See back cover.

TRANSACTIONS

OF THE

INSTITUTION OF ENGINEERS

IN SCOTLAND.

VOLUME I.

FIRST SESSION, 1857-58.

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GLASGOW:
PRINTED BY WILLIAM MACKENZIE, 45 & 47 HOWARD STREET.
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PREFACE.

The Institution of Engineers in Scotland was established for the encouragement and advancement of Engineering Science and Practice, to facilitate the exchange of information and ideas amongst its members, and to place on record the results of experience elicited in discussion.

It owes its origin, in a great measure, to the very successful Meeting held in Glasgow, in 1856, by the "Institution of Mechanical Engineers" of Birmingham; the great utility and probable success of a similar Institution holding its meetings in Glasgow, the chief seat of practical mechanics in Scotland, being at the time strongly impressed upon several Engineers residing in and near Glasgow, who held a few preliminary meetings, succeeded by a general one on 1st May, 1857, which was numerously attended, and at which a constitution was decided upon, and office-bearers were elected for the First Session, 1857–58.

The great accession of members, the numerous papers read, the very excellent attendance at the meetings, and the well-sustained discussions rendered interesting by the exchange of valuable information—during the First Session, place the success of the Institution beyond doubt.

At the termination of the Session in April last, the Institution numbered one hundred and eighteen members, one associate, and eight graduates, and numerous additions are expected early in the Second Session.

Eight meetings were held during the Session, and at these as many as twenty-one papers were read, on various subjects connected with the objects of the Institution. Each paper was followed by a discussion on the subject of which it treated, and there were in addition two discussions (on Decimal Measures), not preceded by papers.

Glasgow, *August*, 1858.

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EIGHTH MEETING, 14th APRIL, 1858.

OFFICE-BEARERS.

Elected 1st May, 1857.

FIRST SESSION, 1857-58.

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W. J. MACQUORN RANKINE, LL.D.

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EDMUND HUNT, Esq., 28 St. Enoch Square, Glasgow.

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.

PLATES.

INSTITUTION

OF

ENGINEERS IN SCOTLAND.

SESSION 1857-58.

THE FIRST MEETING of the Session was held in the Philosophical Society's Hall, Andersonian Buildings, George Street, Glasgow, on Wednesday, 28th October, 1857—Prof. W. J. MACQUORN RANKINE, LL.D., F.R.SS. L. & E., President, in the chair.

The PRESIDENT delivered the following Introductory Address:—

On the Nature and Objects of the Institution.

GENTLEMEN,—We have had several general meetings already, but they were of a preliminary character, and this is the first meeting at which we are about to proceed to the transaction of our regular ordinary business—the reading of papers, and the discussion of those subjects in which we are interested. Since this society was first formed, I am happy to see that many names of new members have been proposed, and many members who were not present at previous meetings are here now, and it is therefore desirable that I should make a short statement as to the nature and objects of this society, as distinguished from those of other scientific societies.

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 those 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. And this is a most important object; for much time and money may be wasted, and much trouble be thrown away, by making experiments that have been made already; and an institution such as ours does much to prevent that evil. 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. A society of this kind is different from those of the second class that I have mentioned, which tend towards making science popular; for we shall, to a great extent, have to consider details uninteresting or unintelligible to the general public. One of the objects of this society is, that its members shall discuss details with which they could not venture to take up the time of a mixed and popular meeting.

Having explained to you the nature of this Institution, I will state how it originated. Amongst previously existing institutions of the same class, is the "Institution of Civil Engineers," which for many years has held its meetings in London, and the benefits arising from which are generally acknowledged; also the "Institution of Mechanical Engineers," having its chief place of meeting at Birmingham, and holding its meetings at other places besides, such as Manchester, Newcastle, and (last year for the first time) in Glasgow. I may also refer to the "Institution of Civil Engineers in Ireland," which is of recent date, but of great utility. I think I may trace the origin of the foundation of our present society to the effect of the meeting of the "Institution of Mechanical Engineers," held in Glasgow in the autumn of last year. Almost all the members here will recollect that meeting, which, for one of the kind, was almost unparalleled as to attendance, and excited immense interest among the practical men of this city. One thing remarkable about that meeting was the fact, that a large quantity of interesting and useful machinery was exhibited at it by Glasgow makers. Those proceedings very naturally produced the impression, that a society of engineers holding its meetings in Scotland, and in Glasgow as the chief seat of practical mechanics in Scotland, would be successful; and that idea having occurred to a few individuals, was gradually discussed by more and more, until it led, about six months ago, to the foundation of this Institution.

We are distinguished from the Institution of Civil Engineers, and from the Institution of Mechanical Engineers, by combining those two branches, as well as mining engineering, founding, and iron shipbuilding; and I think that combination is a most judicious measure. In former times, one could draw a line between civil engineering and mechanical engineering. There was a time when civil engineering was confined to works in stone, earth, and timber, and when the use of iron was restricted to the purposes of the mechanical engineer. But now, iron has become so important a material in the great works of civil engineering, that the two branches have been very much assimilated, and it is difficult to draw the line where one pursuit ends and the other begins; and the same may be said of various other branches of engineering. It is on this account that the Institution has included amongst its members, civil engineers, mechanical engineers, mining engineers, founders, and iron shipbuilders.

The object of this society is the advancement of engineering and practical mechanics, and the keeping of the members informed of what is being done elsewhere by other engineers, thereby enabling each one of our members to have the benefit of the experience of many. The advancement of engineering and practical mechanics comes from experimental knowledge. Experiments are of two kinds:—First, those which are made expressly for the purpose of testing the properties of some particular material, or ascertaining the laws governing some particular phenomenon, and which are intended for experiments and nothing more. Few men engaged in practical engineering have time enough at their disposal to carry on such experiments as these, and the leisure necessary for doing so is, for the most part, confined to a very limited number of persons. The second class of experiments comprises those which occur incidentally in the course of practice, and by which many important facts are brought to light, but which often pass unrecorded, and are, in that case, of no use to the great body of scientific and practical men. The observation of them may, indeed, be of use to the individual who observes them; but unless they are collected and recorded, the benefit to be derived from them is lost to the profession and to the public at large. One of the objects of this Institution is to collect and combine all those different experiments which occur incidentally in the course of the practical experience of engineers, and to deduce useful conclusions from them. With regard to the benefit of combining the experience of many practical men, an excellent remark was made by Mr. Scott Russell at the meeting of the "Mechanical Engineers" in Glasgow last autumn. He said, that in a society of, say one hundred members, a member bringing the experience of one man, gets in exchange the experience of ninety-nine.

This is a most favourable time for the progress of such an institution as ours; and to show you clearly that such is the case, I may direct your attention to one or two facts in connection with the history of practical mechanics. In the early part of this century, the discoveries of Watt more especially, and also those of Smeaton and others, gave a great impulse to engineering and practical mechanics. Then Tredgold, Rennie, and Telford, and many more eminent engineers, made still further improvements in mechanics. That period of improvement, however, was followed by a time less favourable to sound progress in mechanics: a time which has happily now expired, for we are again advancing, and I shall tell you what appears to me to be the reason.

If I were required to state in one word what constitutes the characteristic advantage of skilful and scientific practice in the useful arts, I should say—ECONOMY. By economy I do not mean parsimony, or the use of inadequate means towards an end; neither do I mean economy in money only; but economy of means of all sorts—economy of materials, of power, of time. The fact is, that perfect economy in any operation consists in accomplishing the end proposed by an amount of means just sufficient, without waste. For example, to construct a viaduct with just so much iron as is enough to support the required load safely, and no more; or (to go to machinery for an illustration) to drive a machine by just so much power as is necessary to do the work without waste:—that is economy:—to the attainment of it all our skill should be directed, and I am glad to find that such is being done every day. Some years ago, however, the case was different. There was then a period of wild speculation, which was most detrimental to the development of that kind of skill that leads to economy. For speculation and extravagance lead to the consequence, that where a structure is required to be strong, it is made so, not by skilful design, but by clumsy and costly massiveness; and that where a machine is required to perform much work, it is enabled to do so, not by economical use of power, but by its lavish expenditure. At a period of that sort, there is a tendency to neglect economy, and the inevitable result is the bringing about of a state of public opinion that discourages true skill in the useful arts. It leads to a prejudice in favour of structures and machines in proportion to their cost, irrespective of the results accomplished by them. At such a period, a line of railway will be regarded as a great undertaking, merely because it has cost a hundred thousand pounds per mile, and a bridge will be looked upon with admiration in proportion to the number of thousands of tons of superfluous material which it contains. The reaction after a period of extravagance tends to produce the opposite extreme—parsimony: the using of bad materials, and the attempting to effect ends by inadequate means. But I have very little to say about a reaction of that kind; for parsimony is a fault we very seldom fall into in this country: it is not in accordance with the British character. I think the period at which we have now arrived, is a period of PRUDENCE, when we have hit the right mean between economy and parsimony, and endeavour to produce all our results as effectively as possible, and without waste of any kind. In fact we are now arrived at a time when there is every encouragement to form institutions like this, and to feel confidence that the result of our labours will be appreciated.

It has been the practice on the opening of societies of this description, to give a sketch of the previous history of the art or science with a view to the promotion of which the institution has been founded; but it seems to me that, instead of congratulating ourselves upon past progress, it would be better that we should look forward, and see what farther improvements are yet to be made; and, therefore, I will make a few remarks upon the various questions occurring to me on which knowledge is wanting, and to the elucidation of which our future labours may contribute.

I shall begin by a few observations with regard to the properties of materials. True economy and true skill require the best possible material; and the best material is that which is strongest in proportion to its weight; and that is the quality which makes iron the most useful and important of all materials. Iron is the most difficult of all materials to obtain pure. We can easily obtain the other ordinary metals in a pure state—gold, copper, silver, lead, tin, zinc; but the obtaining of pure iron, or iron even approaching to purity, is almost impossible. We know that there are immense varieties of qualities of that metal as regards strength, and that those variations of strength arise from impurities. One mode of obtaining good iron, is to bring it from the localities which produce it best—such as those where it is smelted with charcoal—Russia, Sweden, the British possessions in America; but the obtaining of it from these places is very expensive. Still, we know that in the weakest, as well as the strongest qualities, the iron itself is the same substance, and that its variations in strength arise from combination with other substances, such as carbon, manganese, sulphur, phosphorus, arsenic, silicon, calcium, &c.

The question then arises, "Can iron produced in our own country be so improved as to remove those foreign substances that lessen its strength?" Now, I have no doubt that a strong light may be thrown on that important question, by collecting the experience of the members of a society like this.

There are other materials besides iron that demand our attention—timber, for instance. A very important question may arise as to seasoning it, and preserving it from decay. For a long time it was thought that timber took years to season, and that the operation should take place in the open air; but we now find that it can be done in a few days by means of an oven. Of course that process, being in its infancy, can be improved. As to the preservation of timber, it is of consequence that we should collect the results of as much practical experience on this head as we can. The manufacture of artificial stone, and the strengthening of natural stone, and improvements in the manufacture of bricks, are also subjects of great importance.

As to the strength of materials, I scarcely need say that it has for a long time been a subject of inquiry; and much has been discovered in reference to it; but the discoveries themselves show how much yet remains to be discovered. I shall mention a few of the leading questions that have lately arisen on this subject. There is a very well-known rule for calculating the transverse strength of beams, founded on certain suppositions respecting the laws of the resistance which the particles of a bent beam oppose to the force which bends it. The rule is as follows:—Divide what is called the *moment of inertia* of the cross section of the beam by the leverage of the load, and by the greatest distance of any particle from the neutral axis; and multiply the quotient so obtained by a *constant multiplier*, depending on the nature of the material. Now, it has always been well known to scientific men, that the suppositions upon which that rule is founded are, in some respects, not exactly true; but it has been very generally taken for granted, that the error in the calculation is too small to be of importance in practice; and in order to obviate, in a measure, the defect that was apparent, different multipliers were used. Some recent experiments, by Mr. W. H. Barlow, have shown that no *constant multiplier* will give the strength. If we take several beams of similar figures, the same multiplier will answer; but as soon as we vary the form of the section of beam, we require a new multiplier for the same material; and Mr. Barlow has made considerable progress in determining what law the variations of the multiplier follow. But still, our knowledge of that subject is incomplete; and it yet remains to be discovered what is the exact and true law on which to found a rule for ascertaining the transverse strength of beams. As another example, I may refer to Mr. Fairbairn's experiments on the resistance of hollow cylinders against crushing, such as the flues of boilers. Mr. Fairbairn has found that by increasing the length of the cylinder the resistance is diminished; so that, within the limits of his experiments, the strength is inversely as the length; but this must be only an approximate law; for, if it were exact, a tube, how thick soever, could be made so long that the slightest pressure would cause it to collapse: and we have yet to discover how the strength of a cylinder against outward pressure can be exactly computed. I have still another question to refer to with regard to the strength of materials; and it is one that has attracted much attention, having been discussed at great length at the late meeting of the "British Association" in Dublin. I refer to the stiffening of suspension bridges. This description of bridge is that which requires the smallest quantity of iron to support a given load; but an objection to its use on railways is its vibration, which would be so great, on the passing over of a train at high speed, as to be dangerous. It has been proposed to stiffen those bridges; and this has been done by means of lattice girders, that is to say, diagonal braces and horizontal bars along each side. It was formerly supposed that, to make a suspension bridge as stiff as a girder bridge, we should use lattice girders sufficiently strong to bear the load of themselves, and that, such being the case, there would be no use for the suspending chains. But Mr. P. W. Barlow, having made some experiments upon models, finds that very light girders, in comparison with what were supposed to be necessary, are quite sufficient to stiffen a suspension bridge; that, in fact, girders of a certain stiffness, attached to a suspension bridge, require, in order to produce a given deflection, twenty-five times the weight that would produce the same deflection if they were not connected with the suspension chains. And it turns out that, if mathematicians had directed their attention to the subject, they might have anticipated this result. It is true that Mr. Barlow's experiments were made upon models only; and it remains to be determined on a large scale, whether a suspension bridge, with girders to stiffen it, is more economical than other forms of bridge, and whether we ought to use plate girders, half-lattice girders, lattice girders, bowstring girders, stiffened chains, or girders of some other form. That is a question about which there is much controversy, and which can only be settled by the collection and scientific discussion of the experience of practical men. The progress that has of late years been made in the crossing of large valleys by means of viaducts of moderate cost, has been very great indeed. Not long ago, it was considered very moderate if a viaduct could be constructed at the rate of 7s. per cubic yard of space covered; now the work can be done for 3s. 6d. or 4s. per cubic yard of space.

The construction of iron ships is a topic of importance to which I shall call your attention. There are very many questions remaining unsettled on this subject. Mr. Scott Russell pointed out, at the meeting of the British Association, the error into which builders fall in constructing iron vessels on the same plan as they do wooden vessels, with keel, ribs, and planking, although the materials of the two do not at all resemble each other. But although this error is evident, no one likes to be the first to run the risk of constructing a ship, or anything else of such magnitude, upon a new principle; and it must be regarded as showing great courage on the part of Mr. Brunel and Mr. Scott Russell, that they have undertaken the building of so large a vessel as the *Great Eastern** on an entirely new plan, substituting cells for ribs, and dispensing with the keel. There is much yet to be discovered in the art of building iron ships; and in this locality, where iron shipbuilding is practised on so extensive a scale, we look forward to the exertions of this society for the collection of important results of experience.

With regard to boiler explosions, I think it is most important that, in all cases of such accidents, the exact facts should be minutely recorded; and that is one of the duties that should be performed by this society.

I shall now pass to the consideration of the means which we use for the purpose of performing work, and for effecting changes in the condition and form of materials. The agent we chiefly use for that purpose is heat; and the great agent for the production of heat is the combustion of coal; so that economy of fuel is, perhaps, the most important subject coming before any one studying practical mechanics. Numerous experiments are made upon this subject every day, by almost every person using a furnace; but the benefit of these experiments is lost to the profession for want of their being recorded. I would suggest, therefore, that a register should be kept of the consumption of fuel in the different furnaces of the city. The economy of fuel is a subject that, forty years ago, attracted the attention of the Rev. Dr. Robert Stirling, who invented an apparatus for saving heat, called the "regenerator," or "economiser." This apparatus is intended to be used when any fluid, whether liquid or gaseous, requires to have its temperature alternately raised and lowered. The fluid is passed alternately backwards and forwards through a grating or network of some solid conducting substance, which alternately takes away from the fluid and gives back to it a large proportion of the heat required to produce the alternate changes of temperature. Heat which would otherwise be wasted is thus stored up and saved, to be used over and over again. This apparatus, though employed to a limited extent, has never been brought into general use. But recently, Mr. Siemens devised an application of the same principle to furnaces, which seems to have answered well; and it is to be hoped that the use of this principle may be farther developed. As another invention for the economy of fuel will be brought before you in a paper to be read this evening, it is unnecessary for me farther to advert to the matter.

The subject of economy of fuel leads us naturally to the consideration of the steam-engine, and the economy of its power. All steam-engines now extensively used in practice, are, in fact, Watt's engines, more or less developed and improved; and it appears that, in some instances, an economy has now been attained, such that the consumption of coal is from 2 lbs. to 2½ lbs.

* Since named the *Leviathan*.

per hour per indicated horse-power. Theory shows that this is almost the greatest economy we can arrive at; and if we want to economise farther, we must introduce some new principle, such as the use of superheated steam, or heated air, which is analogous to superheated steam, inasmuch as it can be worked at a high temperature without attaining a dangerous pressure. The theory of this subject is now well understood; and the only difficulty that exists is as to its convenient practical application.

The use of electro-magnetic engines is also a subject for consideration: and to show that these are not mere matters of speculation, I may mention that they are actually used in France for driving small and delicate machinery, and are found to be well adapted for nice workmanship, where great power is not required, as they are clean, easily managed, and cool. But they are more expensive than steam-engines. To produce a given total amount of energy, the electro-magnetic engine consumes thirty-two pounds of zinc for every six pounds of coal that the steam-engine consumes; but, from the better economy of power of which the electro-magnetic engine is capable, it is possible that, for a given *useful effect*, the ratio of consumption may be one pound of zinc for one pound of coal, which would still leave a great excess of cost against the electro-magnetic engine. The subject is, however, well worthy of attention.

With regard to railways, there are many questions yet to be decided; for instance, we do not at present possess a perfectly satisfactory permanent way, and we require much more experience before we shall possess it. The quality of rails used, too, is unsatisfactory, and requires improvement. Another want in railways is the means of going up inclines as steep as those on common roads, without the use of stationary or auxiliary engines, and that is a thing which, I have no doubt, can be attained by perseverance and careful study.

Improvements in canals are also proper for our consideration, such as the form of boats causing the least resistance, and also the best mode of traction along canals. At this late hour of the evening, I shall only mention docks, harbours, and sea-works in general; for the subject, if I went into it, would lead me to occupy your time too long.

The electric telegraph is also a subject in which mechanical engineers are concerned—at least with reference to the machinery required for the submersion of submarine cables. It is evidently a problem, what is the best machinery for that purpose.

Then there is sanitary engineering—drainage, cleansing, ventilation, water supply—and the ventilation of mines. There is the arrangement for the production and supply of gas; and on this subject I may say, that it is desirable the matter should be studied with a view to discover some mode of diminishing the cost of gas.

The next subject upon which I shall touch is that of accurate workmanship, one of the most important means of promoting economy in machinery, for it is the means of diminishing friction, wear and tear, and breakage, and tends to economise power, money, and materials. It is simply by accurate workmanship that Mr. Whitworth has produced a rifle that will carry a ball accurately a mile. This leads to the question of improvements in tools, another most important matter, but so well appreciated in this great mechanical city, that I need not do more than mention it.

Another point of great interest is the reform of the present system of measures, especially those of length. The civil engineer uses the *mile* for measuring a long distance, the *chain* for a shorter distance, the *yard* for earth or rubble, the *foot* for ashlar masonry, timber, and the larger dimensions of iron structures; for scantlings of timber and iron, he uses the *inch*, which is also the unit of the mechanical engineer, and this is divided into eighths, sixteenths, and thirty-second parts. Now this complexity is most inconvenient, and should be reformed; but the difficulty is to get people to agree to a standard.

Legislation, too, as it affects engineering, is a subject of most important moment for our consideration. The patent law, although now greatly better than it was some years ago, still requires improvement, as regards both the law itself and its administration; and that is a topic that should be thoroughly discussed by an institution of engineers—of persons who both hold patents of their own, and use those of others, and who are therefore liable to be concerned very frequently with the patent law. Another kind of legislation to which an institution of engineers should turn its attention, is that concerning the public safety. If any laws of the kind be provided, they should be such as shall not check the enterprise of engineers and mechanics, nor waste time, nor involve any greater restraint or inconvenience than is absolutely necessary. And in order that the legislature may be fully informed of the facts that should guide them in framing laws on such matters, it is of the utmost importance that those subjects should be publicly discussed by such institutions as ours. I refer to this now, because I am sorry to observe a disposition on the part of some very eminent persons, to recommend restrictions that I should think very injudicious. For instance, at a recent meeting at Birmingham, one of the most distinguished men in the world—Lord Brougham—suggested that the speed of railway trains should be limited to twenty-five or thirty miles an hour. Now, with proper care and good management, a speed of seventy miles an hour can be made as safe as one of seventeen: accidents do not arise from the degree of speed, but from bad construction or mismanagement; and the putting of a restriction on the speed is not, therefore, the proper way to prevent them. Good workmanship and good management are what are required, and not a diminution of speed. To prevent a horse from running away, we should not tie his legs, but put a good rider on his back.

Having thus far touched upon a few of the subjects which it will be our province to elucidate, I shall conclude. The matters I have brought under your notice, are but a few of those which lie in the vast field that is before us. The locality in which our Institution is established, is probably the very best we could have selected, and on this point I cannot help repeating to you the excellent observation that Sheriff Bell made at a public meeting last year. He remarked that Glasgow combined in itself the advantages of Manchester, Liverpool, Birmingham, and Newcastle, with some peculiar advantages of its own; that it had the manufactures of Manchester, the shipping of Liverpool, the hardware of Birmingham, and the coal of Newcastle, along with its own advantages. In fact, considering the vast extent and great perfection with which some branches of practical mechanics are here carried on, more especially in undertakings on a large scale, such as iron shipbuilding, and steam-engine making, we may say that Glasgow is the METROPOLIS OF MECHANICS. If an institution of engineers is to make good progress anywhere, it ought to be in Glasgow. I trust that, in this respect, my most favourable anticipations will be before long fulfilled, and that our Institution will prove of benefit to practice, to science, and to the country.

On the motion of Mr. NEIL ROBSON, seconded by Mr. JAMES FERGUSON, a cordial vote of thanks was passed to the President for his address.

The following discussion then took place:—

On Mr. Whitworth's proposed System of Decimal Divisions of the Inch.

The PRESIDENT—referring to the observations which he had made, in the course of his introductory address, on the acknowledged evils of the existing system of measures of length—said, that proposals for obviating those evils were proper subjects for the Institution to discuss. Amongst those proposals was that of Mr. Whitworth, to adopt a decimal division of the inch for all purposes of mechanical engineering, instead of the binary division now used. Mr. Whitworth proposed to adopt a system of gauges and sizes, which should be certain exact numbers of *thousandth parts* of an inch, instead of certain exact numbers of *thirty-second parts*, and to substitute for the present numbers on the wire-gauge, which are of uncertain meaning, and indicate different sizes in different localities, a series of numbers expressing the number of thousandth parts of an inch in the thickness of the wire or other thing measured. Thus, No. 64 on Mr. Whitworth's wire-gauge would mean ·064 inch ($\frac{64}{1000}$ths), and would nearly agree with the present No. 16; and the numbers on the new gauge would follow the order of size, instead of the reverse order, as they now do. Mr. Whitworth's proposal had been discussed at great length at the recent Manchester meeting of the Institution of Mechanical Engineers; and its essential principle had been adopted by that body to the extent expressed by the following resolution:—

"This meeting pledges itself to the adoption of the decimal scale, the inch being divided into a thousand parts."

The President added, that he did not propose Mr. Whitworth's system for adoption by the present meeting, but as a matter worthy of consideration and discussion.

Mr. JOHN DOWNIE laid before the meeting a scale used by him in the execution of Government orders, and in which the inch is divided into hundredths. He also exhibited, as a practical application of the decimal system which had long obtained, a couple of gauges for shot—one being what is termed high gauge, and measuring 4·117 inches; and the other low gauge, measuring 4·083 inches. He remarked, that very great difficulty was found in working to the $\frac{1}{1000}$th, or even the $\frac{1}{100}$th of an inch; that these quantities were quite inappreciable by the present class of workmen, although he did not doubt that, in course of time and with proper training, the accuracy of workmanship corresponding to them might be attained.

In reply to a question from Mr. NEIL ROBSON,

The PRESIDENT stated that, at the Manchester meeting, it was only with reference to the inch that the decimal system of subdivision had been discussed.

Mr. ROBSON thought it was somewhat premature to come to a determination on the subject, especially as regarded larger measures than the inch. He would not, however, oppose the passing a similar resolution to the Manchester one as far as regards the inch, that being, in his opinion, a step in the right direction, so far as it went.

Mr. WALTER NEILSON thought that there was no difficulty in working to hundredths or thousandths of an inch, such as to affect the principle of decimal divisions. Where minutely accurate workmanship is not required or attainable, the smaller divisions need not be used. It was a question of mere name. If a size were expressed in thousandths of an inch, a man could work as near the particular thousandth required as he could if it were a sixteenth or an eighth, although his work when finished might be more than one-thousandth of an inch from the truth in either case. The subject was undoubtedly one of great importance. It caused an extraordinary excitement at the Manchester meeting of engineers at which he was present; and it was then attempted to settle and fix upon the adoption of Mr. Whitworth's system without further consideration. He (Mr. Neilson) would certainly object to adopt a decimal division of the inch. Our whole system of measurements required reformation. Any partial plan would merely increase the confusion. No one could for a moment deny the absurdity of the existing system of weights and measures of this country. He did not believe a single person present could repeat from memory the entire table of weights and measures. Our neighbours, the French, have long since adopted a beautiful and complete system—one that can be taught to a person of ordinary intelligence in a very few minutes, whilst its elements are so simple, that the whole will be easily remembered during one's whole life. Now, if we in this country adopt a new decimal system with the inch as unit, we shall copy the French as far as regards the principle, whilst our actual measures will be quite different from theirs. Their system and measures have now had a long trial, and are found to work very satisfactorily. Why, then, should we not at once adopt their system and measures thus ready to our hand, instead of wasting time in discussing a new or different unit? Mr. Neilson was aware that it was a matter of controversy, whether we or the French had adopted the best standard of linear measurement; but he did not think the difference was of any practical importance, and he should certainly advocate the adoption of the French system.

The PRESIDENT remarked, that those who spoke at the Manchester meeting, being mechanical engineers, discussed the decimal system with the inch for its unit as being the most convenient for them, and did not enter into the question as to what might be convenient for others.

Mr. D. MORE said, he understood the Government contemplated before long taking into consideration the reformation of the weights and measures of the country; and he thought the Institution should send up a petition to Government in favour of a general decimal system, and that the various scientific institutions in England should be invited to join in such a petition. He quite agreed with Mr. Neilson, that Mr. Whitworth's proposed system was of too partial a nature.

After a few further remarks from various gentlemen, the discussion of the subject was adjourned to a future meeting.

The following paper was then read:—

On M. Beaufumé's System of Heating Steam-Boiler and other Furnaces by means of Gas produced by a Partial Conversion of the Coal. Compiled from Documents communicated by the COUNT DE LA TAILLE DES ESSARTS.

