 14 horse-power would be ample: an additional horse-power for every 100 fathoms of extended workings would be required. The Espieside machine bore out the late Professor Rankine's remarks as to the loss of power in using compressed air. To drive three coal-cutting machines within a short range, as at Espieside, there are in operation here two high-pressure steam engines, diam. of cylinder, 1 ft. 4 in., stroke, 3 ft. 10 in. (short cut off), 55 strokes per minute, steam at 45 lbs. per □″. At this speed the two air-pumps (double-acting) of equal dimensions with the steam cylinders, can only maintain an air pressure of 37 lbs. in the receiver attached; and under 30 lbs. at the motor attached to the coal cutter, so that at least 80 per cent. of the power is lost through loss of heat and friction. The first cost of using compressed air was necessarily large: about three times as much as for rope power; besides compressed air machines were limited in their range of cut, from the use of flexible tubes which can only be used along the face; which tubes are also liable to be damaged. A great disadvantage arose from the machine not being kept fully employed. Rope power can be applied to any of the existing machines.

Mr MORTON was glad Mr Simpson had made these explanations, for they were not evident either by the drawings or by the paper. Mr Simpson, however, had not replied to his question as to the depth cut per minute.

Mr SIMPSON said he had already explained that the diamond tool-cut in coal $\frac{1}{4}$ of an inch, and an $\frac{1}{8}$ of an inch in sandstone; the cutter traversed forwards and backwards along the frame till the depth of groove required was complete. As to the boring of coal, the rate of boring could be done at a foot per minute, or more, according to speed. A large allowance must be made in estimating underground manual contrasted with engine power, as from the position of the colliers a great part of their physical power was cancelled.

The late Professor Rankine.

Jan. 21, 1873.—Mr Robert Duncan, President, in the Chair.

After the preliminary business of the meeting, the President said that it now became his very painful duty to put before them formally what they were already aware of—the death of their distinguished member and first President—Professor Rankine. He would remind them that on the night of their last meeting, at the very time when the Secretary was reading a few remarks sent by Professor Rankine on the subject of that evening's paper, the eminently gifted spirit was passing away from this earth. It might be truly said that in losing Dr Rankine they had lost their greatest and best member, and that they would have cause to lament his loss to society, to science, and especially to this Institution, for many a day. At a meeting of Council held shortly after his death, a special minute was passed, recording the deepest sorrow of the Council, and their extreme appreciation of the loss the Institution had sustained by the death of Professor Rankine; and it was unanimously agreed that the Secretary be instructed to prepare a memorial of the late Professor, with special reference to his connection with this institution, to his many valuable services to it, and to his numerous able contributions to its Transactions, during the fifteen years of its existence. He felt that it would be quite unnecessary for them as an Institution to dilate upon the merits of Professor Rankine at greater length, as several notices, biographical and otherwise, had appeared in scientific and other journals, more or less fully detailed, which many of themselves could verify, and perhaps amplify, from personal experience. But Professor Rankine's life had yet to be "written large" among the eminent men of this age; and it would be sufficient, in the meantime, for us to extract from the records of this Institution the memorial of Professor Rankine's life and work in connection with it, as the least testimonial we are at present called upon to pay, to the useful and generous service, as well as to the world-wide fame, of Professor WILLIAM JOHN MACQUORN RANKINE.

The SECRETARY then read as follows:—

EXTRACT MINUTE OF COUNCIL OF 7TH JANUARY, 1873.

On the motion of the PRESIDENT, seconded by Mr DEAS, it was resolved that there be recorded in the minutes of the Council the expression of their deep sense of the great loss sustained by the Institution through the death of Professor Rankine, who had always taken a great interest in the prosperity of the Institution, and by his eminent ability and world-wide fame, as one of the foremost scientific men of this age, had conferred lasting honour on the Institution of which he was one of the founders, and first President, and which had from the first been privileged to reckon his name upon its roll of membership.

Sketch of Professor Rankine's connection with the Institution of Engineers and Shipbuilders in Scotland.

Before commencing the business of the present evening it is the painful duty of the Council to refer to the death of Professor Rankine, which has taken place since we last met.

The circumstances of his death are now probably known to all the members. Having been ailing for some time, he was at last struck down by paralysis, and passed away on the 24th December last.

Sketches of his life have appeared in the daily papers, but the Council believe that a few remarks upon his connection with this Institution, are a slight acknowledgment of his great services to the Institution, and may be of use to ourselves to stimulate to renewed endeavour to promote its interests.

Professor Rankine was one of the promoters of the Institution, and at its first meeting, held in the Philosophical Society's Hall, Andersonian Buildings, George Street, on 28th October, 1857, occupied the Presidential chair, to which he had been elected at a preliminary meeting held on 1st May, 1857.

His introductory address as President was on "The Nature and Objects of the Institution," a short extract from which may not be out of place. He said:—"We may consider that the various Societies of a scientific nature are divided into three classes. In the first class are those which are devoted specially to the advancement of science, and to the keeping of the members informed of the progress that science makes elsewhere. To this class the Royal Society belongs, the Geological Society, and many others.

"In the second class are Societies intended for the popular diffusion of scientific knowledge, and the cultivation of a taste for science in those persons whose ordinary pursuits are not calculated to promote that knowledge, or to impart such a taste.

"Many Societies combine the objects of these two classes—such as the British Association and the Philosophical Society of Glasgow.

"In the third class is the Society to which we belong; and the object of this class is the IMPROVEMENT OF PRACTICE; and, combined with that, is another important object—that of keeping practical men informed of what is going on elsewhere in their art, and of the experiments made by others. . . . . Now this class of Society is distinct from that whose object is specially the advancement of science; for, in that class the practical results are only regarded as experiments from which scientific conclusions may be drawn; they are used merely as the data for some scientific investigation; whereas, in our Society, practical results are the main object."

At another of the meetings of the same session, Professor Rankine read a paper on "A Blowing Fan," descriptive of an experimental fan designed by himself and Mr J. R. Napier, with the results obtained in actual practice. The fan is illustrated in Plate 2, Figure 6, Vol. I., of the Transactions.

As President during Session 1858-59, Professor Rankine delivered the customary introductory address, where, after referring to the success of the Institution by addition to its membership and otherwise, he made remarks on "The condition of the branches of practical science cultivated by the members"—the Great Eastern steamship—the strength of boilers—water supply—drainage of large towns—the Atlantic telegraph—and other matters.

At two of the meetings of the session he read papers, one on "The working of certain furnaces at Messrs Charles Tennant & Co.'s chemical works, St. Rollox;" the other "On a method of estimating the probable evaporative power of fuel and efficiency of boilers." The first-named paper contained a description of furnaces which prevented the production of smoke, combined with a saving of fuel. The second paper contained formulæ deduced from experimental data obtained by himself and other experimenters.

During Session 1859-60, Professor Rankine held office as a member of Council, and contributed two papers, one being a "Description of Mein's improved machine for making glass-bottles," the other on "The Density of Steam," in which he gave a table of the "Specific Volumes" of steam, as computed "from the mechanical theory of heat, and as determined by the experiments of Messrs Fairbairn and Tate."

At the conversazione of the Institution held in the Corporation Galleries, on 17th April, 1860, he spoke "on the subject of Musketry."

During Session 1860-61, we find him acting as a member of Council, and reading a paper "On the application of transversals to engineering field-work," where, after explaining the meaning of the word "transversal" to be "a line either straight or curved, which cuts another system of straight or curved lines," he described the applications of the theory of transversals, by means of which the ranging and measuring of inaccessible parts of straight lines and circular curves was facilitated.

The office of Vice-President was held by Professor Rankine during Sessions 1861-62 and 1862-63.

During the former session he contributed two papers, one "On a Frictional Oil Test," illustrated by an apparatus, the object of which was to test the "friction-reducing properties of oils for the pivots of spindles, and for bearings of the same class."

The other paper was entitled, "Remarks on experiments on the liquefaction of steam in the cylinder of an engine working expansively." The paper was illustrated by a table of experiments made by Messrs Isherwood, Stimers, & Long, U.S. Navy. The experiments showed the condensation of a large quantity of steam on its admission into a cylinder previously cooled by the previous expansion of steam. The paper concluded by practical conclusions deduced from the experiments.

For this paper, Professor Rankine was awarded the Institution medal.

During Sessions 1863-64 and 1864-65, Professor Rankine held office as a member of Council, and during the first-named Session he read two papers, one on "The expansive energy of heated water;" and the other "On trials of the speed of steam-vessels in a tideway."

In Session 1865-66 he read a paper "On the tenacity of some fibrous substances," containing an account of some experiments carried out by himself on the strength of flaxen and silken thread.

The Session of 1866-67 contained no paper by Professor Rankine. During that Session and the following one he officiated as Vice-President, and in the latter Session (1867-68) he read a paper, entitled, "Description of a Chimney at the West Cumberland Hematite Iron Works," the principal feature in the construction of this chimney being the bonding of the fire-brick lining with the common brick of the outside shell.

During Session 1868-69 Professor Rankine was a member of Council, and contributed a paper, entitled, "Account of experiments on Mr Alex. Morton's ejector condenser," which embraced a description of the invention, and of experiments made by himself with the apparatus. For this paper he was awarded the Institution medal, but, on account of having previously received this honour, he, with characteristic generosity, declined it, and placed it again at the disposal of the Institution.

The Presidential chair was again held by Professor Rankine during Session 1869-70, and this at the request of the Council to supply the vacancy caused by the death of Mr John Elder, who had been elected to the office of President at the annual meeting of the previous Session.

The Session was opened by some "Introductory Remarks" by Professor Rankine upon various subjects connected with civil and mechanical engineering.

In the Session of 1870 71 he acted as member of Council, but contributed no paper.

On the 9th, 10th, 11th, and 12th of August, 1870, a joint meeting with North of England Institute of Mining and Mechanical Engineers, was held in Glasgow. At the Conversazione which was held during that meeting, a presentation was made to Professor Rankine by this Institution, of a marble bust of himself, and an address was read by Mr David Rowan, the President, expressive of the regard entertained towards Professor Rankine by the members of the Institution. A duplicate bust was presented to the Institution, and now adorns the Library.

Small size copies of the bust were prepared by the sculptor, Mr G. E. Ewing, Glasgow, for such gentlemen as wished to possess one.

During Session 1871-72, Professor Rankine held office as a member of Council, and contributed a "Sketch of the life of John Elder."

During the present Session, 1872-3, on account of the state of his health, he was unable to continue his active interest in the affairs of the Institution. He, however, was present at the joint meeting of the Institution of Engineers and Shipbuilders in Scotland, the South Lancashire and Cheshire Coal Association, and the North of England Institute of Mining and Mechanical Engineers, held at Newcastle on 2d, 3d, and 4th July, 1872, and presided at the first day's meeting in place of the President, Mr R. Bruce Bell, who was unable to be present on account of bad health.

A short communication from Professor Rankine was read at last meeting of the Institution, and is now published in the Monthly Transactions just issued.

Various donations to the Library, both of his own works and of other publications, have been received from Professor Rankine from time to time. He was an active member of many of the Committees appointed at various times, and took a prominent part in the discussions arising out of papers read at the meetings.

The PRESIDENT moved that the meeting should endorse the minute and memorial read, and instruct it to be engrossed in the Transactions of the Institution.

This was unanimously agreed to.

On "Improvements in the Construction and Working of Swing Bridges Spanning Water Spaces, Caissons, and the Gates of Dock and Canal Locks, &c."

By Mr DAVID CUNNINGHAM, C.E.

(SEE PLATES X., XI., AND XII.)

Received and Read on 21st January, 1873.

These improvements consist in the application of a simple principle to the construction and working of swing bridges spanning water spaces, caissons, and the gates of dock and canal locks, for which Letters Patent have recently been granted to me.

Hitherto, swing bridges have generally been constructed with large girders projected from the top of the wall on one side of the passage bridged, which girders necessarily have been made long enough and heavy enough to afford safe counterpoise to their own overhanging weight.

In revolving or projecting such bridges, great weights require to be moved, and suitable apparatus provided therefor. Steam or hydraulic power is thus necessitated for the opening and shutting of all but bridges of the smallest dimensions, in order to overcome the great friction which such heavy weights produce. Then the pivot, rollers, and roller paths, and subjacent masonry must be of the nicest and at the same time heaviest description, all of which involves large expenditure. After all, the tear and wear on such structures is great.

This invention, when applied to swing bridges, enables all these heavy overhanging weights, which are so typical of present bridges, to be dispensed with, for the whole is borne by the water in the passage itself. The main features of such a bridge as that proposed and explained by the drawing and model of bridge are:—

1st. A floating body placed below low water so as to be always submerged, which generally speaking shall constantly bear the dead load of the bridge.

2nd. Girders of open work braced together and supported vertically by hinges at one end of bridge, on which the whole may revolve horizontally, so as to admit of the bridge being opened for the passage of vessels; and,

3rd. A vertical tube situated in the bridge at the further end from the hinges, which tube is closed and in communication with an air-pump at its upper end, and open to the outer water at its lower end. The function which this tube performs is that of regulating a small balance of vertical pressure on the bridge, by which it may be sunk or floated as desired, for when the water level is the same internally as externally to it, the bridge may have a tendency to sink into its place as a bridge, and when air shall be forced into it, and the water displaced, the downward or sinking tendency shall be counteracted, and the bridge floated, by which means it may be conveniently opened on its hinges. The difference of buoyancy in the bridge caused by the varying levels of the water will thus be readily counterbalanced. As the bridge is raised at the further end by such means, a certain amount of play is to be allowed on the lower hinge.

Thus we have two air tubes, one exerting a constant vertical pressure, and the other a varying vertical pressure, which together are capable at any moment of carrying the whole dead weight with little trouble or cost in working, and practically with no tear and wear whatever. To save time in raising the bridge, an intervening air chamber may be employed in which the air may be compressed, previous to its introduction into the vertical air tube, which may be done at a moment's notice. When the bridge is sunk in position, shoulders projecting from its ends may rest in the side walls of passage, and these may be secured by vertical keys dropped through the masonry so as to prevent vibration in stormy weather.

The general principle, of which the bridge I have just described is a special application, consists, 1st. In supporting the whole or a large portion of the dead weight of the bridge by a floating body permanently submerged; and 2nd. In raising and lowering said bridge so supported, so as to float or sink it by another body or bodies which shall be temporarily immersed or withdrawn from the water, and when the water level varies considerably, these latter bodies must be sufficiently large to compensate additionally for the differences in displacement so caused.

This principle is also capable of application to caissons and the gates of dock and canal locks. In doing so, all the ballasting sluices, bulkheads, water-pumps, rollers, and roller-paths, with their adjacent masonry, and also the capstans or winches and chains ordinarily employed for the opening and shutting such gates at the present time, may be entirely dispensed with. When a caisson or gate is constructed, so that it may float at all times, except when sunk in its berth, it is apparent that the difficulty of working such, and the tear and wear occasioned thereby, will be reduced to a minimum; indeed, by the adoption of compressed air as a column on which the balance of weight may be floated, we may say that the tear and wear will be quite inappreciable.

The models of caissons show two different arrangements—one with, and the other without, vertical hinges on which to revolve horizontally. The one having the hinges has one vertical air tube, situated at the end furthest removed from the hinges; the other having no hinges has two vertical air tubes—one situated at either end, which are connected together at their upper ends by a pipe, which is intended to be in communication directly with an air pump, or indirectly through a chamber for the reception of compressed air.

The Dundee Harbour Trustees have resolved to adopt, for the entrance to their new graving dock at Dundee, a caisson, to be constructed according to the first-mentioned arrangement, namely, with vertical hinges and one air-tube, but capable of being wrought by the second arrangement, having a vertical man-hole situated at the hinge, and which may be used as an air-tube, if desired, and being ballasted so as to float vertically when detached from the hinges. In this way I have, in designing it, been able to dispense with all the ballasting sluices, pumping gear, capstans, &c., usually employed, and also with a large proportion of expensive mason work which was included in the contract for the dock works, so that about £1000 will be saved in first cost alone.

The construction of swing bridges on the principle of this invention will, in relation to existing methods, be greatly simplified and reduced in cost. The drawing and model represent a bridge 120 feet in length, spanning a clear space of 100 feet, and a recess space of 20 feet additionally. If designed according to the drawing, having the floating body placed towards the centre of the bridge, so that the girders overhang it at each end, the top and bottom booms and the lattice bars may be made so light as to be just sufficient to withstand flexure as long columns, and they will still be so strong as to enable the bridge to bear safely a live load of 50 tons, or 25 tons on each girder. Indeed, a large proportion of this load will act contrariwise to that of a load properly so called, for the strains in the various members induced by the vertical pressure of the floating body when situated towards the centre of the bridge, as in the drawing, must be first counteracted by a part of the load before the remainder can begin to act as a load at all. Thus, not only will the dead load of the bridge be supported by the water, but it will be supported in such a way as to enable the bridge to bear a considerable live load additionally before any appreciable strains are induced, and also to bear a much heavier live load than it could otherwise do.

I estimate that the cost of constructing such a bridge, as compared with that of a bridge built on the present overhanging system, would not be greater than one-fourth, and also that the cost of working would be proportionally reduced.

In Plates X., XI., and XII.:—Fig. No. 1 is an elevation, and fig. No. 2 a section, and fig. No. 3 a plan of a caisson. It is furnished with (1) N N N N′ N′ buoyant chambers, the lower of which N′ N′ may be conveniently filled with ballast. These buoyant chambers are at all times situated beneath the water level when the caisson is to be floated, and they will therefore exercise a permanent vertical pressure upwards, which, generally speaking, will be equal to the dead-weight of caisson. It possesses (2) floats B B situated as fenders at the sides of caisson. These being actuated by the gearing shown, uniformly in a vertical direction, are intended to regulate the balance of dead-weight on the caisson.

Thus, if we suppose B B to be withdrawn above the water level the caisson will sink; when again they are lowered into the water, the balance of weight will be counteracted, and the caisson will float.

It will be observed that the outer water flows freely through the caisson above the buoyant chambers N N N N' N', so that the difference of displacement caused by the varying areas of the skin or structure of the caisson at varying water levels is reduced to a small fraction of the whole displacement. One side of the caisson above the buoyant chambers may be constructed, therefore, advantageously of open work, having no skin proper.

P P is a manhole by which access to the buoyant chambers may be obtained at any time. It is arranged with a small sluice which must be shut, and the water that may be in it at the time, pumped out previous to opening a water-tight manhole door on the upper floor of the buoyant chambers.

With the arrangement shown in figures 1, 2, and 3, it will be preferable to ballast the caisson so as to admit of its floating steadily in an upright position in the water.

Figure 4 is a diagram showing relative positions of caisson when the entrance to the dock or other water space is shut and open.

Figures 5, 6, and 7, are respectively elevation, section, and plan of a caisson furnished with tubes B B, instead of floats. These tubes are intended to regulate the balance of vertical pressure on the caisson, so that it may conveniently be opened and shut, and with this object they are intended to be connected together at their upper ends by a pipe which shall be directly in communication with an air pump, or indirectly through a chamber for the reception of compressed air, and their lower ends are to be in communication with the outer water. If the dead-weight of the caisson be made greater, than the vertical pressure of the buoyant chambers, then when required, air is to be forced into the tubes B B to counterbalance the difference, and cause the caisson to float, by which means it can be drawn into a convenient position for the passage of vessels. If, on the other hand, the dead-weight of the caisson be made less than the vertical pressure of the buoyant chambers, the air is to be withdrawn from the tubes B B to cause the caisson to sink.

The caissons above referred to, may either rest upon the bottom of the lock or passage way, or they may be furnished with shoulders projecting from their ends, which shall rest upon corresponding benches or brackets secured in the side walls. The weight to be sustained in either case will be only the small portion of the dead-weight above referred to, plus whatever live load shall pass over the caisson.

The shoulders when resting on the benches prepared for them may be secured firmly, by vertical keys dropped through the masonry of wall, which being turned one quarter round upon the top of the shoulders, will prevent motion, even though the weather be stormy and the water level the same on each side. These may be used when the caisson is both shut and open.

Figure 8 is a diagram showing an arrangement for the reception of compressed air in chambers situated at the top and forming part of the pneumatic tubes. Figure 9 represents an arrangement of tube which except when the caisson is intended to be shut or opened, shall float on the surface of the water, being kept in position by suitable guides. When the caisson is to be floated, set screws may be employed to secure the tubes in position previous to the displacement of the water within them.

Figures 10 and 11 represent respectively an elevation and cross section of a swing bridge intended to span a water space. A A A is the buoyant chamber, which, generally speaking, is capable of bearing the dead-weight of the bridge. B B B is a vertical tube intended to regulate the balance of vertical pressure at one end of the bridge. The structure is formed of two double-triangular parallel boom girders, braced together and sustained vertically in the water by sufficient anchors, spindle and hinges, on which the whole is intended to revolve horizontally when opening and shutting. From the situation of the bearing buoyant chamber A A A, towards the centre of the bridge, the girders are normally in an opposite condition to those of ordinary bridge, for whereas the latter must bear its own weight before it begins to bear any live weight, the former has not only none of its own weight to bear, but it is capable of bearing considerable live weight before it attains a neutral position, and appreciable proper strains begin to be induced. It is therefore obvious that such a bridge may be made of the very lightest description; that its booms and lattice bars being made safe as long columns, will enable the structure to bear exceptionally heavy loads. By the adoption of open girders, such as those shown, sufficient space is left between the bars for the passage of small craft. It is obvious that such space may be increased by cutting off the further ends of the large girders sufficiently, and substituting for the balance of span so cut off, girders whose lower flange shall be on a level with the roadway.

This system of bridging water spaces, may be applied with great efficiency and economy, when the situation is sufficiently wide to admit of a central pier being built where the vertical hinge on which the bridge revolves may be secured. The bridge would then be formed, one-half on each side of the central pier. In a river way where the current runs strong, the force of the water on the one-half or leaf of bridge would be counterbalanced by the force on the other, and the bridge being caused to float on the principle described, a revolving motion would be obtained by presenting a sufficient disc on either leaf to the force of the water, by which means the passage could be opened and closed when required.

In answer to questions,

Mr Cunningham said that the live load was carried by the shoulders, which, being projected from the ends of bridge, rested on the side walls, and that the bridge was stronger in consequence of the dead weight being carried by the water. It bore the live load similarly to an ordinary bridge, while the dead load was supported, generally speaking, by the water.

Mr Simpson had invented a bridge on the same floatation principle, and had found the leading objection was the tendency to leakage. See *Practical Mechanics' Journal*, vol. ii., p. 241. He was of opinion that it would be very difficult to manage the turning of this bridge at one corner.

Mr CUNNINGHAM said that the bridge floated in consequence of the pressure of the air exerted within the vertical tube. So much water was thereby displaced, and the pressure thereby produced on the interior parts of the tube raised the balance of the weight on the bridge. The pressure could be adjusted with comparative nicety. A bridge such as that represented by the model could be raised by pumping in, say, from forty to fifty cubic feet of air The leakage, if any, in the buoyant chamber was very easily attended to under water. There was a man-hole shaft, and a pump could be used. There was a caisson closing the entrance to Camperdown Dock, Dundee, which occupied a very exposed situation, but in ordinary weather there was no leakage. The bridge was suitable for canals. The leading object was to make a much better bridge at much less cost. It would be constructed with open girders, and would not be a fourth the weight of ordinary bridges constructed as at present. Ordinary bridges had to bear their own dead weight as well as the live load; whereas with the method proposed the whole dead weight was borne by the water, and the live load alone had to be supported by the girders which rested at the ends.

Mr DEAS said that, as the tide was always changing, the bridge must be constantly attended to, so as to adjust it to any deviation in the height of the water.

Mr CUNNINGHAM said it mattered not what was the state of the tide, for the water always flowed at the same level both inside and outside the vertical tube. When the tide was at its highest, there was by construction a sufficient balance of weight to cause the bridge to sink The expense of power in raising a bridge like that referred to was represented by pumping forty or fifty cubic feet of air into the vertical tube, which could easily be done by one man in a minute or two. Even in the case of a tidal current running at three miles an hour, a bridge on this principle would work well.

Mr SIMONS asked if the principle would be applicable to graving docks?