INSTEAD of burning coals in the furnaces of steam boilers in the ordinary way, M. Beaufumé first converts them into gas, and then burns this gas beneath the boilers. The ordinary coal gas or carburetted hydrogen produced by distillation in closed retorts, though well adapted for lighting purposes, is too costly where great heating power is required. The gas produced by M. Beaufumé, is a mixture of carbonic oxide and carburetted hydrogen, and possesses great heating, but small lighting power. He obtains the gas by partially burning and wholly distilling the coal in a furnace or gasifier, into which the proper quantity of air is forced. This air passes through an incandescent layer of the coals, and its oxygen combines with the carbon to form carbonic acid gas, which passing upwards through less heated layers of coal, assumes a second equivalent of carbon, and becomes converted into carbonic oxide. It is a mixture of this carbonic oxide with the distilled hydrocarbons of the coal which is conveyed to and burned in the furnace of the steam boiler, after being mixed with the quantity of atmospheric air necessary for complete combustion, which takes place without the production of smoke.

The inflammable gas is produced in what M. Beaufumé calls a gasifier. This apparatus is represented in longitudinal and transverse vertical section in figs. 1 and 2, Plate I., and consists of a furnace, A, very like a locomotive fire-box in shape, and surrounded on all sides except beneath the grate-bars, B, by a water space, C, which prevents loss of heat by radiation, and in fact constitutes a small detached boiler raising a certain amount of steam to be added to that of the main boiler. The furnace is filled with fuel to a considerable height, say 20 to 28 inches, according to the quality of the coal. The coal is introduced by two double-valved passages, D, in the roof of the furnace. When the outer cover, E, of either passage is opened, the valve, F, at the inner end is closed to prevent the escape of gas. When the fuel is introduced into the passage, the outer valve, E, is closed, and the inner one, F, opened, and the fuel falls into the furnace, no more gas escaping from the furnace than the small quantity filling the passage, D. Instead of leaving the supply of air to the uncertain action of a draught, the proper quantity is forced between the firebars by a blowing-fan. The air enters the ashpit, G, by apertures, H, on opposite sides, whereby a uniform pressure is obtained without partial currents. When the apparatus is properly regulated, the top layers of coal remain in a black and comparatively cold condition, the layers near the fire-bars alone becoming incandescent. Carbonic acid gas is produced amongst the incandescent layers of fuel; but this gas passing up through the comparatively cold layers, combines with additional carbon to form carbonic oxide. This carbonic oxide, mixed with whatever gases are formed from the bituminous constituents of the coal, passes off by an outlet, L, near the top of the furnace, and is conveyed by the pipe, M, to the furnace, N, of the steam boiler, O. Certain simple but peculiar arrangements are necessary in the boiler furnace for the efficient combustion of the gases. The air to be mixed with the gases is supplied by means of the same blowing-fan which supplies air to the gasifier, and is made to traverse a circuitous passage, P, exposed to the waste radiant heat of the furnace, so as to become heated. The inflammable gases issue from the supply pipe, M, by a series of passages, R, arranged in a horizontal line at short intervals apart, whilst the air issues by passages, S, occupying the intervals between the gas passages, R. In fig. 1, the section is taken through one of the air passages, whilst in fig. 2, the pipe, M, is sectioned in such a way as to show the gas passages. With this arrangement the air and gases become well mixed, and are burnt in a uniform and complete manner. Several fire-brick arches or deflectors, T, are arranged in the furnace to insure the complete inflammation of the gases, by receiving a portion of the heat of the flames already formed, and communicating it to the as yet uninflamed gases. These deflectors also serve to a certain extent to protect the boiler surface from the too intense action of the flames. The gases remaining after combustion pass through the flues, and escape into the atmosphere, under the pressure due to the blowing-fan, no chimney being required.

Amongst details not specially referred to in the preceding description, are—

The air-ducts, I, J, the former of which conveys air to the steam boiler furnace, whilst the latter admits the supply for the gasifier into a passage, K, beneath the ashpit, G, and communicating with the apertures, H, at each end. A portion of the air-duct, I, is seen in fig. 1, where a damper, Q, is applied for the purpose of regulating the supply. From this point the passage is carried along to the back-end of the boiler, near the bottom surface of the furnace, and is shown returning at P, fig. 1; this circuitous route being adopted to heat the air by the heat that would otherwise be wasted. A pipe, U, is provided for the discharge of the products of combustion on the fuel in the gasifier being first lighted. The gasifier boiler is provided with safety valves, V, and the steam from it passes off by the pipe, W, from which a branch, X, conveys a supply to the small donkey-engine driving the air-fan, whilst another branch, Y, communicates with the main boiler, O. It is found advantageous to inject steam occasionally below the furnace-bars, B, of the gasifier furnace, and this is done by means of the pipe, Z. Valved openings, *a*, are formed in the side of the gasifier for the purpose of examining and stirring the fuel, and doors, *b*, are provided for cleaning the furnace-bars and ashpits.

RESULTS OF EXPERIMENTS MADE AT CHERBOURG WITH M. BEAUFUMÉ'S HEATING APPARATUS.

Date.	Duration of Experiment.		Total amount of Fuel Consumed.	Kind of Fuel.	Water Evaporated.			Observations.
					During the Expmt.	Per Hour.	Per lb. of Coal.	
Series No. 1. The Boiler of the Forge heated by the ordinary Furnace.								
May	H.	M.	lbs.		lbs.	lbs.	lbs.	
7	8	30	970½	Large Newcastle Coal.	4620	543·5	4·865	
8	8	31	1014½		4905	561·9	4·835	
Series No. 2. The Boiler of the Forge heated by the Beaufumé Apparatus.								
May								
28	8	45	908½	Large Newcastle Coal.	5640	644·4	6·21	
29	8	30	1058½		7110	836·5	6·71	
30	8	30	1021		6621	778·5	8·26	
Series No. 3. The Boiler of the Forge heated by the Beaufumé Apparatus.								
June								
2	8	30	847	Small Coal.	6131	875·6	7·24	
4	8	30	811½	Cardiff.	6744	791·8	8·30	
6	8	0	761	Newall's Llanelly.	5518	689·7	7·25	
Series No. 4. A Tubular Boiler heated by the Beaufumé Apparatus.								
June								
12	7	0	1500	Newcastle Coal.	12751	1821·6	9·035	Weather cold.
15	5	15	849		7353	1400·4	8·066	
16	7	15	1235		12218	1676·2	9·820	
17	7	0	1235		11618	1659·7	9·407	
18	6	0	1058½		9788	1631·3	9·245	
23	5	0	1058½		9420	1884·0	8·897	Weather temperate.
25	9	0	2029		17719	1969·5	9·038	
26	2	30	476½		6921	1885·7	9·898	36 out of 106 tubes closed.
29	3	45	653		6923	1846·0	10·600	42 out of 106 tubes closed.

An apparatus constructed on M. Beaufumé's system was last year tried by the French Government, at the Imperial Arsenal at Cherbourg,* and the above table and notes are abstracted from a report of the experiments then made, by MM. Guesnet, Admiralty Engineer, and Sochet,

* Permission has been obtained to erect M. Beaufumé's apparatus at Woolwich dockyard, for the purpose of testing its capabilities.

Director of Naval Construction. Four series of experiments were made, the results of which are given in the table. The first three series of experiments were made with the boiler of the establishment, called the Northern Forge at Cherbourg. This boiler was of 12 horses power, it had a total heating surface of 167¼ square feet, and its ordinary grate surface was 12¼ square feet. The gasifier supplied by M. Beaufumé had a grate surface of 5¼ square feet, and a depth of fuel of 27½ inches could be consumed in it. The apparatus was 11½ feet high, and occupied a space of 10 feet by 6½ feet. The air-supplying fan was driven by a donkey-engine at the rate of 1000 revolutions per minute, and the blast produced was equal to a column of water 1·97 inches high.

The fourth series of experiments were made with one of four tubular boilers, lying in the boiler-yard at Cherbourg, ready for the steamer *Antelope*.

MM. Guesnet and Sochet conclude their report in the following words:—

"From what has been said, it is obvious that M. Beaufumé's heating apparatus works with perfect regularity; is quite free from smoke; and effects a great saving. The saving derived from it, as compared with the ordinary system of heating, reached as much as 38 per cent. in our experiments, and there is no doubt that the saving of one-third may be reckoned upon with certainty.

There are no difficulties in working the apparatus; it requires perhaps a little extra care and attention, but not so much as to constitute a matter for serious consideration.

It has the advantage, above all, of being able to use economically fuel of a kind which can only be burnt in ordinary furnaces with great difficulty, such as small coal.

It has the inconvenience of throwing a quantity of carbonic oxide into the boiler-house, and although this is not of much importance on land, it might be serious on board ship. This defect is less, the less frequently the fuel is stirred up; and with Cardiff coals it scarcely exists, as they do not require stirring up. We must also remark, that although M. Beaufumé's apparatus has reached a practicable state, it is still too recent an invention to be incapable of improvement, and M. Beaufumé hopes, and we believe it quite possible, to remove the defect in question altogether.

With this apparatus the getting up of steam at starting requires no more time than with ordinary furnaces, when the boiler works every day; but it is otherwise when the apparatus is cooled down, and no motive force is at hand to drive the blowing-fan, before the gasifier is itself capable of driving it. An extra half hour is, under these circumstances, always required to get up steam in the boiler. This is doubtless a great inconvenience, but it would disappear if a small donkey-engine, with a small boiler capable of getting up steam very rapidly, were employed specially to set the apparatus agoing.

Finally, this apparatus takes up a little more room than is ordinarily required.

We do not think that the inconveniences we have pointed out can be compared with the advantages of regularity, freedom from smoke, and great saving which it possesses, more particularly over all land boilers; and we consider this new system of heating so decided an improvement upon other systems, that it will be desirable to make some attempts to introduce it for marine purposes also.

We must not conclude this report without mentioning, that the Beaufumé apparatus may be employed in the arsenal in other ways besides heating steam boilers. It could probably be used with great advantage in the furnaces of the forge, and it would be desirable to try it for this purpose at Guérigny."

The PRESIDENT gave the following additional particulars:—The experiments at Cherbourg were made under very unfavourable circumstances. The boiler used in the first, second, and third series of experiments was evidently a very bad one, as, with the ordinary furnace, only 4·83 lbs. water were evaporated per lb. of coal. In all the experiments the water supplied to the boiler was cold; and as it is usual to reduce the results of experiments of this kind to the results which would have been obtained if the boiler had been supplied with water of a temperature of 212°, we must add 18 per cent. to the results obtained in the first, second, and third series, and 16 per cent. to those obtained in the fourth series of experiments. With this correction, the results obtained become in one case 9·8 lbs., and in another 10·5 lbs., evaporated per lb. of coal. The proprietors of the apparatus obtained even better results in their own experiments, in which the water supplied was of a temperature of about 100°. One of the best results obtained was equivalent to an evaporation of nearly 12 lbs. of water per lb. of coal from a temperature of 212°.

Mr. WALTER MACFARLANE, being under the impression that the paper on Mr. Beaufumé's apparatus had already been published in one or two scientific periodicals, expressed his opinion that sufficient original talent might be found amongst the members of the Institution without having recourse to materials which were patent to the entire public, as appeared to have been the case in the present instance.

The PRESIDENT explained that the report of the experiments at Cherbourg had been translated into English, and printed for private circulation only; and that one or two copies had been given to the editors of the periodicals referred to, after it had been arranged to bring the matter before the present meeting. Nothing, however, but the report or portions of it had as yet been published, whilst the abstract from the report formed only a portion of the paper just read, that paper containing, in addition, a full description and drawing of the apparatus, and various important particulars—in fact, the more valuable portions of the paper had not been published.

Mr. WILLIAM DARLING said, that a great portion of the heat derivable from the fuel was already given out during the formation of carbonic oxide, and that the combustion of this gas could only yield a small additional quantity of heat corresponding to its conversion into carbonic acid. The furnace was a variety of the many schemes for admitting air behind the fire-bars, a mode which failed in practice, as evinced by the large quantities of carbonic oxide poured forth from our chimneys every day. He thought M. Beaufumé's system too roundabout.

Mr. J. G. Lawrie thought the Beaufumé apparatus a mere modification of the innumerable smoke-burning furnaces already in existence. Its chief point seemed to be a proper regulation of the supply of air, although this regulation might not be effected in the same way as in other arrangements. The whole secret of smoke-burning lay in proportioning the supply of air to the actual requirements of the fuel. If there was too little air, there was smoke; and with too much air, there was waste of fuel.

Mr. John Elder thought the evaporation of 10 lbs. of water per lb. of coal was too strong a fact to leave room for a theoretical discussion on the action of the gases and the burning of the smoke. Such a result was much beyond his experience; and if the fact of its being obtained could be established, the value of the system could not be disputed.

The President remarked, that the results mentioned rested on the authority of the French engineers appointed by Government.

Mr. Elder thought that the burning of 40 lbs. of coal per square foot of grate might be due to the blast.

The President said that the burning of so much coal per square foot was owing to the fact, that a partial combustion only took place in the gasifier.

Mr. G. Harvey remarked, that the heat given out on the formation of the carbonic oxide was not lost, the gasifier being surrounded by a water-space which utilised it.

Mr. D. More remarked, that, however good the results obtained might be, we must think of the stokers. The escape of the gas into the boiler-house was a great objection; and, unless that could be done away with, the apparatus could not be used. He thought that if the coals were thoroughly consumed, and reduced to ashes in a common furnace, as much heat would be got as by the roundabout plan of first making gas of them, and then burning the gas. No more heat could be got out of the coal than was in it.

Mr. J. Elder had generally observed that the greater the heat of the furnace the better was the result obtained; and he thought that the good results in the present case might arise from the very great heat in the furnace.

The President remarked, that the gasifier furnace was surrounded by water to keep down the heat, as the inflammable gases could not be produced in the manner wanted were the heat of the gasifier to become too great. The furnace of the main boiler was fitted with fire-brick arches to distribute the heat amongst the gases, and to render the combustion complete.

Mr. D. More said, that however interesting patent smoke-burning schemes appeared to be theoretically, he had generally found the promised saving of fuel to end in smoke. He was disinclined to believe French experiments and figures, having more faith in English ones.

Mr. Tait said, he should receive the particulars and alleged results of such experiments with much doubt and hesitation, and from what he knew of similar experiments, he believed that the economy of fuel consequent on the peculiar arrangement of this furnace, would be found when worked with ordinary care, and under ordinary circumstances, to be somewhere about half that reported. It was possible, however, that its economy might be on a par with that of furnaces of ordinary construction.

The President mentioned that an apparatus on Mr. Beaufumé's system was shortly to be erected near Glasgow to heat four reverberatory furnaces; and when it was in action, the members of the Institution would have an opportunity of ascertaining the results for themselves. He moved a vote of thanks to the Count de la Taille des Essarts, by whom the paper had been communicated. This vote was seconded by Mr. Robson, and passed.

The Second Meeting of the Session was held in the Philosophical Society's Hall, on Wednesday, 25th November, 1857. The President occupied the chair during a portion of the proceedings, after which it was taken by Walter Neilson, Esq., of Hyde Park Foundry, Vice-President.

The following paper was read:—

On Blowing-Fans. By Mr. John Downie.

About ten years ago the writer had his attention drawn to the subject of fan-blowing, in consequence of the great absorption of power by two 4-feet fans of the ordinary eccentric construction, applied to the blowing of foundry cupola furnaces at the works with which he was then connected; and with the view of endeavouring to economize that power, a series of experiments were then begun, which have since led him to adopt a totally different form of wind-case and rotating propeller. Figs. 1 and 2, Plate II., are vertical sections of the apparatus, and a working specimen of a 3-feet drum or propeller is exhibited, which last will give a much better idea to practical men of the general construction employed.

The first alteration from the old stereotyped form, was suggested by the fact, that in nearly all fans of the ordinary construction, a considerable outward current, or "blowing-out" of the air, takes place at the ear opening—generally in the directions indicated by the arrows at A in fig. 3—whilst the air rushes in at the lower portion of the opening, as shown by the arrows at B.

Conceiving that if this counter-current (through which the propelling blades or paddles had to be driven) were removed, a considerable saving in power and gain in effect might reasonably be looked for, the first alterations that were made went solely to remedy that defect. This was done by bringing the circumferential sheet-iron of the case down to the vertical centre line, a piece, of the form indicated by the dotted lines, being introduced in the common fan, so as to do away with the blunt point, C, and presenting instead a knife-edge, as it were, at the point of delivery. This simple expedient had an extraordinary effect in reducing the "blowing-out" qualities of the fan under experiment, although the fan still adhered to a little of its old practice.

It, however, gave sufficient indication of being a move in the right direction, by saving power and gaining effect, to induce the writer to design a new fan, to blow in two opposite directions at the same time, and to do the work of the two fans already referred to. This gave an opportunity for going into the question of the general proportions of the parts of such a machine. The first thing that strikes one as peculiar in a 4-feet fan of the usual proportions, is the large allowance of ear opening (generally half the diameter of the blades), compared with the area of the discharge aperture (usually about 12 inches square in such a fan); and the inquiry naturally arises, why an area of more than 900 square inches should be allowed in the ear openings, to supply a discharge of about 144 square inches? Again, the large ear openings necessarily induce a shallow case, and admit of only a very short blade or paddle, so that the inward current of air is met by the heels of the blades running at a very high velocity, and it does not, nor can it, impinge on these without considerable resistance. The blunt point, too, at C, fig. 3, is not much in favour of speedy egress after the air has attained the velocity of the blades. In fact, it cannot be expected, that air, brought gradually to a high velocity by circular motion, will, without resistance, leave at a tangent the circle in which its motion has been generated; and it is this resistance which causes and explains the counter-current, or "blowing-out" at the ear openings, and the consequent loss of effect and absorption of driving power.

The writer, following out these ideas, constructed the double eccentric 4-feet fan-blower, shown in section in figs. 4 and 5. In this blower the ear openings are of only one-third the diameter of the blades, and have an area of about 400 square inches. The points of discharge or deflection, D, are carried round about 45° past the vertical centre line of the fan, and the discharge aperture is increased to 36 × 12 inches, or to an area of about 430 square inches, so as to be a little in excess of the inlet area, and thus secure free egress to the air, which, being driven off in the circle in which it is set in motion simultaneously at the opposite knife-edge points, D, is then gradually brought to the straight line of the conduit pipe. The rotating propeller was similar in form to those used in the two superseded fans, the only difference in construction being the substitution of a wrought-iron centre disc, to which the blades were riveted, instead of the usual cast-iron centre. It may here be observed, that the same driving pulleys and gearing were used in both cases. The distance the air had to travel before discharging into the cupola furnace, was about 100 feet, and the indicated pressures were all taken at the tuyere pipe at that distance from the fan. The power absorbed was ascertained by a dynamometer brake, and the pressure of the air by a siphon tube filled with water in the usual way.

The following experimental data and results exhibit the effect obtained by altering the form of the fan-chest or wind-case.

Kind of Fan.	Diameter.	Revolutions per Minute.	Velocity of blade tips in Feet per Second.	Pressure in Inches of Water.	Power Expended.
No. 1, Common, ...	4 feet	1500	312·5	7½	16 H.P.
No. 2, Common, ...	4 feet	1200	250	5	12 H.P.
No. 3, Double eccentric, (Figs. 6 & 7).......	4 feet	1500	312·5	10	14 H.P.

Fans, Nos. 1 and 2 thus absorbed altogether 28 H. P., these results being obtained whilst the fans were blowing into the tuyeres, the area of which was about 100 square inches.

The results noted for fan, No. 3, were obtained when discharging air both ways, whilst on the blast being concentrated to one set of furnaces (the velocity remaining the same), the pressure was equal to 12½ inches water, about 9¾ H.P. being expended. The tuyere area of the cupolas was enlarged fully 50 per cent., or to about 160 square inches, when the new fan was started, the results consequently showing a greater proportionate advantage arising from the alterations.

Other fans were constructed on the same plan, with similar results, but with no modification in their construction, save that the wind-case formed a separate part, and side cheeks were bolted on, of the full diameter of the blades; so that in case of accident, or for repair, they might be taken off, and the propeller removed from the case, without taking the whole machine to pieces. This arrangement has frequently been found of much importance in the writer's practice, as fans so constructed have been taken apart for trifling repair and put together again in little more than half an hour, thus saving great trouble with furnaces and much valuable time, a consideration of no mean importance to the ironfounder.

We now come to the modified form of propeller represented in figs. 1 and 2. Hitherto the form of wind-case was nearly all the writer had attempted to alter, but, about five years ago, a new feature presented itself in the requirements of two large cupola furnaces, which were connected to a chimney 200 feet high, by a flue near their tops, and consequently necessitated a very great increase in quantity and also in density of blast. On looking around for something to supply this want, and on comparing notes, the writer found that the fan with improved wind-case (which has just been described), gave as good results for the same expenditure of power as any of the ordinary fan-blowers then in use, and he set about designing a propeller of the form exhibited and represented in figs. 1 and

2. This fan or air-propeller is made with curved thoroughfares diverging from points near the centre to the periphery of the drum, the whole being closed at the sides, and also between the outer ends of the thoroughfares round the circumference.

The objects the writer had in view in adopting this construction were—

1st. To prevent the air in front of the blades from getting over their side edges and ends, to react inside the wind-case.

2nd. To prevent the air driven off at the points of discharge from getting back again, and to thus compel it to go right ahead.

3rd. To cause the air driven off in the circle in which it is set in motion (as already described) to leave the case with the minimum resistance, and thus produce a better effect.

The results obtained on trial exceeded the writer's expectations, and they forcibly indicate that the propulsion of a forced current of air is a matter as yet little understood by mechanical men, and that a large field for investigation is still open to all who choose to give the subject their attention. To ironfounders, particularly, the per-centage of saving obtainable in time and fuel is enormous, and will in a few months' time well repay the expense of a properly-constructed machine.

The following tabular statement gives the results obtained by the fan, combining the various improvements.

Kind of Fan.	Revolutions per Minute.	Velocity of Blade tips in Feet per Second.	Pressure in Inches of Water.	Power Expended.	Area of Tuyere Discharge.
30 inch Fan,............	1100	162·5	8½	abt. 5 H.P.	150 sq. in.
36 inch Fan,............	1200	188	11½	" 8 H.P.	500 "
Do.	1500	235	15½	" 10 H.P.	500 "
50 inch Fan,............	1000	218	15	" 12 H.P.	500 "
Do.	1200	260	18½	" 15 H.P.	500 "

These are the results obtained with the fans in use at the North Woodside Iron Works, where they may be seen at work during melting time by any one desirous of examining them.

The writer some months ago supplied a 50-inch fan to the Anderston Foundry Company for their large 10-feet cupola furnaces, but as their steam-engine was already burdened, they could not spare the power necessary to drive it efficiently. It was taken out after trial, and their old one, a very excellent specimen of the common construction, 42-inch diameter, again put in. During the time the new one was in use, the results were noted by Mr. M'Ilwham, the manager, who has very kindly furnished the following details:—

"The old 42-inch fan running at 1814 revolutions per minute, the velocity of the blade tips being 240 feet per second, gave 10 inches of water, when blowing into tuyeres with an area of about 450 square inches.

The new 50-inch fan running at 1054 revolutions per minute, the velocity of the blade tips being 230 feet per second, gave 14 inches of water, when blowing into the same tuyeres."

The conclusions to be drawn from the experiments described are, that with a given proportion of driving power, a considerable increase in effect, both as regards pressure and quantity of air discharged, may be obtained, by a suitable adaptation of parts in the fan-blower; and no doubt many improvements remain to be made in this much-neglected, though most valuable assistant in the daily enlarging operations of the engineer and ironfounder.

At this stage of the proceedings the President vacated the chair, which was taken by Walter Neilson, Esq.

The discussion of Mr. Downie's paper was deferred until after the following paper was read:—

On a Blowing-Fan. By W. J. Macquorn Rankine, LL.D.

To reduce to the smallest possible amount the waste of power in a blowing-fan, the changes in the velocity and direction of motion of the air ought to be made as gradually as possible.

The velocity of the air required in the discharge pipe is in general considerably less than that of the air in contact with the tips of the fan-blades. In order that this diminution of speed may take place by degrees, and may give rise to increased pressure instead of merely wasting power in eddies, friction, and noise, there should be a certain clear space all round the fan, in which the air, after leaving the fan-blades, may perform a certain number of revolutions before being discharged. The advantage of such a space appears to have been known by practical experience to Mr. Appold some years ago. Mr. James Thomson was the first to point out the theoretical reason for it.

In the experimental fan, made by Mr. J. R. Napier and the author of this paper, the mean radius of the case is to the radius of the fan, as the velocity of the tips of the blades is to the velocity of the air in the discharge pipe; that being the proportion indicated by theory as the best.

Besides the change of velocity which the air undergoes in passing from the fan to the discharge pipe, there is the previous change, both in velocity and direction of motion, when the air receives its whirling motion from the fan; and this also ought to be performed as gradually as possible. In the experimental fan referred to, the blades are made of the curved form shown in fig. 6, Plate II., so that their inner edges *cleave* the air without striking it. The air, in passing outwards along the blades, gradually receives from them a more and more rapid whirling motion, until at the outer edges, where the blades are in the direction of radii, the velocity of the air is the same with that of the blades.

The fan works with no noise, except a slight fluttering sound, inaudible beyond a few yards. The absence of noise is a sign of economy of power.

The proportion of the power wasted during the changes in the motion of the air, may be estimated by comparing the pressure which would be produced in the discharge pipe if there were no waste of power, as computed theoretically, with the actual pressure as ascertained by experiment.

The theoretical pressure depends on the figure of the blades, and the ratio of the diameter of the fan to that of the case, and is determined by a mathematical equation, which will be found in an appendix to this paper. It is sufficient to state here, that the theoretical pressure at the outlet of a fan formed and proportioned like that now described, is that due to the weight of a column of air of *one and three quarter times* the height from which a body must fall to acquire the velocity of the tips of the blades.

In the experiment made, the number of turns per minute was 1000.

The circumference of the fan is 11 feet.

Hence the velocity of the tips of the blades was 183 feet per second.

The height due to that velocity is 520 feet; and one and three quarter times that height is 910 feet.

It is usual to measure and state the pressures produced by blowing machines in inches of water. For the purposes of this calculation, it is sufficiently accurate to take air as having one-eight-hundredth part of the specific gravity of water.

Then 910 feet of air $= \frac{910}{800} = 1\cdot14$ feet of water $= 13\cdot7$ inches of water, which is the theoretical pressure at the *commencement of the discharge pipe.*

The pressure was ascertained by experiment at a part of the discharge pipe, between 40 and 50 feet from the fan; the pipe was about one foot square, and the loss of pressure in overcoming the friction in it, must have been at least two inches of water.

Hence we have—

	Inches of Water.
Theoretical pressure at outlet of case, as above,	13·7
Less friction in discharge pipe,	2·0
Theoretical pressure at the part of the pipe experimented on,	11·7
Actual pressure,	11·0
Leaving pressure wasted in the moving of the air by the fan,	·7 inch;

or *one-nineteenth* part only of the theoretical pressure at the outlet of the fan-case.

More experimental fans are now being made, and the results produced by them will be communicated to the Institution.

Dimensions of Fan.

Diameter of each ear,	20	inches.
Do. of fan,	40	"
Least radius of case,	36	"
Greatest,	48	"
Breadth,	12	"
Discharge trunk,	12	inches square.

Appendix.

The following is the formula to calculate the theoretical pressure at the outlet of the fan-case.

Let V = velocity of tips of blades, in feet per second; v = velocity of air discharged at the outlet of the case, in feet per second; then theoretical pressure in feet of air $= \frac{2 V^2 - v^2}{64 \cdot 4}$; finally, the theoretical pressure in feet of air $\times \frac{12}{800}$ = theoretical pressure in inches of water, nearly.

The difference between this and the actual pressure, shows the loss by friction and agitation of the air.

The following discussion took place on the subject of the two preceding papers:—

Dr. RANKINE further explained the principles on which his fan was constructed, and particularly the necessity of leaving a sufficient space round the tips of the fan-blades for the air to make one or two revolutions, and become reduced in velocity before leaving the case. He said it was to be regretted, that the power expended in the experiments could not be ascertained, from the impossibility of applying a dynamometer to the shaft, which drove other machinery besides the fan. In the portion of the air-pipe between the fan and the point at which the pressure was tested, there were several abrupt angles, making the course of the air very irregular, and $2\frac{1}{2}$ inches would probably more nearly represent the loss of pressure sustained, than the 2 inches mentioned in the paper; but it was thought better to err on the safe side. The result obtained was therefore very good, as, notwithstanding the smallness of the deduction made for resistance in the pipe, it showed that not more than the power corresponding to $\frac{1}{10}$ inch of pressure was lost or misapplied in moving the air. He intended making further experiments in which he should not adhere exactly to the form shown. He would communicate the result of those experiments to the Institution.

The CHAIRMAN (Walter Neilson, Esq.) remarked, that the subject before the meeting was one of great importance. Blowing-fans were of late years much more generally used than formerly. He had no doubt many present could remember the time when there were only one or two in all Glasgow, whilst there would now be hundreds. Not only smiths' forges, but large cupolas used to be blown by bellows. Many would agree with him that a large amount of coals or H. P. was daily wasted in Glasgow in driving improperly-constructed fans. It was undoubtedly a question of great practical bearing, and the Institution would be doing its duty in requesting Dr. Rankine to follow up the application of his theoretical principles. Whilst we had the theory from Dr. Rankine, we had, on the other hand, Mr. Downie's practical results. There seemed to be a little difference of principle in the two arrangements; Mr. Downie's fan expelled all the air as it was admitted, whilst the other fan expelled only a portion.

Dr. RANKINE said, he had not come forward with theory merely, but with practice; he had given the performance of an actual fan. The theory had been understood many years ago; but the subject of air in motion was at present so obscure, that he would be a bold man who should publish an untried theory about it. He had said nothing about the fan, until he had actually seen it working. It was not quantity, but pressure which was required from this fan. The tips of the fan-blades moved at the rate of 183 feet per second, which was much faster than the rate at which the air was required to move along the pipe, and it was proper to let the velocity gradually subside, before the air left the case. In the fan he had tried, the air would perform about two revolutions in the space outside the blade tips before leaving the case. All the air entering the cases goes onward, and none reissues at the eye. He thought there was more resemblance between his and Mr. Downie's fan, than was at first apparent. Mr. Downie's fan was constructed on good principles, and he liked it much. The practical results Mr. Downie had obtained, were certainly very good.

Mr. J. R. Napier said, there was a remarkable circumstance connected with Dr. Rankine's fan, which was erected at the works with which he was connected. Dr. Rankine said it ought to produce 12 inches of pressure, and they got 11½ inches. The theory was, therefore, not far off the mark in this case. He thought the absence of noise was a direct proof of economy of power.

Mr. James Russell inquired on what grounds the absence of noise was considered to indicate economy of power? They had an ordinary paddle-fan some time since, which made a terrific noise; when, however, the blades were fixed to a central disc instead of the common arrangement of arms, there was almost no noise at all; but there was no apparent diminution in the power expended. If the having little noise was a criterion, it would be easy to ascertain which was the best fan.

Dr. Rankine said, that of two similar fans, the quieter one would certainly be the more economical. The degree of noise was by no means the sole criterion, but the presence of noise was an indication of vibratory motion, which must have had power spent on its production, and it would be better to save this power than make the noise.

Mr. David Rowan inquired the reason of the peculiarity in Dr. Rankine's fan of giving the air just two turns in the case. Would not more power be consumed by conveying the air over a longer course, and could not the velocity be reduced otherwise? Would not a difficulty be experienced in arriving at the conclusion that the air did make two turns, seeing there was no division in the case to separate the currents? If two turns in the case did the air good, why not give it four or five turns? He thought that in the fan shown in the diagram (fig. 6), the air would be too violently acted upon in consequence of the smallness of the blades.

Dr. Rankine said, there was no particular virtue in two turns; but it happened to be what was required according to theory, in the particular case for which the fan was designed. There was in every case a certain proportion of the parts which would leave just sufficient space to reduce the velocity of the air to what was wanted. If the air made three turns instead of two, its velocity would be still more reduced. The rule was simply to the effect, that if the velocity was to be reduced one-half, the outside diameter of the case should be double that of the blade tips. Partitions were not put in the case to separate the successive turns of the current of air, as it was better to avoid the increased friction that they would cause. No doubt a slight loss of power was caused by the increased length of course, but this loss was to be put against the loss that would accompany a too sudden change in the velocity of the air. There was undoubtedly less loss with a gradual change in the velocity. The matter rested only in part on reasoning, seeing the experimental results that had been obtained. Other experiments were to be made, and he did not think they had as yet by any means reached the best forms and proportions.

Mr. Downie remarked, that if the diameter of Dr. Rankine's fan was increased, it would give a longer and a better form of blade. In his opinion, the sooner the air was discharged the better, as it would get rid of friction inside the case. As regarded the loss of pressure caused by the friction of the air along the pipe, he had found in actual experiment, that at 100 feet distance the loss was equivalent to 2½ to 2¾ inches of water. For every rectangular bend in the pipe, there was about 5 per cent. of pressure lost. The quantity of air discharged was a point of great importance with reference to the power expended. He had found that the same power supplied a much greater quantity of air under a given pressure, when the discharge took place from two points of the fan, than with the common arrangement. His improved fan gave a much higher result for the velocity of the tips of the fan-blades, than most other fans. Mr. Schiele had seen a 30-inch fan of his running at 1200 revolutions per minute, and giving 8½ inches of pressure, whilst blowing into tuyeres 150 square inches in area; when he stated that a fan of the same diameter on his own principle would require to run at the rate of about 3000 revolutions per minute, and would not even then produce so great a pressure with the same area of discharge.

Mr. William Howie remarked, that a great deal depended on a proper arrangement of the pipe conveying the blast. By rounding what had been angles in a blast pipe, and extending the tuyeres, he had some years ago very much improved the action of a cupola. In comparing the result of different fans, it would be necessary to ascertain if any of the differences were caused by the arrangement of the pipes.

Dr. Rankine said, it would be useful to place some sort of instrument in the pipe to register the velocity of the air, so as to afford a means of comparing results.

Mr. Downie said, the velocity of the air depended in a great measure on the size of the discharge aperture; if this were enlarged, the velocity would be increased. If the outlet were too small, a portion of the air would have a tendency to come back through the ear.

Mr. Isaac Whitesmith thought the form of the blade had not been sufficiently discussed. In the ordinary fan, the blade was convex on the leading side, and the blade imparted the greatest velocity at the ear, and caused the pressure to increase as the air moved outwards. Such a form might be given that the air would be gradually taken up at the ear, and have its velocity as gradually reduced towards the periphery.

Dr. Rankine said, the velocity in an outward or radial direction was certainly greatest at the ear, but the circular or whirling motion increased as the air moved outwards from the ear to the blade tips, and it was desirable to change this as gradually as possible.

Mr. Thomas Brown said, that the blade in Mr. Downie's fan being concave on the leading side, would have a tendency to hook in the air. He should certainly turn the curve the other way, as it was an object to throw off the air as soon as possible. He (Mr. Brown) had made fans which discharged the air at two opposite points, and had found it a good plan. He thought the ear opening in Mr. Downie's fan was too small.

Mr. Downie said, that a convex blade tended to batter the sides of the case, and appealed to the practical results that had been obtained with his fan.

Mr. William Johnstone, considering that the subject was one of great practical importance, proposed that a small committee should be named to investigate, and report upon it.

Dr. Rankine seconded this proposal, which was unanimously approved of.

After some discussion, Messrs. John Elder, Isaac Whitesmith, Wm. Tait, and W. S. Dixon were named for the committee, but a final arrangement was postponed until a future general meeting.

The thanks of the meeting were passed for the papers communicated by Mr. John Downie and Dr. Rankine.

A portion of the following paper was then read:—

Description of a Steam Pumping-Engine now being constructed for the Glasgow Water Commissioners, at their Reservoir in Drygate Street. By MR. D. MACKAIN.

This engine is represented in side elevation in fig. 1, Plate III., and in plan in fig. 2, the pump being shown in section in the plan. The engine consists of a horizontal cylinder of 25 inches diameter, with a stroke of 4 feet, and is provided with a fly-wheel. It works two horizontal pumps of 14 inches diameter, with a stroke of 4 feet, and by means of two ram plungers.

This engine is being constructed from the designs of the writer, and is nearly a counterpart of another engine which has been in use for some years at the same place; the difference being that in the case of the earlier engine, the two pumps were closely connected, having only a plate with a stuffing-box between them; whilst in the engine now being made, there is a space of about 3½ feet between the pumps, permitting each to be more easily inspected and repaired.

The inducements for constructing the engine in this form are—1st, The lessened cost of building the engine-house, nothing beyond a foundation being required. The side walls are merely for shelter from the weather, and are in no way connected with the engine. 2nd, The construction of the engine, requiring no heavy weights to be raised when the ordinary repairs of pumping-engines have to be made, which, at a station, where there is no staff of men beyond the engineman and fireman, is found to be important.

One of the upper clacks is represented in vertical section in fig. 1, Plate IV., and in plan in fig. 2. It is of brass, and consists of an annular ring, working on a spindle in the centre. With this construction, the water passes through the centre of the valve when it is raised, as well as round the sides. The extreme diameter is 15½ inches, that of the central space being 6 inches.

The lower clacks are of the usual butterfly-valve shape, of leather strengthened with iron plates. A valve of this kind, in use in the engine at Dalmarnock, is represented in vertical section in fig. 3, Plate IV.

The valve seats, or cases, are all bulged out round the sides at A, so as to permit the free passage of the water past the valves when the latter are raised.

The piston-rod of the steam-engine passes through both ends of the cylinder, being connected to the fly-wheel on one side, and to the pump plungers on the other side. The plungers slide in brass collars in the pumps, and are connected by pump-rods which pass through stuffing-boxes, so that every precaution has been taken to prevent the "sagging" to which horizontal engines are liable.

The water pumped by the engine in use, is the surplus, beyond the wants of that part of the city termed the low-service district, which the main engines at Dalmarnock raise from the filters on the banks of the Clyde.

This surplus escapes by two overflow pipes, at the height of about 100 feet above high water of neap tides, and it is collected in a reservoir of masonry.

The average level of the water in this reservoir is from 5 to 6 feet below the overflows. From this level, the engine at Drygate raises the water to the further height of from 180 to 200 feet above the reservoir, or to a total height of from 270 to 300 feet above low water. The points of delivery of the water are not of these heights, but it is necessary to force the water under the pressure corresponding to them, in order to overcome the friction in the distribution pipes.

Th eengine already in use began to work permanently in August, 1855; and, with little intermission, it has continued to work since that time for seven days per week, and about twenty-three hours per day.

Only one of the lower clacks has as yet been changed, as worn out. The two upper valves have been removed, the injury to them having proceeded from defects in the brass of the lids, or valves.

The districts of the city which this engine supplies with water, are:—

St. Rollox, and Garngad Road.
The Rottenrow, and houses on the high ground near it.
The upper floors of Blythswood Hill.
Garnet Hill.
Hillhead, and the Great Western Road.
Woodside Crescents, and the New West-End Park.

The rapid increase of the population in these important districts, has rendered the construction of an additional engine necessary,

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Mr. Mackain said the engines described had been adopted on account of their simple construction. They required very little repair and their expense was much less than that of ordinary pumping-engines. He thought the smallness of the wear was attributable to the employment of a fly-wheel, by which the working of the valves was better regulated. It was well known that in pumping-engines without fly-wheels the valves experienced severe shocks from the steam. In answer to an inquiry Mr. Mackain said, that the pressure on the pump-valves was about 80 lbs. to the inch; that the engine worked at the rate of 25 revolutions per minute; that the pump raised 1200 gallons of water per minute 200 feet high; and that the engine cost £1200.

Mr. Walter Neilson said, he had seen the earlier of the two engines described, at work. It was exceedingly simple, compact, and cheap. He thought, however, that a short stroke for pumping-engines was entirely wrong. The longer the stroke was the better. His firm had recently made pumping-engines with strokes of eight to ten and even twelve feet, for sixteen to eighteen inch pumps, and he should recommend a stroke of twenty feet where it was attainable. The great aim in constructing pumping-engines, was to reduce the shocks occurring at each reversal of the motion of the parts. In an engine with a five-feet stroke, this reversal occurs three times as often as in an engine with a fifteen-feet stroke, the same quantity of water being lifted in both cases. He would recommend any future pumping-engine like Mr. Mackain's, to be made with a sixteen-feet instead of a four-feet stroke, and he did not think the cost would exceed half as much again as the engine described, whilst it would stand much better. The fly-wheel performed an important duty; it caused the motion of the plunger to gradually increase to a maximum at the centre, and then as gradually decrease towards the end of the stroke. In the common Cornish pumping-engines, on the other hand, the steam lifted a dead weight throughout the stroke, and then let it suddenly fall. At the same time, the shock was found to be very little in the Cornish engine; but this class of engine was not so suitable for supplying water to towns as for mining operations.

Mr. Mackain quite agreed with Mr. Neilson as to the preference to be given to long-stroked over short-stroked pumping-engines; but the engines he had described were merely for a temporary purpose, and looking forward to their being superseded by works of a more permanent character, he had, as much as possible, studied economy in the construction and working of the present engines.

Mr. Walter Neilson said, he ought to have mentioned that he was aware the present engines were auxiliary engines, and merely temporary. As such, they were the cheapest, and did the greatest amount of work that could be obtained for the outlay.

The President remarked that the different principles upon which pumping-engines were constructed, formed a very important subject for discussion by the Institution. The engine described by Mr. Mackain appeared to be the best that could have been adopted, considering the special circumstances of the case. He had seen the earlier Drygate engine, and could speak highly of it.

The discussion of this subject was continued at the next meeting, as will be found reported at page 84.

THE THIRD MEETING of the Session was held in the Philosophical Society's Hall, on Wednesday, 23d December, 1857, the PRESIDENT in the chair.

Mr. D. MACKAIN gave some particulars of Pumping-Engine Valves, in completion of his paper read at the previous Meeting. These particulars are incorporated in the paper as given at page 30.

The following paper was then read:—

On a Pumping-Engine Valve.—By MR. WALTER NEILSON, (of Hyde Park Foundry.)

The accompanying drawing, fig. 4, Plate IV., is a section of valve-boxes and valves, as made by the writer, for plunger pumps.

The suction opening is marked S; the discharge, D; and the opening to the pump, P.

The valve-seats, A, are, in this case, of cast-iron, and have grooves turned in them to receive hardwood bearing surfaces, O, for the valves to beat upon. The wood is driven in, in short pieces, and afterwards turned up in the usual manner. It will be observed, that the valve-seats are fitted into the chests or boxes with a very great angular bearing, so that, on taking off the valve-chest cover, the valves and seats can at any time be easily lifted out. When put in, they are kept in their places by spindles; a solid one, B, for the under or suction valve; and a tubular one, C, for the upper or discharge valve—these spindles being screwed through the valve-box cover.

The valves, which are made of gun-metal, resemble what is called the double beat or equilibrium class, being indeed designed from the double-beat Cornish steam valves, as made by the writer.

The stroke of the pumps attached to these valves is 33 inches; the diameter of the plungers being 14 inches.

The head pressure is from 200 to 300 feet; and the speed 23·825 strokes per minute. The valves work with remarkable ease, being scarcely heard to fall, and they are free from the concussion generally attending force pumps with any considerable head pressure. The plungers are worked from crank discs on a shaft over the well; this shaft gearing with the crank shaft of the engine. The fly-wheel is upon the pump shaft, which makes rather less than one turn for two of the engine.

With a long stroke, the valves should, perhaps, have a larger opening in the top than is shown in the figure, particularly if there is a great head of delivery, so as to reduce the pressure upon the valve. In such case, more time would be given at the turn of the stroke for the valves to close, as in all cases the valves ought to close before the return stroke of the pumps acts upon them. It is very probable similar valves may have been used by other parties; but the writer thinks no apology is necessary for bringing the matter before the meeting, as it is one of the chief objects of this Institution, to collect and discuss the results obtained in actual practice.

The following discussion then took place on the subject of Pumping-Engines, in continuation of what was said at the previous meeting, as reported at page 32.

Mr. Mackain said the valves in use at the main engines—the cylinders of which were 72 inches in diameter—at Dalmarnock, on the banks of the Clyde, were butterfly valves of 36 inches diameter, formed of leather (hippopotamus hides), having malleable iron plates above and below, rivetted together, as represented in fig. 8, Plate IV. When the engines were first started, and the demand for water by the city did not require them to be driven at a greater speed than 160 feet per minute, these valves lasted from six to twelve, and sometimes fifteen months; but the great increase in the demand for water since that time, had required the engines to be worked at the rate of about 280 feet per minute, and this speed subjected the valves to great concussions, and caused much wear. He had now great difficulty in obtaining iron of sufficient strength to withstand the concussion, without being too heavy. The iron used was Lowmoor plate, ½ inch thick. The valves generally split in two, and thus the leather mounting was lost. This had made them expensive, and he was making some experiments to ascertain the safety and economy of brass valves as a substitute.

In the ordinary pumping engines, the sides of the clack seats were cylindrical, and the valves filled nearly the whole space, so that when the water was forced through them, they had to rise high to afford sufficient area for its passage, and frequently broke the guards used to restrain them. The shock on shutting was also great, being proportioned to the square of the extent of fall of the valve. To remedy this defect, in reconstructing the clack seats, he had enlarged their diameter immediately above the valves, to the extent of about 6 inches beyond the body of the valve seat. This afforded a clear lateral space all round the valve for the escape of the water, as shown in the figures. The result was, that the valves did not now rise to the guards, and their fall being much lessened, the shock was consequently greatly diminished.

He had tried a lower, or suction valve, of the form of Harvey & West's, at the Cranstonhill Works. Its diameter was 20 inches, and the weight of the valve was 2 lb. per inch of area, whilst the height to which the water had to be raised by atmospheric pressure was about 24 feet, thus making, with the weight of the valve, a virtual column of nearly 29 feet of water. This was too much for the velocity of the piston; the water did not flow with rapidity enough to fill the pump barrel, and the engine struck heavily on the return stroke. This compelled him to abandon this kind of valve, after three or four hours' use.

In reply to questions from Mr. Dixon and Mr. Elder, Mr. Mackain said that the reservoir from which the Drygate engine pumped water, was about 10 feet below the pumps, and the average height of the surface of the water about 5 or 6 feet more. The water pumped by the six main engines at the Glasgow Water Works, Dalmarnock, was drawn from the filters on the opposite bank of the river by suction pipes placed under the Clyde. The water was drawn up through the suction valves or lower clacks, and fell into the pump barrel above the piston or plunger. The vacuum required was about 18 feet in ordinary circumstances, but when the filters were drained, and the Clyde low, the vacuum was greater. The pump plunger, when at the top of its stroke, was about 4 feet above the suction valve.

Mr. Elder, recurring to the question before the previous meeting, regarding long and short strokes for pumps, said it was very important. Did not the question resolve itself into one of capacity? If two pumps were of the same capacity, say one twice the length of the other, and the other twice the transverse area of the first, and they made the same number of strokes per minute, the action on valves would be precisely the same in both cases, notwithstanding the difference in the length of stroke.

Mr. Neilson said, that whilst he gave due weight to the preceding observation, he should not give up the notion of "long strokes," particularly in pumps used for mining purposes, where they were limited as to the diameter of the pump. An enlarged diameter also involved an enlarged plunger, which would increase the difficulties connected with the gland, whilst there would also be more friction with the larger plunger. These objections were of much importance in connection with mine pumps, more of which were at work, perhaps, than any other. He should certainly adopt as long a stroke as possible for such pumps.

Mr. Bell remarked that it would be useful to have a record of the various proportions of transverse area to stroke that had been adopted, with the results obtained in each case.

Mr. D. More being asked his experience of the friction of glands and collars, and of large and small plungers, said that he had, some time back, had something to do with a pump, 14 in. diameter, 3 feet stroke, for pumping very dirty water, when they were very much bothered with valves resembling that in fig. 6. The pump barrel eventually burst, and they substituted three pumps, 10 in. diameter, 2 ft. 6 in. stroke, with valves like that shown in figs. 1 and 2, and they had since had no trouble whatever with them, beyond putting in a new bucket once. These pumps were worked by triple cranks and had been seven years in use.

Mr. Elder stated that he had recently made a pump four feet in diameter, with a stroke of fourteen inches, and had found it to act very well. He was to a certain extent compelled by the peculiarities of the case to adopt this proportion, but it had succeeded so well that he should be inclined to adopt similar proportions in future, when circumstances admitted of it.

Mr. Ferguson thought some mechanical difficulties would attend the use of such proportions. In the case of plunger pumps, the gland would present a very serious difficulty.

The President observed that the subject before the meeting was one of great importance, and that much valuable information had been given, not only by the authors of the papers, but also by various other gentlemen. He proposed a vote of thanks to Mr. Mackain and to Mr. Neilson for their papers, which was unanimously passed.

The following paper was then read:—

On a Speed Governor. By Mr. G. H. Smith.

[CONDENSED REPORT.]

Mr. Smith exhibited a working model of his governor, of a size sufficiently large for a small steam-engine. In this governor, a set of vanes are mounted loosely upon arms radiating from a boss which is capable of sliding longitudinally upon, but turns with the revolving spindle of the apparatus, and which is connected to the throttle valve, or other regulator, so as to adjust it when moving longitudinally. The main acting surface of each vane lies to one side of the arm on which it is mounted; but the vane also projects a short distanee on the other side of the arm, where it is jointed to a link, which last is jointed to a boss, fixed or adjusted upon the spindle. When the engine rotates at its proper speed, the vanes are disposed obliquely, and the resistance created by their rotation balances a weight or spring acting in the opposite direction. On the engine's rate increasing, the resistance to the motion of the vanes acts with considerable leverage upon the sliding boss, and causes it to rise and adjust the valve. On th eengine's rate becoming too low, the weight or spring, being underbalanced by the resistance to the rotation of the vanes, causes the sliding boss to descend, and so adjusts the valve. The stationary boss to which the inner ends of the vanes are linked, and which acts as the fulcrum whereby an increased leverage upon the sliding boss is obtained, can be adjusted for different speeds, when the apparatus is in motion. The working model has adapted to it a simple self-recording apparatus, by which it has been ascertained that the time occupied by a rise of the sliding boss, sufficient to close the throttle valve of a steam-engine, never exceeds one second.

Mr. Smith considers this governor to possess the following advantages: —1. Simplicity, rendering it inexpensive, and not likely to get out of order; 2. Rapidity of action much greater than in common governors; 3. Power of adjusting the governor for different speeds whilst in action; and 4. Suitableness for marine engines, in consequence of its acting equally well in all positions.

Mr. Smith put the working model of his governor in motion, and explained its action.

Mr. P. Stirling, observing that the principal feature in the governor appeared to be its being made to run much faster than the main shaft of the engine, inquired how the high velocity rendered the governor more sensitive than the ordinary ball governor. Suppose the vanes were detached and free to rise in the air, and revolving at a rate just sufficient to maintain them in one position; how many more revolutions per minute would be required to raise them up?

Mr. Smith said, his governor did not act like a solid screw in water. The vanes were contrived so that the up-bearing pressure of the air acted with considerable leverage to turn them on their arms. As the vanes rose they became more nearly horizontal, or at right angles to the spindle, and if they attained the horizontal position they would not rise further, but before they did so the throttle valve would be closed.

In reply to an inquiry by Mr. Stirling as to what would occur if the vanes did not change their obliquity, Mr. Smith said no practical velocity would then make them rise with sufficient force to do the work required from the governor. The model governor exhibited was capable of raising a weight of 5 lbs. on its velocity being increased.

Mr. Howden thought, from the description of Mr. Smith's governor, that it would be incapable of keeping an engine at its normal speed. It possessed the same faults as the ordinary ball governor.

Mr. Smith said, it was much more sensitive than the common governor, and that it was capable of being adjusted to different velocities whilst in motion. He had not seen any other governor possessing this power.

Mr. J. R. Napier said, Mr. Smith's governor might be of great importance at sea. A sensitive governor was much wanted for marine engines, the resistances to which varied so much and so rapidly. A screw propeller, for example, was at one time in the water, and at another time quite out of it, and a governor was wanted which would prevent the engines from running away in the latter case. Mr. Smith's governor appeared to be more sensitive than the ball governor, and to possess more power to overcome the resistance to its adjusting action. It would be desirable to try it at sea.

Mr. Elder remarked that sensitiveness was undoubtedly very desirable. Ordinary governors in many cases did not operate until after the change of velocity had caused the injury which the governor was intended to prevent. Before the ordinary governor could act on the throttle-valve, the change in the velocity had to overcome the inertia of the balls. The action of Mr. Smith's governor did not depend on its rotating mass, but on the atmosphere. On an increased velocity increasing the pressure of the air, this shifted the vanes at once, the inertia to be overcome in them being inappreciable. The leverage obtained by the arrangement of the vanes was a great improvement on the ordinary fan governor. He referred to Hick's governor, which he had seen tried, and which, if anything, acted too soon, or continued to act on the throttle valve longer than was necessary. It would sometimes quite close the throttle valve without being able to reopen it.

Mr. Howden observed, that the ordinary ball governor was wrong in theory, as was also Mr. Smith's. Assuming the normal rate of the engine to be 40 revolutions per minute, as long as this was maintained the balls would move in a particular plane. On an increase in the velocity, the balls would rise and close the throttle valve to an extent which should bring back the speed to 40 revolutions. If the engine, however, returned to this speed, the balls would descend to their former position, and reopen the throttle valve to its former extent. But as this would cause the velocity to increase again, it is obvious that the balls would not descend to their former position, but to some point between that and the position which the increased velocity caused them to assume. In other words, the engine could not, under the circumstances, continue at a uniform speed. He could not see the benefit of adjusting the governor whilst in motion. If it required adjustment when a uniform speed was wanted, a man might just as well stand at the throttle valve, and regulate the speed by means of it without a mechanical governor at all.

Mr. Stirling remarked, that in most cases the governor would be adjusted to the required velocity once for all, and that the power of adjusting it when in motion would be of little use; neither did he think this was new. He had not received an answer to his former question; wherein was greater sensitiveness due to higher velocity? If the vanes moved

32 times faster, and were 32 times lighter than the balls of a common governor, the momentum would in each case be the same, and a given change of velocity would in each case take the same time to produce a given effect.

Mr. Elder said, that if the vanes acted in water, the difference between their action and that of the common ball governor would be more perceptible. In the new governor the effect was produced by the action of the vanes on the atmosphere, and not by the mere inertia of their mass, as in the common governor. He thought the new governor would be more sensitive.