Mr CUNNINGHAM answered that it would. He had designed a caisson for the western entrance to the new Graving Dock at Dundee on this principle, which would save the Harbour Trustees about one thousand pounds sterling in first cost alone. The whole, except the platform, was to be of iron.

Mr MORTON asked what effect a rise of tide of 10 or 15 feet would have on the bridge.

Mr CUNNINGHAM said the bridge could be raised at any moment when required to open it by pumping air primarily into a reservoir under sufficient compression, from which it could be allowed to escape into the vertical tube at once.

Mr DEAS asked if, when in position as a bridge, a wave came and altered the height of the water several feet, would there be a tendency in it to vibrate from the force of the wave striking it. The waves caused by vessels passing down the Clyde were pretty considerable, so that sometimes they lost their steering power in consequence.

Mr CUNNINGHAM said that when the bridge or caisson was open, it should be situated in a recess at the side of passage way. In that position it might rest on benches in the masonry, as it did when shut, and it could thus be readily secured. There could be no objection to hinge the bridge at one end or corner. A spindle of seven inches diameter would be amply sufficient for this purpose. A bridge could be ballasted so as to float vertically without hinges. The model showed one special illustration of the principle. He did not confine himself to one illustration in his patent.

Mr SIMONS asked whether Mr Cunningham was aware of the caisson at Greenock. It was a sliding caisson, and slid back into a recess.

Mr DEAS—Just like the Malta Graving Dock.

Mr CUNNINGHAM said that the construction of his bridge was different.

On the motion of Mr Conner, the further discussion of the paper was postponed till next meeting.

The discussion on this paper, adjourned from last general meeting, was resumed on 18th February, 1873. After Mr Cunningham had again explained his models illustrative of his paper,

The SECRETARY read the following communication to the President from Mr Walter Robert Kinipple, M. Inst., C.E., of Westminster and Greenock, in reference to bridges across dock entrances, and caissons for docks :—

To the President of the Institution of Engineers and Shipbuilders in Scotland.

SIR,—I observe in a paper read on the 21st ulto. by Mr David Cunningham of Dundee, that he claims certain "improvements in the construction and working of swing bridges spanning water spaces, caissons, and the gates of docks and canal locks, &c."

By reference to the minutes of the Institution of Civil Engineers, the author will find similar examples having the same object in view, with the exception that in his case he has apparently incorporated something very like a portion of Mr F. J. Bramwell's arrangement for "screw docks."

Since 1858, I have designed several combinations of caisson gates and swing bridges, with a view to the entire abolition of the ordinary cumbersome and costly swing bridges about docks and harbours.

One example may be noticed in "Engineering," at p. 333, October 9th, 1868, which is a part print from my Greenock competition report of March, 1868, in which I recommended caisson swing bridges precisely similar to those patented by Mr Cunningham, but were afterwards abandoned by me, for reasons not only founded upon my own experience, but also that of other engineers.

Immediately after the abandonment of these in 1868, I designed another combination having the same object in view, which design will be found illustrated and described at p. 91 of "Engineering," dated February 5, 1869. In this case, also, we have caisson gates, swing bridges, and water or air tanks to relieve the entire weight of the gate. This latter arrangement I found preferable, because it effected a saving in the cost of extra length of jaw of entrance, which it would be necessary to construct to form a safe recess for the reception of the gate.

As to the air chambers below low-water line, in Mr Cunningham's caisson or gate bridge they will be found an exact copy of my patented caisson now in course of construction for the Garvel Graving Dock at Greenock, which caisson or bridge was designed in December, 1868, and patent rights obtained 9th September, 1870. See specification of patent, p. 4, as follows:—"In order that the weight upon these rollers or trollies may not be too great, I provide the caisson or bridge with *air chambers below low-water level*, so that the weight may be reduced to any extent. The caisson and bridge I also form so that it may be readily disconnected, unballasted, and floated away for repairs as with ordinary caissons."

Without such an arrangement, Mr Cunningham's caisson would be unworkable, for he states as a requisite:—"1st. A floating body (or air chamber), placed below low water, so as to be always submerged, which, generally speaking, shall constantly bear the dead load of the bridge."

As the Greenock caisson and bridge will be completed within a few weeks, I defer making any comments upon what I consider are (after long experience in designing and constructing dock gates and caissons) substantial merits in favour of its adoption over all other systems yet brought into use for bridging across the entrances to graving docks, harbours, rivers, or estuaries.

(Signed) WALTER ROBERT KINIPPLE.

Mr METHVEN, assistant to Mr Kinipple, said that the arrangement of parallel motion was one of the principal novelties in Mr Kinipple's arrangement, and gave some further information as to Mr Kinipple's arrangement by sketch diagrams, and read the following extracts from Mr Kinipple's description of his bridges contained in his Greenock Harbour competition report of 31st March, 1868.

"Many such openings between tidal docks would be made larger than they are in general, except that the cost of gigantic swing bridges, immense bridge pits, foundations, and enormous power requisite to work them, with results, in many instances, so doubtful and unsatisfactory that several harbour authorities have been deterred from constructing swing bridges at the entrances of docks, mainly on account of the enormous labour they entail and machinery in working them, and the notable dissatisfaction now generally expressed as to their demerits at dock entrances. For some years past I have directed my attention to the fact that it is possible to make ordinary caissons, and even dock gates, carry a public carriage roadway, if properly designed and adjusted, and thus bridge over an apparent difficulty at a very small cost; preserving the same level as the dock quays, avoiding all inclines and steep approaches. At the present time I am engaged in considering a similar arrangement to that I am about hereafter to describe, the only difference being that, in the case I now mention, the bridge is on the top of the lock gates, but that which I propose for Greenock would be erected upon skeleton-gates, if I may so term them. As the surface of the bridge is proposed to be on the same level with the quays, not the slightest obstructions would be created to interfere in any way with the working or hauling in of vessels through the communication openings, especially when heavy checks are required to be brought to bear upon the vessels, as the whole of the girders, roadway, &c., of the bridge would be down to the level of the quays.

"*Description of the Gate-bridge, for the 100 feet opening at the western end of the Middle Harbour.*

"In every respect the two leaves of the bridge are to be, and to work, as ordinary dock gates, and in point of construction to be very similar, viz., heel pivots, posts heads, anchors and straps, meeting posts, and rollers, together with segmental racer plates or roller paths, and working on general centres, on the middle line of the tramways on the bridge, as shown upon the plan. The whole framework of the bridge is to be of lattice construction—*a a a a* (see Plate XIII., Fig. 4) are water-tight tanks so placed below low water that their buoyant power shall be the same at all times of the tide, and may be pumped out by small hand pumps, or water let into them by small sluices, in order to keep up the adjustment, so that the working weight of the bridge shall be reduced to a minimum, as to almost take off the entire weight of the gates and give perfect freedom of action in travelling—that is to say, the bridge would be held in position by the heel pivots and straps, thus producing but little pressure to cause friction on the rollers and paths, so that the power required to open and close such skeleton gates shall be as little as possible, viz., only one man with a rack and pinion to each gate."

Then, in his specification of his patent, dated 9th September, 1870, Mr Kinipple said:—

"The caisson or bridge I arrange to be carried on rollers or trollies to run along rails laid across the bed of the entrance; and in order that the weight upon these rollers or trollies may not be too great I provide the caisson or bridge with air chambers below the low water level, so that the weight may be reduced to any extent desired. Caissons thus made capable of sliding readily into and out of a recess at the side of an entrance to a dock or harbour may, when they have been moved into position across an entrance, be, if desired, wedged or keyed against stop faces by means of cam levers, screws, or otherwise. The caisson or bridge I also form so that it may be readily disconnected, unballasted, and floated away for repairs, as with other ordinary caissons."

The following description of a caisson for a wet dock at Alloa was read by the Secretary as a communication from Mr A. Mason, Edinburgh:—

The caisson is square in form—not ship-shaped as the general form of caisson is; nor is it let into a groove in the masonry on each side of the entrance as the usual form is; nor is it that it can be opened and shut only at a certain level of tide. It floats at different levels of tide by water ballast let out or in as required. It needs no rollers nor roller paths—no water pumps, capstans, winches, or chains. It is made for foot passengers and carriages of all kinds, and turns about similar to a swing bridge to allow of vessels getting in and out. It is made to keep the water of the highest tide into the wet dock (formerly done by hinged gates), which water rises from 14 to 18 feet above low water; therefore, it is close from side to side of the entrance.

If it were to be placed in such a position as the entrance to the tidal basin on the Clyde at Glasgow Harbour, where the water on the outside is always level with the water in the inside, it might be open in the middle for the passage of boats, &c., only making each side so as to give ample floating power to carry the weight above.

The position of this Alloa caisson is so that the water can be let into or out of the ballast chambers by common brass cocks or small square sluices of trifling expense—the water of the wet dock being above the ballast chambers, while on the outside it is below them as the tide falls.

If such a caisson were to be placed between two wet docks where the high tide level was to be kept in each dock at about the same level, or only a foot or two of difference between them, then it is easily seen that another system must be adopted for getting quit of some ballast water to allow the caisson to float a little above the flow, so that it might be swung round; and to accomplish this the simple plan of constructing the one side of the caisson of open work above the floating level, and having a small compartment below the deck, immediately above the highest tides, where a small quantity of water ballast could be kept, to be let out by a cock or small sluice. By this plan no air vessels or pumps would be required.

I have no doubt the inventor of this caisson has well considered all this. The dock master at Alloa tells me that their caisson has rollers, but they are screwed up, and are only used when the dock is run dry, to move the caisson about on the stone platform while cleaning it.

Mr LYALL asked Mr Cunningham what benefit he sought by confining the tank, under the bridge shown in the drawing, to the middle part in place of making its whole length as shown in model? Also, what means he had for preventing the hinge being wrenched off, by the great leverage of the bridge's length, and the action of waves, when the bridge was being opened and shut?

Mr METHVEN said there were four rails running upon parallel plate walls.

The CHAIRMAN said the rails were somewhat about the centre of the tank, which ran upon ordinary strong iron rails, running upon the sole and into the recess. There was a parallel motion, whereby the upper part or roadway folded back like a pair of parallel rulers, and went into the recess formed for it.

Mr METHVEN said that the plans exhibited showed the general construction very well.

Mr LYALL said that fitting tanks on dock gates, and of laying circular rails under dock gates, was not new. He thought what Mr Cunningham claimed as new was, not merely the application of his arrangement to dock gates, but to a bridge.

Mr METHVEN said Mr Kinipple's plan was for quite the same purpose, as the parallel motion would be arranged, he would suppose, in the ordinary way.

Mr LYALL said that against this plan of Mr Kinipple's must be placed the increased cost of masonry. Mr Cunningham said that £1000 was saved by his plan, while Mr Kinipple's plan would increase the price of the masonry required over the usual dock.

Mr METHVEN said he thought not. It certainly saved length of "jaw."

The CHAIRMAN said that a strong retaining wall of the full depth of the bridge would be required.

Mr METHVEN said he might mention that there were now large-sized models of both the bridge and the caissons in Mr Kinipple's office, in Greenock; and that, in the event of any of the Members of the Institution being there, he had no doubt Mr Kinipple would be glad to show them.

Mr D. Rowan said that the subject before them yielded another illustration of the great advantage which a tribunal of the kind, provided by this Institution, conferred on men whose minds happened to be running in the same channel. It was often found, when the question was raised as to priority of invention, that men had been going on maturing schemes, while others had previously taken up the same questions, and the whole matter had developed, while others were yet labouring at it in ignorance of what had been accomplished. They had had many cases of that kind before this Institution; and here again were two rival schemes which appeared to be very much identical. He thought Mr Cunningham's idea of a bridge was a very good one, although it apparently had been thought of before by somebody else. The plan of this bridge was very good, although the means of floating it at the end might be liable to a difference of opinion. It was a dock gate, and very like some other forms, and in its simplicity of shutting seemed to work very well. He did not think any objection could be taken to it. He thought this Institution was a very suitable place for discussing such a matter, and for doing so in a fair and honourable manner.

Mr Methven said there was one thing he forgot to mention:—that there were balance weights included in Mr Kinipple's invention to facilitate the rising, and which worked in the upper compartment of the caisson.

Mr Cunningham said he had listened with considerable attention to the communications which had been read from Mr Kinipple and Mr Mason. In regard to the caissons, which formed the subjects of their letters, he had, some time since, fully informed himself of the matters to which they referred. He was quite aware of the character of Mr Kinipple's caisson. The fact was, that it seemed to him to be a comparatively old system, improved by Mr Kinipple so as to remove the difficulty of rolling the caisson into a covered recess. He does so by causing the platform or roadway to rise up as it comes into its place in the entrance, and *vice versa.* That part of the improvement forms the sole basis of his arrangement. The placing of an air-tight tank below low-water level, and allowing the water to flow freely above such tank, so as to reduce the difference of displacement between high and low tide, was an old arrangement. It was nearly as old as the making of malleable iron into plates for caissons. He thought the first engineer who took out a patent for it was Mr Wild; and in the same patent he included a number of other considerable improvements, such as the construction of graving docks of cast iron and wrought iron floats as a support to vessels when being repaired. So that the reducing of the difference of displacement to a minimum when the water varies was an old fact; and no modern engineer could lay claim to any merit as to that. In reference to Mr Mason's letter, he might say that the caisson at Alloa was a caisson with which he was quite familiar, Mr Ower, his predecessor, at Dundee Harbour, who also made the caisson which closed Camperdown dock at Dundee, which was almost identically the same, being the designer. The plan adopted in these two caissons was a very simple, and a very obvious one:—it was ballasting the caisson with water, at high water, from the one side, and allowing the balance of ballast, so let in, out at the other side towards low water. When the caisson was to be raised against the incoming tide, of course the water ballast had to be let out sufficiently to allow the caisson to float when the tide flowed, and was level on each side. In all the references which Mr Kinipple had made, he did not know that anything approximated to the combination that he had brought before them. He might refer to another inventor and patentee, Mr Edward Finch, of Chepstow, who, 18 months or two years ago, took out a patent for raising caissons by means of compressed air over their whole internal surface. In that way he required to pump air so as to raise the caisson independently of any float—in fact, he had no float. He trusted to the air that he pumped all over the caisson, which air was to raise the whole weight of the caisson. Now, they would see by his arrangement that he had chosen the advantages which were derivable from two methods. He supported the caisson or bridge—and the principle was the same in both—by means of a floating body, which, generally speaking, might be said to bear the whole weight; and then he pressed air into a pneumatic tube, or he might use any buoyant body, such as wood or hollow tubes, for the purpose of causing the necessary displacement when these were lowered, so that the weight of the bridge was counteracted, and the bridge might be raised or sunk with the smallest amount of labour; and, consequently, by this combination, the use of steam or hydraulic machinery was entirely obviated, and time was, to a great extent, economised. He thought they would see that if the principle which he showed more particularly upon the bridge, and which he showed upon the drawings of the caissons incorporated in his specification, had ever been adopted in the case of caissons that it would be so obvious a benefit to swing bridges it would have been applied to them, but it had never been. They would all see the immense advantage in the construction of a bridge thus shown over those heavy and expensive overhanging bridges which formed the only bridges to cross water spaces or dock locks at present. In reply to Mr Lyall, who asked how he had placed the tank towards the centre of the bridge, he might refer to his paper in the last issue of the Transactions, where he stated the reason, as far as possible, of his so doing—that it caused the strains on the structure to be opposite in character to those induced by an overhead load, so that the bridge was rendered much stronger in consequence of the position of the floating body. With ordinary loads it might not be of any great advantage; but still there was an advantage in having the floating body towards the centre of the bridge, for there was more leverage obtainable, by whatever means were employed, for opening the bridge. To refer to Mr Kinipple's caisson, he wished to say that the fact of sliding a caisson into a covered recess, as was necessary on such a plan, entailed a considerable amount of masonry. That caisson was about 70 feet long, and the recess or groove into which it slid must be longer and wider, so as to give free access to it. He fancied, from what he knew of the character of that work, that the cost of the masonry alone would range from £4000 to £5000. In either of the caissons he proposed—for a caisson might either be hinged or it might float freely; no wall space whatever was required. In fact, the caisson which he had designed for the entrance to the graving dock at Dundee, which designs were now completed, opened out into the dock itself, and did not even require a recess, although it was hinged by the one end, and revolved on the hinge. In the other caisson, where there were two vertical tubes, one being at either end, the caisson would float freely, and might be towed into any convenient situation, so that it would not interfere with the accommodation of the dock, and would not necessitate extensive walls, such as that caisson which was intended to close the dock at Greenock, required. Perhaps he might be allowed to read a note which described accurately the working of such a bridge, giving the figures in a more particular and practical shape than had been yet done :—

The varying level of the water in a passage way which is bridged, will cause a varying displacement by the structure of the bridge. With the form of bridge proposed, namely, consisting of two double triangular parallel boom girders, I think the variation in such displacement will be reduced to a minimum. The displacement for every vertical foot on the structure of the bridge between high and low water will equal about 4½ cubic feet of water; that is to say, that that quantity of water will be displaced by the braces and other iron work, for every foot the level of the water rises; and, therefore, if the difference between high and low water levels is ordinarily 9½ feet, as I have supposed it to be in the case before us, the bridge will be considerably more buoyant at high water than at low water. This difference in buoyancy will be correctly represented by the abstraction of the weight of 43 cubic feet of water, that is, 21½ cubic feet of water at each end of bridge. Now at high water we must impose an additional weight on the bridge to cause it to sink. Let us suppose this weight to be half-a-ton on each end of bridge, this weight will be originally imposed by construction on the outer or moving end of bridge, the other end being retained in position by the hinges. Now this half-ton on the outer end will increase as the level of the water falls towards low tide, till it has added to it the weight of 21½ cubic feet of water, equal to 1344 lbs., so that the sinking weight will then become 2464 lbs. at one end of bridge at low water. This is to be counteracted by pumping air into the vertical tube. In doing so, the air is compressed to about one pound per square inch over atmospheric pressure. Thus we require (1) about 40 cubic feet of air to take the place the water occupied; and (2) about 12 cubic feet of air to take the place of the void caused by the compression of the air within the tube. Together, 52 cubic feet of air require to be forced against an average pressure of half a pound per square inch, so as to raise the one end of the bridge off its supports at low water, and we will find that this is no more than one man can do in a minute and a-half. At high water, from the weight to be raised being only about one half, one man can do the work in less than one minute. Thus it will be seen that the management of the bridge is a very simple, inexpensive matter. A caisson may be considered equally easy to work, for although the structure may be bulkier, the width of span is generally less. If the position should be liable to exceptional high tides, I conceive the adoption of a subsidiary float or displacing body, which in general shall be immersed, but when required as additional ballast, shall be withdrawn from the water, will be, in conjunction with the vertical tube, the best arrangement attainable.

On the motion of the Chairman, a vote of thanks was awarded Mr Cunningham for his paper, and for his second illustration of his paper by means of his models.

Mr W. R. M. Thomson considered that Mr Cunningham's new floating bridge possessed considerable novelty, resulting mainly in a saving of first cost, and of outlay in masonry over those in use; but thought that a further saving might be effected by placing a high pressed air receiver (say below the roadway of the bridge, charged by motive power pumps or otherwise, at convenient intervals) from which the air could be admitted to the floating towers of the bridge, automatically or by hand, to suit and float the bridge at any state or level of the tide, without requiring men to wait on night and day to work the pumps when it was required to float and open the bridge.

Mr CUNNINGHAM explained that the bridge was always resting upon four supports, two at each end; that during that time there was no need for attention to regulating the pressure of the air. It was only when it had to be opened or shut that there was the slightest need to regulate the pressure of the atmosphere, and that was done within a small tube, so that there was no difficulty in the matter whatever.

Mr HOWDEN said that a swing bridge on Mr Cunningham's plan would, in some cases, be objectionable; for example, in such a place as the entrance to the Kingston Dock. The bridge there would be about 30 feet across, so that if Mr Cunningham's plan were adopted, it would necessitate the entrance to the dock being made 30 feet wider, seeing the bridge could not be made to swing either into the harbour on the one side, or into the dock on the other. The dock entrance between the pier walls would therefore have to be made equal to its present width, and the cross measurement of the floating bridge additional.

Mr CUNNINGHAM said he might explain that it was a very common thing at the present time to open a caisson into a recess. It was just as easy to make a recess in the wall of a passage as to make it anywhere else.

Mr J. L. K. JAMIESON said that evidently the bridge had been designed to go into a recess, and there was no doubt that had made the working out of the design very simple. It was a very strong structure, composed of very little material compared with a swing bridge. The only advantage which he saw in Mr Kinipple's plan was that of shortening the throat of the dock, which was a very important thing. There was no doubt that Mr Cunningham could get over that objection, viz., that the recess and the opening of the dock must be equal to the length of the bridge.

Mr HOWDEN wished Mr Cunningham to understand that he did not object to his bridge otherwise than he had mentioned.

Mr KAY said there was one objection to Mr Kinipple's plans, and that was the recess. In a place where the tide flowed or ebbed strongly it would be very apt to get jammed in working out or into position. He thought Mr Cunningham's plan was the best in that respect. He thought Mr Cunningham well deserved their thanks for his paper.

The CHAIRMAN said that it must be very gratifying to Mr Cunningham to hear the commendatory remarks of such men as Mr Jamieson. He would personally take close notice of the bridge which Mr Cunningham was building; and he had no doubt if it were successful it would lead to its adoption elsewhere.

On an "Automatic Steering Apparatus."

By Signor MICHEL ANGELO SICILIANO, Palermo.

(Extract Translation by the Secretary of Donation to Library, entitled "Timone Automatico.")

SEE PLATE XIII.

Read 18th February, 1873.

(1.) The object of this communication is to describe an automatic arrangement whereby the steering of a vessel may be effected with more certainty and with more promptitude than by the present means.

In this arrangement the helm turns without the least aid from the hand.

(2.) The principal features of the mechanical part of this arrangement will be best understood by reference to the drawings.

The helm T, to which the tiller *a t* is fastened, has two leathern bands fastened to it at X. These bands, after passing round the pulleys *m* and *n*, are divided in two and pass round the shafts Q and U, lying in the grooves *t* and *t'*. (See Fig. 2), which represents part of Fig. 1 on a larger scale.

The double cog wheel V transmits its motion to either of the shafts Q or U.

Each of these shafts carries a collar, B E (Fig. 2), the upper part of which forms a bevel wheel, gearing with the wheel V.

Fig. 3 shows a horizontal section of part of Fig. 2. The ring E has attached to it, by pins *c a*, the forked piece A B.

This forked piece is free to move as a lever about K, and can be lowered or raised from C to D. (See Fig. 2.) If the soft iron armature N of the electro-magnet X is acted upon by the magnet, then, when the armature N is attached to the magnet, the collar B E is raised and is caught by the polygonal face of the upright shaft F, now bringing the bevel part of the collar into gear with the wheel V.

A similar action takes place in connection with the shaft U U'.

Now, when the electro-magnets are not acting, *i.e.*, when the electric current is not circulating, the collars will always remain *down*, and the two upright shafts will be free to turn. On the contrary, if one of the electro-magnets attracts the corresponding lever, the collar united to this lever will rise, and the bevel toothed part at B' will gear with the wheel V, and so the whole shaft U U' will be put in movement. The other shaft Q Q' still turns, because of the motion of its bands, which are united to the other bands of the shaft U U', which is in motion; but this movement fails to produce any effect.

(3.) The motive power used for turning the helm.

The wheel V is put in motion by the prime mover of the ship; and, therefore, this arrangement of steering gear is not so suitable for a vessel not furnished with such a machine, unless by special appliances.

By means of the shaft O L' (see Fig. 1), this motion is transmitted through the bevel wheels at L' to the wheel V, and so to the shafts Q and U, and will actuate these shafts either to right or left by the action of the bands which encircle them, and which are attached to the tiller. It is evident that, by turning the shaft Q, the helm will move to the left; and, by turning the shaft U, to the right. Therefore, the movement of the said two shafts depends on their collars. If these remain down, the wheel V turns idly, and neither moves the shafts Q nor U.

The mechanism adopted to change the direction of the current of electricity from the battery, whereby the right or left hand magnets may be magnetised, is by means of a "contact breaker," by touching certain buttons or studs attached, to which the current is deflected to right or left.

In the after discussion,

Mr W. R. M. Thomson suggested that the tooth-gearing shown was objectionable, and to make the principle successful in practice, he considered friction gearing or friction couplings would be absolutely necessary for throwing such a steering gear into the forward or backward action, and a powerful friction brake for holding the helm up or steady in a rough sea, when the apparatus was out of action.

Mr JAMIESON said that, as the wheel marked V was continuously revolving, any jarring between it and the bevel wheels must only be momentarily until the bevel wheel got into gear. The principle of the apparatus seemed very good. It was merely the bringing the one magnet or the other into play, so as to bring the bevel wheels into action, and thus to deflect the rudder to one side or the other. In the form of apparatus at present in use, the engine had to be reversed; but here the motion was constantly in one direction, and the magnets had only to be affected in order to turn the vessel from right to left.

Mr KAY said that, in sailing up a river, a donkey engine would be required for working the steering gear.

Mr LYALL asked whether the projector of this plan had tried his gear on ship board? and with what success? also, whether there was any other medium, not mentioned in the paper, for preventing the wheel gearing striking when the levers were being changed? It appeared, from what had been communicated, that with the shaft, which gave motion to the gearing, continually revolving, a heavy sea would so act on the gearing, through the rudder, as to break the former completely. He thought it would be found impracticable to throw the one wheel out of gear and the other into gear at the same moment in a sea way, without breaking the gear.

The SECRETARY said that the inventor appeared to have arranged for this by means of catches acting on the toothed arc shown below the tiller.

Mr JAMIESON thought this apparatus had got over the difficulty long felt of working the engine-room signals from the bridge.

Mr ROWAN said he thought it was only respectful to Signor M. Siciliano, in order to ascertain precisely the opinion which the Institution entertained of his apparatus, that they should adjourn the discussion till next meeting. There was no doubt it was a very ingenious arrangement; but whether it could be brought into practical use or not, remained to be seen. He had no doubt that the principle was good.

Mr JAMIESON said the time was in his remembrance when steam steering gear was looked upon with suspicion; but now they expected to find it in every well appointed ship.

The CHAIRMAN suggested that the Secretary should communicate to Professor Piazzi Smyth what had taken place; and perhaps they might get more information on the subject previous to next meeting.

The discussion on this paper was resumed on April 22nd, 1873.

The CHAIRMAN said that the author had sent a tracing of the apparatus, which was now exhibited.

Mr LYALL said he had received a pamphlet, through the Secretary, from the inventor—he presumed that other members had been likewise favoured—which he was getting translated. He thought the inventor had taken a great deal of trouble about this matter in his endeavours to make a clear communication to the Institution; and it might be well for the members to reciprocate that trouble. This could best be done at a future meeting, after they had become acquainted with the pamphlets and the tracing now shown.

On Signalling through Submarine Cables, illustrated by Signals transmitted through Model Submarine Cable, exhibited by Mirror Galvanometer, and by Siphon Recorder.

By Professor Sir WM. THOMSON, A.M., LL.D., &c.

Read 18th March, 1873.

In a submarine cable the wire constitutes, as it were, the inner coating of a Leyden jar, the gutta percha or india rubber takes the place of the glass, and the water touching the outside represents the outsidecoating of the jar. Faraday showed that if several thousand Leyden jars were distributed along an ærial line of telegraph, each with its inside coating connected with the telegraph wire, and outside coating with the earth, the signals through the line would exhibit exactly the same inductive retardation as those sent through the actual submarine line. Mr Cromwell Varley had devised and constructed a beautiful practical method for realising this suggestion. He first made condensers of sufficient capacity to represent the submarine line. A dozen or so of these condensers distributed along the line of resistance coils, according to Faraday's rules, gave the electrostatic capacity to which the comparative slowness of a long submarine cable is is due. In these condensers in a moderate compass a large number of sheets of tinfoil packed closely together with insulating material between them in order, gave, by the great amount of surface thus got, and the thinness of the coating, the enormous amount of electrostatic capacity (*quasi* Leyden jar capacity) which is necessary to represent a few hundred miles of submarine cable. By these condensers, applied properly to resistance coils, Mr Varley constructs what he calls an artificial line, and such a line was supplied by him to Sir W. Thomson with capacity equal to a quarter of that of the French cable and resistance equal to four times that of the conductor of that cable—that is to say, equal to the resistance of about 10,000 miles of such a conductor as that of the French cable. The degree of inductive embarrassment of the French cable on account of its great length—about 2500 miles—is greater than that of any other cable except those between Suez and Aden, and between Aden and Bombay, which in that respect are about equal to the French cable; because, although of shorter length, their conductors are of less weight per mile. Thus the appliances exhibited may be regarded as a model of any one of these three cables. To illustrate the signals through this model cable I have here a mirror galvanometer composed of a small mirror, with four small magnets attached to its back (weighing, in all, mirror and four magnets, less than half-a-grain), hung by single silk fibre in proper position in the hollow of a bobbin of fine wire, through which the current passes, and controlled by means of a large fixed magnet placed on the outside of the apparatus. On the passage of a current of electricity the needle will be deflected, and by means of the lime-light placed in front of the mirror, any small movement of the needle will be exhibited in a magnified degree on the scale hung on the wall. When I press down one or other of two springs belonging to the *sending* instrument you will observe a deflection of the spot of light on the scale to right or left. Representing the letters of the alphabet by certain movements of the spot of light, we are enabled to transmit messages by this means.

The Siphon Recording Instrument is an automatic arrangement whereby we have the message printed off on a slip of paper kept in uniform motion, and by means of electrifying the ink in a siphon shaped capillary tube the ink flows through the tube, and then marks the paper. The combined movement of the needle and paper will be seen on the slips of paper exhibited as a wavy line.

On the Rope-Dynamometer, with application to Deep-Sea Sounding by Steel Wire.

By Professor Sir WM. THOMSON, A.M., LL.D., &c.

(SEE PLATE XIV.)

Read 18th March, 1873.

The object of the present paper is to point out methods for using a flexible band, rope, or chain to regulate and measure resistance applied to a revolving drum or shaft. The general character of the methods, some of which I now propose to describe in detail, is indicated in the following passage extracted from Thomson and Tait's "Natural Philosophy," § 436:—

"Dynamometers are instruments for measuring energy. *White's* "*friction brake* measures the amount of work actually performed in "any time by an engine or other 'prime mover,' by allowing it, "during the time of trial, to waste all its work on friction. *Morin's* "*dynamometer* measures work, without wasting any of it, in the "course of its transmission from the prime mover to machines in "which it is usefully employed. It consists of a simple arrangement "of springs, measuring at every instant the *couple* with which the "prime mover turns the shaft that transmits its work, and an inte-"grating machine from which the work done by this couple during "any time can be read off.

"Let L be the couple at any instant, and ϕ the whole angle "through which the shaft has turned from the moment at "which the reckoning commences. The integrating machine "shows at any moment the value of $\int L d\phi$, which (§ 240) is the "whole work done.

"White's friction brake consists of a lever clamped to the shaft, "but not allowed to turn with it. The moment of the force required "to prevent the lever from going round with the shaft, multiplied "by the whole angle through which the shaft turns, measures the

" whole work done against the friction of the clamp. The same " result is much more easily obtained by wrapping a rope or chain " several times round the shaft, or round a cylinder or drum carried " round by the shaft, and applying measured forces to its two ends " in proper directions to keep it nearly steady while the shaft turns " round without it. The difference of the moments of these two " forces round the axis, multiplied by the angle through which the " shaft turns, measures the whole work spent on friction against the " rope. If we remove all other resistance to the shaft, and apply " the proper amount of force at each end of the dynamometric rope " or chain (which is very easily done in practice), the prime mover " is kept running at the proper speed for the test, and having its " whole work thus wasted for the time and measured."

And again § 586 (after investigation of the equilibrium of a cord stretched on a fixed surface):—

" A very important practical case is supplied by the consideration " of a rope wound round a rough cylinder. We may suppose it to " lie in a plane perpendicular to the axis, as we thus simplify the " question very considerably without sensibly injuring the utility of " the solution. To simplify still further, we shall suppose that no " forces act on the rope but tensions and the reaction of the cylinder. " In practice this is equivalent to the supposition that the tensions " and reactions are very large compared with the weight of the rope " or chain, which, however, is inadmissible in some important cases, " especially such as occur in the application of the principle to " brakes for laying submarine cables, to dynamometers, and to wind- " lasses (or capstans with horizontal axes).

" If R be the normal reaction of the cylinder per unit of length of " the cord, at any point; T and $T + \delta T$ the tensions at the extremi- " ties of an arc δs; $\delta\theta$ the inclinations of these lines; we have, as " in § 576,

$$T\delta\theta = R\delta s.$$

" And the friction called into play is evidently equal to δT.

" When the rope is about to slip, the friction has its greatest value, " and then

$$\delta T = \mu R\,\delta s = \mu T\,\delta\theta.$$

" This gives, by integration,

$$T = T_0\epsilon^{\mu\theta},$$

" showing that, for equal successive amounts of integral curvature " (§ 10), the tension of the rope augments in *geometrical* pro- " gression. To give an idea of the magnitudes involved, suppose " $\mu = \cdot25$, $\theta = 2\pi$, then

$$T = T_0\epsilon^{\frac{1}{2}\pi} = 4\cdot81 T_0 \text{ approximately.}$$

" Hence if the rope be wound three times round the post or cylinder " the ratio of the tensions of its ends, when motion is about to com- " mence, is

$$(4\cdot81) : 1 \text{ or about } 111 : 1.$$

" Thus we see how, by the aid of friction, one man may easily check " the motion of the largest vessel, by the simple expedient of coiling " a rope a few times round a post. This application of friction is " of great importance in many other applications, especially to " Dynamometers."

The simplest form of rope-dynamometer is that in which the resistance is produced by a fixed cord bent on a revolving drum or pulley, and some convenient plan used for applying and measuring, or estimating, the force at each end of the cord. The easiest realization is, when circumstances admit, to be had by simply passing a cord over a grooved pulley, and hanging unequal weights on the two ends. An example of this was shown to the meeting, by the measurement of work done by the original model of Stirling's air engine, presented by the Rev. Robert Stirling, D.D., of Galston, to the Natural Philosophy Class in this University, probably about sixty years ago. The fly wheel, a light iron casting of about three feet circumference, has recently had, for this purpose, a semi-circular groove cut in its circumference. A silk thread, with 700 grains attached to one end, and several little lead weights of 50 grains each attached at different points of the thread near the other end, are led over the wheel, so as to rest on the semi-circumference, with two vertical portions hanging down on the two sides. When the wheel is turned so as to tend to lift the weight of 700 grains, the friction lifts it so far up as to let down to the table on the other side all of the 50-grain weights, except two. It was found that when the wheel was kept turning there was a very nearly constant strain of 100 grains on one side of the cord, and 700 on the other. The wheel was, as it were, continually winding up a weight of 700 grains, and letting down a weight 100 grains, the weights in reality neither rising nor falling, but the whole work being spent in overcoming friction between the thread and wheel, and generating its equivalent in heat there. The work done per turn of the wheel was therefore equal to 3×600 foot grains, or ·26 of a foot pound. The engine made 84 revolutions per minute, and therefore performed 22 foot pounds of work per minute. It was therefore working at two-thirds of a thousandth of a horse-power. With the same co-efficient of friction between cord and cast iron, the cord, if wound more than half round the wheel, would have its tension reduced by $\frac{6}{7}$ in every half turn. Thus, if the thread is put once round the wheel instead of only half round, the strain at one end would be only $\frac{1}{49}$ part of that at the other, or there would be an error of only about 2 per cent. in neglecting altogether the tension at the light tension end, and calculating simply as if the heavy weight hung on at the other end was being wound on a drum equal in circumference to the pulley. For many purposes, a dry cord once, or one and a half times, round the circumference of a metal wheel, and simply held fixed at one end, while stretched with a weight hung on at the other end, forms a very ready and sufficiently accurate dynamometer. The end on which the weight is hung must be that which would be wound up on the wheel if the cord did not slip. A spring balance is very easily applied to the other end when greater accuracy is necessary. The accompanying sketch shows a very convenient way of doing this. With dry hemp cord on dry cast-iron, I find that a single turn of hemp cord round a flat, moderately-smooth rim of cast-iron, or round a pulley with a wide, smooth, flat-bottomed groove, gives a tension at the light-tension end equal to about one-fifteenth of the tension at the heavy-tension end. A large fly wheel of cast-iron, with a wide rounded groove cut in its circumference, which is 12 feet round (used ordinarily for dynamical illustrations in my class) was shown to the meeting as an illustration of this form of dynamometer. With a weight of 56 lbs. on one end of a cord bent once round the wheel, and having its other end attached to a spring balance, two men turning the wheel by handles can keep it running at about one turn per second. The tension measured by the spring balance at the other end, when the cord is dry, is about 4 lbs. The work done, therefore, per revolution is about 624 foot-pounds. Hence, 550 foot-pounds being the work of one-horse power, I find that two men can work at rather more than one-horse power; but this is severe work, and can hardly be continued for as long as a minute. With a fly-wheel of four times this diameter, driven at the same angular velocity (60 turns per minute, or one per second), a weight of 1,222 lbs. hung on one end of the rope measures about 120 horse-power. The tension at the light-tension end, if the rope is just once round the wheel, is about $\frac{1}{6}$ cwt., or 76 lbs., a very moderate force to be measured by a small ordinary spring balance.

According to Joule's equivalent, the heat generated by 100 horse-power amounts, per minute, to $\frac{3300000}{1390}$, or 2374 thermal units centigrade. The heat generated at the circumference of the wheel at any instant would, in the course of two or three minutes, be diffused almost uniformly through the whole rim by the high thermal conductivity of iron. Hence, to reckon the heating effect in ten minutes, calculate the rise of temperature in a mass of iron equal to the rim produced by the whole heat generated in any time. Now, suppose there to be a ton of iron in the rim, its thermal capacity would be equal to that of 224 lbs. of water (as the specific heat of iron is ·1). Hence, if no heat were lost by radiation, or by convection of the air, the elevation of temperature in ten minutes would amount to 106 deg. Hence, the rope dynamometer might, without over-heating, be applied safely for ten minutes to consume and measure, on a fly-wheel such as that described, the work of an engine working at 100 horse-power. If in any case it is desired to continue the trials hour after hour, it would be necessary, in order to prevent the rope from taking fire, that the heat should be carried away artificially; for radiation, and convection of the air even with the rapid motion of the wheel through it, and with a temperature as high as 200 deg. or 300 deg. Cent., would not carry off the heat as rapidly as it is generated. This may be done, however, by keeping a little water dropping on the inside of the rim of the wheel.

It is desirable to keep the rope dry, because the great difference between static and kinetic friction of wet rope on metal gives rise to a tendency for the rope and spring balance to get into a state of intense vibration, which is sometimes very troublesome. In any case in which, whether for carrying off the heat or for other causes, it is required to keep the rope wet, precautions are necessary in commencing the motion. Thus, if the heavy weight be allowed to hang on the cord when the wheel is at rest, and then the wheel be set in motion, the clinging of the cord to its rim (on account of the greatness of the statical friction between wet cord and iron) may cause the weight to be wound up to a considerable height, and the other end of the cord to be altogether slackened; and then, after a time, the weight falls down suddenly, and may produce an accident; or, before it falls down, the slackened rope may be thrown off the pulley. At best, the motion commences with a series of jerks; then the cord and spring balance get into a state of rapid vibration, sometimes emitting a musical sound, until the speed rises above a certain limit, after which the action goes on with perfect smoothness. To avoid those initial troubles, the heavy weight should be lifted so as to leave the rope almost quite free from tension before the wheel is started, and kept so until nearly the regular speed has been attained, when the weight may be gradually let down until it hangs altogether on the cord.

The method above described may be applied with great readiness to an ordinary engine fly-wheel without any groove cut in the rim. A cord passed once round and arranged in the manner represented in the drawing, may, by two or three fixed guides, be kept from slipping off the wheel, without in the least degree interfering with the dynamometer measurement. Thus, all that is necessary for measuring the work done by a steam engine working up to 100 horse-power, or more, is weights amounting to 11 cwt., a piece of rope strong enough to bear them, and a spring balance capable of weighing 100 lbs.

I used this form of dynamometer in a first experiment of deep-sea soundings with piano-forte wire in the Bay of Biscay last summer, and found it to work most satisfactorily. The whole length of wire, amounting to three nautical miles, was coiled on a light drum of tin plate, 6 feet in circumference. A rim projecting on one side gave a cylindrical bed for the dynamometer cord, and was also used for an endless rope, wound once and a half round it, for hauling in the wire and sinker after the sounding was taken.

One objection to this application of the simple rope dynamometer is the wearing of the friction rim by the dynamometer cord, which, although it produced no sensible effect in one operation of letting the weight down to a depth of 2700 fathoms, would certainly, after repeated operations, render a renewal of the rim necessary. Another objection was, that the cylindrical rim, with the endless cord once and a half round it for hauling up, required a plough to guide the cord. I have, therefore, substituted a very sharp V groove for the cylindrical rim; and I have thought it advisable not to use this for the slipping surface of the dynamometer. A modified plan by which the slipping is transferred to a fixed bollard, and which has the advantage of using the same rope both for the dynamometer and for hauling in, was exhibited to the meeting. Since the meeting I have substituted for the fixed bollard a pulley, prevented from running round by a cord of which the tension is measured by a spring balance. The accompanying sketch (see Plate XIV.) shows (with the exception of a continuous counter with endless screw and train of train wheels applied to count the turns of the same,) the apparatus as I now have it.

The endless rope passes rather more than half round the V groove on the wire drum, and is stretched horizontally by a pulley with a moveable frame, hauled with the requisite force by a winch, and steadied by hand (or by any suitable guiding appliance if desired). The lower part of the cord is guided by a dynamometer pulley, which is pivotted as close to the wire drum as may be. This pulley has two semi-circular grooves in its rim—a large one for the endless rope and a small one for the dynamometer cord. When the weight is being let down with the dynamometer in action, the endless rope is led from the bottom of the V groove of the drum obliquely upwards to the top of the dynamometer pulley, on which it is coiled rather more than once round, so as to pass away horizontally to the stretching pulley; and the dynamometer pulley is prevented from running round by a small stout cord attached to its rim, and passing tangentially from the small groove to the spring balance. In the sketch this cord is shown passing horizontally to the spring balance, but it may sometimes be more convenient to lead it vertically downwards. The frame of the stretching pulley is drawn by the winch with such force as gives rise to the required resistance against the egress of the wire. If the friction of the cord were perfect, and the stretching pulley frictionless, the force shown by the spring balance would be exactly equal to the amount by which the tension of the upper part of the rope as it approaches exceeds the tension of the lower part as it leaves the V groove—that is to say, equal to the amount of tangential resistance applied to the wire drum. Hence, if (as is very nearly the case), the circumference of the V groove is equal to that of the circle from which the wire is running out, the force indicated by the dynamometer will be just equal to the tension of the wire where it leaves the drum; and from time to time the winch must be tightened up or relaxed, so as to bring the indication of the spring balance to the desired degree of force.

To arrange for hauling in, all that is necessary is to let the dynamometer pulley run round freely, which is done by detaching from it the cord which passes to the spring balance, and to haul the endless rope by hand. Two men walking along the deck, and pulling the upper part of this rope, can do the work with ease, when the weight to be lifted is 60 or 70 pounds. But for a long haul from a depth of two or three miles there should be three men pulling; and to keep hauling about as fast as men can walk along the deck, six men should be employed, so that three men may be always hauling on the upper part of the rope while the others are returning along the deck towards the wire wheel. For a long haul it would probably be found worth while to uncoil the endless rope from the dynamometer pulley, which is done in a moment by lifting the pulley off its bearings. When this is done, the slack must be taken up, of course, by the winch and stretching pulley. The sounding apparatus was exhibited to the meeting, and shown in action, letting down and hauling up the sinkers through a depth of 26 feet between the lecture-room window of the Natural Philosophy Class Room and the ground. The chief sinker is an oval-shaped lead weight of 30 pounds, with a brass tube and valve attached to its lower end for bringing up specimens from the bottom. This weight is hung by a piece of stout cod-line from a lighter lead weight of two or three pounds attached directly to the wire. The object of this arrangement is to prevent the wire from reaching the bottom. Were it to do so, it might become slack and coil itself into kinks, entailing a risk of breakage in the attempt to haul up the sinker again from the bottom. In the only experiment I have yet made at sea the cod-line was 19 fathoms long; but this experiment gave me so great confidence that I believe five or six fathoms would be quite sufficient.

The plan to be followed is simply to apply resistance, measured by the dynamometer, always to an amount exceeding by about ten pounds the weight of the wire hanging down in the water. Thus the wire runs out regularly (although with very varying speed, on account of the motion of the vessel) until the sinker reaches the bottom, when the wheel suddenly stops, and no more wire runs out. From my one experiment, I believe it will generally be quite easy to prevent more than two or three fathoms of wire from running out after the main sinker touches the bottom. I was agreeably surprised by the perfect definiteness with which I could feel the bottom at a depth of 2700 fathoms by the simple apparatus described above.

I found that the sailors would not believe that the bottom had been reached until the sinker was brought on board with its brass tube filled with fine oaze. One very important precaution which I had neglected to anticipate is necessary. The tension of the wire on the drum must be frequently relieved by stopping, for a moment, the hauling in, and allowing the wheel to run back through a small part of a turn—the wire overboard being held up for the time by a proper clamp. The sounding wire used in my first experiments was made up partly of half-mile lengths of piano-forte wire, weighing about 11 lbs. per nautical mile, and partly of steel wire specially manufactured for me by Messrs Richard Johnson & Nephew, of Manchester. The form of joint by which I connected the several pieces was a long splice, with very gradual spiral lay, extending over about 18 inches of the wire, and soldered along the whole length of the twist. It seemed to answer perfectly well. I have not yet, however, tested the strength of a splice of this kind, but I expect it will be found nearly equal to that of the simple wire. As a precaution it is advisable to serve with fine twine over the whole length of the splice and to look at each splice occasionally while paying out the wire in taking a sounding.

It is very desirable to have no splices, or as few splices as possible; and it is therefore important to have as great lengths as possible of continuous wire. It seems that hitherto no lengths of more than about half a mile piano-forte wire had been made; but Messrs Johnson succeeded, with great difficulty I believe, in making for me a three-mile length of their special steel wire. This wire is made of crucible steel. It weighs 14½ lbs. per nautical mile, and bears a weight of 250 lbs.

On the motion of the PRESIDENT, a hearty vote of thanks was awarded Sir Wm. Thomson for his very interesting paper.

Note Received May 19th, 1873.

Since the reading of the preceding paper I have succeeded in making a clamp or stopper, which will, no doubt, prove thoroughly satisfactory in practice, for relieving the tension of the wire of the drum, as often as is found necessary during the hauling in. To apply the stopper, a broad breech-piece of lignum-vitæ is first dropped into a rectangular aperture, so as nearly to press the wire against a backing of galvanized iron. Half a turn, or a turn of a screw, acting upon this breech-piece, clamps the wire securely without damaging it. If the ratchet has been in action, the paul should be lifted before the stopper is applied, the men holding fast but not hauling on the upper part of the endless rope. As soon as the stopper is applied, they should let the rope run back through a few inches, as much as is perceived to be necessary to thoroughly relieve the tension on the drum. The only use of the ratchet is to allow the men at any moment to take their hands off the rope without letting the sinker run down; and, in general, during a long haul, the paul may be lifted, as the ratchet will be found quite unnecessary.

Since the reading of the paper I have gone carefully into two very important points—(1) the conservation of the wire and wheel; (2) splices.