Mr. Tait said, that when recently in the United States, he had seen what he considered to be the simplest, neatest, and most efficient of governors. It was the invention of a Mr. J. P. Morris, and was very similar in principle to the ordinary ball governor. A great peculiarity about it, was its smallness. Its entire weight was 14 lb. The ball arms were only 9 inches long, the balls being 2½ to 3 inches in diameter. It was applied to an equilibrium throttle valve; and the steam cylinder was 4 feet long, and 16 inches in diameter. With an average rate of 30 to 40 strokes per minute, an alteration of 2 to 3 strokes was checked on the instant. The Americans generally made the steam pipes of their engines much smaller than we. He thought we erred much in the form of our throttle valves, and that instead of the common form with a heavy spindle working in stuffing boxes, it ought to be light, and as easily moved as possible. He would lay a drawing of Mr. Morris' governor before the Institution at a future meeting.

After a few further remarks, a vote of thanks was passed to Mr. Smith for his paper, and for his exhibition and explanation of the working model.

The following paper was then read:—

On a System of Decimal Measures of Length, Surface, Bulk, and Weight, having the Sixteenth-of-an-Inch as its unit and basis. By Mr. J. Simon Holland.

[CONDENSED REPORT.]

This paper comprehended a condensed resumé of the various papers previously published by Mr. Holland on the subject of Decimal Measures, advocating the Sixteenth-of-an-Inch, or, as he proposes to term it, the *Steen*, as a unit and basis, together with some extensions of his system, to meet measurements of mechanical force and power. It was argued, that if the pound were made the basis of a decimal system of weights, the gallon of bulk, the acre of surfaces, and the inch or foot of lengths, we should abandon above twenty old measures, and then have a very imperfect system; whereas, by removing only three more, we could make the system perfect, or nearly so: that if a single unit were to be adopted as the basis of measurements of every kind, mechanical engineers must allow that the *steen* was immeasurably superior to any other, as there were millions upon millions of bolts, nuts, rivets, rods, bars, chains, and other articles measured by multiples of the sixteenth-of-an-inch. Allusion was made to the several proposals to make the inch, foot, or mètre the unit of a new decimal system, and attention was called to the subjoined table, which will afford a means of comparing the effect of their adoption in the case of measurements below two inches:—

Comparative Table, showing dimensions below two inches in present measures, in decimals of an inch, in decimals of a foot, in the French metrical system, and in "Steens," or sixteenths of the present inch.

Present Measures.	Inch Decimalised.	Foot Decimalised.	French Mètre.	Steens.
Inches.	Tenths of an Inch.	Hundredths of a Foot.	Millimètres.	Steens.
$\frac{3}{16}$	1·875	1·5625	4·76241	3
$\frac{1}{4}$	2·5	2·0833	6·34989	4
$\frac{5}{16}$	3·125	2·604167	7·93736	5
$\frac{3}{8}$	3·75	3·125	9·52483	6
$\frac{7}{16}$	4·375	3·64583	11·11230	7
$\frac{1}{2}$	5·	4·16667	12·69977	8
$\frac{5}{8}$	6·25	5·20833	15·87471	10
$\frac{3}{4}$	7·5	6·25	19·52483	12
$\frac{7}{8}$	8·75	7·291667	22·22460	14
1	10	8·333	25·39954	16
$1\frac{1}{8}$	11·25	9·375	28·57448	18
$1\frac{1}{4}$	12·5	10·4167	31·74943	20
$1\frac{3}{8}$	13·75	11·4583	34·92437	22
$1\frac{1}{2}$	15.	12·5	38·09931	24
$1\frac{5}{8}$	16·25	13·5416	44·27425	26
$1\frac{3}{4}$	17·5	14·5833	44·44920	28
$1\frac{7}{8}$	18·75	15·625	47·62414	30
2	20.	16·667	50·79908	32

It was argued that no instrument for measuring quantities of any kind, was so much used as the two-foot pocket rule of the mechanic, and it was obviously desirable to have a rule as long as could be conveniently carried in the pocket, but not too long, nor should its folding joint break a unit of length. The *steen* suited all this very well.

The paper went on to show how nearly a variety of measures, expressed in multiples of, or derived from the *steen*, would coincide with measures in actual use in Britain, and in various foreign countries; and, in conclusion, the author proposed that a steam-engine should be called a one-horse power engine, which gave out 1000 *pedlibs* of work per second; the pedlib, derived from the steen, resembling our present foot-pound, the ped being equal to $6\frac{7}{8}$ old inches, and the lib. to 1·102,310,62 old pounds.

For a full account of Mr. Holland's proposed system, readers may consult the *Mechanic's Magazine*, Vol. LXV., pp. 392, 415, 461, 564; Vol. LXVII., pp. 176, 444, 495.

The discussion on the subject of decimal measures was deferred until after the following paper was read:—

On Decimal Measures. BY MR. WALTER NEILSON (of Hydepark Foundry).

[ABSTRACT.]

A system of measures ought to be as simple as possible, easily committed to memory, and easily retained there;—like the mechanic's rule in his pocket, not cumbersome, but convenient, and always at hand when wanted.

Memory evinces its power through association; and the parts of the system should therefore, when contemplated together, be so connected in the mind that one of them will at any time recall the others, or introduce a train of thought which without any extra mental effort brings them all forward in the order in which they were originally associated.

To illustrate the application of this important principle to a system of measures—let us take the French measures of length, capacity, and weight.—In the first place, it is necessary to fix upon some standard, some quantity or unit by which the measurement is to be made, and the standard should be a quantity conveniently between the maximum and minimum quantities, to which the measure is to be applied.

The standards adopted by the French are:—

For length,... a mètre.
For capacity, ... a litre.
For weight, ... a gramme.

Here we have only three standards, a single one for each of the three kinds of measures. The decimal multiples are designated by the unit, with the specific terms taken from the Greek for 10, 100, 1000, &c. prefixed, whilst the decimal submultiples are designated by similar specific prefixes, taken from the Latin.

The superior simplicity of this system is obvious at a glance when we compare it with our own system of measures, if, indeed, we can apply the word "system" to a congeries of the most dissimilar terms imaginable, no one of which gives the least indication of the kind or proportion of the term next it in the scale.

Inches, feet, yards, fathoms, poles, furlongs, miles; these are the words which *ought* to be so associated in the mind as to simplify the exercise of the memory. The proportions between the quantities bearing these names are expressed by the numbers: 12—3—2—2¾!—40—8!—a greater jargon of dissimilar numbers could scarcely be conceived. As to standards, one is reminded of the showman's answer, "Whichever you please, my little dears;" the mechanical engineer takes the foot, the civil engineer the yard, and the mining engineer the fathom.

It is not the writer's intention to discuss the various decimal systems proposed, but he would call attention to the fact, that the French have been using a decimal system for many years, and that French engineers can think and calculate in mètres and millemètres much more easily than we can in feet and inches; and, although he is not altogether prepared to recommend the mètre system as the best that can possibly be got for our adoption, he still thinks that much could be advanced in favour of such a step.

Setting aside the Americans as forming part of ourselves, the French are the nation, of all others, whose intercourse we most court, whilst they are amongst the most advanced in science and art. It is not likely that if we adopt a peculiar decimal system, they will change theirs to assimilate it to ours, whilst it is undoubtedly desirable that our and their systems should be alike.

The attention of the Institution has already been drawn to the decision recently come to at Manchester, by the Institution of Mechanical Engineers—to divide the inch into hundredths and thousandths. This will probably suit the convenience of the machine-makers in Manchester, but it will be of little advantage to marine engineers, shipbuilders, and others, towards simplifying *their* calculations.

The Manchester resolution is unmistakeably a tacit admission of the propriety of adopting decimal divisions, but why take up the inch, divide it—and stop there? The stop can be but temporary—go on we must; but on attempting to do so, we find ourselves saddled with a particular unit, the suitableness of which is far from being general, unless we patch up the new system in nearly as confused a manner as the old.

Before adopting the Manchester resolution, we must be prepared to adopt the inch as the standard or unit for *all* measures of length. Are we prepared for this? Are we prepared to take 10 inches as the next decimal multiple? If we are, we take a measure equal within one-sixth of an inch to a *quarter* mètre, and if we come so near the mètre system, why not adopt it at once? It would only reduce our inch by less than one-sixtieth.

As far as engineers are concerned, there appears to be no great obstacle to the adoption of the mètre system. Many think the 12 in. rule the most convenient workman's measuring instrument possible, as regards size, but speaking as an engineer, I do not see that a rule measuring half a mètre, and folded in two, into a quarter of a mètre, would not be quite as convenient.

The following are the various divisions the rule would have, with their equivalents in inches:—

Entire rule..............................	½ mètre or 50 centimètres	=	19·68 inches.
Folded into..............................	¼ " " 25 "	=	9·84 "
¼ mètre divided into 5 parts,......................	5 "	=	1·968 "
5 cèntimetres " 5 "	1 "	=	·394 "

This last measure is within one-fiftieth of an inch, equal to ⅜ inch, a quantity the mechanical engineer has perhaps more to do with than any other. Finally, dividing the centimètre into 10 millimètres, we get a measure slightly larger than $\frac{1}{32}$ inch, more familiarly known by the anomalous appelation, "half a sixteenth." This would be a convenient minimum division, as low as sight could command. Lower divisions must be known by touch and measured only by gauges.

One important difficulty would present itself on introducing a new system, in connection with the various valuable publications bearing on science and art. They cannot be so easily changed, and are a class of works the production of which in new editions would be most costly. It is to be feared that nothing but time would relieve us of this difficulty: nevertheless much assistance would be derived from comparative tables and scales of the old and new measures, which an extensive demand would soon call into existence.

The following discussion took place on the subject of the two preceding papers:—

The PRESIDENT feared the greatest difficulty connected with the introduction of a decimal system of measures would arise in teaching workmen to use it. There were many present who were qualified to judge whether this would be the case or not, and he hoped they would state their opinions.

Mr. J. R. NAPIER said, he had contemplated using decimal measures, and adopting the foot as a unit or standard; but if Mr. Neilson would adopt the mètre, he would follow his example.

Mr. RAMSAY thought it would be easy to supply workmen with decimal rules, and that they would soon get into the way of using them.

Mr. HALL said he had resided thirty years in France, and would state his experience of the French system. When he first went there, he had to get rid of English measures and use French ones—those existing before the present mètre system. When it was proposed to introduce this system, it was said by many that there were difficulties that would never be got over. There were three different kinds of the foot unit to be done away with. However, all difficulties were quite overcome in from eighteen months to two years, and the mètre system was found a very great improvement. There was no practical difficulty experienced in its introduction. The relation which, in the new system, existed between the different kinds of measures, and the manner in which the several standards were determined, had many advantages and conveniences. Thus the weight in kilogrammes of any substance gave its specific gravity. The new system was introduced in 1832, and was now universal.

Mr. W. TAIT said that if the various employers gave sets of decimal rules to their workmen, and directed them to work with them, the latter would soon be able to use them more easily than the old rules. He did not anticipate any difficulty on this score.

Mr. MORE thought that before deciding on a new system of measures they should ascertain what the government proposed to do in the matter. They should not pledge themselves to any system, unless it was to be a national one. He thought the French system as good as any other. He suggested that the council should communicate with government, and offer to assist in introducing whatever system should be decided upon.

Mr. J. FERGUSON remarked, that the foot divided into tenths had been used by civil engineers for several years.

Mr. W. NEILSON remarked that, as regarded communicating with government, we could scarcely step before the Institution of Mechanical Engineers, who had first taken up this matter, and he thought we should communicate with them. He considered the Manchester resolution as decidedly wrong. He thought this society should express their agreement or disagreement with that resolution. They should either raise their voice against, or support it.

The PRESIDENT said, that at the Manchester meeting, it was the inch only that was discussed, and regarding it they came to the conclusion that it was best to subdivide it into thousandths. The question whether any other unit was better than the inch, was not at all discussed. If the Institution of Engineers in Scotland intended to express an opinion on the matter, it would be well first to consider other measures besides measures of length, such as measures of weight. It would be comparatively easy to make standard measures of length, bearing any determinate proportion to the standard yard kept in the Exchequer Office at Westminster; but it would be very different with weights bearing complex ratios to each other. The present government standard of weight was a piece of platinum weighing 1 lb. It was a delicate matter to make weights equal to multiples of this standard, but even this was easy compared to the making of a weight bearing the ratio to the standard that a kilogramme would have.

Mr. W. JOHNSTONE said, a general system could not be adopted without the intervention of government. Land was at present conveyed by the imperial acre, and the laws respecting such conveyance, as well as all the laws in which measures of any kind were adopted, would require to be modified. He thought we were not yet in a position to communicate with government, and that the matter had not been sufficiently discussed.

The thanks of the meeting were passed to Mr. Holland and to Mr. Neilson, and the discussion of the subject was adjourned.

THE FOURTH MEETING of the Session was held in the Philosophical Society's Hall, on Wednesday, 20th January, 1858, the PRESIDENT in the chair.

The following paper was read:—

On a Screwing Machine.—By MR. S. M'CORMICK.

Some years since, the writer being extensively engaged in manufacturing screw bolts and wood screws for railway fastenings, was much troubled with continual stoppages, arising from breakage and rapid wearing out of the screwing apparatus. The constant annoyance and expense attending the old system, led him to search for some other mode of screwing; and it occurred to him, that if bolts could be screwed whilst the material was red-hot, a great saving would be effected, and the annoyance removed. The idea of rolling with three rollers suggested itself, and a small machine was immediately made, with which, after a great many trials and failures, he succeeded in making screws of both fine and coarse threads with considerable facility. At this stage the matter was laid aside for a considerable time; but in 1853, a favourable opportunity offering, further experiments with improved machines were made, and the plan was fully tested and proved to be really practicable.

The machine before the meeting is one of the latest, and certainly one of the best made according to the writer's system, and he thinks that as far as it goes, it admits of little if any improvement. Several additions have suggested themselves, but these have for their object merely to facilitate the insertion of the blanks, and to determine the length to be screwed; they are all of an automatic character, and would make the machine almost entirely self-acting. The operator would only have to lay the hot blank in a receptacle provided for it, and to move a small engaging lever. These additional contrivances can be applied to this or any other of these machines.

The distinguishing feature of this machine is, that it forms the screw threads whilst the material is red-hot, by simple rolling. In the ordinary screwing machines the threads are cut out of the material; in this they are formed by simple pressure, and there is consequently no waste. It will be readily understood that the operation must be performed with great rapidity, otherwise the cooling of the material would render it impossible. The rolling matrices or dies move at the rate of about 180 revolutions per minute, and being at least three times the diameter of the screw or bolt, the latter will make 540 revolutions in the same time. Suppose a wood screw to have 15 turns in $2\frac{1}{2}$ inches, it will require 30 turns to screw it and will take $\frac{1}{18}$th of a minute, so that such screws would be screwed at the rate of 18 per minute. In practice, however, not more than one half of this number can be completed in the time, as it requires more time to put the bolt into the machine than to screw it. From 2,000 to 6,000 per day may be stated as the performance of one machine, but the number altogether depends on the size and length of the screws. Besides rolling screws, the machine is well adapted for rolling iron or other metal into ornamental or useful shapes. The writer is informed that there are some small machines so employed in the vicinity of Birmingham. A few rough experiments were made to try the comparative strength of bolts made on this principle, and common bolts. A hole of the length to suit the bolts to be tried, was drilled through a piece of metal. The bolt was put into the hole and screwed up until it gave way, and either broke or had the thread stripped off. All the hot-screwed bolts were broken, the others stripped. These bolts were of the same kind and size, made from the same bars and by the same workmen.

The working part of the machine substantially consists of three spindles mounted in brasses of a peculiar form, which will be understood by examining the drawings. One end of each of the spindles is formed into a toothed pinion cut out of the solid. The other end is prepared to receive a matrix or die, and each has turned on it a spherical bearing near the pinion end. The spindles are shown in fig. 1, plate V; and in section, and numbered 1, 2, 3, in figs. 2 and 3. The brasses in which these spindles work are placed in the front pedestal, B, of the frame, figs. 1 and 2, and are constructed so as to be adjustable to all the angles and distances of the spindles required to suit the different sizes and pitches of the screws, being fixed by set screws. A pedestal, C, figs. 1 and 3, supports the graduated plate, in the centre of which is fixed the brass forming the bearing for the three die spindles. This plate partially revolves in the pedestal, and carries round with it the three spindles, which assume a twisted appearance in turning with each other. It is to admit of this twisting that the journals of these spindles are made spherical, no other form being suitable. Each pitch and diameter of bolt requires an angle of its own, which is found by applying a directing screw of the pitch and diameter required to the under side of the upper or central die, and turning round the graduated plate until the screw is parallel to the central line of the machine.

Motion is communicated to the machine by two pulleys, D, E, fig. 1, driven by separate belts in opposite directions. The insides of the rims of both these pulleys are turned conical, corresponding in taper to the rim of the internal pulley, F. This pulley, F, is connected to a hollow shaft, G, fig. 1, by a broad cutter which passes through an elongated slot in the shaft, and also through the spindle, H. This spindle, H, is fitted loosely in the hole in the shaft, and is connected by a peculiar coupling to the end of a bent lever, I; thus connecting the pulley, F, by means of the spindle, H, with this bent lever, the end of which extends beyond the front of the machine a sufficient distance to allow the operator to depress it with his foot. At J, fig. 2, is a catch jointed on the front of the machine, and actuated by a slight spring, and having two notches cut in its edge, to retain the bent lever in position. When the lever is placed in the upper notch, the pulley, F, is then in a central position, and the machine is at rest. When the lever is placed in the lower notch, the pulley, F, will be in contact with the pulley, E, and will revolve with it; and when the lever is released from the catch altogether, it will be elevated by the spiral spring, and the pulley, F, will then be brought into contact with the opposite pulley, D, and will revolve with it in the reverse direction. A toothed pinion, seen in section at K, is keyed on the shaft, G, and drives the large toothed wheel, which is keyed on a shaft, L. On the end of this shaft, L, is cast a hollow case, M, figs. 1 and 4, in which is keyed an internally toothed wheel, gearing into and driving the three die spindles simultaneously.

In making a screw, the operator first pushes down the bent lever, I, into the lower notch of the catch, and the machine then revolves in the direction which screws the bolt inwards. He then puts a bolt, N, fig. 1, into the central opening between the dies, pulls down the handle with his left hand to a regulated stop, which depresses the upper die upon the bolt, whereupon it immediately turns, and is screwed inwards by the simultaneous revolution of the three dies as far as the thread is required. The operator then with his toe touches the catch, which releases the bent lever, and the spring instantly elevates it, whereby the pulley, F, is pushed into contact with the opposite pulley, D, and the motion of the machine is reversed, so that the bolt is screwed out, and when released from the guide, drops upon a shelf or other receptacle. During the operation a stream of water is constantly running on the dies.

The furnace in which the bolts are heated should be close to the machine, so that as little time as possible be lost in handing them from it to the machine. The heat required for bolts is not high—just fairly red; that for wood screws is higher—a brighter or full red.

The matrices, or dies, for coarse threads or wood screws, are best made of cast-iron, cast in a chill mould; those for fine threads, of cast-steel or malleable iron, case-hardened.

The machine before the meeting is constructed for screws of from $\frac{1}{2}$ to $\frac{3}{4}$ inch in diameter. Machines may be made, however, to screw from $\frac{1}{4}$ inch upward. The following are some of the advantages claimed for this mode of making screws:—Additional strength acquired by the peculiarity of the operation; saving of waste (in wood screws this amounts to 15 per cent. of the finished weight), the whole quantity cut away in the common way being compressed into the screw; great rapidity and facility of production; saving of all antifrictional material, such as oil; non-requirement of high-priced labour, three trained boys only being needed.

Mr. A. M'Onie, who exhibited one of Mr. M'Cormick's machines at the meeting, stated that six or seven of them had been made, and that the machine shown was one of the three last constructed, with improved arrangements of parts. One machine had been sent to Manchester, and another to Belgium. Mr. Whitworth, who had seen a machine at work in their (Messrs M'O.'s) establishment, in September, 1856, expressed himself as much pleased with its ingenious arrangement. Mr. M'Onie, however, considered that the machine was better suited for making wood screws than for screw bolts. He also thought that the machine was yet susceptible of improvement, by having some kind of self-acting gearing attached to reverse the screwing action, so that the length screwed might be certain, and not dependent on the attendant, as in the present machine. The cost of the machine shown was about £80, inclusive of the dies, or screwing rings,

Mr. M'Onie exhibited some specimens of wood screws and screw bolts, made by the machine, and some of the dies used. He remarked that he could not himself say much about the results obtained with the machine, as he had not given that point close attention, the inventor having himself superintended the construction of the machine, and any experiments that were made with it.

The Chairman proposed a vote of thanks to Mr. M'Cormick for his paper, and to Mr. M'Onie for exhibiting the machine at the meeting, remarking that it would be exceedingly advantageous if such an example were followed, since actual machines would be much better understood than drawings, and even than models. The vote of thanks was unanimously passed.

The following paper was then read:—

On the Navigation of Canals by Screw Steamers. By NEIL ROBSON, C.E.

IT is not the object of this paper to go into any lengthened history of the various modes of haulage which have been tried on canals in general; but rather to collect and make known to the members of the Institution some facts connected with recent successful attempts to introduce screw-propulsion on the Forth and Clyde Canal, with which the author is best acquainted, and which, as is well known, is one of the principal arteries of inland navigation in Scotland. And by so doing, to direct the minds of the ingenious mechanical engineers of which the society is composed, to the great importance of the subject, and to elicit opinions as to its farther development, with a view to improve the mechanical details and arrangements of the power employed.

But whilst this is the chief object of the author in bringing the subject before the Institution, he will venture to digress so far as to introduce a few preliminary observations on inland navigation in general, and will briefly notice a few of the English Canals on which this new mode of haulage has been tried and is now in use. The several experimental attempts which have been made to introduce other modes of haulage on the Forth and Clyde Canal, will then be given somewhat in detail, and the paper will be brought to a close by a description of the system now being introduced on that canal; reference being made to drawings illustrative of the boat *Thomas*, and her engine, with which the first really successful experiment was made under the Canal Company's more immediate control, with the advice and under the superintendence of their officers. In the concluding remarks, the author will contrast the expense of horse and steam haulage, as brought out by the results so far as they have gone.

It cannot be denied that, since the introduction of railways, canals, which prior to that event formed the principal mode of conveyance for a very large proportion of the goods and mineral traffic of the country, have been thrown into the shade; and that the attention of practical men has been more devoted to the development of railway traffic, not only as regards the mechanical appliances for its transit, but also as regards the acquisition and carrying of large quantities of merchandise and minerals, than to the improvement of the more ancient mode of conveyance.

There is no good reason, however, why this should be so; for although in some cases canals may be the avowed rivals of railways, in others they are or might be made the means of feeding their traffic, or of relieving them of a portion of the heavy merchandise and mineral traffic which railways cannot always carry with advantage to themselves. It does not follow that, because a railway may be carrying a large amount of tonnage, it is doing so profitably; on the contrary, it is to be feared that in many cases, if the cost were fairly set against revenue, the result would be found quite the reverse; the rates obtained being inadequate to meet the greater wear and tear of the iron road, as compared with the water-way, and the many sources of expense to which railway plant is subjected. For passengers, and for light and perishable goods, and for goods requiring quick despatch, canals never can nor ought to compete with railways; but for bulky and heavy goods and minerals, the author is convinced that they can and will maintain their ground, provided their managers keep pace with the improvements and requirements of the day.

In Great Britain and Ireland, the total length of canal and inland river navigation is about 4000 miles; and it is estimated that there has been expended in the construction and improvement thereof at least £50,000,000 sterling. These figures of themselves sufficiently demonstrate the importance in a national point of view of this great interest.

For the most part, canals carry on toll; that is to say, they are open to any trader, however small, who chooses to send his own boat with horses to tow it, on payment of the fixed rate of toll, and in this respect they are similar to turnpike roads. In a few instances, canal companies act as carriers on their own account, but it is questionable how far they do wisely in this. It consists with the author's knowledge that the Forth and Clyde Company, who ceased altogether to be carriers about five years ago, except to a very small extent, have made more money by falling back on their simple province of keeping the canal in repair, and acting as recipients of toll.

It appears that the first attempt to propel boats by the screw on the English canals was made about twenty years ago between London and Manchester; but from the great number of locks—there being about one to every mile—and from the narrowness and want of depth of the canals which compose that route, it was not so successful as to lead to any practical result at the time. Within the last three or four years, navigation by screw boats has been introduced on the Air and Calder navigation, on the Leeds and Liverpool canal, and on several others in that country; and so far with success. The best practical result, as regards speed and economy of working, is obtained on those canals of which the depth is not less than six feet; breadth at water level 50 feet, and at bottom about 35 feet; but as the majority are of less size, it is to be hoped that the time will come when screw propulsion may be applied with advantage on our shallowest and narrowest canals; and to that end, the bringing of the subject to the notice of such meetings as this will no doubt tend.

The first attempt to move a vessel by steam on the Forth and Clyde Canal was made about the beginning of the present century, and it appears that Mr. Symington was connected with the fitting-up of the boat. This boat was propelled by two paddle-wheels, close together at the stern, with the driving cranks between them. It ran for some little time; but its chief merit was considered to lie in its being an ice-breaker, for which it answered admirably. Although the records of the canal do not mention the fact, there can be little doubt that this was the *Charlotte Dundas*, constructed by Symington in 1802, and with which he made one of his first essays in steam navigation.

In 1828, the *Cyclops*, a boat for carrying passengers, was fitted up as a steamer with paddle wheels at the stern. She was 64 feet long, 16 feet broad, and six feet deep; carried about 40 tons of goods, and went about 3½ miles per hour on the canal, and about six miles on the Firth of Forth.

In 1831 the *Manchester* steamer was built, propelled likewise by one wheel at the stern. She carried from 50 to 60 tons of goods, and steamed about 4½ miles on the canal, and seven miles on the firth.

The *Lord Dundas* was also built in 1831 as a passenger boat. She had two paddle-wheels, one on each side of the stern, and steamed about 7½ miles an hour on the canal.

All these boats ceased to be used on account of the cost of working being greater than horse haulage, and from constant failures in the machinery.

It was proposed at one time, and actually tried, to haul vessels on the canal by laying a chain along the bottom, to be acted upon by a pulley in the boat, the pulley being worked either by hand or steam power.

Another experiment was the laying down a line of railway on the towing path, on which a locomotive engine ran and hauled boats behind her; a previous trial for hauling them by a locomotive for common roads running on the towing path having signally failed, as might reasonably have been expected.

In 1844, a Mr. Kibble patented a paddle wheel composed of a number of float-boards fastened on an endless chain, working round two drums. It was thought that this mode of propulsion was well adapted for canals, and a boat fitted with a paddle of this description on each side was tried, but given up on account of the expense.

The late Mr. Smith of Deanston had a plan which he intended for the small canals in the West India Islands, of having a wheel passing through and projecting below the bottom of the boat, so as to run on the bottom of the canal, and thus haul the boat. This plan was tried on a reach of this canal about ten years ago, but did not answer.

In addition to these, the author understands that several attempts were made to introduce steam on the Union and Monkland Canals, which communicate with the Forth and Clyde Canal, but are of less depth and width. In 1846, a steamer with double screws was tried on the Union. In 1845, a steam tug built by Mr. Wm. Napier, junior, was tried on the Monkland Canal.

From some cause or other, it appears that all these attempts, not only on the Forth and Clyde, but on other canals running into it, were more or less failures; and that it is only within the last two years that anything like a systematic carrying out of steam propulsion has been accomplished. The available depth of water on this canal is about eight feet six inches; average width at water surface, 60 feet; and at bottom, 30 to 40 feet. Its length is 39 miles, and there are forty locks, the dimensions of which are:—Length, 70 feet; width, 20 feet; and least depth on sill, 9 feet 4 inches. The Monkland Canal now amalgamated with it is 12 miles long, but its available depth is only about half that of the Forth and Clyde; width at water surface, 40 to 50 feet; and at bottom, 25 to 30 feet; length of lock, 70 feet; width, 13 feet 6 inches. The total merchandise and minerals conveyed on the Main Canal and its Monkland branch, is upwards of two millions of tons per annum.