(1) Instead of seeking protection by galvanizing the steel wire, I now use thin sheet galvanized iron (in place of the tin plate which I first used) for the wheel. The zinc surface of the wheel, and of the galvanized iron case mentioned below, gives full galvanic protection to the wire when coiled on the wheel, and kept under water. As an additional security, thin slips of sheet zinc are supplied, to be bent round the wire on the drum. To protect the wire at the place of attachment of the weight, and for a short distance above it, I have substituted a galvanized iron ring for the small lead weight described in the preceding paper. As described there, the heavy sinker (30 lbs.) is to be attached to a few fathoms of cod line—say about 20 fathoms. The upper end of the cod line is to be attached to the ring, and the ring to the wire. I shrink from galvanizing the wire

tself, because this process would probably impair the fine temper required to give the great strength possessed by pianoforte wire and Johnson's special wire; would certainly add considerably to the weight; and would probably roughen the surface to a degree which would diminish the value for deep-sea soundings. Experiments are, however, being made in respect to galvanizing the wire by Messrs Johnson, and I wait for their report before coming to a decided conclusion on this point. Meantime, I have not much apprehension of serious damage from rust during the time the wire is actually in use. The protection for it during intervals between use, in which I have most confidence, has been suggested to me by Mr James Young, and consists in keeping the wire and drum, always when out of use, immersed in water rendered alkaline with quick-lime, or caustic soda or potash. On account of their superior solubility, I prefer soda or potash to quick-lime, although experiments made by Mr Young proved that lime water, when prepared with sufficient care, is thoroughly efficient in preventing rust on fine steel wire. I find that soda ash—containing 60 per cent. of caustic soda—can be had for twenty-four shillings per cwt. This, I believe, will be an exceedingly economical and secure protection to the wire and drum. A galvanized iron case is now made, with a lid bolted to it, and kept tight by an india rubber washer, to hold the drum with the wire wound on it, completely immersed in the alkaline solution, during all intervals when out of use. Another method, which has been suggested to me independently by Mr Froude and Commodore Ammen, consists in keeping the wheel with the wire immersed in oil, and may possibly be found preferable. The iron case will serve either for the alkaline solution or for oil. If oil is used, a small aperture with pipe and stopcock should be applied to the lower part of the vessel to drain off the salt-water, which would be displaced by the oil, and sink to the bottom. In hauling in the wire, as much as possible of the salt water ought to be rubbed off from it by cloths, cotton waste, or other convenient rubbers applied to it below the aperture of the clamp.

(2.) A long series of experiments made by Mr M'Farlane has led to most satisfactory results in respect to splices. In the first place, the twisted and soldered splice, which was described to the meeting, was found, as I anticipated, to break (even with the most careful soldering) with a force a little less than the breaking weight of the simple wire: and the fracture was generally found in the single wire just where the solder commences at one end or other of the splice. I therefore went back to the simple twisted splice. By making such a splice *over a sufficient length of the wire*, and serving over an inch or two at each end of the twist, it is obvious that a splice as strong as the wire itself, may be made. But an inconveniently long splice, probably not less than three or four feet, is required to prevent slipping, on account of the smooth character of the steel surface. A splice of not more than a foot long stands perfectly well when served tightly over its whole length, with twine well waxed with "shoemaker's wax;" but I found that after having lain in a weak solution of caustic potash for a few weeks, it became so much loosened through the disintegration of the wax, that the wire slipped under a strain much short of the breaking weight. On the other hand, by the simple expedient of slightly heating the wire and varnishing it with marine glue before making the splice, I obtained splices of from one foot to two feet long, each holding fast up to the very breaking weight of the wire, after having been kept in the alkaline solution for several weeks. I can therefore now confidently recommend a splice of two feet long, with the wire thus previously varnished. The ends of the wire must be carefully served over with twine, through a space of about an inch on each side of each end. As an additional security, marine glue may be melted on over the whole length of the completed splice, the wire being, of course, slightly heated. With, or without this final soldering with marine glue, the splices hold perfectly well. I have tested many splices after having roughly bent them backwards and forwards all over, so as to crack away as much of the marine glue as would leave them: and in no one case has the splice given way. In every case, when loaded up to the breaking weight of the wire, the wire itself has broken at some distance on either side of the splice. The breaking weights which I have found, range from 206 lbs. to 236 lbs.—the wire having all been from the same hank of Johnson's special steel wire, weighing about 14½ lbs. per nautical mile. To make the splice, the best plan is to lightly clamp the end of one wire to the other wire, at about two feet from the end of the latter, by a small vice guarded by slips of wood; and then to lay the two together by hand, with a long spiral lay of about an inch for the full turn of each spiral. To secure the full strength it is necessary to avoid sharp bends—one person holding the two wires in his two hands, and keeping them nearly straight, can make the spliced with ease in a very short time. The whole process, including the serving of the ends, and the final soldering with marine glue, may be completed in a few minutes.

TESTING OF SPLICES.

The splices were made by twisting the wires together to the length required, so as to have one twist in a length of from ¾ to 1½ inch, and served either throughout or a short space at the ends with thin twine rubbed with shoemakers' wax.

Nos. 1 to 4 Splices.—1½ to 2½ feet long; served the whole length; wire broke with from 206 lbs. to 220 lbs.—splice entire.

No. 5 Splice.—7 in. long; similarly prepared and immersed in lime water, containing a little caustic potash, for 17 days —splice slipped with 125 lbs.

No. 6 Splice.—6 in. long, similarly prepared and treated; wire broke with 210 lbs.—splice entire.

Same Splice.—One half of the serving cut away in the middle; splice slipped with 108 lbs.—wire unaffected by the water.

No. 7 Splice.—6 in. long; similarly prepared and treated—splice slipped with 150 lbs.

No. 8 Splice.—6 in. long; served at each end for half-an-inch, and rubbed over with white lead.—splice slipped with 56 lbs.

No. 9 Splice.—12 in. long; soldered throughout; no serving; wire broke at end of soldering with 206 lbs.

No. 10 Splice.—12 in. long; having 2 in. in the middle soldered, with half-an-inch of serving at the ends; broke at the end of soldering with 189 lbs.

No. 11 Splice.—12 in. long; 2 in. in middle soldered; served throughout; wire broke 4 in. from splice with 210 lbs.

No. 12 Splice.—2½ in. long, soldered; no serving wire; broke at a distance from splice with 204 lbs.

No. 13 Splice.—8 feet long; 1½ in. serving at each end; supported 192 lbs. for 20 hours, 224 lbs. half-an-hour without yielding; wire broke at a distance from the splice with 225 lbs.

No. 14 Splice.—5½ feet long, 1½ in. serving at the ends; wire broke at a distance from the splice after supporting 200 lbs. for three minutes.

No. 15 Splice.—24 in. long; rubbed over with coal tar; half-an-inch serving at the ends; supported 203 lbs. several hours without yielding; wire broke during the night.

No. 16 Splice.—26 in. long; varnished with marine glue (heated just enough to melt the glue); 1½ inch serving at the ends, soaked in potash lime water 14 days; wire broke with 224 lbs.—splice entire.

No. 17 Splice.—24 in. long; prepared as the last, supported 200 lbs. 24 hours without yielding, was then twisted about in various ways, and rolled into a coil of about one inch diameter; when tested again, the wire broke 4 in. from the splice with 200 lbs.—splice entire.

No. 18 Splice.—19 in. long; prepared as No. 16; wire broke with 210 lbs.

No. 19 Splice.—12 in. long; prepared as No. 16; supported 210 lbs. for 24 hours, 230 lbs. for some time, and broke with 236 lbs. —splice entire.

On a Proposed Steamer for Channel Service.

By Mr JAMES LYALL.

(SEE PLATES XV., XVI., XVII.)

Received and Read on 22nd April, 1873.

The endeavour to accomplish a means of communication between two important places which shall be safe, comfortable, and cheap, as compared with the schemes which have been proposed for the same object—involving enormous expenditure for their execution—may be an apology for again bringing under the notice of this Institution a subject already recorded in the transactions of a former session.

In submitting this scheme—novel in its construction, and the means adopted for safety and comfort, either or all of which may be extended to the largest steamers built for the merchant service—I rely upon your readiness to point out any defects which I may have wrapped up therewith.

That a scheme of this kind should prove a successful undertaking, it is necessary it should combine with economy great tensional strength and rigidity of structure throughout, with lightness, and so constructed that those in charge, as well as those embarking their lives and property, should have confidence in their safety, even if by an external injury the vessel was known to be making water while on the run; and that, by the dimensions and form, the vessel would be enabled to make the passage in the shortest time, and with the least practicable annoyance to the passengers, which will induce, instead of deter, a large passenger traffic, while the nature of the construction and the dimensions will allow the vessel to be examined and repaired at any first-class port in the kingdom. The vessel now proposed is 400 feet long from outside of stem to outside of stem, and 53 feet beam at the load line, and 12 feet deep. The vessel is sponsoned the whole length, by which the breadth on deck over the timber rubber measures 60 feet, with a draught of 7 feet.

The deck is made perfectly straight, and parallel to the keel, without sheer, in conformity with an opinion the writer advanced in a paper he brought before this Institution about seven years ago, which has since been carried out in some very large steamers. The vessel is to be propelled by a screw, 18 feet diameter and 25 feet pitch, at each end, worked by two pairs of direct action engines, and is fitted with a rudder at each end. Means are provided for locking the latter at the "fore" end of the vessel when not in use. As will be seen by the drawings, the propellers are intended to work at a greater depth in the water than the keel of the vessel is at. The sponson and rubber is to keep the centre of the vessel sufficiently removed from a quay wall to insure safety to the propeller blades, and to assist in breaking the sea from coming on board.

The Construction.—The keel is of tee iron, inverted, 15 inches deep by 5 inches by 1 inch thick. The centre web is further stiffened by a plate fitted on each side, 11 inches deep by 1 inch thick. On the outsides of these plates the garboard strakes are fitted—their lower edges fitting close down on the flange of the tee iron. The upper part of the tee iron is made intercostal for a depth of 4 inches, through which it is rivetted to the centre intercostal keelson plates, $\frac{7}{8}$ inch thick, by which it is united to the floors of the vessel.

The frames are of strip iron, 10 × $\frac{9}{16}$ inch of section, shown at Fig. 7, and are spaced 5 feet apart. They are connected to the shell plating by short angle irons, 4½ × 4 × $\frac{9}{16}$ inch. In addition to these strip frames, there are longitudinal angle iron runners, of angle iron, 4½ × 4 × $\frac{9}{16}$ inch, which are *continuous* for the entire length of the vessel. They form stiffening ribs to the strakes of shell plating, along whose centres they are fitted, and to which they are rivetted. The outer edges of the strip frames and floors are punched out at the positions of the longitudinal angle iron-runners, to allow of their being carried through. The angle irons which connect the strip frames and floors to the shell plating are fitted on in short lengths between the longitudinal stiffening ribs. It may here be noticed that, as only these short angle irons require to be bevelled, and the bevel being very little over their entire length, they may be bevelled and bent under the steam hammer, or other pressing machine; while one-half of the body plan is all that is required (one-fourth in the present instance) to be laid on the board for bending the strip frames to their respective forms.

The Floors are 42 × $\frac{8}{16}$ inch deep, rivetted to each frame, and have an angle iron, 4 × 3½ × $\frac{8}{16}$ inch, rivetted on their upper edges. Openings are made through the floors for the purpose of reducing their weight, and serve as man-holes, and give easy access to the parts under the cabins for examination, painting, and repairing.

The strake of plating rivetted to the tops of the floors, and forming the centre strake of the bottom plating of an iron tank, within which the cabins are fitted up, is made to serve as the upper flange of the centre of intercostal keelson, on and of the keel, by its being rivetted to the short angle irons, 4 × 3½ × $\frac{9}{16}$ inch, fitted between the floors, which connect it to the intercostal plates.

All the other intercostal plates, which are fitted in the bottom and between the longitudinal angle-iron runners, are united similarly at their upper edges to the bottom plating of cabin-casing, while those beyond the width of cabin-casing are fitted between double angle irons, 5 × 5 × $\frac{9}{16}$, on their upper edges in the ordinary manner. (See Figs. 6 and 8.)

By this arrangement, with that provided for uniting the shell plating at the butts (hereinafter described), the highest tensional resistance is imparted for the material employed; and the maximum rigidity is secured over the vessel's length, while the transverse strength is in no way sacrificed.

The Deck Beams are of flanged bulb iron, 7 × 5 × $\frac{7}{16}$ inch, rivetted to every frame to which they are kneed, and also to the outsides of cabin casing. A strake of plating 36 × $\frac{9}{16}$ inch, is run along each side of cabin casing, to take the ends of deck beams, and forms the inner flange of a huge girder, whose web is made up of the deck beams and iron deck rivetted thereon. The inner ends of the beams are supported by the vertical iron sides of cabin casing, which are of $\frac{6}{16}$ inch plating, stiffened with tee irons, 4 × 4 × $\frac{9}{16}$ inch, whose flanges form buttstraps for side plating. These tee iron stiffening frames are continued round, and made to form beams for the weather deck on top of upper cabin house.

The beams carrying the upper cabin floor are of tee irons, 6 × 5 × $\frac{6}{16}$ inch, suspended by knee plates to sides of cabin casing.

The iron deck is of $\frac{7}{16}$ and $\frac{6}{16}$ inch plating, with a margin strake 36 × $\frac{11}{16}$ inch, and is covered with a pitch pine deck 3½ inches thick.

A strake 36 × $\frac{9}{16}$ inch, forms the upper part of upper cabin-house, and is rounded over on the tee iron beams to which it is rivetted. (See Fig. 6.)

The Shell Plating.—The garboard strake and all the *inside* strakes of plating are $\frac{9}{16}$ of an inch thick. The remainder of the strakes are $\frac{8}{16}$ of an inch thick, excepting that, behind the wood rubber, at the beam ends, which is $\frac{12}{16}$ of an inch thick; the butt straps of all the outside and inside strakes are $\frac{12}{16}$ of an inch thick, and those for the strake behind rubber are $\frac{13}{16}$ inch thick.

The objects sought to be attained and secured by this provision and arrangement are (1) the maximum *tensional safety;* (2) the maximum rigidity of the rivets to *resist tilting* and *bending* under severe tensional stress; and (3) the maximum *durability* of the *surfaces* of the *rivets* and of their *holes* in the plating on the minimum employment of material.

That the first may be attained it is indispensable the butt straps should be so proportioned to the plating they connect that all liability on their part to *suffer by fatigue,* during construction, shall be reduced to a practical impossibility; and that all disposition to *elongate* at their reduced sections—through the lines of rivet holes—shall be entirely overcome. It has been an opinion held by the writer for some years that, butt straps of the same thickness as the plates they connect, are greatly impaired in their tensional value, through the lines of rivet holes, by the *fatigue* they are made to undergo, during construction, in throwing on *them* the work of drawing the ends (always the most difficult parts) of the plates, to the same curves as their bodies have been set to, or drawn to, by the frames of the vessel, when their only duty is generally considered to be that of connecting and *maintaining* the adjoining plates in their first fixed positions. The *loss* the butt straps sustain by this fatigue, forced on them *during construction*, renders them very sensitive to elongation at their most reduced sections—already weakened beyond the actual section taken out by punching—under stress; together with that by the bending inclination of the rivets—in the direction of the stress—aided by the *distortion* of the *rivet holes*—the results of elongation, point to a need for the increase now advocated.

One of these defects might remain latent for a very long time, but when they are multiplied at the same place in a structure, or when they are of a nature that will induce a combination of weak or defective parts, which are so affected by stress as to take a permanent set after they have been relieved, or partially relieved of that stress, these weak parts will continue to give trouble so long as the first cause is allowed to remain a part of the structure. The results of such elongation, with its attendant distortion of rivet holes and bending of rivets—which, by the former, will be readily loosened in their holes—will show in fine steamers at their fore ends by that continuously *varying* load on the outside plating producing a motion known as "panting," by its peculiar bellows-like movement, and in the midship parts of long steamers, where the most *varying* loads are carried during the voyage, by the coals, stowed in these parts, being constantly taken out for raising steam—which are subjected to double the stress (in addition to the alternation of tension and compression experienced) in each rise and fall of the ends of the vessel when pitching and scending.

As a remedy for such defects—which must increase as the length and draught of steamers increase—the writer respectfully submits this scheme of construction, as shown in transverse section Figs. 6 and

8; and would direct attention to the additional advantages derivable from increasing the thickness of the butt straps, by which the second object sought by the arrangement and provision here advocated, viz., the maximum effectiveness of the rivets to resist *tilting* and bending, will be most effectually met (1) By an increased *body-tight bearing or holding surface* being given to the rivets, which imparts greater *stability;* and (2) by an increased *leverage* being given to those parts of the rivets which are held in the butt strap. By these they are better fitted with the butt straps, to resist tension, communicated to their opposite ends, through the plates forming the outside strakes. The butt straps have yet another claim for being increased in thickness, over the plates they connect, beyond those just advanced, viz., that they are more severely *strained* by stress, communicated through their plates, than are the plates they connect —by reason of the former's removal from the centre of that stress. The simple expedient of increasing the thickness of the butt straps also places at our command the benefits of that very important desideratum—the maximum *durability* of the *resisting* or *wearing surfaces* of the *rivets* and of their *holes* in the material so increased, which is the third object sought by the proposed arrangement and provision. This, in common with the other advantages, already brought under notice, derivable from increasing the thickness of the butt straps, I am inclined to think demand more attention and practical application if the full constructive benefits accruing from so simple an expedient are to be utilized.

To admit the longitudinal stiffening ribs being rivetted to the butts of the plates, as well as their bodies, the butt straps are fitted in two widths on the inside strakes. The whole of the butts are treble rivetted for 300 feet amidships—the rivets in the last row, or row nearest the body of the plates are wider spaced than those in the two adjoining rows, as is now the general practice.

The rivetting of the seams as well as the remainder of the butts, are zig-zag or "reeled" in preference to what is generally known as chain rivetting. By this the sections of both strakes of shell plating are better balanced through the line of rivet holes; and their sections at the butts are slightly increased.

The inside strakes are made *thicker* than the outside ones, for the purpose of getting the heavier plating directly attached to the framework of the vessel, and of securing a better holding medium for the outside strakes—as has been already pointed out to be one of the advantages attained by *increasing* the thickness of the butt straps.

Thus it is seen that, by the simple expedient just advanced, a better value is obtained out of the weight of material expended in construction, and transported over the distances traversed by ships, in which the increase has been made, by the additional margin of strength obtained which removes, or places the butt straps so increased beyond all susceptability to suffer deterioration through the "*nip*" or *fatigue* forced on them during construction—by the margin of strength it imparts to prevent *elongation* at the most reduced section, which elongation distorts the rivet holes, and allows a certain play, which permits the rivets to tilt from their fixed positions, and become bent by stress; by the additional hold the rivet heads have in the strap, through the increased length of bearing and consequent *leverage;* by the increase given to the *wearing surfaces* of the rivets, and of their holes; and by the rigidity imparted to the butt straps, which effectually checks that hinge-like movement, resulting from unequal or varying pressures between the frames of the vessel, which not only gnaws the straps at their weakest parts, but enables the ends of the plates forming the butts to *rub* on each other; and this, with the action of the sea water, accelerates disintegration of the parts of those butts which have already been cut in the process of caulking.

With these advantages, accruing from the increase given to the butt straps, and those attained by making *all* the *inside* strakes of the shell plating thicker than the outside shell strakes; and when the breadths of the former strakes are in excess of that of the latter, so that the butts of the latter shall not be longer than the butts of the former, taken between the caulking edges of the outside strake landings, we have something approaching, if, indeed, we have not embraced, the very highest practical value for the material employed, which is yet known in the art of construction, for tensile strength and durability. If to these be added the advantages the means here submitted give, for increasing the longitudinal rigidity —crossing and resting on the butts of shell plating—we have what is needed to construct such ships as were pointed out for future service by our respected President at the opening of the present session, without increasing the difficulty of construction or of cost by large quantities of *spare* materials being necessary for building operations —the maximum tensile strength and durability, combined with the most rigid framework which has been introduced into naval construction, on the minimum of materials employed.

Cabins.—As formerly mentioned, all the cabin accommodation is fitted up within an iron casing 270 ft. long × 36 ft. broad × 19 ft. deep, which is designated the cabin casing. This casing is made an independent water-tight vessel, and secures the cabin from being flooded, even if the steamer made water through external injury. It will be seen from the transverse section that, both upper and lower cabins are enclosed within the same water-tight casing—which is built upon the floors of the steamer, and rises to the weather-deck—the bottom as well as the sides being of iron, is rivetted to the tops of the steamer's floors and caulked. The iron sides of this casing are fitted with brass side lights, closing on india-rubber so as to be made water-tight when required, in the usual manner. These side-lights act as auxiliaries to the sky-lights fitted down on the weather-deck. Iron bulk-heads intersect the cabin casing, and extend to the sides of the steamer, at intervals of their length. By this means the steamer and the cabin casing are divided into water-tight compartments, as usual. The upper cabin is a shelter in rough or wet weather, and is fitted up with saloons, and with retiring cabins for ladies and gentlemen, in which means are provided for writing and reading. A smoking room, entering from the gentleman's cabin, is fitted up for those who prefer this kind of pastime, where no annoyance need be experienced by the other passengers who prefer any of the former employments during the passage. Beyond these cabins, the remainder of the upper cabin house is fitted up for the accommodation of the captain, officers, engineers, firemen, and crew, with bath room, lamp room, and a mail sorting room, the extreme ends being occupied by the stearing gear—the men at this work are under shelter at all times. As will also be seen by the plans Figures 3 and 4, the engines and boilers are situated at each end of the main saloons and retiring cabins. The lower height of the cabin casing is fitted up with dining saloon, steward, and stewardess's rooms; and those portions beyond the engines and boilers for wine and other store rooms for the vessels use—goods and passengers' luggage being carried in the wings of the vessel, amidships, between those parts fitted-up as coal bunkers outside of the cabin casing. The centre part of this (lower cabin casing) is a saloon specially fitted up for those who are less fortunate than their overhead friends in their abilities to combat the disagreeable sensations of a sea voyage—this part between the dining saloon and the steward's room being selected for its comparative freedom from the pitching and scending, and rolling motions of the vessel, which are so irritable to many. To mitigate these objectionable motions, this saloon is specially designed. The passenger accommodation in this saloon is fitted on a platform which is suspended from *two* piston rods at each corner. These eight piston rods, with their pistons, derive motion from water contained in the vessel's bottom, between the outside shell plating and the bottom plating of the cabin casing, which is made a water ballast tank for the length of this saloon. Before starting on the run, the water is let into the water ballast tank, and in filling presses up the eight pistons—the lower parts of whose cylinders are open to the free inlet of the water—until the tank is completely filled, when these pistons, with their load—the platform—become water-borne, and are independent bases on which the platform, and its occupants, rest. It will be seen that, with such a base—subject to change with every motion of the vessel—as the vessel rises and falls, or rolls from one side to the opposite, the water in the water ballast tank—which partakes of the vessel's motions—will give a variation of pressure on the undersides of the opposite sets of pistons, which will elevate and depress the platform in an opposite direction, or counteracts that of the vessel.

The water carried in the bottom of the vessel is thus made to do double duty, by acting as ballast to make the vessel more difficult to roll; and by giving motion to the pistons, and thereby neutralising the motions in the saloon communicated to the vessel by the action of the sea. Figure 6 shows this platform with its seats, and cylinders, &c.—*a* is the platform, *b* seats, *c* cylinders, *d* footways, *e* a foot-way communicating with steward's room, lavatories, &c., free from moving platform, fitted with a hand-rail for safety, *f* is water ballast tank, *g* a screen concealing ladies' side from gentlemen's side of platform, *h* longitudinal angle iron runners, *i* cabin casing. The platform cylinders are each four feet in diameter.

The sofa seats fitted on this platform are provided with a foot-way between the lines of seats, and the backs of those seats before the foot-ways are carried up, and are fitted with hand-rails to enable passengers to walk along with safety.

As noticed in an early part of this paper, the plan of construction —advanced for the proposed boat now under consideration—can be applied to the largest merchant steamers—the longer the vessel the better will be the comparative results of its application, and the water-tight iron casing can be added with great advantage for vessels engaged in trades requiring special care taken of cargoes, or when large portions of the cargoes are grain in bulk. In addition to an annual saving of grain destroyed, considerable space in the vessel and cost would be saved, now expended on grain ceiling. Then as to its advantages, for safety in such vessels, I venture to say that with such an acquisition to the merchant navy, no vessel could be lost by grain getting into the bilges, and choking the pumps; and vessels making water could be steamed to some shelter without an additional calamity threatening to overtake all on board, by the water rising and putting out the fires, or driving the engineers from their posts—each being protected from all such risks by the water-tight iron casing within which they are enclosed.