At present there are five screw-steamers belonging to different traders, daily at work on the main line, and one belonging to the Canal Company, who are also fitting up another with screw-machinery to serve as an ice-breaker, and have drawings in progress for engines to be fitted to a canal and sea-going steamer.

The lighter *Thomas*, to which this paper more particularly refers, was not originally built for being fitted with the screw, nor is she of a class adapted for going out into the firth, but nevertheless she may be taken as a fair sample of a large class of lighters in use on the canal. She is 66 feet long; 16½ feet broad; draws about 6½ feet of water; and carries from 70 to 80 tons of cargo. The screw lighters belonging to the traders are larger, and are fitted to navigate the firths of Clyde and Forth, as well as the canal, and carry from 100 to 120 tons of cargo.

The engine and boiler of the *Thomas*, as will be seen from the drawings, Plates I. and II., are placed in the stern behind the bulkhead, which partitions off the stern portion to the same extent as the stern portion of the other lighters of the class which are used for horse haulage; and this space, small though it is, is found amply sufficient for the boiler, engine, and coal bunker, with room for attending the engine and stoking the boiler. Fig. 1, Plate I., is a longitudinal vertical section of the after part of the *Thomas;* fig. 2, Plate I., is a transverse vertical section taken immediately behind the boiler; and figs. 1 and 2, Plate II., are vertical and horizontal sections of the boiler, the latter being taken at the fire-box tube plate. The weight of the engine, boiler, and propeller, including 13 cwt. of water, does not exceed three tons. The dimensions of the boiler and engine are as follows, viz.:—

Inside diameter of body of boiler, 3 feet; and swelled to 3 feet 5 inches, at surface water line. Height of boiler, from fire-bars to crown, 7 feet 3 inches. The boiler is furnished with 54 brass tubes of the average length of 3 feet 5 inches; and tapered from 2¼ inches diameter inside at the fire-box tube plate, to 1¾ inches inside diameter at the uptake tube plate; which gives the heating surface in fire-box and tubes as follows, viz.:—

	Square feet.
Fire-box, 2′ 6″ × 1′ 6″,	11·78
" Tube plate,	2·54
Total fire-box surface,	14·32
54 tubes 3 feet 5 inches long, and 2 inches average diameter,	96·60
Total heating surface,	110·92

	Ft.	In.
Diameter of cylinders,		6½
Stroke of piston,		10
Valves worked by link motion, extreme throw,		3
Diameter of screw propeller,	3	6
Pitch of screw,	4	0

The engine cylinders are bolted together, forming the steam chest between them, in the usual way. The cylinders lie on the bilge of the lighter, and their connecting rods are attached directly to cranks at right angles to each other on the engine-shaft which is coupled to the propeller shaft. The screw of four feet pitch at 130 revolutions per minute, gives a speed of five miles an hour, while the advance of the screw due to the speed is 5·909 miles per hour, showing a slip of the screw of $\frac{2}{13}$ths.

It is found that 35 lbs. per square inch of pressure in the cylinders is sufficient for propelling the lighter with a full cargo of from 70 to 80 tons. In breaking through the ice on the canal in December, 1856, the boiler was worked up to 85 lbs. pressure, and at that pressure the boiler was more than capable of supplying the cylinders with steam. The contracted area of the water surface gave rise to a suspicion that the boiler might be liable to prime, and after some experiments with a glass model boiler, it was resolved to fit in a current plate, round the inside of the boiler shell. Without estimating the merits of the current plate, it may be stated that the boiler is quite free from priming with the steam taken from the crown with a 1½ inch pipe. The taper tubes were deemed a desideratum, with the view of obtaining an increased influence from the fire throughout the short distance it has to pass from the furnace to the uptake, and also to allow the upper tube plate to be reduced in diameter, thereby increasing the surface of the water in the boiler.

On a late trial of four trips from Port-Dundas to Bowling (a distance of 12 miles) and back, making a distance of 96 miles run, passing through 144 canal locks, and getting up steam eight times, the consumption of coal (good Monkland soft coal) was one ton three cwt., which, at average length of runs on the Forth and Clyde Canal, might be stated to be equal to 100 miles steaming by one ton of coals.

As the engines were fitted to the lighter as an experiment, it was deemed desirable to make them of sufficient power to tow another lighter of similar size, which they are quite able to do; but the traffic the lighter is at present employed in, does not afford opportunities for using the surplus power in towing.

The boiler has been proved to be so capable of raising steam, that the Canal Company have contracted for two similar boilers with iron tubes, to supply steam for two 9½ inch cylinders with 15 inch stroke of piston. These are to be fitted to an ice-breaker, which is also used for the service of the canal works.

The lighter has been constantly at work for the last 15 months between Port-Dundas and Bowling, a distance of 12 miles, carrying general merchandise in connection with the Dumbartonshire Railway, and without losing a single trip through any accident, injury, or repair of the machinery. The only alteration made in the engine was the substitution of cast-iron valves for brass valves, and the only mishap which has befallen any part of the working gear was the breaking of one of the arms of the screw propeller. She can easily make three trips a week, and usually performs the voyage each way in four hours, when not detained at the locks by the passing trade; which, including the detention in passing through the 18 locks, is at the rate of three miles an hour; but when fairly clear of the locks, her average speed is five miles per hour.

There is very little additional swell, or washing of the banks, at this speed, and, on the whole, there does not appear to be any appreciably greater wear and tear of the canal than that arising from the passage of boats drawn by horses; at all events, no more than would be compensated for by the saving in upkeep of the banks, in having no towing path to uphold, were horse haulage done away with.

Altogether, the result proves that by means of the screw the navigation of canals by steam is perfectly practicable. But it is still doubtful how far this power can be applied to propel, with advantage, more than the boat in which the engine is placed, owing to the difficulty of steering boats towed behind, especially in narrow canals; and to the circumstance that when the tug, with its train of boats, approached a lock, each would have to be disconnected and taken through singly. The author inclines to the belief that, as a general rule, an engine must be put in each boat. That this can be done to advantage with boats for goods, he thinks has been proved; but the problem has still to be solved, whether the system can be profitably applied to boats carrying minerals alone, on such canals as the Monkland, of which the available depth is only 4½ feet, and the width proportionably small. These boats, or "scows" as they are termed, carry on an average 55 tons; are in length 66 feet; width 13 feet 4 inches; cost, built of iron, about £250; and are usually hauled by one horse. The speed when loaded is about two miles an hour clear of the locks, and going back empty it is a little more.

It is obvious that if every such coal boat must have an engine for itself, three things will be required. 1. The machinery must occupy little room, in order to leave space for the cargo. 2. The first cost must be small. 3. Its working must be economical, both as regards repairs and consumption of fuel. The author does not despair of seeing all these accomplished, and hopes that the time is not far distant when the haulage, even of coal "scows," will be done more cheaply than by horses.

Meantime, he wishes it to be understood that the following comparison of the cost of the two systems, applies exclusively to the results obtained from the experiment with the *Thomas*, running to and from Bowling with goods, and being somewhat in favour of steam, may be accepted as a good omen that better results will yet be obtained. For, although this portion of the canal is favourably adapted for steaming, so far as depth and width are concerned, yet, owing to the great number of locks, and detention there, it is, in other respects, less favourably adapted than other portions, where the reaches are longer and the locks fewer.

COMPARISON OF COST OF HORSE AND STEAM HAULAGE.

Horse Haulage to and from Bowling. Goods Lighter.

	£	s.	d.
One master, per week,	£1	1	0
One mate, do.		18	0
One horse and one man tracking, and making two trips per week,	1	8	0
Ropes for tracking,		2	0
	3	9	0
Add interest on cost of lighter, £450, at 5 per cent., and for repairs and depreciation, 7½ per cent. on same amount, per week,	1	1	7½
Total per week,	£4	10	7½

Thus, at two trips per week, £4 10s. 7½d. ÷ 48 miles gives 1s. 10½d., as the cost per mile per boat load of 75 tons, or 3-10ths of a penny per ton per mile.

The same with Steam.

One master, per week,	£1	1	0
One mate, do.		18	0
One engine driver, do.	1	0	0
Oil, tallow, and gasket, do.		3	8
15¾ cwts. coals per week,		5	6¼
	3	8	2¼
Add interest on cost of lighter, £450; engine, £320; together £770, at 5 per cent., and 7½ per cent. on same sum for repairs and depreciation, amounting per week to	1	17	0¼
Total per week,	£5	5	2½

Thus, at three trips per week, £5 5s. 2½d. ÷ 72 miles gives 1s. 5½d., as the cost per mile per boat load of 75 tons, or 23-100ths of a penny per ton per mile.

From the slow rate of trackage by horses, no more than two trips per week are got, while with steam three trips are easily made; and hence arises a very considerable part of the above saving in favour of steam power.

From these figures it appears that the cost by steam haulage is at the rate of 17·5 pence per boat load per mile, or 23-100ths of a penny per ton per mile; and by horse haulage 22·5 pence per boat load per mile, or 3-10ths of a penny per ton per mile; including, in either case, an allowance for tear and wear, and repairs and interest on the price of the boat, and the same on the machinery in the case of steam. These rates are calculated on the supposition that the full load of 75 tons is carried both ways; but as that will not always be so in practice, the cost will generally be somewhat higher, whether by steam or horse haulage. And when the boat is only loaded in one direction and comes back empty, the cost will, of course, be still higher.

Mr. Robson remarked, that the paper showed how the navigation of canals, by steam, had been effected at a less cost than by horse-haulage, in one particular instance. It would be observed that in the *Thomas*, with which this result had been obtained, the engine and boiler were put into a very small space at the stern. If, however, steam power was to be rendered applicable to canals of very small depth, like the Monkland, the engine and boiler would have to be squeezed into a still smaller space. He confidently expected this would be done, and it was one of the objects of his paper to bring this point before the institution, in the hope of eliciting a suitable plan from some of the ingenious mechanical engineers amongst its members. If the system was to be applied to coal scows, it was necessary that the engine, boiler, and propeller should not cost more than £150. Mr. Milne, the superintendent and engineer of the Forth and Clyde Canal, was present, and would be glad to answer any questions.

In answer to an inquiry from Mr. W. JOHNSTONE, Mr. MILNE stated, that at the low speed of five miles per hour of the *Thomas*, no appreciable wave was raised in the canal. If that speed was exceeded, a wave would rise; but at a speed of five miles and under, the canal banks were unaffected. That speed was quite sufficient for all the purposes of the traffic.

In reply to Mr. DIXON, Mr. MILNE said that the *Thomas*' engine was sufficiently powerful to carry a much larger cargo than the present boat was capable of taking.

Mr. TAIT expressed his surprise that so small a boiler as that in the *Thomas* should do so much duty. Seventy tons was a large load for the boiler to propel at the rate mentioned.

Mr. MILNE thought the efficiency of the boiler arose, in some measure, from the use of the tapered tubes. He had had considerable difficulty in getting such tubes; but he had recently succeeded in obtaining tapered iron tubes, a specimen of which he exhibited, and he intended to use them in future. The heating surface in the *Thomas*' boiler was 1·8 feet per superficial inch of piston, whilst in a number of locomotives, with which he was acquainted, it was, on an average, 2·8 feet.

The CHAIRMAN, referring to the mention in the paper of trains of boats, asked if the different traders could be got to bring their boats punctually at the times appointed for starting the trains?

Mr. MILNE thought that this was one of the great difficulties connected with trains of boats—the several traders could never be depended on to have their boats ready at the proper times; but the greatest difficulty with trains would be at the locks. The boats would have to be detached, and passed through one at a time, and when boats were passing in the opposite direction, further delay would be caused, as, if the going boats claimed the lock each time it was full, the returning boats would claim it each time it was empty.

The CHAIRMAN remarked that, in the comparison given in the paper between steam and horse-haulage, the latter had been put down at $\frac{8}{10}$d. per ton per mile. He had ascertained that with minerals, the cost of horse-haulage was, in many cases, not more than $\frac{1}{8}$d. per ton per mile.

Mr. MILNE stated, that in the case from which the data for comparison were derived, there were only two-thirds of the mileage that was generally got with minerals. There were three locks every two miles on the canal between Port-Dundas and Bowling; whilst on the mineral canals where the horse-haulage was so low, the number of locks was much less; besides the coal scows met with much less detention, when loading and unloading, than boats carrying a general goods cargo.

Mr. ROBSON said he was aware of instances where the cost of horse-haulage was as low as $\frac{1}{8}$d. per ton per mile. In one set of figures he had seen it $\frac{1}{8}$d. per ton per mile, and he had thought it would be difficult to do it more cheaply. However he had seen reason to alter this opinion. In horse-haulage, the number of trips was limited, whilst with steam, one-third more trips could be got with a boat.

Mr. MILNE was satisfied that with steam they would be able to carry at two-thirds of the cost of horse-haulage, under any circumstances. Horses could not last beyond a certain time, whilst with $7\frac{1}{2}$ per cent. set aside for repairs, the duration of an engine might be said to be unlimited.

The CHAIRMAN observed, that Mr. Robson's paper was a most important one. Canals were the best means of conveyance for heavy goods of small value for their weight, at low speeds, on account of the small propelling power required, and the consequent small cost. They had been neglected of late years, but undeservedly so, and it was gratifying to see them again attracting attention. Steam power had been found advantageous in every other application, and he thought it would eventually prove so in this. As mentioned in the paper, many schemes had been tried; amongst others was that of warping, by means of a chain lying along the bottom of the canal. He believed this plan had been used with advantage in tunnels where there was no towing path; but he thought it must be expensive. He thought it a pity that some other ingenious projects that had been formed had not been tried. There was one in particular, invented by Mr. Charles Liddell, in which fixed engines and wire ropes were to be used, and which would probably give very good results, if the traffic were sufficiently great to keep the apparatus continually at work.

In conclusion, the CHAIRMAN remarked that the case of the *Thomas*, detailed in the paper, was one of the first, if not the only instance, in which steam power had been applied with practical economy.

A vote of thanks was passed to Mr. Robson for his paper, and to Mr. Milne for the information he had communicated.

The following paper was then read:—

On a Joint-Chair for Railways.—By Mr. William Johnstone.

The object of the present paper is to bring under the notice of the Institution a joint-chair recently adopted by the writer in constructing the permanent way on new lines of railway, and also on old lines requiring to be laid with new material.

The ordinary plan of joining the rails is to secure the two ends of the bars in a joint-chair, by means of a wooden key.

The new chair is made to fit the section of the rail, leaving it only as much play as will allow it to slip on, and it consequently requires no key. All the intermediate chairs are made so as to receive the ordinary key for fastening the rail in its place. The sleepers on which the chairs are fastened, are placed at equal distances of 3 feet 8 inches from each other, excepting those next the joint, which are each 2 feet 6 inches apart.

The advantages gained by this kind of chair are:—

1st. Security against accident, since the rails cannot get displaced at their joinings, as in the old plan, where the safety of the train passing along depended on the key at the joint being in its place.

2nd. Simplicity of application to either new or old roads.

3rd. The reduction in expense attending both its first application and its future maintenance.

Where railways are constructed upon the old plan of having the joints secured by keys, the surfacemen of the railway require to make morning and evening examination of the rails, and sometimes oftener, principally to see that the joint keys are in their places. Notwithstanding this examination, the writer is aware of accidents, some of a serious nature, having occurred in consequence of the joint keys getting displaced; and it was to obviate this, and to render the security of railway travelling independent of the faithfulness of such an examination by ordinary workmen, that he was induced to adopt this plan of joint-chair.

Previous to introducing this chair, the writer is not aware of any permanent way having been constructed on the plan recommended. It has now been used upon upwards of forty-five miles of railway, and it has been found to suit the purpose, making a very smooth road. So far as safety is concerned, this chair appears to be equally as good as any kind of fish-jointing, whilst its first application and future maintenance are entirely free from complication.

A specimen was produced at the meeting, showing the manner in which the rail and chairs were placed. The arrangement is shown in figs. 3 to 6, Plate VII., fig. 3 being an end elevation of the common intermediate chair, with the rail in section wedged in its place; fig. 4 an end elevation of the improved joint-chair, with a rail end in its place; whilst figs. 5 and 6 are side elevation and plan of the ends of two rails, with the joint-chair and the adjoining intermediate chair on one side.

Mr. NEIL ROBSON said, he could bear testimony to the smoothness of road where the new joint-chairs had recently been laid down; but he had doubts if it would last. When the joints began to wear, the ends of the rails would get loose, and there being no wedges to tighten them, would be liable to shake. As a proof that the rails did wear in the chair, he might mention that he had recently seen some I rails which had been turned, and of which quite one-eighth of an inch had been worn away. The loosening consequent on the wearing of the rail would, when once begun, be always getting worse. Notwithstanding this drawback, he considered the joint-chair very ingenious and very safe. He wished to know how long it had been in use?

Mr. JOHNSTONE said, that wedges were used in the adjoining intermediate chairs, and would prevent or very much reduce the shaking anticipated by Mr. Robson. Some of the joint-chairs had been in use three years, and not the slightest wear was perceptible in them.

Mr. TAIT thought the new joint-chair was much better than fish-jointing. Fishing always got loose, in consequence of the great weight which was brought to bear on the bolts. He thought that the new joint-chair would eventually wear loose; but the nearness of the adjoining wedged chairs would render the leverage very small, with which any lateral strain could act on the end of the rail.

Mr. ROBSON remarked, that he never had a very high opinion of "fishing," according to the mode first introduced. Several years ago he had occasion to be on a part of one of the Scotch lines, where they had just commenced that system of securing the joints, when he had noticed both nuts and bolts lying loose at the sides of the rails, and was informed by the platelayers that this occurred constantly, so much so that a man had to examine and screw them up almost daily. More recently, on asking a former advocate for it his opinion of the system now, his answer was, that "it was not worth the money it cost over and above the ordinary mode of laying." He ought, however, to state that very great improvements had been made on the system since it was first introduced, and that the objections to it were thereby to a great extent removed, and he would not like his remarks to be considered as condemnatory of all kinds of fish-jointing. He understood that some of the most important railway companies were now making use of it, and that in particular the London and North-Western Company, who looked after these matters as well as any railway company in the kingdom, were adopting a plan of fish-jointing of a superior kind.

Mr. JOHNSTONE said, that any kind of "fishing" was complicated, and it was difficult to get ordinary workmen to do it properly. He had always found that where ordinary workmen were employed upon a thing, it was necessary that every part about it should be as simple as possible; otherwise it was impossible to get it done efficiently.

Mr. ROBSON inquired if, in repairing the road, there was greater difficulty in taking out a rail and putting in a new one, than with the ordinary plan? The great merit of the common plan consisted in the facility and rapidity with which the chair keys could be knocked out, and a new rail inserted at once. He thought the new joint-chairs would require a little more time.

Mr. JOHNSTONE stated that the new joint-chair did not render the putting in of a new rail any more difficult than in the common plan. It was simply necessary to shift the sleeper a little, and although a little additional time might be required for the operation, it was nothing compared with the advantages attending the use of the new chair.

The CHAIRMAN said the new joint-chair was very simple and ingenious. The invention was one of those, respecting which it struck one as strange that it had never been thought of before. It had been in use during three years with success, and was certainly a considerable improvement in "permanent way," in which, as every one would allow, much improvement was wanted.

The thanks of the meeting were voted to Mr. Johnstone for his paper, and for the specimen chair exhibited.

The following paper was then read:—

On Pointing Fire-Arms. By Mr. J. G. Lawrie.

[Abstract.]

Every improvement in the power of a fire-arm, every increase in the distance to which shot can be thrown, demands additional accuracy in pointing the piece.

When the soldier's musket was harmless at a distance beyond 250 yards, and field-pieces were limited in effective power to 700 yards, very different means sufficed for taking aim than are desirable with a power of impulsion increased fivefold. Fire-arms are now constructed, as regards the distance to which, and the accuracy with which they throw projectiles, with a perfection unknown a few years ago. The soldier's former musket, called "Brown Bess," was incapable of throwing a shot with a force to penetrate beyond a distance of 200 to 300 yards, and even at that or a much less distance was altogether uncertain of hitting. The same imperfection existed in all classes of ordnance.

To remove this uncertainty of hitting in the use of small arms, or in other words, to make a musket when placed in a fixed position, throw a shot twice through the same path, rifled barrels are successfully employed, and there are grounds to believe that by means of Whitworth's polygonal rifle bore, the same important desideratum will shortly be accomplished with ordnance. Before the invention of the Minié bullet, rifled barrels were objected to in consequence of the difficulty and time required in loading the gun; but now that this bullet so facilitates the loading of a rifle as to require for that operation no more time than is necessary to load a plain barrel with a plain ball, the soldier's musket has in the Minié rifle reached a high degree of perfection.

What is the history of this unrivalled weapon? Its history is the same as that of all other revolutionary improvements. The work of twenty years, the labour of a lifetime, was necessary to introduce it. In 1826, M. Delvigne first invented it, and having made experiments with the elongated ball, brought it before the French authorities. From 1826 till 1837 no official would listen to him, and he had to contend against the ignorance and prejudice of all the civil and military authorities of France, although he pointed out that the best troops of France under the most experienced officers had been beaten by the rifles of the peasantry of the Tyrol. The loss, however, of officers and men in Algeria was so great, that in 1838 the Duke of Orleans before going to Africa organized a battalion of the *Tirailleurs de Vincennes* (then called *Chasseurs d'Afrique*) to take with him. In 1844 Captain Minié invented the hollow ball. At length in December, 1854, during the heat of the Crimean war, through the influence of public opinion, brought to bear chiefly by the *Times*, Mr. Sidney Herbert, the Secretary-at-war of the British Government, in the House of Commons announced the intention of the Government to arm the whole of the troops with the Minié rifle, and that these weapons were being issued as fast as they could be supplied from the manufacturers.

Thus, a period not much short of thirty years elapsed before the superiority of the rifle barrel, with its peculiar ammunition, was established.

Perfection in ordnance, similar to that attained with small arms, is now the great engineering problem of the day in gunnery. The malleable iron gun made by the Mersey Steel and Iron Company, which possesses great power of throwing heavy shot to distant points, has hitherto sustained all the proofs to which it has been subjected, and is now at Shoeburyness ready for service. The 36-inch malleable iron mortar made by Mallet in London, and called Lord Palmerston's Mortar, has not yet proved itself quite sound, having, on each of the two trials made with it, shown symptoms of defective strength; but it is believed that this mortar will yet be made effective. The object of these arms, and of others which have been made, is to throw heavy metal to great distances; and that object is probably in a fair way of being accomplished; but no attempts to construct rifle ordnance so as to throw heavy weights with accuracy to great distances have hitherto been equally successful. Lancaster's oval bore has proved a total failure, and other efforts having been equally fruitless, attention is now closely directed to Mr. Whitworth's rifle cannon with a polygonal bore. From this gun very favourable results are anticipated.

In proportion, however, as the power of fire-arms is increased, the problem of how to use them presses for solution. When firing at distant objects, or indeed at objects beyond a very limited distance, the piece is elevated to an angle depending in amount upon the remoteness of the object, and therefore a means of arriving at a knowledge of the distance of the object to be fired at is essential to an effective use of the weapon.

At the Government School of Musketry at Hythe in the South of England —a school established for the purpose of instructing the troops in the use of the Minié rifle, now called the Enfield rifle—the soldier is instructed how to handle or manipulate his rifle, and how to judge of the distance of the object to be fired at. The first of these instructions is manifestly of small importance, and of easy acquirement, compared with the second. A soldier of ordinary intelligence should speedily become familiar with the mode of handling a rifle, but it would appear to be exceedingly difficult to convey, even to a soldier of unusual intelligence, the power of judging with much accuracy whether an enemy be at the distance of 600, 800, or

1000 yards, and upon the possession of that power of judging the distance, depends the effective use of the weapon.

The solution of this problem in the manner pointed out at Hythe, is rendered materially more difficult by the varying circumstances in which a soldier is placed by excitement, by change of ground, change of atmosphere, and fatigue.

When an object is distant 100 feet or 100 yards in front of the place from which an estimate is made of the distance of that object, the difficulty of making that estimate with any accuracy, has probably been often experienced by engineers; but if there be such difficulty with so short a distance as 100 yards, how much greater must it be when the object is distant $\frac{4}{7}$ths of a mile! According to Sir Charles Shaw, the accuracy of firing by ordinary troops when the distances are known is remarkable, but those very troops when required to fire consecutive shots upon an enemy approaching at a trot or gallop, would probably be far less successful when in possession of no other means of knowing their distance, than their own estimate by the eye.

The Hythe instructions for judging distance appear exceedingly crude, and seem but little suited for an effective use of the new and powerful fire-arms. Instead of the uncertainty which appears to surround the plan of the instructions, another method of procedure, consisting chiefly in a change in the sight, seems to supply not only the information aimed at by the instructions, but also to remove an imperfection in the construction of the rifle as at present made.

The rifle at present in the hands of our troops is represented in fig. 5, Plate IV. A sight is placed on the top of the barrel, at A B, and is so constructed that the soldier can alter the height of the top of it, by pushing up or down a slide working upon two guides.

In using the rifle, the soldier first, in conformity with the Hythe instructions, estimates the distance of the object, then adjusts the top of the sight, A, to the point graduated as corresponding with that distance, and putting the rifle to his shoulder, elevates the point until his eye, the top of the sight, and the muzzle are in line. If the stock of the musket used in this manner fits the arm of the soldier when firing to one distance, it manifestly cannot fit it when firing to any other—an objection which every marksman knows is by no means immaterial.

Two forms of sight have been devised by the writer—one for ordnance, and one for small arms; or rather one for distances under 1000 yards, and one for greater distances. The sights are very simple, and depend upon the principle that the more distant an object is, the smaller it appears.

For long distances, the sight consists of a small telescope, which is provided with two fine steel wires, or, as is customary with opticians, two threads of spider's web. These threads are placed across the object-glass at its focal distance, and can be separated or approximated in a manner which by a micrometer screw affords the means of measuring the distances between them to any amount of minuteness. Thus, whether the object be cavalry or infantry, the distance is known by a scale graduated on the telescope, indicating the distance asunder of the threads.

The form of sight for field-pieces and rifles, which are not used for distances so great as ordnance, and therefore do not require so much power, is intended to be always attached to the weapon itself. In fig. 6, a rifle is shown with one of the several forms of this sight.

A sight, A, shown enlarged in fig. 7, is placed on the barrel. This sight is a plate having apertures cut through it, which apertures, 2, 3, 4, &c., correspond respectively to the apparent height of a man at the distance of 200, 300, 400, &c. yards; and therefore an eye at E, looking through the aperture 2, at a soldier 200 yards off, will just see him from head to foot. In the same way, looking through the aperture 3, it will just see a soldier 300 yards off, and so on with the other apertures. But in firing at an enemy 200, 300, or 400, yards off, the barrel must, in each case, be elevated to certain angles, each distance having an angle of its own, depending upon the power of the rifle.

In constructing the sight, the several apertures are cut in such positions as to require the elevation of the barrel of the rifle to the proper angle, in order to make the object visible through the corresponding aperture. If, in looking through the aperture 3, for example, the object be seen from head to foot, the barrel is at that moment elevated to the proper angle; and in the same way, if in looking through any other aperture the object be seen from head to foot, the barrel is simultaneously elevated to the proper angle. Thus, in using the rifle, the soldier has no concern with the distance of the object, but has to perform only the one operation of looking at the object through the aperture which contains it from head to foot—a mechanical process unaffected by any external circumstances of ground, atmosphere, or change of dress.