Figure 8 is a transverse section of a screw steamer, 550 feet long ×

50 feet beam, × 36 feet 6 inches depth of hold, with the materials arranged on the proposed plan of construction. The side A differs from the side B, being supplied with the water-tight iron casing, *u*. The side B is made in accordance with the ordinary practice in iron shipbuilding, excepting that the orlop deck beams are cut, and finished on the inner ends with a plate (*c*) on the upper and under sides, to which is united a face plate, *d*. These three plates form the inner member of a huge girder (designated the orlop girder), the orlop deck stringer, *e*, forming, with the longitudinal angle iron-runners, *a*, and the outside shell plating to which they are united, at *é*, the outside member. The web of this girder—the orlop beams—are braced with diagonal plates extending from and uniting the orlop stringer to the plate *c*, and so arranged that any local stress will be transmitted over a large resisting area. The inner face of this orlop girder is straight—being parallel to the centre of the vessel's length—which, with the rounded shape of the outside member—the vessel's side—is a superior form for efficiently checking stress, and preserving the vessel's form. As the vessel narrows towards the ends, the orlop beams are carried across, in the usual manner. The vessel is fitted with a double line of hold stanchions, *f*, the lower of which assist to carry up the ends, or inside member of the orlop girder. The object of this provision is to enable the vessel to take in large and bulky pieces of machinery, boilers, locomotives, &c., as cargo, and to prevent working in the vessel resulting from beams requiring to be cut to admit such articles, and afterwards left to be connected as opportunity and means could afford.

It may here be explained that, when zig-zag rivetting is preferred in this paper, it is on the understanding that the spacing, or pitch of the rivets, shall *not* be closer between the centre lines of the *two parallel rows* than when chain rivetting is adopted. The writer is of opinion that, a disregard of this being carried out, in zig-zag rivetting, makes it unfavourable for reliance when compared with the chain arrangement, in which a broader landing is given. By this difference the *section* left, after punching, is not only *less* in zig-zag rivetting; but the *leverage*, which the adjoining row of rivets imparts, to the *stability* of the joints, is *impaired*, and the joint more easily destroyed under stress.

With the object of showing that this proposed scheme may be generally applied in shipbuilding, and with the desire of making this communication thereby more interesting than if the plan of construction, &c., could only be of use in such special kinds of vessels as that now under consideration, I have been induced to make some short digressions.

Gentlemen, I have to thank you for the indulgent attention you have favoured me with, and have to request that you shall distinctly understand all opinions advanced in this paper, or any I may express in the discussion which may follow its reading, as coming from me as a private person—a member of this Institution, and in no way connected with my official capacity as a Surveyor of Shipping.

The CHAIRMAN said that he thought it would be advisable to postpone the discussion of this paper till a future meeting, as it embraced points which could not well be disposed of that evening.

Mr SIMONS concurred with the Chairman. He thought that Mr Lyall's remarks on butt straps very valuable, and he quite agreed with him that this subject had not received the attention which it deserved; but possibly it would lead to controversy to have the butt straps of a ship made thicker in scantling than the plating throughout. As to the inner strakes being made thicker than the outside strakes, he might observe that that was quite different from what was usual in practice. Probably a benefit might be gained from adopting that course; but, on the other hand, it must be remembered that the wear and tear, and the oxidation of the external plates, probably go on at a more rapid rate than that of the inner plates. Then, again, with reference to the central keelson or backbone, he thought the vessel was sufficiently strong without the external keel. He had always held the opinion that an external keel in an iron ship was a relic of timber construction, and in many cases a source of weakness, and in some the cause of the destruction of the vessel. With regard to the midship section shown in drawing (Fig. 8), were the sides of the iron casing carried to the top of the hurricane deck, in one plate, so to say, or were they divided at the junction of the main deck? If they were in one plate from the keelson up to the hurricane deck, he thought they would make a very strong structure. The view he took of it was, that if it were possible to make that plating central, and to carry it fore and aft, in the interior of the ship, it would tend vastly to its strength, and enable them to strengthen the length of the fabric beyond ordinary rules considerably. He did not know whether Mr Lyall meant the section to apply to an English channel steamer or an ocean-going vessel. Mr Lyall had not gone into any detail as to what amount of power would be required, or the cost and other details that it would be necessary for the Institution to know before they could come to any exact idea of the correctness and soundness of the plans described in the paper. Probably when it is discussed at another meeting, Mr Lyall would be able to give us some opinion onthat point.

Mr Lyall said that propellers were fitted at each end of the vessel, and it was proposed to make them 18 feet in diameter.

Mr Simons supposed the vessel was double-bowed, and the propellers were to run at both ends.

Mr Lyall said both propellers worked at the same time—the vessel was alike at both ends.

Mr Simons remarked, with reference to the four-decked ship (Fig. 8), that he did not agree with Mr Lyall in his disposition of the four ranges of beams. In his opinion the order of the beams should be spar and 'tween-deck ranges from stem to stern, at an angle of 30 or 35 degrees, and to range in the main and orlop decks in the *reverse diagonal direction.* The inference was, that when the vessel lay down on her beam ends in a gale, she would act like a lattice girder, and render it quite impossible for it to give way. He would be very glad otherwise to agree with Mr Lyall's recommendation of the plan of construction, particularly with reference to the butt straps, knowing that in an iron ship there would probably be 1000 of these joints, and that the weakest point was the measure of the strength of the fabric. It would occur to them all, therefore, that the workmanship of those should be thoroughly attended to.

Mr Ferguson said that in a general way he approved of the remarks that Mr Simons had made; but he must say that he expected something different when the subject of Channel steamers came up. He could not say that he understood the paper thoroughly; but he thought that when any particular trade was looked to, or to be criticised, or any impression to be made, that the most defective part should be sought out for remedy. So far as he knew, the chief defect of all channel vessels was their great rolling motion, and he expected that Mr Lyall would have treated the subject more with regard to the structural form of the ship than its strength. What he had said on that point was satisfactory. They had heard a great deal about hollow bottoms, but he expected that the paper would have treated of the best mode of overcoming what was the great evil of channel steamers—the rolling motion—which gave rise to the disagreeableness of journeys made in such vessels. There was no doubt the great advantage a vessel such as that proposed was, that it would have less motion than others, although when the breadth was increased to such an extent, with a shallow draught of water, he did not know that the rolling motion would be very much overcome. He thought that the hollow-bottomed vessels were always the stiffest; but in the channel trade they could not get a hollow-bottomed vessel. The great difficulty was to get a vessel with a light draught not to roll badly. He was not quite sure of the desirability of water ballast being in the bottom. He did not know whether they could obtain that draught of seven feet with water in that tank under the cabin. He approved of the arrangement of the vessel—the engines at each end, and the bulkhead separating from the cabin. He supposed the length of the cabin, from the bulkhead next midships to each boiler, would be pretty considerable?

Mr Lyall—It was about 102 feet.

Mr Ferguson—It was also in the centre of the ship, which suited well for bad sailors, who usually sought the centre of the vessel, so he thought that arrangement was very good, indeed, and he would like Mr Lyall would consider the form of the bottom of the ship.

Mr SIMONS said, with reference to the form of the midship section, he thought that much light could be shed upon it if Mr Mansel would read a paper on the formation of a vessel he was building. Mr Ferguson knew more of that vessel than he did, but it was planned to reduce the rolling motion to a minimum. If Mr Mansel could be induced to give a paper on it he thought it would follow the paper of Mr Lyall nicely, and he was sure they would be all thereby gratified. It would be interesting if Mr Lyall would describe the details of his hydraulic floating berth apparatus. Was it suspended as a sailor's hammock, or was it like Bessemer's cabin?

The CHAIRMAN sympathised with the opinion expressed on the butt straps, and said that it would be very important if Mr Lyall could give them some idea of the cost of the vessel.

Mr LYALL said, in reply to the first question—that of the utility of the external keel—he had two reasons for this keel being made to project below the vessel: the first was, to enable the vessel to be docked without injury to the plating resting on the blocks between the frames, which he believed would be the case if either of the vessels whose sections he showed at Figures 6 and 8, were built with flat plate keels, as suggested by Mr Simons. It was to be borne in mind the transverse frames were spaced 5 feet. The second reason was to impart increased steadiness to the vessel by increasing the period of roll, which would make this kind of motion less frequent during any given time, and, consequently, less frequent during the run. He had been led into a more minute investigation of the construction, because, as mentioned in the paper, it was new; and being a departure from the ordinary mode of construction, he had no other way of communicating its novelty, and the advantages it conferred, and because of the very extreme proportions of the proposed boat. With reference to the arrangement of the deck beams, section Fig. 8, he was perhaps as well acquainted with Mr Simons *Diagonal Plan* as any one, as he (Mr Lyall) had drawn the plans of Mr Simons first vessels built on that arrangement; yet Mr Simons must excuse him if he dissented from him. He thought with the iron deck and deck ties arranged as shown in section Figure 8, all the advantages Mr Simons sought in his diagonal arrangement of beams would be attained. He had not departed from the ordinary practice in the arrangement of the beams, excepting that, as would be seen by the half A of section Figure 8 on the left side, he had a special arrangement for taking in and stowing very large and bulky articles of cargo—as boilers, locomotives, and machinery—by cutting the orlop deck beams, and carrying the ends on stanchions—two lines of these hold stanchions were here fitted for the great breadth of the vessel. As would be seen, the inner ends of these beams have a plate on their upper and under sides, which formed, with a face plate, the inner member of a large girder, whose outer member was formed of the orlop deck stringer, the longitudinal angle iron-runners, and the strake of shell plating along which these are rivetted. The centre web of this girder is formed of the beams which are braced by diagonal plates, connecting the inner and outer members, and so arranged that they shall communicate any local stress over a large area, as mentioned in the paper. The advantages gained by making the inside strakes thicker than the outside ones are, a better union with the framework of the vessel—less weight is put upon the *ends* of the rivets which unite them to the framework and to the adjoining strakes than is the case when the order is reversed; a better hold for rivets, fastening outside strakes, for the reasons already advanced in connection with the advantages obtained by the use of thicker butt straps; the wear being practically the same on the outside and their adjoining inside strakes, it will not be necessary to renew the latter before the former, which in itself is a good reason for adding the increase to the inside strakes, as they cannot be removed without taking off the outside strakes also. The landings of the outside strakes (where these cross the butts of the inside strakes) are, for their widths, double butt straps—with the butt straps proper—and impart the advantages of the double shearing section of the rivets at the most important parts of these inside strake butts—the ends; while the thicker landings of the inside strakes make better straps for the ends of the outside strake butts than if the order was reversed. Thus provided, the butts of the outside and inside strakes are better able to resist stress without any of the work in their locality being strained. With reference to Mr Ferguson's remarks respecting the water ballast tank, and comparing the same to an iron cargo placed in the bottom of the vessel, he would speak, subject to correction from Mr Ferguson, when he attempted to explain the difference which resulted from placing the iron in the neighbourhood of the centre of oscillation, and from placing it in the bottom of the vessel. By placing weight in the latter position, the distance from the centre of oscillation to the centre of that weight, was increased; and the weight was thereby made to travel over a greater distance than it would do if placed near the centre of oscillation. This undoubtedly gave a greater momentum when the vessel rolled; and, by the increased length of radius the reaction, or righting inclination, was greater than if the weight was placed nearer the centre of oscillation, and was more severe on the vessel as a structure; but it must be borne in mind that by the weight being at a greater distance from the centre of oscillation, and requiring to be moved through a greater distance, the *work done* in performing that oscillation was greater, and required a greater force to *produce* motion, while the weight transported in the vessel was *not* increased. This was the object aimed at by the introduction of the water ballast tank. As to any change in the formation of the vessel's bottom—such as making it hollow, as Mr Ferguson remarked, the small draught was much against its adoption, as the rolling of the vessel, together with the constantly varying levels of the waves, would admit volumes of air to rush in, which, by its elastic nature, acted upon by ever-varying pressures of the water, would resemble an air cushion of a treacherous quality, on which the vessel might rest only to be depressed with a greater velocity than if completely water-borne, and the greater girths would increase the surface exposed to friction, which would absorb greater power in propelling. With reference to the means of ventilating the lower cabins, provision, as would be seen at Fig. 4, was made, which consisted of three ventilators over the saloons. The upper parts of these were fitted with figured glass; the lower portions were fitted with sofa seats all round, in keeping with other parts of the cabin. There were also two round ventilators, besides the means afforded by openings for stairs. It would afford him pleasure to give further information respecting the scheme he had just submitted.

On the motion of the CHAIRMAN, a vote of thanks was awarded Mr Lyall for his paper; and the discussion was adjourned.

On the Manufacture of Cast Steel.

By Mr B. D. Healey.

(Supplement to Paper read 23d April, 1872.)

Received and Read 22d April, 1873.

Since the original paper was read, the Elba Steel Company, Swansea, have erected two of my steel furnaces, and a third furnace for heating purposes, together with the plant arrangements shown and described in that paper, excepting that the ingot tables are placed close to the ladle lifts, so that ingots of various lengths may be cast; this will be understood by reference to Plate VIII. (see Vol. XV.), Figs. 3 and 4.

The ingots are cast in groups of 6, being fed from the bottom, as explained on pages 4 and 5 of the paper before named.

The furnace has undergone several minor alterations. The present form differs from the original figures in the following points: The gas chamber is built at one side of the central heat flue K, Fig. 6, and the air chamber on the other side of the flue, so that both can be readily got at by uncovering the chambers. The ports F and G are surrounded by a shallow flue, in which a portion of the waste heat is allowed to circulate, and so prevent the regenerated heat radiating before it arrives at the point of ignition.

The temperature of the waste heat which has passed into the chimney has varied from 302° to 420°, and the regenerators have given from 2540° to 3000° to the incoming air and gas.

The regenerators keep in splendid order, but some difficulty is experienced with the down flues (H'). This, however, I am now setting right, by building the furnaces longer, so as to allow more power for the charge, and lesson the wear and tear.

The charges at present are only about 64 cwts., as it is not considered advisable to work up to the full weight until the men have become better accustomed to their duties.

A charge of the above weight requires at present about 15 hours for conversion, and at the Elba Steel Works is made up of the following mixture:—

	Cwts.	Qrs.	Lbs.
Bessemer No. 1 pig iron, ...	10	0	0
Bessemer No. 2 pig iron, ...	5	0	0
Scrap steel, ...	7	0	0
Wrought-iron scrap, ...	20	0	0
Tinplate shearings, ...	22	0	0
	64	0	0
Spiegeleisen, ...	3	0	22
Manganese ore, 28 lb., equal, say, ...	0	0	14
	67	1	8

The yield being—

	Cwts.	Qrs.	Lbs.			
Ingots, 8 inches, ...	56	2	16			
Scrap and scull, ...	7	1	0			
				63	3	16
Loss about 5 per cent., ...				3	1	20

Carbon by Egertz process, ·50.
Time from charging to recharging, 15 h. 45 m.
Coal used, including drying ladles, 64 cwts.

Before spiegeling, the charge contains about ·15 of combined carbon, and the fracture of a sample, after being chilled in water, is "silky." The effect of the small dose of manganese ore is to prevent red shortness, by taking up the excess of oxide that may have entered into the bath; but as yet I have found the flame to be practically neutral; and as it is always passing over the bath, there is very little chance of any free oxygen getting into the metal from any point.

At the works already named, the charges are weighed off with great care, in order to ensure regularity in the mixture, the usual plan being to take one pig from each stack of the qualities used, and to take the wrought and steel scrap from bulk in such a way as to get a fair average of each. The ore is broken up into small lumps with the same object as above noted, and in using some kinds of ore this is of very great importance.

A notable fact in working my furnace is, that the regulating valves and damper seldom require altering; in fact, one of the best charges has been converted without touching either the valves or the damper; the quantity of gas being regular at the producers would account for this.

It may be interesting to know that it requires 7 turns' work to make a bottom, and 4 turns' to prepare the sand for same—costing for labour about £13, and using about 39 tons of coal.

Experiments have been made with satisfactory results, with a view of making steel direct from Elba ore, the following mixture being used—4 cwt. of ore, 3 qrs. of stone coal, and 16 lbs. of wood tar. These were well mixed and put upon the bed of the furnace, and in 3 hours yielded 2 cwt. 1 qr. 6 lbs. of iron similar to that which is usually drawn from a puddling furnace. This process will shortly be at work with 25 cwt. charges, which I hope to turn out at the rate of 3 per turn, or say 2 tons per turn.

In conclusion, I may remark that the hydraulic arrangements have proved very satisfactory, and that, although there has been some queer spills, as might be expected in starting a new process, the lifts and crane have in every case been brought into use in a very pleasing manner without a single hitch; and the turntables have not been blocked in the least by rubbish or otherwise.

The CHAIRMAN said he hoped that Mr Healey would be able to give them some further account of the process during next session. It would be very interesting to find the best result attained; meantime, he supposed it was the wish of the meeting that they award a vote of thanks to Mr Healey.

Mr HEALEY said it was his only object to get iron direct from Elban or Somorrostro ore, which is nearly free from sulphur or phosphorus and the only difficulty now was to get a process to be able to use the ore direct, which would cause a great saving. He could reduc it at the same cost into steel as into pig iron.

A vote of thanks was awarded Mr Healey for his paper.

Institution of Engineers and Shipbuilders,

IN SCOTLAND.

(INCORPORATED.)

SIXTEENTH SESSION, 1872-73.

MINUTES OF PROCEEDINGS

The FIRST GENERAL MEETING of the SIXTEENTH SESSION of the Institution was held in the Hall, 2 Dalhousie Street, on Tuesday, the 22nd October, 1872, at 7.30 p.m.

Mr ROBERT DUNCAN, President, in the Chair.

The Minute of Meeting of 23rd April, 1872, was read, approved of, and signed by the President.

The following gentlemen were elected :—

AS MEMBERS.

Mr HENRY SIMON, Civil Engineer, Manchester.
Mr WILLIAM JACKS, Engineer, Glasgow.
Mr WILLIAM RUSSELL EVANS, Engineer, Victoria.
Mr DAVID RANKINE, Civil and Mining Engineer, Glasgow.

AS A GRADUATE :—

Mr HARTVIG BURMEISTER, Glasgow.

The President delivered his Introductory Address; and, on the Motion of Mr Brownlee, a vote of thanks was awarded the President for his Address.

The Discussion on Mr Alexander Morton's Paper, read on 23rd April, on "The Expansion of Water," followed, and was terminated.

A paper by Captain Thomson, of Otago, on "Improved Canting Crowned Anchors," was read, and illustrated by models of various kinds of Anchor; a Discussion followed, and was terminated; and on the Motion of the President, a vote of thanks was awarded Captain Thomson for his paper.

The SECOND GENERAL MEETING of the Institution was held in the Hall, 2 Dalhousie Street, on Tuesday, the 26th November, 1872, at 7.30 p.m.

Mr ROBERT DUNCAN, President, in the Chair.

The Minute of Meeting of 22nd October, 1872, was read, approved of, and signed by the President.

The following gentlemen were elected,

AS MEMBERS:—

Mr NICHOLAS WATTS, Civil Engineer, London.
Mr DAVID CUNNINGHAM, Civil Engineer, Dundee.
Mr JOSHUA HYDE IRWIN, Mechanical Engineer, Sunderland.
Mr MIDDLEMOST WAWN, B. of T. Surveyor, Sunderland.
Mr THOMAS FORREST, Mechanical Engineer, Glasgow.

A paper on "A New Form of Equilibrium Water Sluice or Stop Valve," by Mr F. G. M. Stoney, C.E., was read; a Discussion followed, and was terminated; and, on the Motion of Mr Kay, a vote of thanks was awarded Mr Stoney for his paper.

A paper on "Mineral Oil as a Lubricant for Machinery," by Mr J. J. Coleman, F. C. S., was read; a Discussion followed, and, on the motion of Mr Page, was adjourned to next General Meeting.

The THIRD GENERAL MEETING of the Institution was held in the Hall, 2 Dalhousie Street, on Tuesday, the 24th December, 1872, at 7.30 p.m.

Mr. ROBERT DUNCAN, President, in the Chair.

The Minute of Meeting of 26th November, 1872, was read, approved of, and signed by the President.

The Discussion on Mr Coleman's paper on "Mineral Oil as a Lubricant" was terminated, and, on the motion of the President, a vote of thanks was awarded Mr Coleman for his paper.

A paper on "Street Tramways," by Mr John Page, C.E., was read; a Discussion followed and was terminated, and on the motion of Mr Kay a vote of thanks was awarded Mr Page for his paper.

A paper on "Mining Machinery," by Mr George Simpson, C.E., was read; a Discussion followed; and, on the motion of Mr Rowan, was continued to next General Meeting.

The FOURTH GENERAL MEETING of the Institution was held in the Hall, 2 Dalhousie Street, on Tuesday, the 21st January, 1873, at 7.30 p.m.

Mr. ROBERT DUNCAN, President, in the Chair.

The Minute of Meeting of 24th December, 1873, was read, approved of, and signed by the President.

The President made a few remarks on the loss sustained by the Institution through the death of Professor Rankine, and called upon the Secretary to read the Memorial Notice of the late Professor's connection with the Institution, which the Council had instructed to be prepared; also, extract from Council Minute in reference to same.

The Secretary, having read the Memorial and extract Minute, on the motion of the President, it was unanimously agreed that they be embodied in the Transactions of the Institution.

The Discussion on Mr Simpson's paper on "Mining Machinery," adjourned from last General Meeting, was proceeded with, and terminated; and, on the motion of the President, a vote of thanks was awarded Mr Simpson for his paper.

A paper on "The Construction of Bridges, Caissons, and Dock Gates," by Mr David Cunningham, C.E., was read, and illustrated by working models; a Discussion followed; and, on the motion of Mr Conner, was continued to next General Meeting.

The FIFTH GENERAL MEETING of the Institution was held in the Hall, 2 Dalhousie Street, on Tuesday, the 18th February, 1873, at 7.30 p.m.

Mr JAMES DEAS, M. Inst., C.E., Vice-President, in the Chair.

The Minute of Meeting of 21st January, 1873, was read, approved of, and signed by the Chairman.

The following gentlemen were elected—

AS A MEMBER :—

Mr WILLIAM DENNY, Shipbuilder, Dumbarton.

AS AN ASSOCIATE :—

Mr JOHN MAYER, Lecturer on Applied Chemistry, &c.

The Discussion on Mr David Cunningham's paper on "The Construction of Bridges, Caissons, and Dock Gates," adjourned from last

General Meeting, was continued, Mr Cunningham again exhibiting and explaining his models of Dock Gates and Caissons. On the termination of the Discussion, on the Motion of the Chairman, a vote of thanks was awarded Mr Cunningham for his paper, and for illustrating the same a second time by explaining his models. As contributing to the Discussion, letters were read from Mr W. R. Kinipple, Greenock, and from Mr A. Mason, Edinburgh.

A description of an Automatic Steering Apparatus was then read, being an extract translation by the Secretary, of Donation to Library, entitled "Timone Automatico," presented to the Institution by Sig. M. Siciliano, Palermo, through Prof. C. Piazzi Smyth, Edinburgh, with the request that the Institution would express their opinion as to the merits of the apparatus. A Discussion followed, and, on the motion of Mr Rowan, the Discussion was delayed till next General Meeting.

The Chairman then intimated that Professor Sir Wm. Thomson had agreed to read a Paper, before the Institution, at next General Meeting, viz., 18th March; and, as it would be inconvenient to transfer the models illustrative of the Paper, from the University to the Institution Rooms, the Council had deemed it advisable to hold the next General Meeting in the Natural Philosophy Class Room, at the University. This was agreed to; and it was also agreed to invite the Philosophical Society to be present at that Meeting, Sir Wm. Thomson being first consulted as to same.

The Sixth General Meeting of the Institution was held in the Natural Philosophy Class Room, Glasgow University, on Tuesday, the 18th March, 1873, at 7.30 p.m.

Mr Robert Duncan, President, in the Chair.

The Minute of Meeting of 18th February was read, approved of, and signed by the President.

The Candidates for Election to Membership, as named on "Notice," viz:—

Mr Richard Ramage, Shipbuilder, Dumbarton,
Mr Matthew W. Robertson, Engineer, Glasgow,
Mr Robert Dundas, Civil Engineer, Glasgow,

were approved of by the meeting—the formal Election by Ballot being delayed to next General Meeting.

Sir William Thomson then gave a description of the methods of Signalling through Submarine Cables, and illustrated the same by means of Mirror Galvanometer and Siphon Recorder; also, a description of a Friction Dynamometer and Deep Sea Sounding Apparatus, illustrated by models.

On the motion of the President, a vote of thanks was awarded to Sir William Thomson.

The Annual General Meeting of the Institution was held in the Hall, 2 Dalhousie Street, on Tuesday, the 22nd April, 1873, at 7.30 p.m.

Mr James Deas, M. Inst. C.E., Vice-President, in the Chair.

The Minute of Meeting of 18th March, 1873, was read, approved of, and signed by the Chairman.

The following candidates for Membership were elected.

AS MEMBERS :—

Mr RICHARD RAMAGE, Shipbuilder, Dumbarton.
Mr MATTHEW W. ROBERTSON, Engineer, Glasgow.
Mr ROBERT DUNDAS, Civil Engineer, Glasgow.
Mr MARTIN PETERSEN, Chief Surveyor of Bureau Veritas, Glasgow.
Mr H. W. BALL, Glasgow.

No award of the Institution Medal for Session 1871-72 took place, as in the opinion of the Meeting no paper had been read during that Session which entitled the Author to receive the Medal.

The Treasurer's Annual Statement was laid before the Meeting and received.

The election of Office-Bearers, to fill up vacancies caused by the retiring Members of Council, took place ; the following gentlemen being unanimously elected :—

President—ROBERT DUNCAN.

Vice-Presidents.

J. L. K. JAMIESON. | H. R. ROBSON. | J. Z. KAY.

Councillors.

GEORGE RUSSELL. | JAMES LYALL.
BENJAMIN CONNER. | EBENEZER KEMP.
JAMES DEAS, C.E. | ANDREW BROWN.

A paper on "A Proposed Steamer for Channel Service," by Mr James Lyall, was read. A Discussion followed, and was continued to First General Meeting of next Session. A vote of thanks was awarded Mr Lyall for his paper.

Mr B. D. Healey read his supplementary paper on "The Manufacture of Cast Steel," and the Discussion was delayed till next Session. A vote of thanks was awarded Mr Healey for his papers.

The discussion on Sig. M. Siciliano's Automatic Steering Apparatus was delayed till next Session.

TREASURER'S STATEMENT—SESSION 1872-73.

Dr. GENERAL FUND. Cr.

		£	s.	d.	£	s.	d.
To Balance in Union Bank at Close of Session 1871-72,					£197	0	9
Subscriptions received:—							
Session 1872-73, ...		£406	5	0			
Deduct Entry Money transferred to Building Fund, ...		9	15	0			
					396	10	0
Arrears of Previous Sessions, ...					55	0	0
Dividends on Preference Stock, London and North-Western Railway, ...					15	9	3
Sales of Transactions, ...					9	5	0
Landlords' Proportion of Property Tax, ...					4	3	4
Bank Interest, ...					2	6	9
					£679	15	1

	£	s.	d.	£	s.	d.
By Rent of Rooms for three half years, ...				£150	0	0
Printing, ...				105	17	6
Lithography, ...				83	8	6
Institution Medal, ...				10	0	0
Salary to Secretary, ...				100	0	0
Commission to Secretary for Collecting Arrears of Subscriptions, viz.:—						
For Session 1872-73, ...	£214	5	0			
For previous Sessions, ...	55	0	0			
	£269	5 @ 5 %		13	9	3
Secretary's Expenses at Joint-Meeting, held at Newcastle on 2nd, 3rd, and 4th July, 1872, ...				5	0	0
Salary to Sub Librarian, ...				25	0	0
Coals, Gas, and Cleaning, ...				2	12	3
Police and Poor Rates, and Property Taxes, ...				15	19	2
Stationery, &c., ...				8	2	1
Postages, ...				17	15	9½
Petty Cash, ...				2	11	11½
Balance in Union Bank at 12th April, 1873, ...				144	18	7
				£679	15	1

MARINE ENGINEERING MEDAL FUND.

Dr.	£ s. d.	Cr.	£ s. d.
To Balance in Union Bank at Close of Session 1871-72, ...	£43 14 1	*1873.* *April 2.—By* Balance in Union Bank, ...	£54 9 8
Dividends on Debenture Stock, Glasgow Corporation Water Works, ...	1 3 6		
Dividends on Preference Stock, London and North-Western Railway, ...	8 17 0		
Bank Interest, ...	0 15 1		
	£54 9 8		£54 9 8

RAILWAY ENGINEERING MEDAL FUND.

Dr.	£ s. d.	Cr.	£ s. d.
To Balance in Union Bank at Close of Session 1871-72, ...	£29 5 11	*1873.* *April 2.—By* Balance in Union Bank, ...	£35 14 2
Dividends on Debenture Stock, Glasgow Corporation Water Works, ...	0 15 6		
Dividends on Preference Stock, London and North-Western Railway, ...	5 2 6		
Bank Interest, ...	0 10 3		
	£35 14 2		£35 14 2

BUILDING FUND ACCOUNT.

Dr.	£	s.	d.	Cr.	£	s.	d.
To Balance in Union Bank at Close of Session 1871-72, ...	£115	9	6	*1873.* *April 2.*—*By* Balance in Union Bank, ...	£144	17	7
Entry Money for Session 1871-72, ...	9	15	0				
Dividends on Debenture Stock, Glasgow Corporation Water Works, ...	17	12	8				
Bank Interest, ...	2	0	5				
	£144	17	7		£144	17	7

Glasgow, *16th April, 1873.*—We have examined the foregoing Annual Financial Statement of Treasurer, the Accounts of the Marine and Railway Engineering Medal Funds, and the Building Fund, and find the same duly vouched and correct, the Amounts in Bank being as stated.

(Signed) ANDw. MACLEAN,
DAVID KINGHORN, } Auditors.

SUBSCRIPTION ACCOUNT.

Dr.

To Subscriptions due as per Roll—			
Arrears due at Close of last Session, ...			£177 15 0
Struck off since as irrecoverable, ...			4 10 0
			173 5 0
Add Subscription received, formerly struck off, ...			1 10 0
			174 15 0
Session 1872-73 :			
299 Members,	@ £1 10 0 ...	£448 10 0	
9 New Members,	" 2 10 0 ...	22 10 0	
3 Do.	" 2 0 0 ...	6 0 0	
8 Do.	" 1 10 0 ...	12 0 0	
41 Associates,	" 1 0 0 ...	41 0 0	
1 New Associate,	" 1 5 0 ...	1 5 0	
18 Graduates,	" 0 15 0 ...	13 10 0	
1 New Graduate,	" 1 0 0 ...	1 0 0	
			545 15 0
			£720 10 0

Cr.

By Subscriptions received as per Cash Book—			
Arrears of Sessions previous to 1872-73, ...			£55 0 0
Session 1872-73—			
227 Members,	@ £1 10 0 ...	£340 10 0	
8 New Members,	" 2 10 0 ...	20 0 0	
3 Do.	" 2 0 0 ...	6 0 0	
3 Do.	" 1 10 0 ...	4 10 0	
26 Associates,	" 1 0 0 ...	26 0 0	
11 Graduates,	" 0 15 0 ...	8 5 0	
1 New Graduate,	" 1 0 0 ...	1 0 0	
			£406 5 0
Arrears due for Session 1872-73, ...		£139 10 0	
Do. previous Sessions, ...		119 15 0	
			£259 5 0
			£720 10 0

BANK ACCOUNT.

Dr.

To Balances at close of Session 1871-72—	
General Fund, ...	£197 0 9
Marine Engineering Medal Fund, ...	43 14 1
Railway Engineering Medal Fund, ...	29 5 11
Building Fund, ...	115 9 6
Amounts Lodged, Session 1872-73, ...	337 17 3
Interest, Session 1872-73, ...	5 12 6
	£729 0 0

Cr.

By Amounts Drawn, ...	£349 0 0
Balance in Union Bank, ...	380 0 0
	£729 0 0

CAPITAL ACCOUNT.

	£	s.	d.	£	s.	d.
GENERAL FUND.						
London and North-Western Railway Preference Stock, ...	£363	13	5			
Cash in Union Bank, ...	144	18	7			
				£508	12	0
MARINE ENGINEERING MEDAL FUND.						
London and North-Western Railway Preference Stock, ...	£209	4	6			
Glasgow Corporation Water Works Debenture Stock, ...	30	0	0			
Cash in Union Bank, ...	54	9	8			
				£293	14	2
RAILWAY ENGINEERING MEDAL FUND.						
London and North-Western Railway Preference Stock, ...	£120	15	6			
Glasgow Corporation Water Works Debenture Stock, ...	20	0	0			
Cash in Union Bank, ...	35	14	2			
				176	9	8
BUILDING FUND.						
Glasgow Corporation Water Works Debenture Stock, ...	£450	0	0			
Cash in Union Bank, ...	144	17	7			
				594	17	7
ARREARS OF SUBSCRIPTIONS.						
Arrears due for Session 1872-73, ...	£139	10	0			
Do. previous Sessions, ...	119	15	0			
				259	5	0
				£1832	18	5

Publications received at Library in exchange for the Institution's Transactions:—

Annales Industrielles.
Colliery Guardian.
Engineer.
Engineering.
Iron and Coal Trades' Review.
Iron.
Mining Journal.
Nature.

Annales de la Propriété Industrielle.
Revue Industrielle.

The INSTITUTION exchanges Transactions with the following Societies:—

Institution of Civil Engineers.
Institution of Civil Engineers of Ireland.
Institute of Mining and Mechanical Engineers.
South Wales Institute of Engineers.
Institution of Mechanical Engineers.
Institution of Naval Architects.
Society of Engineers.
Iron and Steel Institute.
Philosophical Society of Glasgow.
Royal Scottish Society of Arts.
Royal Dublin Society.
Liverpool Polytechnic Society.
Literary and Philosophical Society of Manchester.
American Society of Civil Engineers.
Smithsonian Institution.
Royal Society of Tasmania.
Royal Academy of Sciences, Lisbon.
Mémoires et Compte rendu des travaux de la Société des Ingénieurs Civils de France.
Société Industrielle de Mulhouse.
„ d'Encouragement pour l' Industrie Nationale.
„ des Anciens Elevès des Ecôles Nationales d'Arts et Métiers.
„ des Sciences Physiques et Naturelles de Bourdeaux.
Austrian Engineers' and Architects' Society, Vienna.

DONATIONS TO LIBRARY.

Spectroscopic Observations on the Zodiacal Light, by Professor C. Piazzi Smyth, F.R.S.S.L. & E., Astronomer Royal for Scotland. From the Author.

Report on the Glasgow Water Works, by James M. Gale, Esq., C.E. From the Author.

Report on the Bombay Water Works, by Major Tulloch, Executive Engineer. From the Author.

Regulations and List of Members of the Institution of Naval Architects. From the Institution.

Report of Progress—Geological Survey of Canada. From the Directors.

Drainage and Sewerage of Bombay. By Major Hector Tulloch. From the Author.

Timone Automatico and Scrutinatore Autografico. By Sig. Michel Angelo Siciliano, Palermo. From the Author.

Daily Weather Maps. From the Chief Signal Service Office, Washington, U.S.A.

On Some Evidences as to the very Early Use of Iron. By St. J. V. Day, Esq., C.E. From the Author.

Intorno Alla Prima Idea delle Caldaie Tubolarie, nota di Guido Vimercati. From the Author.

Ueber die Beziehungen zwischen den bei Centralbeevegungen vorkommenden characteristichen Grössen, von R. Clausius. From the Author.

United States Coast Survey, 1868. From Professor W. J. Macquorn Rankine, C.E., LL.D., &c.

Rough Castings in Scotch and English Metal, by William Allan, Esq., Sunderland. Two copies. From the Author.

Experimental Inquiry into the Mechanical Properties of Fagersta Steel, by David Kirkaldy, Esq. From the Author.

The Library of the Institution is open daily at the Rooms, 2 Dalhousie Street, for the use of Members. Books will be lent out on presentation of Membership ticket to the Librarian.

The Portrait Album lies on the Library Table for the reception of Members' Portraits with Signature attached.

LIST

OF

HONORARY MEMBERS, MEMBERS, ASSOCIATES, AND GRADUATES,

OF THE

Institution of Engineers and Shipbuilders in Scotland,

(INCORPORATED,)

At the termination of the Sixteenth Session, 1873.

HONORARY MEMBERS.

JAMES PRESCOTT JOULE, LL.D., F.R.S., Cliff Point, Higher Broughton, Manchester.

Professor CHARLES PIAZZI SMYTH, F.R.SS.L. & E., Astronomer-Royal for Scotland, 15 Royal Terrace, Edinburgh.

Sir WILLIAM FAIRBAIRN, Bart., C.E., LL.D., F.R.S., F.G.S., Manchester.

Professor Sir WILLIAM THOMSON, A.M., LL.D., D.C L., F.R.SS.L. and E., Professor of Natural Philosophy in the University of Glasgow.

Professor R. CLAUSIUS, the University, Bonn, Prussia.

General ARTHUR MORIN, Conservatoire Impérial des Arts et Métiers à Paris.

Sir JOSEPH WHITWORTH, Bart., C.E., LL.D., F.R.S., Manchester.

Professor LEWIS D. B. GORDON, C.E., Poynter's Grove, Totteridge Whetstone, London, N.

MEMBERS.

Thomas	Adams,	47 Granby Row, London Road, Manchester.
James	Aitken, junr.,	Shipbuilder, Whiteinch.
William	Aiton,	Caesygidal, Dyffryn, by Carnarvon, North Wales.
William	Alexander	23 India Street, Glasgow.
Alexander	Allan,	Kenilworth Villa, So. Cliff, Scarboro'.
A. B.	Allan,	Office of Public Works, Glasgow.
James	Allan,	70 Great Clyde Street, Glasgow.
Thomas	Allan,	Springbank Foundry, Garscube Road, Glasgow.
Robert	Allan	Scotland Street Iron Works.
William	Allan	Sunderland Engine Works, Sunderland.
James B.	Alliot,	The Park, Nottingham.
Robert	Angus	Lugar Ironworks, New Cumnock.
David	Auld,	23 Duncan Street, Calton, Glasgow.
H. W.	Ball,	Cranstonhill Engine Works.
James	Baird,	Lonsdale Ironworks, Whitehaven.
Andrew	Barclay, F.R.A.S.,	Caledonian Foundry, Kilmarnock.
Edward	Barrow,	Inspecteur General du Veritas, 188 Rue Royale, Bruxelles.
David	Bell,	254 Bath Street.
Edward M.	Bell,	Tinplate Works, Coatbridge.
R. Bruce	Bell, C.E.,	203 St. Vincent Street, Glasgow.
Walter C.	Bergius,	103 West Regent Street, Glasgow.
Christopher	Besant,	36 Oswald street, Glasgow.
Neil	Black,	Neptune Street, Liverpool.
Edward	Blackmore,	Eagle Foundry, Greenock.
Robert	Blackwood, C.E.,	Mill Lane, Kilmarnock.
Thomas	Blackwood,	Shipbuilder, Port-Glasgow.
George M'L.	Blair,	127 Trongate, Glasgow.
James M.	Blair,	8 Cecil Place, Paisley Road, Glasgow.
H. J.	Boolds,	City of Glasgow Bank Buildings, Greenock.

Walter	Brock,	Engine Works, Dumbarton.
Andrew	Brown,	London Works, Renfrew.
Richard	Brown,	37 West Nile Street, Glasgow.
James	Brownlee,	30 Burnbank Gardens, Glasgow.
James C.	Bunten,	100 Cheapside Street, Glasgow.
Amedee	Buquet, C.E.,	33 Rue de Constantinople, Paris.
Andrew	Burns,	Cessnock Road, Govan.
John G.	Cameron,	Mowbray Cottage, Coltman Street, Hull.
Archd. M.	Campbell,	Govan Steel Works, Govan.
David	Campbell,	105 Eglinton Street, Glasgow.
David	Carmichael,	Ward Foundry, Dundee.
Peter	Carmichael,	Dens Works, Dundee.
John	Carrick,	6 Park Quadrant, Glasgow.
Robert	Cassells,	166 St. Vincent Street, Glasgow.
Albert	Castel,	21 Belmont Crescent, Glasgow.
William	Clapperton,	7 Corunna Street, Glasgow.
James	Clinkskill,	176 West Regent Street, Glasgow.
Jose Maria	da Conceicao,	Rio de Janeiro, c/o D. Rowan, 217 Elliot Street, Glasgow.
Charles	Connell,	Whiteinch.
Benjamin	Conner,	3 Hampton Court Terrace, Renfrew Street, Glasgow.
Robert	Cook	Woodbine Cottage, Pollokshields.
James	Copeland	16 Pulteney Street, Glasgow.
William R.	Copland, C.E.,	83 West Regent Street, Glasgow.
S. G. G.	Copestake,	Glasgow Locomotive Works, Little Govan, Glasgow.
Constancio	Costa,	Valparaiso, c/ James Hamilton, 105 Eglinton Street, Glagow.
Antonio	Costa,	Valparaiso, c/o James Hamilton, 105 Eglinton Street, Glasgow.
M. R.	Costelloe,	189 Albert Terrace, Renfrew Street, Glasgow.
M'Taggart	Cowan, C.E.,	137 West Regent Street, Glasgow.

Edwin R.	Couchman,	Cathcart Street, Greenock.
David	Cowan, C.E.,	The Tharsis Mines, Tharsis, Huelva, Spain.
William	Cowan,	Great North of Scotland Railway, Aberdeen.
Archibald	Craig,	Vulcan Works, Paisley.
James L.	Cunliff,	Inch Works, Port-Glasgow.
J. F.	Couderé,	Custom-House Court, Newcastle-on-Tyne.
Robert	Curle,	Stobcross Dockyard, Glasgow.
James	Currie,	34 Bernard Street, Leith.
David	Cunningham, C.E.,	Harbour Chambers, Dundee.
Thomas	Davison,	248 Bath Street, Glasgow.
St. J. V.	Day, C.E.,	166 Buchanan Street, Glasgow.
James	Deas, C.E.,	16 Robertson Street, Glasgow.
Peter	Denny,	Helenslee, Dumbarton.
William	Denny,	Helenslee, Dumbarton.
A. C. H.	Dekke,	Shipbuilder, Bergen, Norway.
William	Dobson,	Shipbuilder, Joy Lodge, Low Walker-on-Tyne.
James	Donald,	Abbey Works, Paisley.
James	Donald,	Engineer, Johnstone.
Robert	Douglas,	Dunnikier Foundry, Kirkcaldy.
John	Downie,	13 Clarendon Place, Glasgow.
Henry	Dubs,	15 Park Circus Place, Glasgow.
Robert	Duncan,	Shipbuilder, Port-Glasgow.
David John	Dunlop,	Inch Works, Port-Glasgow,
Robert	Dundas,	115 St. Vincent Street.
George B.	Edington,	14 Buckingham Terrace, Glasgow.
Mortimer	Evans, C.E.,	97 West Regent Street, Glasgow.
William R.	Evans,	Manager, Warrnambool Steam Navigation Company, Warrnambool, Victoria, Australia.
S. C.	Faviell,	Clarence Iron Works, Leeds.
Robert	Faulds,	61 Parliamentary Road, Glasgow.

John	Ferguson,	Shipbuilder, Whiteinch.
William	Ferrie,	Monkland Iron Works, Calderbank.
J. R.	Forman, C.E.,	160 Hope Street, Glasgow.
Alexander	Fullarton,	Vulcan Works, Paisley.
William	Forrest,	13 Canal Street (N).
Thomas	Forrest, M.E.,	56 Rose Street, Garnethill.
William	Foulis,	Engineer, Corporation Gas Works, 42 Virginia Street, Glasgow.
James M.	Gale, C.E.,	Engineer, Corporation Water Works, 23 Miller Street, Glasgow.
Andrew	Galloway, C.E.,	16 Clyde Place, Glasgow.
William	Galloway, M.E.,	286 Renfrew Street, Glasgow.
Archibald	Gilchrist,	11 Sandyford Place, Glasgow.
David C.	Glen,	14 Annfield Place, Glasgow.
Thomas	Goldie,	Gryfe Bank, Bridge of Weir.
James	Goodwin,	Ironfounder, Ardrossan
Gilbert S.	Goodwin,	Alexandra Buildings, James St., Liverpool.
Joseph	Goodfellow,	83 Taylor Street, Glasgow.
Henry	Gourlay,	Dundee Foundry, Dundee.
Edwin	Graham,	Pallion High Yard, Sunderland.
George	Graham, C.E.,	Engineer, Caledonian Railway, Glasgow.
Alexander D.	Gray,	Lilybank Boiler Works, Eglinton Street.
Thomas	Gray,	Coltness Iron Works, Newmains.
Archibald	Gray,	Middleton, near Dalry.
James	Gray,	New Cumnock, Ayrshire.
James	Grier,	421 St. Vincent Street, Glasgow.
P. B. W.	Gross, M.E.,	Glasgow Locomotive Works, Little Govan, Glasgow.
David	Guthrie, C.E.,	23 Miller Street, Glasgow.
A. A.	Haddin, C.E.,	83 West Regent Street, Glasgow.
James B.	Handyside.	180 West Regent Street, Glasgow.
James	Hamilton,	15 Royal Crescent, Glasgow.

John	Hamilton,	2 Granby Terrace, Hillhead.
Edward	Hartley, F.G.S.,	Geological Survey, Montreal, Prov. Quebec, Canada, B.N.A.
George	Harvey,	42 M'Neil Street, Glasgow.
John	Hastie,	Clyde Foundry, Greenock.
William	Hastie,	2 Oswald Street, Glasgow.
B. D.	Healey,	Swansea.
James	Henderson,	Anneville, Newhaven Road, Leith.
John	Henderson,	30 Lancefield Quay.
James M'L.	Henderson,	Renfrew.
John	Hendrie,	131 Hope Street, Glasgow.
Richard	Henigan, C.E.,	Ordnance Survey, Chester.
Laurence	Hill, C.E.,	59 St Vincent Street, Glasgow.
George S.	Hird, C.E.	123½ Union Street, Aberdeen
Thomas R.	Horton,	Rose Cottage, Smith Street, Hillhead.
John	Hodgart, M.E.,	Milliken Park.
James	Howden,	8 Scotland Street, Glasgow.
Edmund	Hunt,	87 St. Vincent Street, Glasgow.
James	Hunter,	Coltness Iron Works, by Newmains.
John	Hunter,	Dalmellington Iron Works, near Ayr.
Joshua Hyde	Irwin, M.E.,	8 Murton Street, Sunderland.
Anthony	Inglis,	64 Warroch Street, Glasgow.
John	Inglis,	64 Warroch Street, Glasgow.
John	Inglis, junr.,	64 Warroch Street, Glasgow.
William	Inglis,	Soho Iron Works, Bolton.
William	Jacks,	c/o Messrs Robinows & Marjoribanks, 16 Bothwell Street.
George W.	Jaffrey,	The Firs, Partick Hill.
John L. K.	Jamieson	Govan.
William	Johnstone, C.E.,	Engineer, Glasgow and South-Western Railway, Glasgow.
David	Jones,	Highland Railway, Inverness.
Ebenezer	Kemp,	Linthouse Engine Works, Govan.