If the objects, of which the distance is measured, whether by this last sight, or by the telescope, be of an invariable height, and if sufficient care be taken in the observations, results of very considerable exactness are obtained—results, however, not comparable to trigonometrical measurements, but vastly superior to any estimate the most practised eye could make.

These sights appeared to the author so simple in principle, and so simple in construction, that he made a search to learn whether they had not been previously in use. The result of the search was to ascertain from

Coddington's Optics,* that the same principle, embodied in a different mechanism had been used for astronomical purposes, and also that an instrument called the *stadia*, which consists of two divergent limbs, like two sides of a triangle, has been or is in some use in the French service. This instrument is held before the eye at a distance determined by the length of a cord grasped in the teeth, and is graduated to show the distance of the object, which corresponds to the distance from the apex of the parts of the divergent limbs, which just span the object.

It is, therefore, not new to measure distances by telescopes, nor by instruments like the stadia; but the author believes it is quite new to elevate or point fire-arms by mechanism in which a telescope or other sight is used in such a way that the single act of gauging the object elevates the barrel to the proper angle. For long distances the author uses the telescope sight in this manner, and for shorter distances the sight described in fig. 7, or another form depending on the same principles.

Mr. Lawrie not being present when the paper was read, the discussion of it was postponed until the next meeting, when the following observations were made:—

Mr. Lawrie explained the action and advantages of his rifle-sight at length. With the common sight, the distance had first to be estimated or guessed, and the sight to be afterwards adjusted to it. His sight itself afforded a very simple and sufficiently accurate means of ascertaining the distance, whilst the very operation of finding the distance adjusted the piece for firing with the corresponding elevation. With the common sight, again, the fixed reference point was at the muzzle of the piece, and the piece was adjusted by raising or lowering the breech, and the consequence was that the piece had to be applied to different parts of the shoulder for different distances; and if it fitted the shoulder in one position, it could not do so in others. With the new sight the fixed point of reference was over the lock, and the piece was adjusted by raising or lowering the muzzle—the position of the piece against the shoulder remaining the same, or very nearly so, for any distance. The improved sight had been tried upon a rifle, and no difficulty was found in using it.

In reply to an observation respecting the difficulty of adjusting the elevation of a rifle, when firing at troops in a kneeling or lying position, Mr. Lawrie said his sight could do no more than common sights under such circumstances. In reply to a remark that the sight was in an awkward position at the muzzle of the piece, and would be liable to injury, he said it could easily be made strong enough, and it might be made of considerably thicker metal than the barrel, without inconvenience.

Mr. Fenton thought that sights would be of very little use in an engagement, after the first round, as the view would be much obscured by smoke.

* Edition 1825, page 129.

Mr. Tait was of opinion that there could be no question as to the relative merits of the old and new sights. Mr. Lawrie's was clearly superior. If the apertures were correctly made, and in their proper relative positions corresponding to different distances, the use of the sight must give the exact range in each case—and anything better than this could scarcely be expected.

In reply to a question from Mr. Downie, Mr. Lawrie stated that a rifle, with his improved sight, had been placed in the hands of the Woolwich authorities for examination, and was still there, no report having been made.

On the motion of the Chairman, the thanks of the meeting were passed to Mr. Lawrie for his paper.

The Fifth Meeting of the Session was held in the Philosophical Society's Hall, on Wednesday, 17th February, 1858, the President in the chair.

A discussion took place on the subject of Mr. J. G. Lawrie's paper read on the 20th January. This discussion is given at page 66.

The following paper was read:—

On employing Steam expansively.—By Mr. Alexander Morton.

The economy of fuel obtained by the expansion of high-pressure steam, has been the subject of much discussion and experiment amongst engineers; although many have still doubts on the subject, and we hear of many failures, yet there are successful trials which sufficiently prove that economy really does result from expansion, if the proper means are employed. It is well known that, in most cases, success has been owing to the steam being supplied with additional heat, whilst expanding. When steam or air is compressed, a certain degree of heat is made sensible, which disappears on its being again expanded. Gay Lussac says, if air be compressed into one-fifth its original volume it will ignite tinder, but he does not state at what speed the compression takes place. Those workmen who daily use the fire syringe can produce fire when the air is far less compressed, and if the speed of compression could be sufficiently increased, air might ignite tinder when very slightly compressed. It would be unreasonable to believe that the amount or degree of heat made sensible by compression could cause re-expansion, so as to raise the weight by which it was compressed, at a greater velocity than that of compression, without being supplied with additional heat from surrounding bodies. It is a universal law, that force, whether in the form of heat or anything else, cannot be gained or created; therefore the amount of heat made sensible by compressing air or any elastic fluid cannot expand it at a greater velocity than that at which it was compressed, without abstracting additional heat from surrounding bodies. The amount of heat required to expand saturated steam depends wholly upon the speed of expansion; and on examining indicator figures taken from engines working expansively, it will be found that the speed of the piston distinctly alters the curve.

If a given volume of air in contact with a given volume of water of an equal temperature is very slowly expanded, the temperature will very slightly diminish; but when it is expanded at a great velocity, the temperature will be greatly reduced, and as the speed of expansion is increased, a proportionally greater diminution of temperature is indicated by the thermometer immersed in the water. When a piece of copper wire is drawn through a die less than itself, being thereby lengthened, if it is wholly immersed in a given quantity of water, the rise in temperature will correspond to the speed with which the wire is drawn. If a fly-wheel running at a given velocity be immersed in water, the motion gradually diminishes, and the water rises in temperature; but if the wheel be held against the side of the dish containing the water, a greater rise in temperature will be indicated. If the total heat in a given weight of steam is measured by suddenly mixing and condensing it in a given quantity of water of the temperature of 40° Fahr., 1040° becomes sensible; but if the steam is slowly condensed in a small surface condenser, 680° only may become sensible. Experiments which I have performed, giving these and many similar results, prove that the amount of heat made sensible depends upon the speed with which equilibrium is destroyed or restored. The latent heat in steam can be viewed as a motion of its matter, and the heat made sensible in restoring equilibrium depends wholly upon the period of time in which it is restored. Time, heat, and motion, may therefore be intimately connected.

Fig. 1, Plate VIII. is a representation of a column of high-pressure steam issuing freely into the atmosphere. If the hand be held at the base of the column, a great degree of cold is felt in the surrounding air immediately in contact, and the greater the pressure of the steam before liberation, the greater will be the degree of cold felt. If a spring balance (having a very light disc attached) be held in the issuing column, an oscillatory motion will be imparted to the disc, the time of an oscillation depending upon the pressure or on the speed of expansion. As we ascend the column, the time of an oscillation is greater, and as the pressure of the steam is increased, the temperature of the issuing steam near the base of the column diminishes, as shown by inserting a thermometer. The steam on being liberated suddenly expands, and the surrounding air endeavours to supply the demand for heat; but, as the heat in the air is unable to supply the expanding steam with sufficient rapidity, the steam partially condenses, and the heat produced by this partial condensation maintains the remaining steam, which causes the volume to alternately increase and decrease, producing the oscillations shown in the figure. To trace this phenomenon still further, I experimented with a small high-pressure engine, driven at different speeds, with the view of determining the speed best suited for different pressures, with different degrees of expansion. In experimenting at slow velocities, no condensation of the steam in the cylinder was perceptible, and the figure traced by the pencil of the indicator showed a regular curve, represented in fig. 2. When the velocity was increased the figures became oscillatory, and a greater condensation of the steam in the cylinder was very evident on opening the discharge cock. As the speed was further increased, the oscillation and condensation rapidly increased, and the indicator figures became no guide for the quantity of steam used, but the greater amount of fuel required distinctly proved that the steam was not sufficiently supplied with heat for the rapidity of its expansion. On examining figures taken from engines working expansively, it will be seen that the speed of the piston has a great effect in changing the form of the curve. When the piston is at its point of greatest speed the pressure falls quickly, and as the speed of the piston diminishes towards the end of its stroke, the figure falls less and less quickly. The influence of the same law is shown on compressing steam into a less volume; the greater the speed of compression, the greater is the rise in pressure. Locomotive and other engines working expansively, by means of the link motion, compress a certain volume of the exhaust steam at the termination of each stroke; and on measuring any of the figures of such engines, it will be seen that the greater the speed of compression, the higher the pressure of the compressed steam. An example of this is given in fig. 4. When steam of a certain pressure is suddenly exhausted into the atmosphere, or into the condenser, the sudden expansion of the steam robs the cylinder of a great portion of heat, and by altering the speed of exhaust, the condensation of the entering steam can be increased or diminished. Short-stroked engines running at a high speed open the exhaust with a greater speed in proportion, consequently a greater amount of heat is robbed from the cylinder. It is a great mistake to construct an engine with a sudden exhaust and a large condenser. The Cornish pumping engines have very small condensers, and very slow exhausts, which gives them an important advantage over the generality of short-stroked crank engines. If the exhaust steam could be removed from the cylinder before being expanded, then our only loss would be the pressure of the steam at that period. In Cornwall the steam induction passages are virtually the largest, and the eduction the smallest, quite contrary to the general practice elsewhere.

The jacket in these engines supplies heat to the cylinder, and the steam maintains nearly a uniform temperature throughout the stroke, and instead of throwing the whole of this valuable heat into the condenser, a certain portion of it is retained, and compressed in cushioning the moving mass at the termination of the out-door stroke. This portion of superheated steam filling the clearance space above the piston, superheats the entering saturated steam, admitted suddenly by the sudden opening of the large steam valve; and this heat maintains the steam in its gaseous form without extra fuel, since it is recovered from the previous-stroke steam. There are other means of superheating steam; for instance, if steam be generated in a vessel at a high pressure, and then allowed to expand freely into an empty vessel, that portion which enters first expands, and is immediately afterwards compressed by the following portion. The volume of the steam by this compression becomes superheated, and possessed of an elasticity greater than that due to its density. Watt denied that there was any increase in the total heat in saturated steam. Southern asserted that the whole of the augmentation in temperature was so much additional heat. When steam is generated under an increasing pressure, we find that the pressure rises very slowly at first, but the more the temperature rises, the more rapidly does the pressure increase. From this fact many have thought that less fuel was required to evaporate water at the higher pressures, but Watt, Christian, and many others, found that an equal quantity of fuel was required to evaporate equal quantities of water under different uniform pressures. Experience has shown that rather more fuel is required to evaporate water at the higher pressures, and this is probably because the difference of temperature between the furnace and the boiler is less as the pressure is increased, and the loss by radiation is also increased. With ordinary pressures, only about 5 per cent. extra fuel is required. When evaporating water under an increasing pressure, the whole volume of water in the boiler has to be raised to a corresponding temperature, and we know that an increase of about 40° Fahr. is required in raising the pressure from one to two atmospheres, and only 46° Fahr. additional in raising it from two to four atmospheres. If the steam space is small, and if there is a great body of water in the boiler, the fuel required to raise the pressure from 15 pounds per inch to 30 pounds per inch, may be nearly double that required to raise the pressure an additional atmosphere, namely from 30 to 45 pounds per inch. This is the cause of the greater velocity as the pressure increases. Some very successful trials of mixing saturated steam with superheated steam have been made lately, and many would at first wonder when told that two different steams of the same pressure, when mixed together, suddenly became of a higher pressure. In several experiments which I have performed with steams of little above atmospheric pressure, with their respective temperatures about 500° Fahr. and 214° Fahr., the pressure instantaneously increased. I intend in future experiments, if possible, to define the amount. Having already said that the latent heat made sensible by condensing a certain weight of steam depends upon the speed of condensation, I may add that I am of opinion that saturated steam, when mixed with water at about 60° Fahr., is condensed at the same speed as that at which it was generated; because the same quantity of fuel which generated the steam, can, if applied directly to the water, raise the same volume through nearly an equal number of degrees; but apart from this, if high-pressure steam be condensed without being allowed to expand (which is easily accomplished by filling the condenser with air at nearly the same pressure), the heat made sensible is less than that of low-pressure steam, if measured in the same manner. The greater weight of the air slightly prevents the speed of condensation. Steam can be viewed as a body in motion. If its motion is destroyed in a given period of time, the amount of heat made sensible is equivalent to that required to give an equal body the same amount of motion in the same time. In expanding steam under a steam-engine piston, a very small portion would resume the form of water if 1000° Fahr. were liberated to supply the then remaining steam, as generally believed; but as the steam very slowly resumes the form of water in expanding, a great quantity would consequently require to condense to supply the demand, and in a steam-engine where no means of supplying the expanding steam is adopted, if cutting off at, say, half stroke, with an ordinary motion, no water in the cylinder may be perceptible; yet, if the steam be cut off at one-fourth of the stroke, the piston running at the same speed, the greater quantity of water in the cylinder will distinctly tell upon the fuel consumed.

Steam, viewed as a body in motion, cannot be expected to impart motion to another body, without an equivalent diminution in its own motion; yet in considering the action of steam in an engine working with a uniform pressure throughout the stroke, many entertain the idea that the steam is nothing impaired, when the stroke is accomplished, because they find a cylinder full of steam at the same temperature and pressure as at the beginning of the stroke; and a cylinder full of steam is thrown into the condenser. This is no doubt the weight of steam thrown into the condenser; still it forms no measure of the quantity of steam which left the boiler. On motion being given to the piston a certain portion of the steam loses its motion, and becomes water of the surrounding temperature. Additional steam from the boiler occupies the place of the previous steam, and this change of motion continues as long as the piston continues to receive motion. Undoubtedly a very small percentage of the motion in steam is utilized in this manner, compared with the quantity thrown into the condenser; but by increasing the load on the piston it is easy to see that a greater per centage will be utilized, and that greater economy of fuel will follow. Oliver Evans, and many others, have distinctly mentioned that it did not require double the fuel to double the work of an engine working full pressure. There are many aware that steam assumes the form of water in expanding under pressure, who still believe that the portion condensing gives out 1000° Fahr. (which is termed the latent heat) to superheat the steam still remaining. If, however, the motion in steam could be absorbed by producing motion in another body, and still 1000° Fahr. made sensible, we could then gain motion or heat without fuel; but when we consider that the motion in steam is wholly absorbed by another body, we cannot expect even 1° Fahr. to make itself sensible in expanding the remaining steam. On again referring to the indicator figures, shown in Plate VIII., we find that when the steam is suddenly expanded, it rapidly diminishes in both temperature and pressure, and being below the temperature of the cylinder and piston, it abstracts the heat from the cylinder and enlarges the whole volume, which again diminishes by the rapid expansion. This change of motion, or condition, abstracts an equivalent amount of heat from the cylinder which must be supplied from the entering steam, with a proportionally increased expenditure of fuel; consequently, the greater the degree or speed of expansion the slower should the velocity of the piston become, unless the motion in the steam is preserved by heat from another source. The motion in steam, or any other body, can be preserved with a less expenditure than that required for its production, and in steam-engines where this has been attended to, great economy has been obtained. I do not mean that steam should be superheated above what is necessary to preserve its motion, for, if the steam be superheated, the whole is thrown away at the termination of the stroke, unless means are employed for recovering the heat. A certain portion of this heat is recovered in the Cornish engines, as I have already noticed, by closing the equilibrium valve before the end of the stroke; and as the moving mass is increased, the greater volume of this superheated steam is retained and compressed. It is proverbially well known throughout Cornwall, that the duty of the engines has increased as the mines have been wrought deeper, and the moving mass consequently increased; and many have also found a gain by increasing the moving mass in crank engines. I have already briefly explained the cause of this increased duty, when considering the action of an engine working with a uniform pressure throughout the stroke. When the load is increased in the Cornish engines the degree of expansion is also increased, the velocity of the piston diminishes, and a greater portion of the superheat is recovered from the previous-stroke steam, by retaining a greater portion in the clearance space in the manner already explained. These advantages outweigh the loss by the extra friction of the greater moving mass. I have, by repeated experiments, found that, as asserted by high authorities, the consumption of fuel required to raise a given volume of water through a given number of degrees is equal, whatever is the time in which it is accomplished. By the consumption of 1 pound of fuel, a certain volume of water is raised in temperature 10° Fahr. in an hour; and the consumption of 2 pounds of fuel can raise the same volume of water twice as rapidly, that is, 20° Fahr. in an hour. Here is therefore a means of gaining or losing time *ad libitum* if the rise in temperature is the work required from the fuel. It follows, as a consequenee, that if we construct a furnace to consume 4 pounds of fuel per hour, instead of 2 pounds, we can then raise double the quantity of water through a given number of degrees in a given period of time, which will undoubtedly be a great gain. When saturated steam is mixed with water at about 40° Fahr., 1040° Fahr. become sensible; but by another experiment, to which I have already alluded, 680° Fahr. become sensible. Here then is a means of losing heat, because the steam was condensed in a longer period of time. If the motion of a body be absorbed by another body of an equal weight in an almost inconceivably short period of time, an equal amount of motion is produced in the latter body; but if the first body impart its motion during a greater length of time, a correspondingly longer period of time is required to produce the same motion in the second body.

From these considerations, it would appear that time, heat, and motion can be lost; but I have already alluded to the intimate connection between the three, and no one of them can be lost without producing an equivalent of one or both of the other two. We have been led to believe, upon high authority, that there is no more possibility of increasing the power of an engine by merely altering its working parts, than there is of increasing the effect of a waterfall, by arranging the pipes which serve it. Fortunately, those who have found it necessary to apply a constant stream of cold water upon the crank-pin and other bearings of short-stroked engines, cannot believe in such an absurdity, knowing that heat cannot be made sensible without destroying motion. Witness the effects of experimental engines, constructed with the view of economizing fuel, by carrying the expansion of saturated steam very far. Experience has taught us that our previous theory of expansion was at fault; and, without fear of contradiction, I assert that the engines in Cornwall have, for the last twenty years, given more economical results when cutting off at about half stroke, than the generality of our high-pressed double-cylinder expansive engines (excepting cases where an additional amount of heat is supplied to the steam, corresponding to the speed of its expansion).

I shall now endeavour to explain the action of the steam in the cylinder of the experimental engine, when the velocity of the piston was increased, fig. 3 being traced by the pencil of the indicator. I may first mention that almost precisely the same figure was traced whether the paper's surface was rough or smooth, or the pencil spring of the indicator strong or weak. When the steam first enters the cylinder, the piston is at that instant in a state of rest or equilibrium; the action of the steam upon the piston causes it to recede very slowly at first, and a certain portion of the steam's motion is destroyed, having been absorbed by the piston. But as the steam valve is still open, fresh steam is supplied from the boiler, and as the piston's motion is accelerated, a greater portion of the motion in the steam is absorbed; and as soon as the steam supplied is deficient, either from the passage being too contracted, or from being wholly intercepted by the closing of the cut-off or steam valve, the pressure immediately diminishes, as shown by the first fall in fig. 3. At this point the steam has so suddenly imparted its motion to the piston, that its temperature is reduced below that of the cylinder in which it is contained; but although it is at a low temperature, it has not resumed the form of water, but is what I shall term supersaturated steam, being possessed of a density greater than that due to its pressure. This supersaturated steam being of a lower temperature than the cylinder and piston, absorbs heat from the cylinder,—this heat endeavouring to restore equilibrium by supplying the demand, and the motion or pressure of the steam again increases, as shown by the rise of the second oscillation. The piston being still in motion, again absorbs the motion of the steam with greater rapidity than that with which the cylinder can supply the requisite heat; and the steam, consequently, falls in temperature. This change of motion would continue as long as the piston continued to move, the cylinder still endeavouring to supply the heat required by the expanding steam. It will be distinctly noticed, on examining the figure, that as the velocity of the piston diminishes towards the termination of its stroke, the time of an oscillation increases, and the variations diminish, as already explained when considering the same phenomenon in a jet of high-pressure steam issuing freely into the atmosphere. If a certain weight of cast-iron, at the highest temperature of the cylinder, is immersed in cold water, a very small quantity of heat is made sensible; and on noticing the indicator figure at the period when the first abstraction of heat from the cylinder takes place, we find that the whole volume of the steam in the cylinder has been raised in pressure by the heat it has received from the cylinder and piston in a very short period of time. I must remind you that steam supersaturated by expansion, requires very little heat to recover its motion, compared with that required for its production. On comparing figs. 2 and 3, or on measuring the curve of compression, we find that the pressure increases in a much greater ratio at the higher velocities.

We have generally understood that any body falling freely by the action of gravity, and having its motion destroyed by a perfectly elastic material, would rebound and ascend to precisely the same height as that from which it fell, in an equal period of time; if, therefore, a body descends in one second of time, by the end of the next second we expect to find the ascending body at precisely the same height, and equilibrium again restored—quite independently of the time occupied in the change of motion. If we can conceive the change of motion to have been accomplished in no time, then this law would be correct; but as we know this to be impossible, we may rest assured, that whatever time is occupied in destroying motion, the same time is required to reproduce it in the same body. When a body is projected upwards with the velocity of thirty-two feet per second, its motion is destroyed in one second of time by the action of gravity, and we find that exactly one second of time is required before it returns with the same velocity. This is, undoubtedly, a universal law, and shows that time can be lost. I have now to mention an equally important law—namely, that the heat made sensible by destroying motion or restoring equilibrium in any moving body, depends wholly upon the time in which the motion is destroyed. If the heat made sensible by destroying the motion of any body in a unit of time can be wholly utilized, in again restoring an equal motion, this will undoubtedly be accomplished in a nearly equal period of time; but if two units of time have elapsed in destroying the motion, then the heat made sensible cannot possibly restore a similar motion in less than two units of time. I have repeatedly proved this by experiments, and I find steam forms no exception, being merely water in motion. Those who have performed experiments with the view of discovering the amount of latent heat in steam, arrived at different results, the cause of which I shall, with your permission, endeavour to explain in a future paper, along with drawing and description of the apparatus I employed.*

In conclusion, I would remark that the key to the various phenomena I have been discussing, as well as to many others, lies in the fact that gravitation endeavours to restore equilibrium or rest in all bodies. Motion follows on equilibrium being destroyed, and ceases on its being restored. Thus in the case of the jet of steam (fig. 1) issuing freely into the atmosphere, at first a certain portion of the air is robbed of its heat to supply the suddenly expanding steam, and then an equal portion of air is heated, and equilibrium again restored.

The PRESIDENT said he had requested the secretary to put on the board some extracts from a table of results obtained by Regnault, which seemed to bear upon the part of Mr. Morton's paper, in which he treated of the heat made sensible on condensing steam. A

* Mr. Morton's second paper is given at page 97.

translation of the paper from which these figures were taken, was in a volume of the Cavendish Society's publications. With reference to the cold felt in a jet of steam issuing into the atmosphere, he might mention that Messrs. Joule and Thomson had made some experiments with compressed air allowed to rush out freely into the atmosphere. They found that the temperature fell in the rapid part of the current, but the heat was almost all reproduced when the motion had quite subsided. Mr. Joule had also tried some more recent experiments on steam, which had not as yet, he believed, been published. He might, however, mention that nearly similar results had been found in experimenting with steam; the heat, however, not being so completely reproduced as in the case of air. As regarded the latent heat of steam, Mr. Morton differed from other experimenters. In one case he had found 1040° given out, and in another only 680°. These results did not agree with those obtained by Regnault, and noted on the board; Regnault's experiments were most elaborate, and conducted with every possible care at the expense of the French government. The entire table for the boiling point of 212° Fahr., gave the result of 44 different experiments, and the greatest difference in the latent heat obtained was not above 1-300th part. The six experiments noted on the board were made by Regnault, to test whether a difference in the rapidity of condensation made any difference in the result. Thus in one experiment the time occupied was three times as long as in another in which about one-fourth more steam was condensed, and yet the difference in the results was exceedingly small. In another set of 78 experiments, Regnault found that the total heat of steam of different pressures was about 3-10ths of a unit of heat more for every degree of increase of the boiling point, corresponding to the pressure. Thus steam of a pressure corresponding to 222°, would give out 3 units of heat more in *condensing*, and *cooling* to a fixed temperature, than steam of atmospheric pressure corresponding to the boiling point of 212°. With regard to the oscillations shown in the diagram, fig. 3, he might observe that their cause had been much questioned. Some had thought the oscillations entirely due to the action of the indicator spring, but this could not be considered to have been proved, and there were good grounds for attributing them to the varying condition of the steam. Questions of some importance were brought forward in the paper, as to whether cushioning was a source of economy, and as to whether loss of heat was caused by allowing the steam to escape too suddenly from the cylinder.

Mr. Mackain stated that he had been in Cornwall, and had seen several of the pumping-engines there, although he could not say he had had time to examine any of them very minutely. He was much struck with the differences in the speed of the engines; they came home rapidly, and went out slowly. He thought their great economy arose from the thorough condensation which was allowed to take place. The most economical engines only made from 2 to 3 or 4 strokes per minute; when the speed was raised to 6 strokes per minute, the economy ceased.

Mr. Allan said that he had seen diagrams like fig. 3 taken from a locomotive when going at a great speed. He did not think economy could result from cushioning; and the quicker they got rid of the steam the better. Of course, a slight cushioning was desirable, to ease the change of motion of the reciprocating parts, but more cushioning than was necessary for this would be injurious.

Mr. Tait gave particulars of some experiments he had recently made with a cylinder 16 inches in diameter, having a stroke of 3 feet. He had employed steam of various pressures, from 50 lbs. down to 30 lbs. With the steam at 50 lbs., and cut-off at 9 inches, and the speed 36 strokes per minute, the diagram showed oscillations, but not so marked as those represented in fig. 3. He had no hesitation in attributing these oscillations to the tremor of the moving mass. In this experiment 4 cubic inches of water were used per stroke. With a pressure of 30 lbs., and cut-off at 18 inches, only 3 cubic inches of water were used per stroke; this experiment gave far the prettiest diagram. There was 1 or 2 lb. to spare at the end of the stroke, whilst in the first case the pressure was below the atmosphere at the end of the stroke. When altering the expansion by means of the link motion, the cushioning was greater, the greater the cut-off. The link-motion was bad expansion gear, and caused an injurious back pressure, by retaining too much cushioning steam. With regard to the steam jet issuing from the pipe, he thought that the cooling effect was partly due to the inrushing of the air drawn into the steam current.

Mr. B. Connor thought it difficult to conceive how the pressure could vary alternately in opposite directions, in the way shown in Fig. 3. It was natural to suppose that the pressure would vary gradually; he should be inclined to attribute the oscillations shown entirely to the imperfection of the indicator.

Mr. Morton said that in Regnault's experiments, referred to by the President, the quantity of steam condensed in a given time was varied, and consequently the rate of generation; but that did not prove that the speed of condensation was varied. The condenser was the same size, and the water surrounding it of the same temperature in all the experiments. In order to vary the speed of condensation, it would be necessary to use water of different temperatures, and condensers of different sizes. It was by using a small condenser that he had obtained the result of 680° latent heat. In his experiments he had used condensers, each one smaller than the previous one. In one case he obtained 900°; with a smaller condenser he obtained 720°; and with a smaller still, only 680°. He did not consider the three indicator figures as at all good with reference to the performance of the engine. They were, in fact, all bad figures; but he had used them to show the effect on the curve of compression, by altering the speed, and for other special purposes connected with the objects of his paper. With reference to the steam jet, he had in some experiments encased the jet, to prevent the inrush of air, but the fall in temperature was still shown.

On the motion of the President, the thanks of the meeting were voted to Mr. Morton for his paper.

The following discussion then took place on the subject of—

Decimal Divisions.

This discussion was in continuation of that held on the 23d December, 1857, and recorded at page 43.

The PRESIDENT said, it was now time to proceed with the discussion of the subject of Decimal Divisions, which had been adjourned at the December meeting. At that meeting two papers had been read on the subject: one by Mr. J. Simon Holland of London, who recommended that the sixteenth of an inch should be taken as a standard unit of length, that it should be termed a "steen," and that units derived from it should be employed for weight, money, and measures of all kinds. The other paper was by Mr. Walter Neilson of Hyde Park Foundry, who recommended the adoption of the entire French system of weights and measures, the use of which was gradually spreading over the Continent of Europe. At the first meeting of the session in October the Institution had had explained to them Mr. Whitworth's proposed system, the chief feature of which was the division of the inch into one thousand parts. The paper in which Mr. Whitworth explained and advocated his system, had since been published in full, and some extracts from the comparative tables given in it had been put upon the board for the information of the meeting. He would call on Mr. NEILSON for any further remarks he had to offer on the subject.

Mr. NEILSON said, Mr. Whitworth's system was very good for screw-taps and dies, and wire guages, and for such articles of minute dimensions as were made of certain fixed sizes. The main object, however, of that system was to obtain uniformity in small gauges and sizes, and it could scarcely be said to touch upon the broad principle of decimal divisions. Such minute measurements as thousandth parts of an inch, were quite out of the province of an ocular scale, and could only be recognized by touch. Gauges and size scales, marked with subdivisions of the inch, might be used for such minute measurements, without creating inconvenience in connection with scales for larger sizes having quite a different standard or unit. He would, however, go further, and look to the establishment of a complete decimal system, and in that case it would be necessary to consider how the inch would answer as a unit for sizes and measures greater than an inch. He had previously endeavoured to show that the inch would be a very inconvenient standard for a complete system, and he need scarcely observe that one of the chief objects of a new system must be to reduce the number of different units of size, so as to simplify calculations and the retention of tables of measures in the memory. Nothing could be simpler than the French mètre system. He would not then go into the question of its desirability for extra large measurements, but the great convenience of the various subdivisions of the mètre was indisputable. He had had a half-mètre rule constructed, which he exhibited. The smallest divisions on it were millimètres, quite minute enough for any measurement the eye had to estimate; the divisions next in size each measured one centimètre, almost exactly equal to our three-eighths of an inch, than which there was not a more used measurement in engineering practice. Then we had two centimètres, almost the same as our three-quarters of an inch; and three centimètres, almost an inch-and-an-eight, also very much used measurements. From the constant practice into which engineers were forced by circumstances, many acquired a second-nature facility in calculating quantities containing such measurements as $\frac{3}{8}$ths, $\frac{3}{4}$ths, $\frac{1}{8}$th inch, but it was obviously much simpler to calculate quantities in which those often-recurring sizes were designated as 1, 2, or 3 centimètres. If the French system were adopted, there would not be the slightest difficulty in working out Mr. Whitworth's system of tap and die scales, and wire gauges, in accordance with it. The various sizes might easily be numbered to correspond to their measures in the minuter subdivisions in the mètre scale; just as in Mr. Whitworth's system the numbers were made to correspond to thousandths of an inch.

The PRESIDENT remarked that amongst the inconveniences attending the introduction of any new system, would be the necessity of altering a variety of useful memoranda which an engineer carried in his memory, and of which many happened to be very conveniently expressed according to the present system. He might instance the following amongst such memoranda:—The tenacity of good bar-iron, 60,000 lbs. per square inch; that of boiler-plates, 50,000 lbs. per square inch; that of ordinary cast-iron, 16,000 to 18,000 lbs. per square inch. The greatest tension in a square cast-iron bar, when broken across, is 40,000 lbs. per square inch; the weight of a wrought-iron bar, 3 feet long and one inch square, 10 lbs. Such numbers as these would have to be unlearned, and new numbers learned, were the units of measure changed. It would be well that any one advocating a new system should consider how inconveniences of that kind were to be got over.

Mr. NEILSON observed that it was quite possible the data referred to might in many cases be expressed in simpler figures than those at present used. He thought few engineers trusted to their memory for data and figures like those mentioned; for his part, he considered it safer to refer to tables when they were wanted.

The PRESIDENT thought it useful to be able to do without tables as far as possible.

Mr. WM. JOHNSTONE observed that civil engineers had already adopted the foot and acre as units, and invariably used decimal divisions of those units, finding them extremely convenient. He thought great inconvenience would be caused by substituting the French mètre system in civil engineering; as far as regarded civil engineering, the present system was so simple and comprehensive that there was no call for change.

Mr. MACKAIN differed from the last speaker respecting the inconvenience that would attend a change. If the mètre system were once adopted, calculations could be made and quantities compared in it as easily as, if not more easily, than in the present system.

Mr. NEILSON could not see how they differed in principle from the French system, if they divided the foot into ten like the civil engineers, and the inch into ten, as Mr. Whitworth proposed, whilst by at once adopting the French system, they would avoid the awkward combination of two such different units as the foot and the inch.

In reply to a remark from Mr. A. SMITH, to the effect that it was expected that the advocates of a new system should point out its special advantages, Mr. LAWRIE said that any one could easily discover the advantages of a decimal system, by calculating the solid contents of a block according to it and according to the old system. A vast difference in trouble would be met with.

The PRESIDENT mentioned one decimal set of measures which was already used extensively in Britain: the nautical mile, which was divided into 10 cables, each cable being divided into 100 fathoms. The nautical fathom was not exactly six feet, but sufficiently near to be considered as such in rough calculations,—namely, 6·07574 feet.

Mr. NEILSON said it was perhaps unfortunate that none of our present measures exactly came in with any in the French system, but as in any new and complete system all but one of our present measures would have to be rejected, this objection could scarcely be said to apply particularly to the French system. As regarded the comparative facility attending a decimal system, he might observe that he, and he believed most engineers, as it was, reduced everything to decimals in calculating quantities containing our present incongruous measures. He knew of a French engineer that came over and worked in an English establishment, who got a foot-rule in his pocket, but who was so bewildered with eighths and sixteenths, that he found it the simplest plan to convert sizes into centimètres and millimètres, when he had to make any calculation in connection with them. The engineers in the south of France used rules marked with English measures on one side, and French on the other, and converted English sizes by finding them on one side, and then turning the rule for the corresponding French measurement.

The PRESIDENT here introduced to the meeting Mr. FENTON of Low Moor, a member of the Institution of Mechanical Engineers, who stated that they had had the question of decimal measures before them in England for some time. The matter might, however, be said to be *in statu quo*, and it would be premature to put forward any decided opinion, the subject having been referred to the council of the Institution of Mechanical Engineers, who had not as yet come to any conclusion. He was very glad to hear what was being said on the subject at the present meeting, as it might enable him to throw new light upon it at their next meeting in Birmingham.

Mr. WM. HOWIE made, and Mr. NEILSON seconded a motion, which, with an alteration suggested by Mr. A. SMITH, and agreed to by the proposer and seconder, was to the effect that—

The present council be constituted a committee to consider and report on the subject of decimal divisions.

This motion was unanimously carried.

THE SIXTH MEETING of the Session was held in the Philosophical Society's Hall, on Wednesday, 17th March, 1858, the PRESIDENT in the chair.

The following paper was read:—

On Winding Apparatus, including Mining Hoists. By Mr. JAS. ROBERTSON.

[ABSTRACT.]

THE object of this paper is to describe a system of Hoisting Machines, the leading feature of which consists in the introduction of wedge-surface frictional wheels for connecting the winding barrels or drums with the actuating power, instead of the cog wheels ordinarily employed.

From the peculiarity of these wheels as regards the mode in which they act on each other, the forms of ordinary hoisting machines, for many situations, require to be considerably modified to secure their proper action; and it is in their various modifications, joined with the general facilities they afford for simplicity of construction and their safe and effective action, that their claim to attention mainly consists.

The more prominent advantages attending this system of wheel-gearing as applied to hoists are—its non-liability to fracture, its smooth unbroken action, and its ready facilities for reversing, breaking, engaging, or disengaging, without the intervention of clutches or other appliances hitherto in use for these purposes.

In working, all hoisting machines are liable to sudden jerks or strains, arising from various causes, such as the uneven winding of the chain or rope on the winding-barrel, and partial unwinding—caused by its readjusting itself; extension of the slings immediately connected to the weight, sudden entanglement, over-winding, and other accidents, which frequently occur, even in careful hands—causing the body in motion to become suddenly at rest, or to acquire a motion backwards, whilst the winding of the chain continues; thus allowing the load and machine to acquire momentum in opposite directions, and changing the nature of the effect on the machine and lifting chains from a steady tension to an effect approaching percussion.

To meet these irregularities, considerable allowance of strength is usually given in constructing hoisting machines, beyond what is necessary for fair action; but in many cases, especially in high-speed power hoists, the irregularities are such that no practicable extra allowance of strength will give safety in all contingencies, as the jerk or concussion at times becomes so great that something must necessarily give way, where all the connecting gear is of a rigid unyielding nature.

It is chiefly to power-hoists that the improved system has been and is being applied. In large-size and high-speed hoisting machines, such as pit winding engines, it is chiefly the non-liability of the wedge-surface frictional wheels to fracture, and their smooth action, which are of most advantage. In small hoists and steam-cranes this quality is also an advantage; but the facilities for reversing, breaking, engaging, and disengaging, together with the motions peculiar to this system, are of more advantage, as they simplify and render these machines more manageable generally—cheapening and presenting inducements for their more extended use.

A simple and useful arrangement consists of a winding-barrel, driven by a grooved wheel keyed on the barrel spindle. The shaft carrying the pinion may be connected to be driven continously by any power. Motion is communicated to the barrel by drawing the wheels into contact, which can be done very simply in many ways. A small separation of the grooves (grooved surfaces) serves to throw the wheels out of gear; and when out of gear, the barrel being unconnected with any retarding cause beyond the friction of its bearings, is free to unwind by hand or by the weight. Under various forms this simple arrangement has been applied to sack-lifts and other similar lifting apparatus; their arrangement varying with the situation in which they are placed, and with the connecting gear by which they are driven.

In a modification of this movement, having a breaking arrangement, the driving pinion revolves continuously, and the beam on which the barrel bearing rests nearest the wheels is hinged at one end, and is moved up and down at the other extremity by a small eccentric with a handle. When the beam is lowered, the weight of the barrel and wheel holds the wheel effectively in contact; and when the lifting-rope descends in the line of the centres, the weight of the load also tends to hold the wheels in gear. When the handle is lifted upwards, the wheel is lifted up out of gear from the pinion, and is brought into contact with a grooved concave stationary break, fixed on the side opposite to the pinion, so that the connecting and breaking actions are managed by one handle.

In a third modification, an internal reversing wheel is used, which, on changing the grooved pinion from the inner to the outer rim, gives reverse motion, suspending its action when held in a central position. The backward motion works at a higher speed than the lifting one.

In a fourth modification, a bevil-wheel reversing movement is applied to a hoist—the pinion when revolving continuously in one direction communicating a reverse movement to the hoist, when it is drawn from the one wheel to the other. When it is held in a central position, it is out of gear, and the barrel is free to unwind by hand. Self-acting break movements are easily connected to both these last modifications, so as either to hold the winding barrel stationary when the pinion is in a central position, or allow a weight suspended to descend gradually.

Various modes of working grooved-surface concave, convex, and disc breaks are employed, and arrangements for rendering their action simultaneous with the disconnecting or reversing of the barrel motion. This form of break is much more powerful under the same pressure than smooth-surface breaks, and one of its principal advantages is the ease with which the amount of retarding action can be moderated; this arising from the wedge action requiring a greater amount of traverse between tight and loose positions than is experienced with smooth surfaces.

In a simple modification of grooved-wheel winch or hoist, driven by a belt, the pulley spindle has keyed upon it a grooved pinion, and revolves continuously with the pulley. The chain barrel has keyed on it at one end a wedge-surface wheel gearing with the pinion on the pulley spindle, and on the other end an internal break rim. The barrel revolves loosely on its spindle, and the spindle is supported in its position by eccentric snugs formed on each of its ends, which rest in the cheeks. On one end the snug is extended beyond the cheek, and a handle fixed on it. By moving the handles backwards or forwards, the spindle is partially turned round, and in consequence of the eccentricity of the snugs, this motion gives the barrel a small amount of lateral traverse, in consequence of which, when the handle is brought into a forward position, the wheels are in gear and the barrel in motion, whilst on the handle being drawn backwards, the internal break rim is brought into contact with the segmental breakpiece fitted on the cheek; and finally, when the handle is held in a central position, the barrel is free to unwind. This kind of hoist can be variously formed, so as to be suited for fixing either on a floor, wall, or ceiling.

Fig. 1, Plate IX., is a front elevation, and fig. 2 is an end elevation of a steam winch, worked by one steam cylinder, the crank shaft being made to revolve continuously in one direction, whilst the motion of the barrel is reversed by means of an internal reversing wheel of the kind already described. The frame of the winch is constructed of the usual form, with two cheeks, A, connected together by stay rods, B, the barrel gearing working between the cheeks. A small frictional pinion, C, is keyed on the crank shaft, D, which acts on the internal or external rims, E, F, of the reversing wheel, and gives reverse motions, the power being further reduced at the winding barrel, G, by a grooved pinion, H, and wheel, I. The pinion, H, is keyed on the spindle, J, of the reversing wheel, E F, the wheel, I, being keyed on the winding barrel, G. The outer rim of the reversing wheel is grooved externally, to form a break wheel, and is acted upon by a concave segmental break, K. The changing of the pinion, C, to different rims, E, F, of the reversing wheel to suspend or produce motion in either direction, is provided for by passing the end of the crank shaft, D, nearest the grooved pinion through an eccentric bush, L, on turning which bush partially round a slight lateral shift is given to the pinion. The adhesion is maintained on either side by a small balance weight, M, keyed on the bush, L, and when the weight and its connecting lever is in a vertical position, the pinion, C, is out of gear, and when the weight, M, is turned to either side, the pinion, C, is brought into contact with the reversing wheel, E F. For regulating the motion of the winch, a handle, N, extends conveniently outwards from it for the hand, and this handle, N, is keyed on a spindle, O, which passes through the cheeks, A, and along the entire length of the winch, and having upon it in appropriate positions various levers for working the break, reversing movement, and steam valve, and so arranged that when the handle, N, is held in a central position the break is applied, the pinion, C, out of gear, and the steam shut off. When the handle, N, is moved forwards, the break is disengaged, the pinion, C, thrown into gear for lifting, and steam to the amount required at the same time admitted for lifting. When the handle, N, is drawn backwards, a corresponding action at double the lifting speed is obtained for lowering, and at a less distance back for lowering a weight by the break, without the steam. To prevent the engine sticking on the crank centre, a small jet of steam can be admitted to keep the crank shaft constantly in slow motion. All the movements of the winch are managed by one handle, and without any jarring action.

Whilst this frictional system applies with much advantage to small hoists and cranes—simplifying and making them more manageable—for heavier operations, such as pit-winding engines, the writer would urge its advantage more pressingly. In the latter, greater interests are concerned, and from the liability to accident to which the machinery now employed in this branch of industry is exposed, any contrivance offering with reasonable likelihood to lessen this liability, at least deserves attention. In a good example of the application of the improved gearing to a double-cylinder pit-winding engine, with winding gear complete, the cylinder, valve gear, both ends of the crank shaft, and also one end of the pirn shaft, are supported on a pair of triangular cheeks, firmly stayed and bolted together by means of hollow cast-iron stays, made in the form of common flange pipes. The inner pedestal of the pirn shaft rests in the cheek adjoining the pirn, and directly below the centre of the crank shaft, so that the driving pinion, together with the crank shaft and small fly wheel, rest with their entire weight on the driven wheel keyed on the pirn shaft to give the required adhesion. But, incidentally with this design, a firm and compact winding engine is obtained without any necessity for a sole plate, and requiring no greater amount of material than, if so much as, the common winding engine, to give the requisite strength. The connecting rods of both cylinders are coupled on one crank, and the slides and other parts are of simple arrangement and of easy access. The valves are worked by link valve motions, so arranged that the weight of the link and rods of one engine balances that of the other without the intervention of balance weights. The winding shaft extends out in the same vertical plane as the engine shaft, and its outmost bearing is supported on a casting set on the same level as the engine, so that there is little building required for a foundation. A break is hinged on the cheek, and acts on the grooved wheel on the pirn shaft, being pressed on it when required by a foot lever which acts by a small eccentric on the break piece. A small shaft is carried in, and extends between the cheeks of the engine, carrying on it two levers for working the valve motions, and a handing bar for regulating the engine, the link gear giving easy control, whilst, at the same point, are also conveniently placed the foot break and steam valve levers. Steam is admitted by a steam valve at each casing, connected by a rod extending between the casings so as to make their action simultaneous.

To insure the certainty of continuous adhesion, the brasses of the crank shaft next the pinion are set in a guide pillow block, somewhat similar to a railway-carriage or locomotive axle box; so that the brasses are at liberty to slide down free of any obstruction except the wheel. No perceptible wear takes place in the wedge-surface frictional wheels, so that the position of the gearing will not change; but this arrangement of pillow block is adopted to insure the continuance of the adhesion, and as the journal is both secured by a cover and free to gravitate to the wheel by its own weight, the contact can never fail.

Supposing the joint effect of the coupled engines to be equal to 24 horses power when working at 85 revolutions of the crank shaft per minute, and that the pinion on the crank shaft is 2½ feet in diameter, the wheel 7 feet in diameter, and the pirn 3½ feet in diameter, then the circumferential motion of the pinion will be 667 feet per minute, requiring a pressure of 7 cwt. to give sufficient adhesion for that motion and for the power transmitted. As the adhesion is one and a half times the pressure, the force transmitted to the wheel at its periphery is equal to 10½ cwt., which is the standard dynamical effect of the engine. The pirn being one-half the diameter of the wheel, and the motion being reduced to the same extent, the effect or pull at the rope is equal to 21 cwt. The pressure exerted, however, actually in this case, on the wedge surfaces, by the weight of the end of the crank shaft with the pinion and small fly wheel, is equal to 28 cwt., which is four times more than is required for the power of the engine, and it will take a lift of 4 tons 5 cwt. before the wheels will slip. There is, therefore, provision for certain action considerably beyond the power of the engines under all circumstances. Yet, should the cage get jammed in the guides, or should it overwind, or should any other disturbing cause occur whilst the engine is in full motion, the wheels will rather slip than allow the momentum of the engine to break the rope, and so bring the engine to rest gradually. There is, at the same time, no jolting action with these wheels, like that experienced with toothed gear, and fracture is scarcely possible.

A contrivance to prevent overwinding is also connected with this engine, and consists of a shaft parallel to the winding shaft, extending the entire length of the engine and pirn shafts, and passing through and resting in the checks and outer end pirn soleplate. It has keyed on it arms or cams which extend under the pirns, and are set to the exact height which the rope winds when the cage is at the mouth of the shaft. The ropes have on the back of them a piece of rope about an inch thick; and when the rope begins to wind beyond the proper height, it is built upon the pirns higher than usual, and draws in the thickened piece, pressing down the cams on the cross shaft. Opposite the steam valve, and opposite the break, there are arms or levers keyed, which, on either of the pirn cams being pressed down, simultaneously shut off the steam, and press up the break so as to stop the engine suddenly, and prevent the cages from reaching the pithead pulleys.

Mr. Robertson mentioned that about thirty hoists had been made altogether of one or other of the kinds represented in the drawings exhibited. One of the pit-winding engines was being executed, but it was not as yet at work. Some of the hoists made, perhaps half of them, had been fifteen months in use. Eight steam winches of the kind represented in figs. 1 and 2, Plate IX., had been made. The frictional wedge-surface gearing had been introduced in Lancashire to a greater extent than in the Glasgow district.

In reply to an inquiry by the President, Mr. Robertson said, that the adhesion of the surface was found to be about one and a half times the pressure holding the wheels together. The angle of 40° was adopted in the grooves in ordinary cases. For a slow motion, and to transmit a great strain, an acuter angle, such as one of 30°, might be used. The grooves had at first been made with an angle of 50°; but, so far, the angle of 40° had been found the best in practice.

In reply to inquiries from various gentlemen, Mr. ROBERTSON stated, that the largest size of wheel yet made on the wedge-surface system was 13½ feet in diameter; and 24 horses power was the greatest that the wheels had yet been made for. He would be glad to make heavier and larger machinery on his system if he could get orders for them, for he found that the larger the apparatus the better was the action. They had now, after considerable labour and experience, arrived at a proper way of constructing the gearing, and could confidently state that the gearing would run for years without being worn. Some wheels had been running for six, nine, and even nineteen months, and the marks of the turning tool were still perceptible in the grooves. Usually the grooves were turned with half-inch pitch. At first a great deal of trouble was experienced with minor details. The speed rings had not been found to answer where driven by a long "swaggering" belt, but with a short belt they acted quite well.

In reply to inquiries from Mr. Napier, Mr. ROBERTSON stated that the frictional gearing had been applied to a screw propeller in one instance—namely, in a boat built by Messrs. Tulloch & Denny of Dumbarton. Several trial trips had taken place, and the wheels had answered every expectation; the boat, however, was a yacht, and being completed late last autumn, was laid up during the winter. One of the most important applications of the system was that to screw propellers. There could not be a doubt that it was the best thing for geared screw-propeller engines. In the case referred to, the pinion was fitted with three feathers upon the propeller shaft, in a pretty tight manner, but so that the thrust sustained by the shaft would not affect the pinion. Sufficient pressure was obtained between the pinion and driving wheel, by means of springs applied to the bearings of the shafts. The wedge-surface system had been applied, in one instance, in the construction of a ship's windlass. In this case a peculiar arrangement was adopted: a wedge-surface chock, fitted with a long lever, was applied between concentric external and internal wedge-surfaces, in such a way that on lifting the lever the chock slipped round, but took a firmer hold, and turned the windlass on the lever being brought down.

In reply to an inquiry from Mr. More, Mr. ROBERTSON said he had made careful experiments to ascertain the friction on the brasses, having tested it by means of weights. He had found that the surfaces would transmit a strain equal to one and a half times the pressure on the shafts, without the slightest chance of slipping. The cleaner the surfaces were, the better they held; the actual adhesion seemed, in practice, to be greater than what might be expected from Morin's well-known experiments on friction, and it had been suggested that a kind of metallic cohesion came into play.

In reply to an inquiry from the President as to the effect of grease or water upon the surfaces, Mr. ROBERTSON said, that with small sizes the surfaces must be carefully kept free from grease, but with large sizes it was not so important. He had had complaints as to the working of some wheels, and on inquiry found that oil had been poured on them. On the surfaces being freed from the oil, the wheels worked perfectly well. When the wheels were upwards of two feet in diameter grease did not affect the working so much. He had not found water to make any difference; it might increase the adhesion, but, so far as ascertained, it did not diminish it.

The PRESIDENT remarked that water would be likely to increase the adhesion, as it was known to increase the friction of metals.

Mr. WALTER NELSON said, Mr. Robertson had introduced a very great improvement in wheel gearing, and one that would create a revolution in the construction of a great many machines in which wheels constituted an important part. The paper, and the practical information furnished by Mr. Robertson, in reply to the numerous inquiries which had been made, showed that he had devoted to the subject an astonishing amount of time and persevering labour. The value of the paper was also enhanced by the carefully-executed illustrative drawings by which it was accompanied, and he was sure Mr. Robertson was entitled to the best thanks of the meeting.

The PRESIDENT said, Mr. Robertson seemed to have solved the problem of making frictional gearing work in an efficient manner. Frictional gearing, as hitherto made with smooth surfaces, had always failed from the slipping of the wheels; but Mr. Robertson had devised such a form of surface as would give sufficient adhesion. The new gearing had come into very extensive use, considering the short time since it was first introduced. Many present would probably remember that the subject was brought forward at the meeting of the Institution of Mechanical Engineers, which took place in Glasgow about eighteen months ago; considerable advance had been made since that time, as was shown by the great variety of additional applications brought before the present meeting. It would be very desirable to see how the system answered when applied on a large scale. It would soon be known how it answered for the screw propeller, and if it succeeded, that would prove a most useful application. The President said he had much pleasure in seconding the vote of thanks to Mr. Robertson, and it was unanimously passed.

The following paper was then read:—

Description of the Great-West-of-Scotland-Fishery Company's Steamer, "Islesman." By Mr. J. R. Napier.

This vessel was designed for carrying live fish from distant fishing stations to market, and as speed was not very important, if the fish could be kept alive and in healthy condition for about a week's voyage, it was not thought necessary to aim at a greater rate than eight nautical miles per hour. This speed has been attained in the *Islesman*, whose dimensions are—length on the water line, 105 ft.; breadth, 20 ft.; and depth, 12½ ft. Shortness was considered to be a good quality for manœuvering in the narrow creeks, where it was possible many of the Company's best stations might be, and breadth is, undoubtedly, a good quality where the wind is frequently to be taken advantage of as a propelling power. With this in view, two masts were provided—not for appearance, but for use—with three fore and aft sails, it being considered that as these sails were so easily worked with few men they would be more frequently set, and do more duty than any other kind. The Company have lately altered the rig, thinking it necessary to do so in order to deliver their cargoes above the Glasgow bridge. Still, however, the original rig has the most advantages. There is no peculiarity in the form of the vessel to require notice. The arrangements, however, for carrying the live fish are, I believe, new. Though I am not sufficiently acquainted with former arrangements of welled smacks to describe them minutely, I believe one or two bulkheads divided them into compartments, and small holes were formed in the bottom of the vessel to the sea. These compartments or wells were constantly full of water, and the circulation of the water for the preservation of the fish depended on the motion of the vessel. The water went out at the small holes when the vessel rose out of a wave, and a fresh supply entered when she sank into a wave. In calm weather, however, when there was no such motion, I understand the fishes frequently died. The arrangements of the *Islesman* were specially designed to prevent the death of the fishes in calm water, or when the steamer was at rest in a port, and also to get the full use of the vessel when there might be no live fish to carry, but plenty of dry cargo.

Fig. 1, Plate X., is a longitudinal vertical section of the *Islesman;* fig. 2 is a transverse vertical section through the engine-room; and fig. 3 is a transverse vertical section through one of the fish tanks or wells. The vessel is divided into seven water-tight compartments—three of these are the tanks for the live fish—the mode of construction being seen in fig. 3. At the fore part of each tank a sluice opens a passage to the sea, the orifice of which has a cover formed with small holes to prevent the ingress of molluscs, &c., and the egress of the confined fishes. A large pipe from the bottom of each tank, and connected to a centrifugal pump in the engine-room, completes the arrangement. The wells at the load-water line have a capacity of about 3000 cubic feet, and it was considered advisable to have a pump of sufficient power to discharge this volume every ten minutes, or 300 cubic feet per minute. Professor James Thomson of Belfast was applied to, and gave the design of a pump, which has fulfilled every expectation. This pump is seen in figs. 1 and 2, Plate X., and is shown drawn to an enlarged scale and in vertical section in figs. 1 and 2, Plate XI.; whilst the following description, which Professor Thomson has kindly supplied, explains its action:—

DESCRIPTION OF PROFESSOR THOMSON'S CENTRIFUGAL PUMP.—"In centrifugal pumps, when doing actual work in raising water or forcing it against a pressure, the water necessarily has a considerable tangential velocity on leaving the circumference of the wheel. This velocity in wheels in which the vanes or blades are straight and radial, is the same as that of the circumference of the wheel; in others, in which the vanes are curved backwards, it is somewhat less; but in all cases it is so great that the water on leaving the wheel carries away, in its energy of motion, a large and important part of the work applied to the wheel by the steam-engine or other prime mover. This energy of motion in centrifugal pumps and centrifugal fans, as ordinarily constructed, is mainly consumed in friction, and eddies in the discharge pipe, which receives the water or air directly from the circumference of the wheel. In the improved centrifugal pump, there is provided, around the circumference of the wheel, an exterior chamber, in which the water continues some time revolving in consequence of the rotatory motion it has on leaving the wheel. This chamber is called the exterior whirlpool chamber, and is ordinarily about double the size of the wheel in diameter. The water revolving in this chamber is in the same condition as water revolving in the whirlpool, which I have called the Whirlpool of Equal Energies, or Free Mobility. In this whirlpool (when some slightly modifying causes, such as the fluid friction, are neglected), the velocity of the water is inversely proportional to its distance from the centre, and the sum of the accumulated work or energy of motion and the work in the condition of water pressure of two equal masses of water in the same horizontal plane is the same, so that when the velocity diminishes, the pressure increases; the energy of motion given up in the diminution of velocity being converted into water pressure. It is by this conversion of energy of motion into water pressure, through the medium of the exterior whirlpool, that a decided increase in the working efficiency of the centrifugal pump is attained; the work contained in the rapid motion of the water leaving the wheel, which in centrifugal pumps as ordinarily constructed is wasted, being in the improved pump usefully employed in increasing the pumping power of the machine. In connection with the description of the pump, it may here be added, that in fixing on the dimensions of the pipes, it was kept in view not to make them on the one hand too large or too heavy for the convenience of the vessel, nor on the other hand too small for conveying with sufficient freedom the large quantities of water proposed to be pumped."