John Z.	Kay,	Phœnix Iron Works, Glasgow.
Thomas	Kennedy,	Kilmarnock.
John	Key,	Shipbuilder, Kirkcaldy.
David	Kinghorn,	172 Lancefield Street, Glasgow.
Alexander C.	Kirk,	Govan Park, Govan Road.
David	Kirkaldy,	Testing and Experimenting Works, the Grove, Southwark Street, London, S.E.
David	Laidlaw,	147 East Milton Street, Glasgow.
Robert	Laidlaw,	147 East Milton Street, Glasgow.
George	Lauder, C.E.,	c/o Messrs Carnegie & Co., Cokeworks, near Larimer Station, Pa., United States of America.
James G.	Lawrie,	241 West George Street, Glasgow.
Samuel	Lapthorn,	Ashburn, Partickhill.
C. R.	Lawson,	13 Whitevale, Glasgow.
Andrew	Leckie,	Messrs Caird & Co., Engine Works, Greenock.
Robert,	Leys,	9 Constitution Street, Aberdeen.
H. C.	Lobnitz,	Renfrew.
D. C.	Love,	Shipbuilder, Ardrossan.
John L.	Lumsden,	Fairfield Shipyard, Govan.
James	Lyall,	73 Gordon Street, Glasgow.
James M.	Lyon, M.E.,	Bangkok, Siam.
J. W.	M'Carter,	City Saw Mills, Londonderry.
John	M'Andrew	17 Park Street, East, Glasgow.
David	M'Call, C.E.,	160 Hope Street, Glasgow.
Hugh	M'Coll,	Abden Yard, Kinghorn, Fife.
David	M'Culloch,	Vulcan Works, Kilmarnock.
William	M'Culloch,	Vulcan Works, Kilmarnock.
James I.	M'Dermont,	47 New Market Street, Ayr.
Walter	M'Farlane,	46 Washington Street, Glasgow.
Andrew	M'Geachan	Newark Shipbuilding Yard, Port-Glasgow.
James	M'Ilwham	100 Cheapside Street, Glasgow.

John	MacKenzie, M.E.,	11 West Nile Street, Glasgow.
Alexander	M'Kinlay,	Shipwright Surveyor, 12 James Watt Street, Glasgow.
J. B. Affleck	M'Kinnell	Palmerston Foundry, Dumfries.
Robert	M'Laren	22 Canal Street, S.S., Glasgow.
Andrew	M'Lean	Stobcross Dockyard, Glasgow.
Walter	M'Lellan	127 Trongate, Glasgow.
John	M'Michael	55 Drygate, Glasgow.
John	M'Millan	Shipbuilder, Dumbarton.
William	M'Millan	281 Dumbarton Road, Glasgow.
John	M'Nab,	Dumbreck Priory, Paisley Road, Glasgow.
William	MacNab,	Shaws Water Foundry, Greenock.
Andrew	M'Onie,	1 Scotland Street, Glasgow.
Robert	Mansel,	Shipbuilder, Whiteinch.
Alexander B.	Marquis,	Bon Accord Engine Works, London Road, Glasgow.
George	Marquis,	Bon Accord Engine Works, London Road, Glasgow.
John	Mather,	1 Albert Place, West Gorton, near Manchester.
George	Menzies,	Shipbuilder, Leith.
Daniel	Miller, C.E.,	203 St. Vincent Street, Glasgow.
James	Miller,	Kelvin Forge, Partick.
James	Milne, C.E.,	c/o Paton & Grant, 136 Buchanan St., Glasgow.
Robert	Milne,	12 Centre Street, Glasgow.
James B.	Mirrlees,	45 Scotland Street, Glasgow.
John	Moffat, C.E.,	Ardrossan.
John	Montgomerie,	Caledonian Railway Works, Perth.
William	Moore, C.E.,	49 West George Street, Glasgow.
Ralph	Moore, C.E.,	Croft Villa, Rutherglen.
D. G.	Morrison,	c/o James Hamilton, 105 Eglinton St., Glasgow.
Alexander	Morton,	14 Nelson Terrace, Hillhead.
Hugh	Morton,	Victoria Dock, Leith.

William	Moverly,	36 Oswald Street, Glasgow.
Hugh	Muir,	345 Bath Crescent, Glasgow.
Matthew A.	Muir,	100 Cheapside Street, Glasgow.
William T.	Mumford,	36 Oswald Street, Glasgow.
James	Murdoch,	137 Bath Street, Glasgow.
John	Napier,	Saughfield, Hillhead, Glasgow.
Robert	Napier,	West Shandon, by Helensburgh.
G. M.	Neilson,	Burnfoot House, Ardrossan.
Walter	Neilson,	172 West George Street, Glasgow.
Walter M.	Neilson,	Hydepark Locomotive Works, Springburn.
William	Neilson,	92 West Regent Street, Glasgow.
Theodore L.	Neish,	Palmer's Engine Works, Jarrow-on-Tyne
Benjamin	Nicholson,	Shipbuilder, Annan.
Ernest	Nillus,	Ingénieur, Havre, France.
Hugh	Niven,	12 Fitzroy Place, Glasgow.
John	Norman,	16 Pultney Street, Glasgow.
John W.	Ormiston,	Shotts Iron Works, by Wishaw.
T. R.	Oswald,	Pallion High Yard, Sunderland.
John	Page, C.E.,	39 Arlington Street, Glasgow.
John	Paton,	20 Dixon Street, Glasgow.
R. F.	Pearce,	Barrow-in-Furness, Lancashire.
William	Pearce,	Albert Cottage, Copeland Road, Govan.
Eugéne	Perignon, C.E.,	105 Rue Faubourg St. Honoré, Paris.
Martin	Petersen,	Veritas Office, Custom House Court, Newcastle-on-Tyne.
Dundas, S.	Porteous,	Back Sneddon, Paisley.
John	Price,	37 West Sunniside, Sunderland.
Richard	Ramage,	Nether Bank Cottage, Dumbarton.
Henry M.	Rait,	Cranstonhill Foundry.
Charles	Randolph,	The Houff, Pollokshields.
Daniel	Rankin,	Eagle Foundry, Greenock.

David	Rankine,	157 St. Vincent Street.
James	Reid,	Shipbuilder, Port-Glasgow.
James	Reid,	Locomotive Works, Springburn.
John	Reid,	Shipbuilder, Port-Glasgow.
William	Reid,	41 West Regent Street, Glasgow.
James	Robertson,	Stanley Street, Kinning Park, Glasgow.
John	Robertson,	5 Kier Terrace, Pollokshields.
M. W.	Robertson,	387 Duke Street.
Stewart	Robertson,	Barrow Shipbuilding Co., Barrow-in-Furness, Lancashire.
William	Robertson, C.E.,	23 St. Vincent Street, Glasgow.
H. O.	Robinson, C.E.,	6 South Street, Finsbury, London, E.C.
Hazelton R.	Robson,	30 Derby Terrace, Glasgow.
James	Rodger,	5 Park Gardens, Glasgow.
W. W. B.	Rodger, C.E.,	Bagatelle, Greenock.
Richard G.	Ross,	21 Greenhead Street, Glasgow.
Alexander	Ross, C.E.,	Alva.
David	Rowan,	237 Elliot Street, Glasgow.
George	Russell,	Engineer, Motherwell.
Thomas	Russell,	Aberdeen Iron Works, Aberdeen.
James E.	Scott,	60 Eldon Street, Greenock.
John	Scott, yngst.,	Greenock.
Thomas B.	Seath,	42 Broomielaw, Glasgow.
Thomas	Shanks,	Engineer, Johnstone.
Henry	Simon, C.E.,	7 St. Peter's Square, Manchester.
William	Simons,	Renfrew.
Alexander	Simpson, C.E.,	175 Hope Street, Glasgow.
George	Simpson, C.E.,	170 Hope Street, Glasgow.
Hugh	Smellie,	Locomotive Superintendent, Maryport.
Alexander	Smith,	57 Cook Street, Glasgow.
David S.	Smith,	Hellenic Steam Navigation Co., Syra, Greece.
George	Smith,	Kennedy Street, Parliamentary Road.
Hugh	Smith,	8 Cecil Place, Paisley Road, Glasgow.

James	Smith, jun.,	156 St. Vincent Street, Glasgow.
J. P.	Smith, C.E.,	Greenside Villa, Copeland Road, Govan.
William	Smith,	57 Cook Street, Glasgow.
John	Sneddon, M.E.,	149 West George Street, Glasgow.
Edward	Snowball,	Engineer, 135 Hill Street, Glasgow.
Robert	Steele, jun.,	Shipbuilder, Greenock.
William	Steele,	Shipbuilder, Greenock.
John	Stephen,	Lint House, Govan.
Andrew M.	Stewart,	Founder, Irvine.
David Y.	Stewart,	3 Provan Place, Glasgow.
Duncan	Stewart,	47 Summer Street, Glasgow.
James	Stirling,	Glasgow and South-Western Railway, Kilmarnock.
Patrick	Stirling,	The Great Northern Railway, Doncaster.
John	Storry,	4 West Regent Street, Glasgow.
Edward	Strong,	c/o 5 Oakley Place, Southsea, Hants.
William	Swan,	Shipbuilder, Maryhill.
Ch.	Tellier, C.E.,	21 Rue Boulainvilliers, Paris-Passy.
James M.	Thomson,	36 Finnieston Street, Glasgow.
John	Thomson,	36 Finnieston Street, Glasgow.
W. R. M.	Thomson,	62 Buchanan Street, Glasgow.
Thomas C.	Thorburn,	35 Hamilton Square, Birkenhead.
David	Tod,	Meadowside Works, Partick.
W. W.	Urquhart,	Blackness Foundry, Dundee.
Nicholas	Watts, C.E.,	Bigbury Lodge, Rockhampton, Surrey,
Henry Hay	Wake,	Engineer, River Wear Commission, Sunderland.
Middlemost	Wawn,	Board of Trade Surveyor, 23 St. Vincent Street, Sunderland.
Matthew	Waddell,	Meadow Bank, Polmont, near Falkirk.
W. R.	Watson,	16 Woodlands Terrace, Glasgow.
John	Watson,	Govan Foundry, Govan.

William	Weems,	Engineer, Johnstone.
William	Weir,	Portland Iron Works, Kilmarnock.
Thomas M.	Welsh,	540 St. Vincent Street, Glasgow.
Henry H.	West,	73 Gordon Street, Glasgow.
Alexander	Whitelaw,	Gartsherrie House, Coatbridge.
Isaac	Whitesmith,	232 Govan Street, Glasgow.
John	Weild,	Underwriter, Exchange, Glasgow.
John	Wilkie,	33 Renfield Street, Glasgow.
Alexander H.	Wilson,	Aberdeen Iron Works, Aberdeen.
James	Wilson, C.E.,	Water Works, Greenock.
James E.	Wilson,	Clutha Iron Works, Glasgow.
John	Wilson,	226 Springburn Road, Glasgow.
Peter	Wilson, C.E.,	Highland Railway, Inverness.
Robert	Wilson,	Abbey Works, Paisley.
William	Wilson,	325 Eglinton Street, Glasgow.
Thomas	Wingate,	Whiteinch.
John	Young,	Galbraith Street, Stobcross.
James	Young,	103 West Regent Street, Glasgow.
William	Young,	Vulcan Foundry, Ayr.
John	Yule,	23 Carlton Place, Glasgow.

ASSOCIATES.

Thomas	Aitken,	8 Dock Place, Leith.
Andrew	Armour,	68 Anderston Quay, Glasgow.
T. S.	Begbie,	4 Mansion Place, London.
Capt. Alex.	Blackwood,	Leith.
William	Bragge,	Atlas Works, Sheffield.
John	Broadfoot,	28 Lancefield Quay, Glasgow.
Capt. James	Brown,	11 Somerset Place, Glasgow.
John	Bryce,	82 Oswald Street, Glasgow.
George S.	Buchanan,	95 Candleriggs Street, Glasgow.
William	Calder,	Sailmaker, Leith.
Joseph J.	Coleman, F.C.S.,	69 St. George's Place, Glasgow.
Robert	Duncan,	Ironfounder, Partick.
Arch. Orr	Ewing, M.P.,	2 West Regent Street, Glasgow.
Captain R.	Ewing,	Carry Cottage, Govan.
Alexander	Ferguson,	5 East Breast, Greenock.
Robert	Gardner,	2 West Regent Street, Glasgow.
James	Haddow,	94 West Regent Lane, Glasgow.
Captain D.	Harrison,	Howden Villa, Berkley Road, Horfield, Bristol.
George T.	Hendry,	8 Dixon Street, Glasgow.
Capt. David	Hendersen,	52 St. Enoch Square, Glasgow.
Anderson	Kirkwood, LL.D.,	12 High Windsor Terrace, Glasgow.
Rev. J. M.	Kilner,	Chester Castle, Chester.
John Jex	Long,	12 Whitevale, Glasgow.
John	M'Allister,	Mavisbank Sailwork, Glasgow.
John	Mayer, F.C.S.,	2 Carlton Place.

George	Miller,	1 Wellesley Place, Glasgow.
John	Milne,	62 Marischal Street, Aberdeen.
John	Morgan,	Springfield House, Bishopbriggs.
James S.	Napier,	33 Oswald Street, Glasgow.
R. S.	Newal,	Fernedene, Gateshead.
John	Phillips,	17 Anderston Quay, Glasgow.
Capt. John	Rankine,	257 St. Vincent Street, Glasgow.
John	Rattray,	94 Renfield, Glasgow.
William H.	Richardson,	19 Kyle Street, Glasgow.
John	Smith,	Aberdeen Steam Navigation Co., Aberdeen.
John R.	Stewart,	55 Anderston Quay, Glasgow.
Malcolm M'N.	Walker,	45 Clyde Place, Glasgow.
H. J.	Watson,	62 Jamaica Street, Glasgow.
Thomas	Westhorp,	West India Road, London.
John	Whyte,	Prince Consort Place, Leith.
James	Young,	22 Renfield Street, Glasgow.
William	Young,	Galbraith Street, Stobcross.

GRADUATES.

John	Anderson,	c/o J. H. W. Shaw, 11 West Regent St.
W. M.	Alston,	24 Burnbank Gardens, Glasgow.
W. S.	Beck.	12 Derby Street.
Joseph de	Caynoth, Ballardie,	c/o Ballardie Bros., 9 West Howard Street, Glasgow.
Hartvig	Burmeister,	c/o Messrs Rahr & Roundrup, 5 Duke Street, Canon Street, Manchester.

John H. de Jersey Clere,		Clevedon Place, Brighton.
John	Ferguson, jun.,	Larkfield, Partick.
F. P.	Fletcher,	10 Broad Street, Golder Square, London.
James	Gilchrist,	12 Derby Street, Glasgow.
Charles	Hargreaves,	c/o D. Rowan, 237 Elliot St., Glasgow.
James	Hamilton, jun.,	15 Royal Crescent, Glasgow.
John	Hammond,	3 Minerva Street, Glasgow.
Robert	Mackintosh,	c/ James Mitchell, 118 Union Street, Glasgow.
Ebenezer E.	Millar,	Clyde View, Uddingston.
Thomas	Roberts,	64 Hawes Street, Newcastle-on-Tyne.
Thomas	Shaw,	South Barr Colliery, by Paisley.
Hugh	Smith,	57 Cook Street, Glasgow.
Cornelius	Thompson,	17 Albyn Place, Aberdeen.
Alfred	Thorne,	1 Lawrence Pountney Hill, Canon St., London, E.C.

INDEX.

William Munro, Steam Printer, 61 Virginia Street, Glasgow.

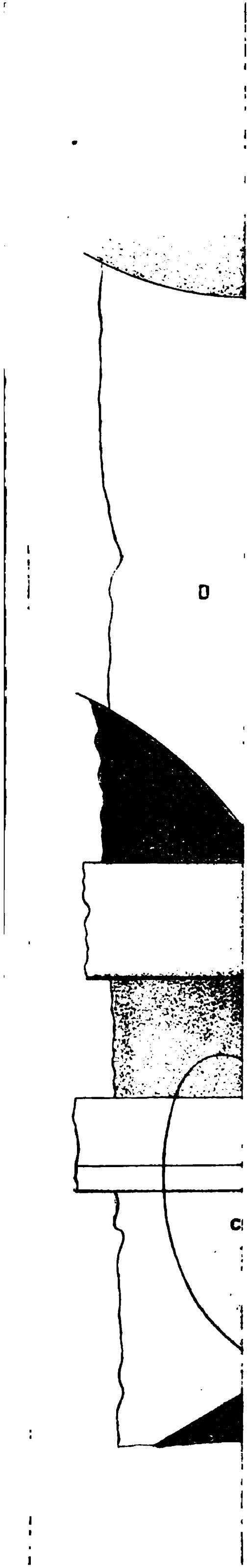
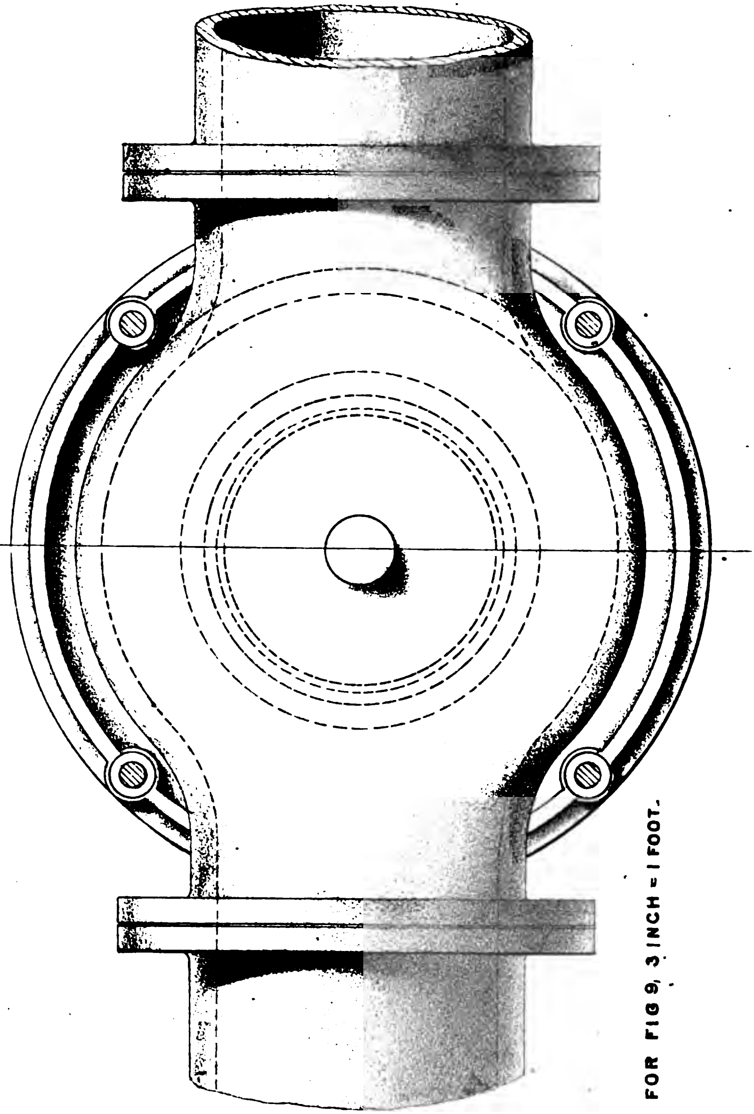

D
C

PLATE III.



GARDNER & STEVENSON,
ENGINEERING LITHOGRAPHERS
3, WEST REGENT St GLASGOW

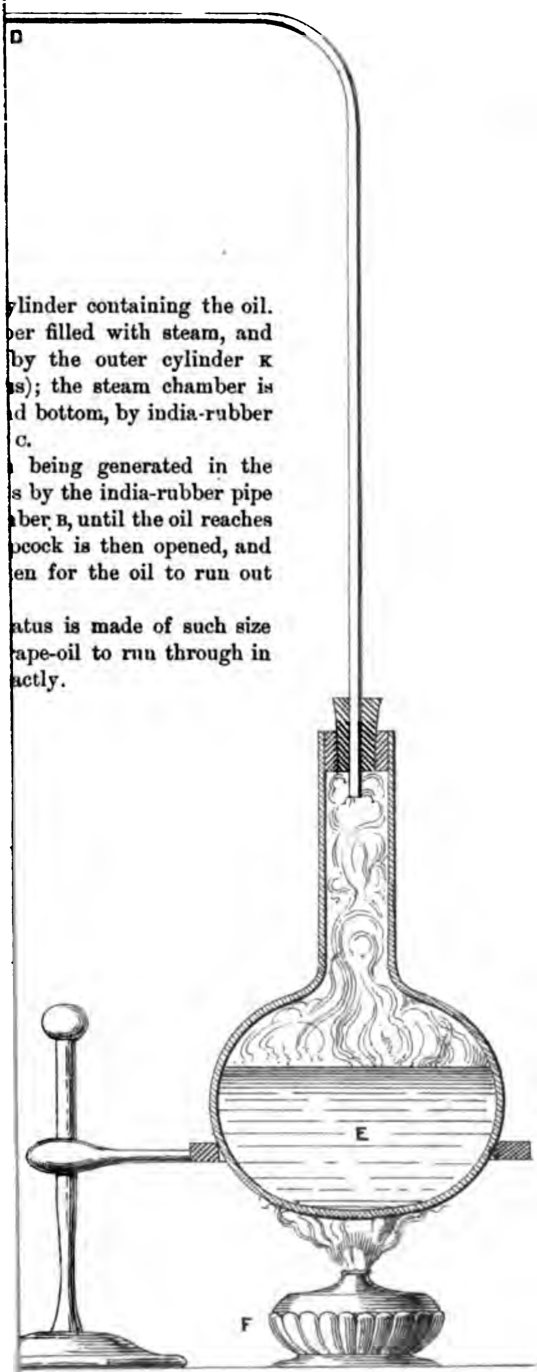
TERM VISCOSITY

LEMAN

ylinder containing the oil.
ber filled with steam, and
by the outer cylinder K
s); the steam chamber is
d bottom, by india-rubber
C.

being generated in the
s by the india-rubber pipe
ber B, until the oil reaches
pcock is then opened, and
en for the oil to run out

atus is made of such size
ape-oil to run through in
actly.



GARDNER & STEVENSON,
ENGINEERING LITHOGRAPHERS
4, WEST REGENT ST GLASGOW.

Fig. 4

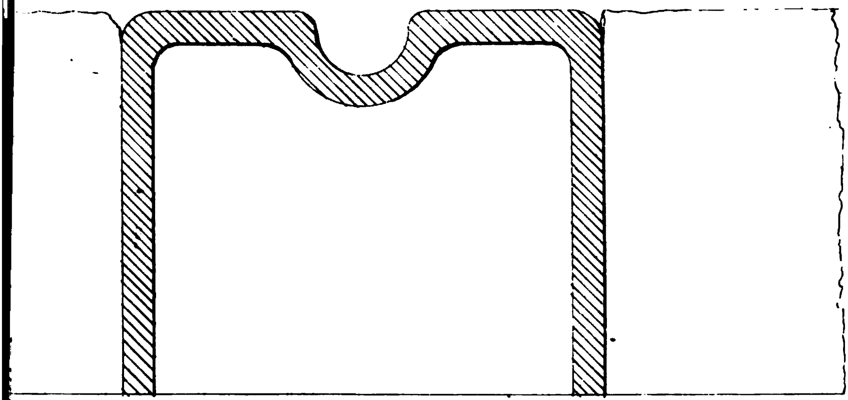


Fig. 8,

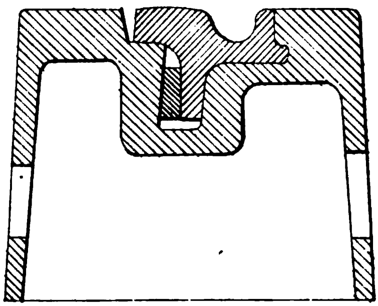


Fig. 9.

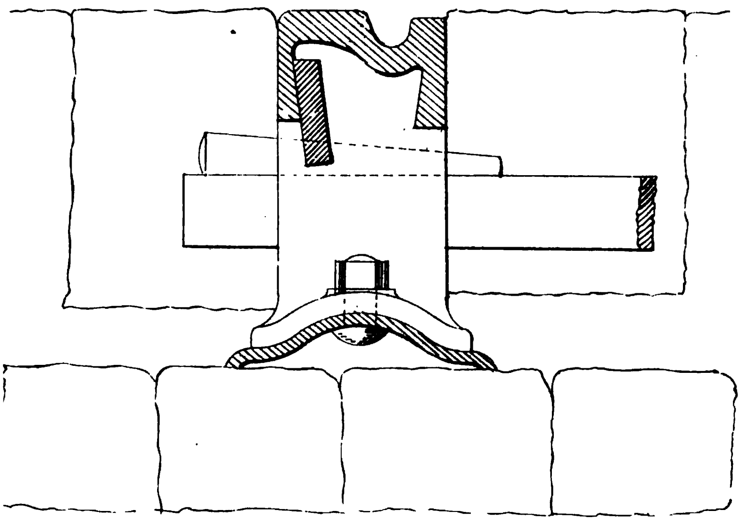
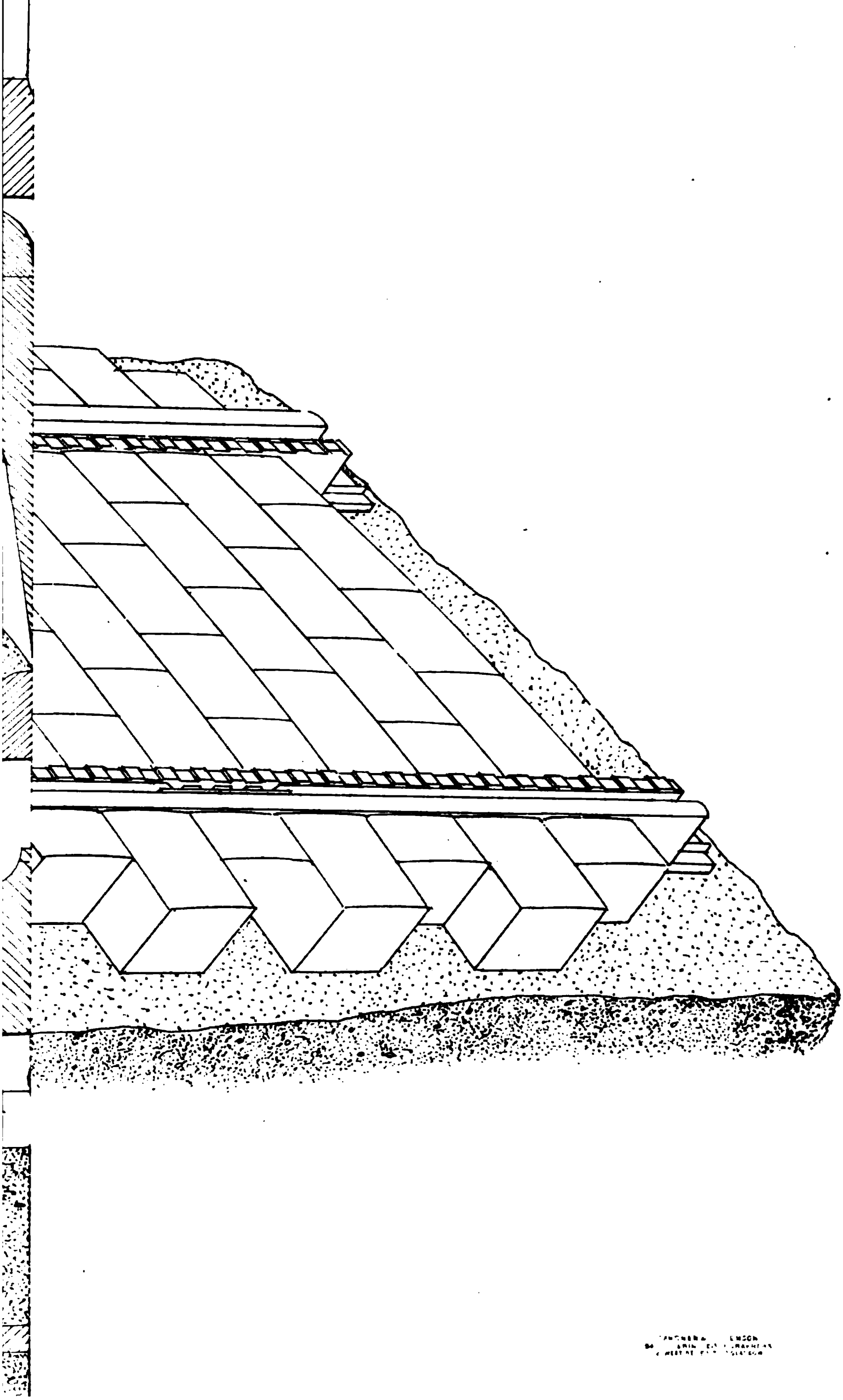


PLATE VI



D ELEVATIONS.

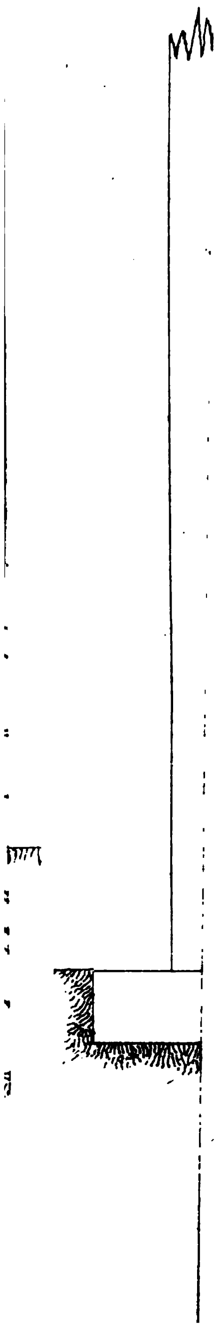
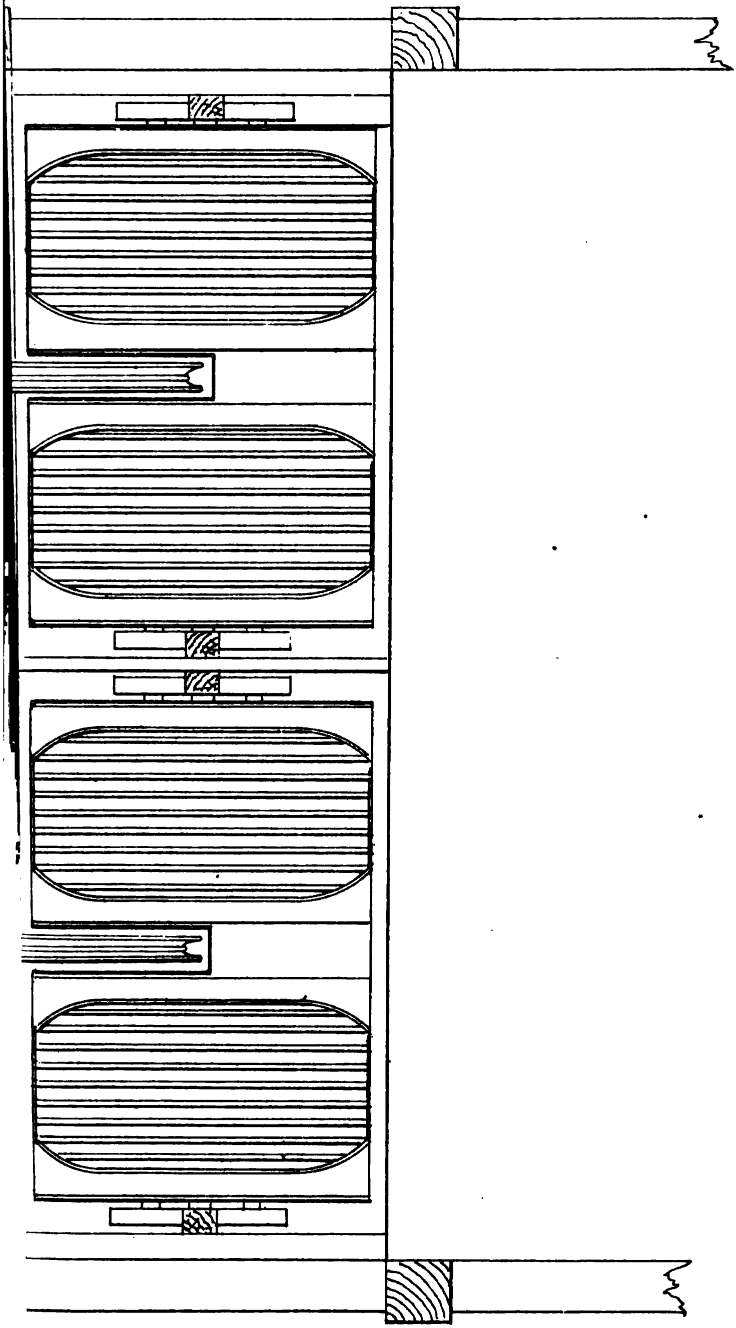


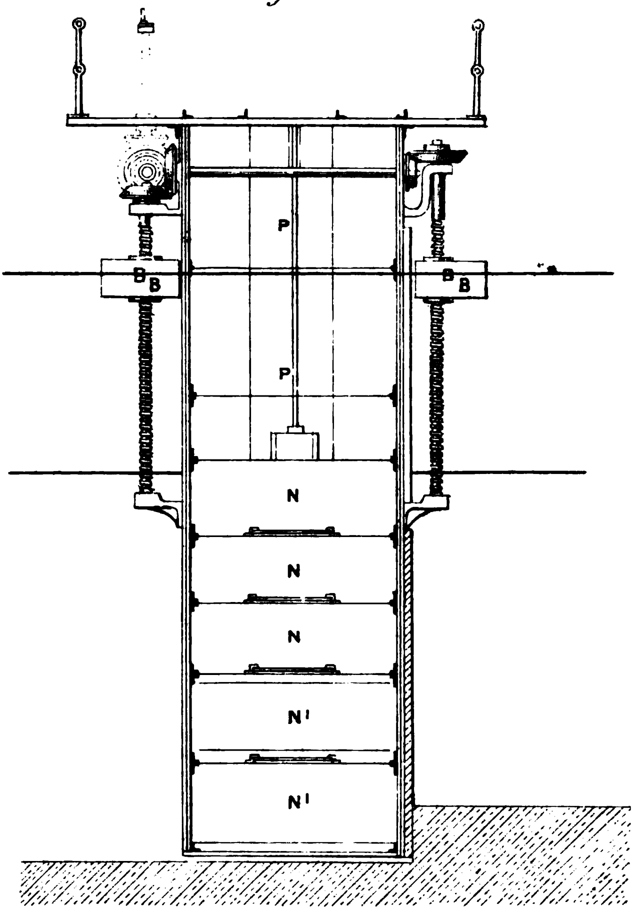
PLATE VIII



GARDNER & STEVENSON
ENGINEERING LITHOGRAPHERS
[illegible]

PLATE X

Fig. 2.



Section on the Line a.b. Fig. 1.

GARDNER & STEVENSON,
ENGINEERING LITHOGRAPHERS.
2 WEST REGENT ST GLASGOW

PLATE XI.

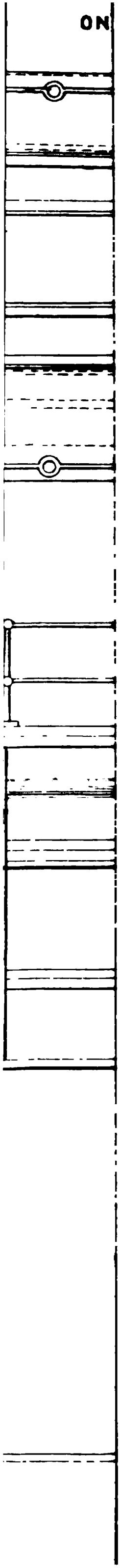


Fig. 4.

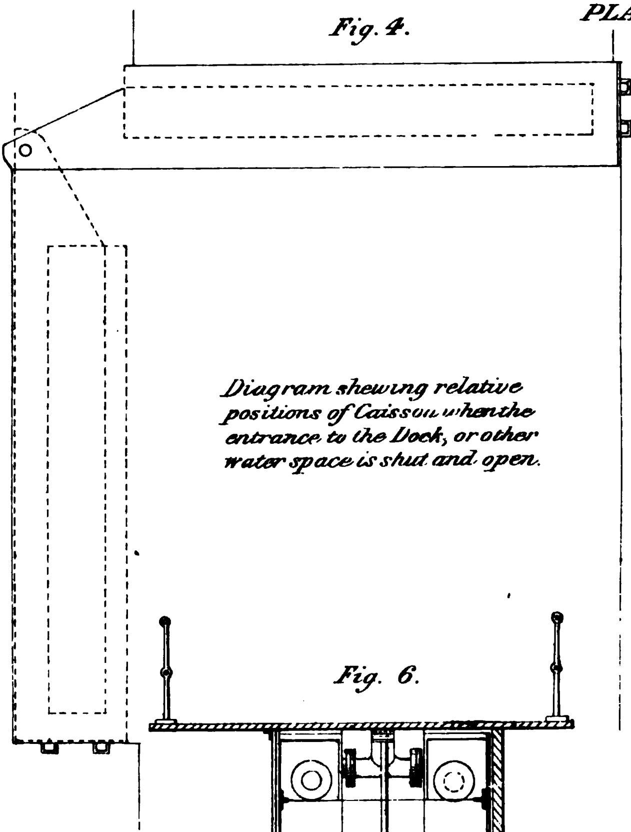
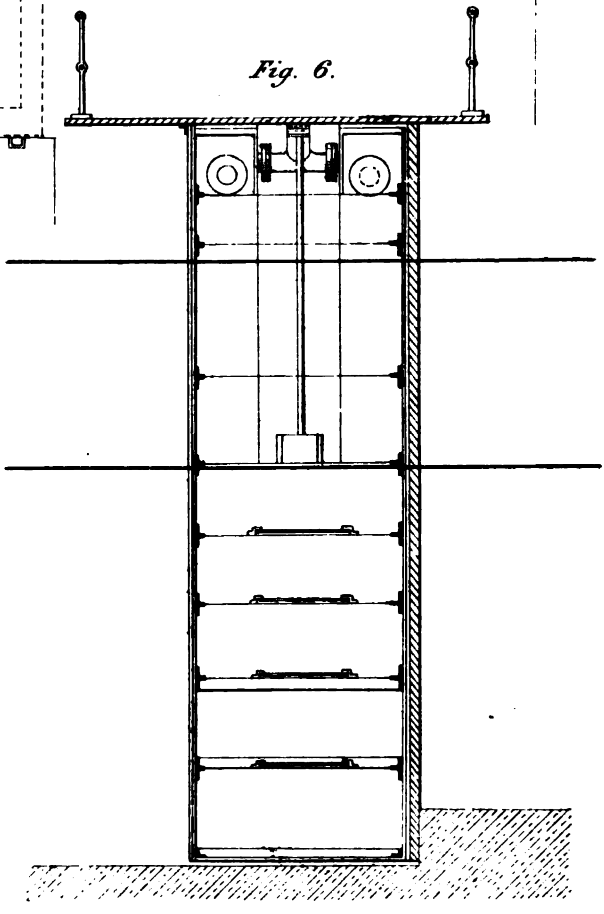


Diagram shewing relative positions of Caisson when the entrance to the Dock, or other water space is shut and open.

Fig. 6.



Section on the Line c. d. Fig 5.

GARDNER & STEVENSON
ENGINEERING LITHOGRAPHERS
WEST REGENT ST GLASGOW

PLATE XII

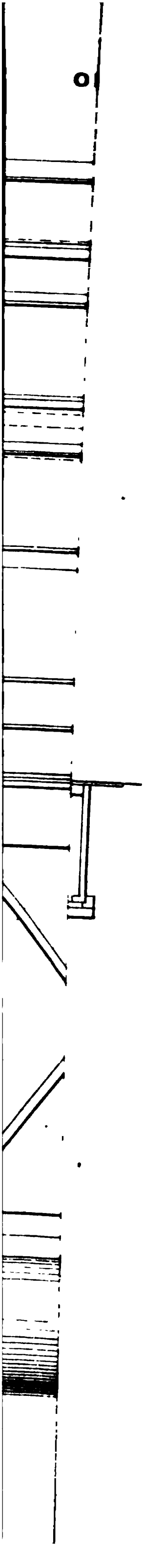


Fig. 8.

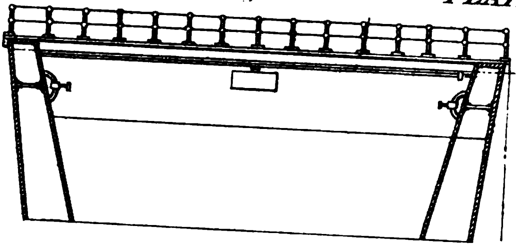


Fig. 9.

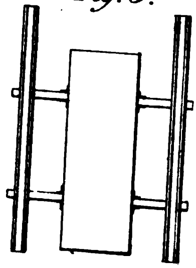


Fig. 9.

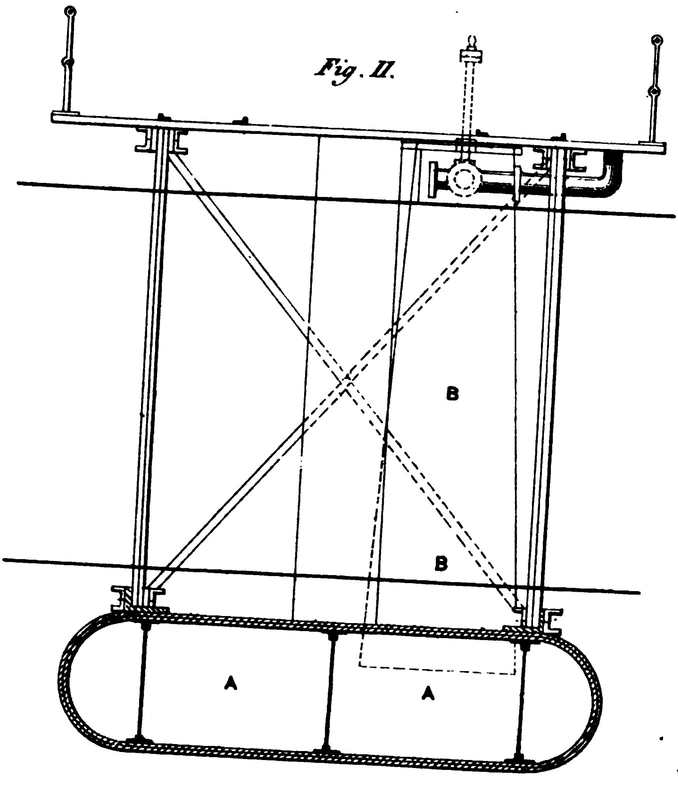
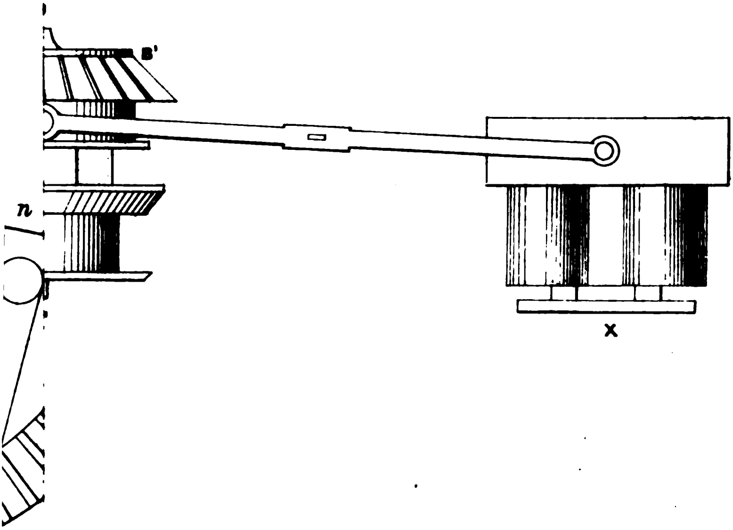


Fig. 11.

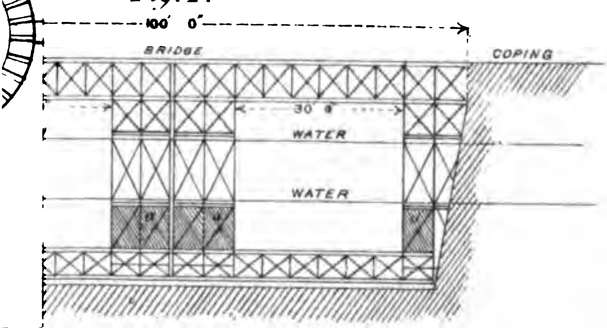
GARDNER & STEVENSON, ENGINEERING LITHOGRAPHERS, 2, WEST REGENT ST GLASGOW

PLATE XIII.



LE'S GATE BRIDGE FOR DOCKS

Fig. 4.



ngi
por

PLATE XVI

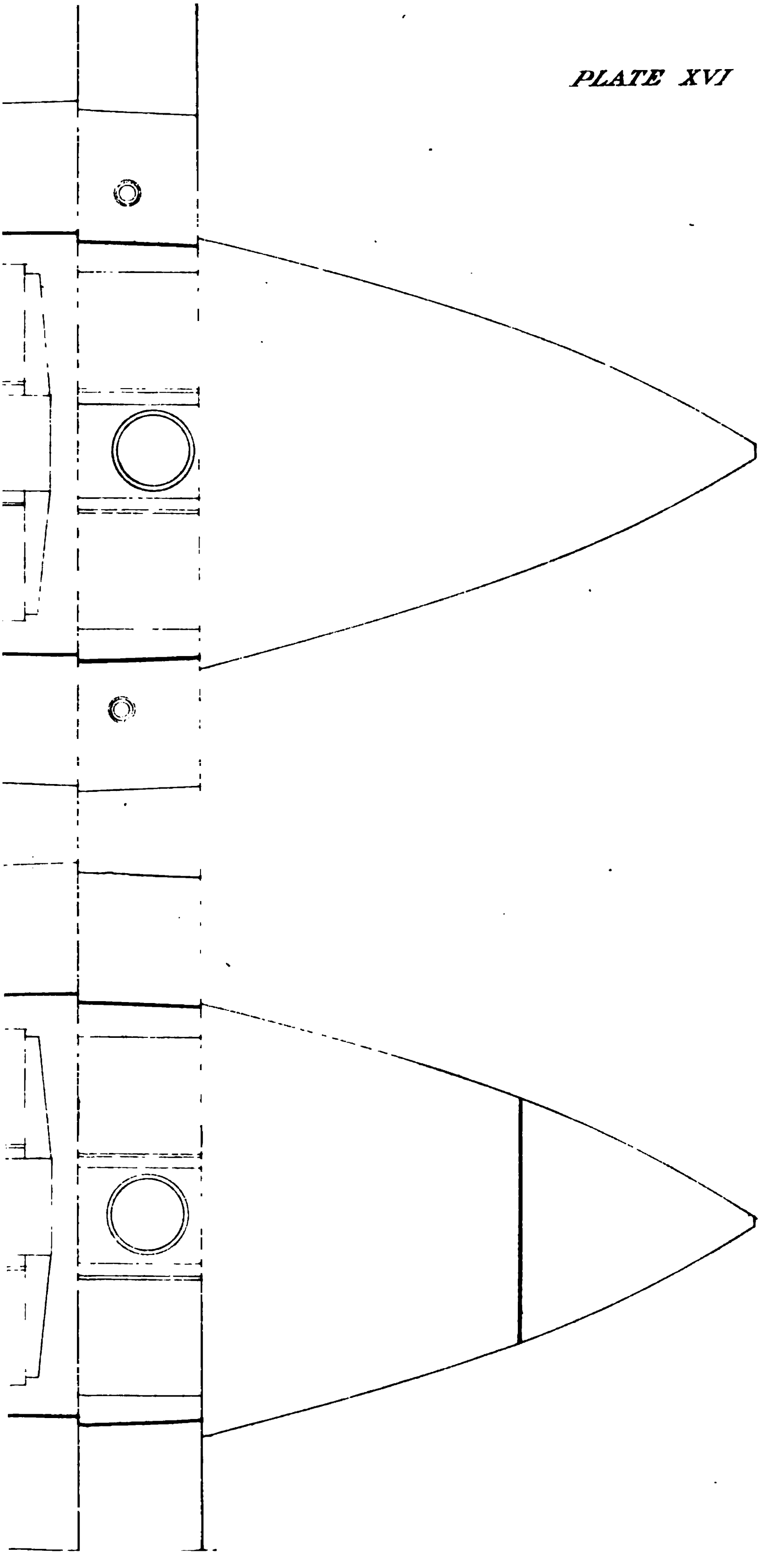


PLATE XVII.