The engines are horizontal, having cylinders of 24 in. diameter and 3 ft. stroke, with a peculiar arrangement for working expansively—the invention of Mr. Dowell, at present in the employment of Messrs. Robert Napier & Sons. It is extremely simple and complete; the lead, or opening of the valve, at the commencement of the stroke, is constant, or nearly so, and the amount of steam admitted when the piston has travelled equal distances from either end of the cylinder is nearly equal, whilst the amount of expansion can be varied with great ease by merely turning a screw. Mr. Dowell has kindly supplied the following description:—

DESCRIPTION OF MR. DOWELL'S GEAR FOR OBTAINING VARIABLE EXPANSION WITH EQUAL DISTRIBUTION OF THE STEAM.—"In this arrangement, the variable expansion is obtained by operating on the steam slide valve of the engine, so as to vary the travel, the lap, and in this case the lead also, remaining the same for all the different travels. The ordinary single eccentric, with its appendages of catches, gab, and starting bar, is retained, whilst a curved lever is introduced, and the usual eccentric rod reduced to a length of about 2½ times the throw of the eccentric, its end being connected to the lever. The curved part of the lever is constructed with a radius equal to the length of the eccentric rod, and is furnished with the means of traversing the eccentric rod pin to any part of the arc at pleasure, the admission being increased on its approaching the fulcrum, and *vice versâ*. This is effected in the simplest manner, by means of a screw and hand wheel attached near the fulcrum of the lever, and acting on the slide. A pointer is fastened on the screwed rod to indicate the grades of expansion. The motion is transmitted to the valve by attaching the gab rod to any convenient point of the lever, generally about the middle of the arc.

"In fig. 3, Plate XI., the mechanism is shown in a position to correspond with the crank on the dead point, the piston being about to commence the out stroke. The valve is shown with the opening for admitting steam sufficiently advanced to give the desired lead. The arc of the lever is constructed, as already mentioned, with a radius equal to the length of the eccentric rod, and in its present position the centre of the eccentric is also the centre of the arc. It will be plain, therefore, that the slide attached to the eccentric rod joint can pass from one end of the arc to the other without disturbing the lever or valve, and consequently with the lead remaining unchanged. Suppose now the crank to have travelled to the other dead point for the commencement of the in-stroke, it will have moved through exactly a semicircle, and will therefore be diametrically opposite to its former position. As the eccentric's motion is similar to the crank's, its new position will likewise be diametrically opposite to its first. Let E E′ be these two positions. On the line, F O, drawn from the centre of shaft perpendicular to the diameter passing through E E′, place the fulcrum of the lever at such a distance from the shaft as will be presently explained. It may, however, be anywhere on the line, F O, as far as variable expansion is concerned. Suppose it placed, for the present, at F: then from F, as a centre, describe an arc of a circle, passing through the points, E, E′; then into whatever position the lever moves, the centre of its arc will always be found in this circle; and on the arrival of the eccentric at E′, both the centres will be found exactly at the same point, so that the eccentric rod can slide from end to end of the arc, as at E, without disturbing the lead.

"It was stated already that the admissions varied as the travels. This, however, is not literally correct, for the lever can be of any length, provided the fulcrum be on the line, O F, and if infinitely long, the travels would be equal for every grade. Correctly then, the admissions of steam vary as the angles, which lines drawn from the centres of the eccentric pins on the lever to the centre, O, make with the radius lines of the eccentric, when in the position, E, or E′. These angles may easily be found by the methods usually adopted for setting the valves of ordinary engines with a single eccentric.

"As regards the equal distribution of the steam, this requirement is accomplished by prolonging the lever to a greater length along O F than would give travels proportional to the admissions, as in the ordinary link motion. In consequence of this prolongation, the angle of the eccentric for the in-stroke is increased by a considerable amount, whilst that for the out-stroke is diminished by about the same amount. This variation in the angles of the eccentric is followed by a corresponding modification in the angles moved through by the crank until suppression occurs, amounting to an increase of twice the small angle for the in-stroke, and a diminution of twice the other angle for the out-stroke. This result exactly suits the angles moved through by the crank for the in and out strokes, the former being considerably in excess of the latter for the same positions of piston.

"It may be noticed that the prolongation of the lever to the extent shown in the diagram has no equalizing effect on the admission at points in the lever corresponding to admissions of three, two, and one-tenth of stroke, the fulcrum being nearly at right angles to the centre line of motion at $\frac{3}{10}$ths grade. These grades are easily managed by a slight alteration in the lead, being made to increase from $\frac{6}{10}$ to $\frac{1}{10}$ for the in-stroke, and to diminish from $\frac{6}{10}$ to $\frac{1}{10}$ in the out-stroke, the change of lead to effect a close enough equality being ⅛ inch in each case.

"This change is accomplished by having the centre of the lever arc in a circle, about ¼ inch farther from the fulcrum than the one passing through the points, E E′. Besides equalizing the admission, this variation of lead is useful in equalizing the openings which would otherwise be less for the in than for the out stroke at these points.

"The accompanying table exhibits the distributions and leads as arranged for the *Islesman*—the points of release and compression being also recorded:—

Points of Suppression; being a mean of both sides, in tenths of stroke.	Distribution; giving the distances travelled by piston at supp. for both sides.		Leads.		Release; measured from end of stroke.		Compression; measured from end of stroke.	
	In.	'Out.	In.	Out.	In.	Out.	In.	Out.
	Inches.	Inches.	Inches.	Inches.	Inches.	Inches.	Inches.	Inches.
6	21	22	¼	¼	3⅛	3¼	5⅞	5⅞
5	17⅛	18⅞	¼	¼	4¼	4¼	7¼	7⅜
4	13⅝	15⅝	¼ full.	¼ bare.	5¼	5¼	9⅝	9⅝
3	10	11⅞	$\frac{5}{16}$	$\frac{3}{16}$	6⅛	6⅜	11	11
2	6¾	8¼	$\frac{5}{16}$ full.	$\frac{3}{16}$ bare.	7⅞	8⅛	13½	13⅛
1	3¾	4¼	⅜	⅛	10	11	16½	16

"The length of the connecting rod of the engine in this case was four times that of the crank. It is plain that the shorter the connecting rod is, the more difficult it is to equalize the distribution, as it requires a greater length of lever. For the usual proportions of connecting rods and cranks in marine engines, a distance from centre to fulcrum of about twice the length of the eccentric rod will be found to give distributions practically correct. In the *Islesman* it was 1·9 times, but it would have given a better distribution if made twice the length, which, however, could not be conveniently accomplished in the arrangement. In oscillating engines, for which the scheme is extremely well adapted, and in other vertical engines, it is not desirable to arrange the distributions perfectly equal; a sufficient excess of admission is usually given to the lower side of the piston, to cause the difference of mean pressure in favour of the lower side to be exactly equal to the unbalanced weight of the piston, rod, &c.; but in horizontal engines, and more especially in those intended for high speeds, there is nothing conduces more to their perfect action than having the distributions as equal as possible."

The engine is connected to the propeller by a wheel and pinion, so as to multiply its revolutions. As regards giving the propeller the same speed as, or a higher speed than, that of the engine, I am aware there are great differences of opinion, but as I believed that the most efficient vessels were those with short-pitched propellers, of such a diameter as not to churn the water, from the upper portion being too near the surface, the Company were advised to adopt the wheel and pinion. The diameter of the propeller is 6 feet, and the pitch 6·5 feet; and when the engine makes 70 revolutions per minute, it makes 172·3.

The windlass may be noticed as a revival of an old form, and I am sure it will be admitted by those conversant with the patent articles usually supplied to ships for raising and lowering their anchors, that a mechanic might turn his attention to the subject with great hope of making a more efficient machine. The *Islesman's* is submitted as simple and efficient. The chain barrel is small, and the wheel large. The motion regular. The space it occupies is small, and by means of the friction break the anchor can be lowered at any velocity the captain pleases. There is a paul on the large wheel, and the chain stopper is a flap or valve on the inside of the hawse pipe.

I have already mentioned that the vessel was divided into seven water-tight compartments, and supplied with a pump capable of discharging at least 800 cubic feet of water per minute. Notwithstanding the great safety of such arrangements, the Fishery Company were obliged to have the after part plated over, and made water-tight, and two of the wells or tanks shut up, ere the surveyors of the Board of Trade would grant a license to carry passengers.

The President observed that the paper, or rather the combination of papers which they had just heard, called their attention to several matters of great interest. Mr. Napier had described the means provided by the Great-West-of-Scotland-Fishery Company, for carrying fish so as to be kept alive until their arrival at market; then they had a description of Professor James Thomson's excellent pump, which had proved so efficient; and finally, they had a description from Mr. Dowell, of his simple arrangement of valve gearing adjustable to different grades of expansion. He might mention that he had seen this valve gearing in operation at Govan, where it answered well.

Mr. Stirling inquired what, if any, economy in fuel, had followed the use of the new gearing?

Mr. Napier could not say what economy had been obtained in this case; but if any was obtainable by "expansion," this arrangement should give it, as with it the valve was actuated as was required by the advocates of "expansion."

The President said that, in the new arrangement, the steam was cut off more accurately than by the ordinary link motion; it had not the defects of the latter, which gave irregular amounts of lead, and cushioning, and unequal admissions on opposite sides of the piston.

Mr. STIRLING said, that as "cushioning" had been mentioned, and as many persons recommended it, he wished to state that he never knew any benefit to arise from it. There could not, he thought, be a better cushioning than that of the crank, which caused the motion of the piston to be reversed in a beautifully gradual way.

At this stage of the proceedings, the arrangement and action of the valve gearing was further explained by Mr. Napier and Mr. Dowell, in answer to inquiries. After which,

Mr. W. NEILSON, recurring to the question of cushioning, remarked that, as the valve gearing at present under discussion was applied to a condensing engine, there would be no cushioning; but as regarded high pressure non-condensing engines, it was a question whether advantage might not be derived from a little cushioning.

The PRESIDENT observed, that Mr. Napier's paper comprehended several other subjects besides the valve motion. There were the tanks for bringing the fish alive to market, the pump for emptying the tanks, and the windlass. The paper next on the list was on steam, and it would be well to postpone further remarks on that subject till that paper was read. He would be glad to hear any remarks on the other subjects referred to.

Mr. FERGUSON inquired what success had been obtained with the *Islesman*—had more live fish been brought to market than previously?

Mr NAPIER said, that the *Islesman* had, as yet, only made one voyage, and it was early to judge of the enterprise.

In reply to a question whether the valve motion could be applied to locomotives, Mr. DOWELL said, it did not reverse. It was very suitable for stationary and oscillating-cylinder engines, and avoided the awkwardness and complexity attending the application of separate expansion valves to such engines.

The thanks of the meeting were unanimously passed to Mr. Napier for his paper, and to Professor Thomson and Mr. Dowell for their contributions to it.

The following paper was then read:-

On employing Steam expansively. By Mr. A. Morton.

Referring to my first paper on this subject,* I shall now endeavour to explain the apparatus employed when experimenting on the latent heat contained in steam. In the diagram fig. 5, Plate VIII., the apparatus is represented in section as employed when the steam was condensed by being mixed with cold water in the calorimeter. The boiler, A, is made of very thin copper, and is covered with felt to prevent radiation. The calorimeter, B, is made of tin plate. At C is the steam pipe for conveying the steam from the boiler to the calorimeter. A thermometer, D, indicates the temperature of the steam in the boiler, whilst a thermometer, E, indicates the temperature in the calorimeter. A small cock, F, is used for adjusting the weight of water in the calorimeter when placed in the balance. In performing the experiments, the boiler, A, was correctly weighed, when empty, in a spring balance; and then a sufficient quantity of water was introduced, and the whole was again weighed. The gas flame was, by repeated experiments, so adjusted that two ounces of water were evaporated in ten minutes. I may mention that a gas flame is a very regular fire to experiment with. The calorimeter, B, was then filled with water at about its maximum density, and at a temperature of 40° Fahr., and when placed in the balance the extra quantity of water was allowed to escape by the cock, F, until the exact weight became 10 lbs. The weight of the calorimeter itself, when empty, was always balanced, so that 10 lbs. was the exact quantity of water introduced. This was a constant quantity throughout the experiments. I at times varied the temperature of the water, but the experiment I am describing was performed with water at 40° Fahr. Although the temperature of the room was 8° Fahr. above the temperature of the calorimeter, the elapse of ten minutes made no difference on the mercurial thermometer, E, perceptible by the naked eye; but, independently of this, I followed Rumford's plan in adjusting the temperature of the calorimeter, so that the opposite differences of temperature between it and the surrounding air at the commencement and conclusion of the experiments were equal; therefore the error on this point was almost nothing. The flame was then applied to the bottom of the boiler, A, and its temperature rose to the boiling point as ascertained by the thermometer, D, the small cock, G, being open to the atmosphere. The quantity of water carried off by the vapour in raising the temperature to the boiling point depends upon the time

* At page 68.

occupied, if it has free access into the air; but this item was so very small in my experiments that I need not give it a figure. The boiler, A, being now ready, the time was noted correctly, and the communication opened between the boiler and the calorimeter by turning the cock, H. At the expiration of ten minutes the communication was closed, and the gas flame withdrawn. After slightly stirring the water in the calorimeter by moving the thermometer, E, the increased temperature was noted and found to be 55° Fahr. The calorimeter was then weighed to ascertain the exact quantity of water added by the condensation of the steam. The diminished quantity of water in the boiler served as a check upon the additional quantity found in the calorimeter, which, by repeated experiment, was rendered always 2 oz. I may mention that the time occupied in weighing the boiler and calorimeter at the termination of the experiment, did not occupy above 30 seconds, the parts being rapidly placed on a spring balance, and the weight, when empty, being a noted quantity. The weight of water in the calorimeter, which was raised 15° Fahr., was exactly 80 times the quantity or weight of steam condensed; therefore the latent heat was readily calculated to be 1040° Fahr. The next experiment was performed under precisely the same circumstances, with the exception that the boiler was turned half round, and the surface condenser, I, inserted in the calorimeter. At the expiration of ten minutes, the water in the calorimeter rose only 13·5° Fahr., which gives 920° Fahr. as the latent heat. By reducing the temperature of the gas flame, the greatest result I ever obtained with this condenser was 960°. I next diminished the size of my condenser, in other respects adhering to the same adjustment as in the first experiment. I then found that I could diminish the sensible heat in the calorimeter; and, with the condenser shown in fig. 5, and made of very thin tinplate, when the boiler evaporated two ounces of water in ten minutes, the latent heat was reduced to 680° Fahr. I may mention that on slightly agitating the water in the calorimeter, during the time of the experiments, I could raise the temperature, so that 720° Fahr. became the amount of latent heat made sensible in the calorimeter. That the slight agitation of the water did not produce the extra heat, proved I by attempting to increase the heat by rapid motion; but although I continued stirring and agitating the water until I was tired, I did not discover 1-8th of a degree extra heat in the ten pounds of water. Now, by merely moving the thermometer occasionally during the time of an experiment, the latent heat became increased. The cause of this increased heat in the calorimeter I now explain, as arising from the extra speed of condensation, from the hotter water in contact with the surface being displaced by the slight agitation, so that the surface of the condenser was maintained at a lower temperature. I don't mean to say that 1040° Fahr. is the greatest possible amount of latent heat made sensible by rapid condensation; but having made hundreds of experiments, I assert that this number is a very near approximation when the steam is at about atmospheric pressure, and the condensing water with which the steam is mixed at about 40° Fahr. Having discovered that the heat made sensible in other bodies depended wholly upon the time in which the motion was destroyed, I conceived that steam would follow the same law, and it was with the view of ascertaining this that I experimented, rather than to define the quantity, as the best experiments ever performed with this subtle agent can only give an approximation; but I have now no hesitation in saying that steam is merely water in rapid motion.

The most elaborate experiments on the latent heat ever performed have been at the expense of the French Government; and until the recent experiments by Regnault, the sum of the sensible and latent heat was supposed constant at all pressures. Agreeing with Watt, Arago, Dulong, and many others, and knowing of their experiments and the manner in which Regnault's experiments were generally received, I hesitated, and repeated my experiments before venturing to write anything on the subject. In all Regnault's experiments of which I have read, I find from drawings of the apparatus he employed, that he adopted a large surface condenser, and that the speed of condensation was nearly the same in all his experiments, except that the higher the temperature of the steam when admitted into the condenser, the greater the speed of condensation, and consequently the greater was the heat made sensible in the calorimeter from the same weight of steam. On examining the experiments which he has tabulated we find, in the column indicating the weight of water condensed, sometimes a double *quantity*, and one would at first imagine that the steam must have been condensed at a proportionate speed. But, suppose one particle of steam enters the condenser, the difference of temperature will, in a very short period of time, cause it to resume the form of water; whilst if *two* particles of steam had entered the condenser instead of one, it would be quite possible for them to be condensed with exactly the same *speed*, quite independently of each other, provided the condenser was sufficiently large, as it appears to have been in Regnault's experiments, when the weight of steam condensed in the time is considered. An increase in the difference of temperature between the condenser and the entering steam, is the only means of increasing the speed of condensation with the same apparatus. I believe steam can be condensed with the same *speed*, independently of quantity; and, as a consequence, the generation of steam must follow the same law; hence, if the difference of temperature between the furnace and the boiler remains the same, any *quantity* may be generated in a certain time, the speed of generation remaining constant.

Regnault found, that as the temperature and pressure of steam was augmented, the greater was the amount of heat made sensible. From this it is concluded that high pressure steam contains the greatest amount of total heat. The heat made sensible, I find, depends upon the conditions of the experiment, and when high pressure steam is condensed without being allowed to expand (as mentioned in my first paper), the heat then made sensible in the calorimeter is not any greater than that of low pressure steam when treated in the same manner. I also mentioned that when high pressure steam expanded from one vessel into another, it suddenly became superheated steam. Now, unless Regnault had followed a similar course (that is, unless he prevented the steam from expanding in the act of condensing), a greater amount of heat would undoubtedly become sensible in the calorimeter. I have experimented on the latent heat contained in steam for some years, and like many others, could not satisfactorily account for the different results obtained, varying from 940° Fahr. to 1070° Fahr., with exactly the same weight of steam condensed; but, on considering steam to act like other bodies in motion, I followed a different track.

It is easy throughout numerous experiments to generate exactly the same weight of steam in the same time, and it has caused much astonishment that the total heat should vary so much in different experiments. In fact, of all the experiments made public no two agree; but what I have already mentioned indicates in what direction we may look for a solution of the difficulty. It is now my opinion that, although Regnault paid every attention in his experiments, he was unaware of the influence of time in them.

We are all aware of the heat made sensible at the crank pin and other bearings of short-stroked engines when running at a high speed. This may, to a certain extent, be modified, by cushioning a certain portion of steam at the termination of each single stroke in proportion to the weight of the moving parts, and the time in which the reciprocating motion is destroyed. Short-stroked engines should run with a less mean velocity of piston, because the motion is more quickly produced and destroyed. Three or more times the strain of the greatest steam pressure may be exerted on the crank pin if the weight of the moving mass is too suddenly brought to rest, and therefore we need not wonder at the heat made sensible at the crank pin. If, for example, a pendulous cylinder engine is so proportioned that its cylinder is suspended at exactly the same distance from the centre of oscillation as a second's pendulum, and if this engine be driven at double the velocity of a second's pendulum, viz., 60 single strokes per minute, then a greater power will be absorbed in giving it motion, and there will, consequently, be a greater motion to be destroyed at the termination of each oscillation, and a certain heat will be made sensible in the bearings. In the numerous instances in which power is misapplied in a similar manner, the same cause will satisfactorily account for the heat made sensible where it ought not to be; and until time is considered, and every steam-engine regulated according to its construction and to the degree of expansion adopted, economy cannot be the result. Many expansive engines would have proved themselves very economical had they been driven at the proper speed; but, unfortunately, this has to be settled when the engines are designed, and when on starting the engines their speed is found deficient, they are then forced at the expense of extra consumption of fuel. If the Cornish pumping engines were forced to run at double their velocity, where would the economy stand? Their speed is diminished, accordingly as a greater degree of expansion is adopted, the boiler pressure remaining the same, that is, generally, two or three times the highest pressure required in the cylinder.

I have some remarks to make upon the oscillations produced in steam when rapidly expanded. Many consider that the oscillatory motion produced in the pencil of the indicator is due to the elasticity of the spring and to the action of its own momentum. No doubt such effects can arise from the elasticity and momentum of the spring, but why cannot steam exhibit a similar oscillatory motion? Steam is more elastic than any spring, and at high pressures, or, in fact, at any pressure, is not void of weight. Josiah Parkes was the first who studied this phenomenon in steam, and I daresay many still recollect his percussive theory. I have made experiments on indicators loaded with weights, and many similar to Parkes', and I am confident that if the steam in a steam-engine cylinder is expanded at a greater velocity than corresponds to the heat surrounding bodies can supply, oscillations will be produced exactly like those seen, felt, and heard, when a jet of steam issues freely into the atmosphere as explained in my previous paper. I have made an indicator so that it would not oscillate by its momentum, and still the oscillatory figure was produced by the pencil when the velocity of the piston was sufficiently increased.

I have, in these papers, endeavoured to show that time is required for the generation, expansion, and condensation of steam, and there is no practical difficulty in giving sufficient time to accomplish either with economy. I have before suggested the use of two condensers for each double-acting engine, so arranged that one would receive the greatest volume of the steam before the completion of the stroke, and the other would communicate and act during the return stroke, alternately. Still, I see no difficulty, in many instances, in having the steam fully expanded long before the termination of the stroke; a greater time could then be obtained for condensation, by opening the exhaust slowly before the completion of the stroke, the momentum of the moving mass being sufficient to fulfil or complete the stroke. Considering gravity as the result of motion, it follows as a probable hypothesis, that bodies descending are acted upon differently from those ascending against that force; however, if this force be destroyed by artificial means, a motion is the result, and any body having this motion against the force of gravity will, in a certain time, have it destroyed, and equilibrium will be restored without producing one fraction of heat; but if the motion be destroyed in a less period of time, then a proportionate amount of heat will appear as the result. Could we supply a force acting against gravity so as to neutralize its effects, any body once in motion would continue so for ever; but so long as any constant force in one direction exists, every body in motion on this earth will, by that all-prevailing force, have its motion destroyed and equilibrium restored. When motion is destroyed by other means, a certain heat becomes sensible, according to the time in which the motion is destroyed. This heat would have constantly increased by every sudden destruction of motion, had we been deprived of an atmosphere; but the heat is absorbed by the air which, in consequence, ascends, causing an equal quantity to descend and occupy its place. The heat which the ascending quantity of air absorbs is required by that portion which descends, consequently equilibrium is restored by the motion of the air during a certain time. Heat cannot be measured quantitively, as if it were an isolated fluid; but motion must be included, and we can form no measure of motion without including time.

The theory which I now advocate is based upon my experiments; and if I am correct, a low temperature with slow combustion will evaporate a greater quantity of water per pound of fuel than a high temperature, because the higher the temperature of the furnace, the greater is the speed of generation. The motion of a steam-engine piston may be accelerated, during the first part of the stroke, in such a way that the expanding steam cannot follow with sufficient rapidity for its motion to be utilized before the completion of the stroke (see fig. 3); but if the steam be supplied with heat sufficient for the speed of expansion, it will follow the piston at any velocity, the greater heat increasing the velocity at which the steam can expand. When speed is required, the saturated steam may be supplied with heat whilst expanding or on its way to the cylinder by the gases passing from the furnace to the chimney. This would prove economical in engines already constructed, because the portion of heat which the expanding steam requires for its velocity may be said to be wholly converted into power on expansion, as the steam is then found to be minus that additional heat at the termination of the stroke. Steam may be superheated beyond what is due to the velocity of its expansion; and, in that case, the extra heat would be uselessly thrown into the condenser at the termination of the stroke, unless means were employed to recover it. I have already mentioned the way in which a certain portion of this heat is recovered in the Cornish pumping engine; also the increase of pressure which arises when superheated steam is condensed by being mixed with saturated steam. My opinion at present is, that the elasticity of the steam thus suddenly mixed, becomes equal to that of saturated steam of the mean temperature of the two.

Future experiments may determine the advantages to be derived from this system, and I have little doubt that we will arrive at a better mode of recovering the superheat than that adopted in Cornwall. Steam when suddenly expanded extracts heat from surrounding bodies, and from the experiments which I have adduced as proof of this phenomenon, it would appear to demand an exact equivalent of heat for the increase of its own motion. I mentioned that on experimenting with a jet of steam issuing freely into the atmosphere, a mercurial thermometer was the instrument used in determining the degree of heat in the surrounding air, as also in the jet itself; but in other experiments I employed a quantity or mass of wire gauze (similar to that used in Stirling's refrigerator), which I immersed amongst a known quantity of water so as to measure the quantity of heat contained in itself after the experiment, and I found less heat as the velocity of expansion increased; the higher pressures abstracting more heat from the wire gauze instead of increasing its heat, as one would have expected from the descriptions of Ericsson's caloric engine. These facts first led me to consider what heat would be abstracted from a steam-engine cylinder when high-pressure steam was suddenly exhausted; and on experimenting with a high-pressure engine, the steam being suddenly exhausted at about two atmospheres' pressure, the indicator fell about 3 lbs. per inch, and, least the spring of the indicator should assist, I clamped the indicator 2 lbs. below the atmospheric line, and at every exhaust it lowered to almost the same point as when free. I tried oil at the grease cocks, and found a partial vacuum. As the cause of this partial vacuum, I assign the great abstraction of heat from the cylinder by the sudden exhaust. Alban, in his work on the high-pressure engine, attributes this phenomenon to the momentum of the steam, but I think my experiments on the abstraction of heat by sudden expansion show that, in all cases, a slow exhaust will be economical. I am aware that many engines, with their present arrangement of valves, would be crippled in speed if the exhaust was in any way throttled. But what I advocate is economy, and there are many existing engines wherein the steam could be fully expanded long before the termination of the stroke, the moving parts having sufficient momentum to accomplish the stroke, thereby admitting of a slow opening of the exhaust.

The discussion on this paper was deferred until after the reading of a paper "On the Expansion of Steam in Steam Engines," by Mr. J. G. Lawrie, which, from the lateness of the hour, was postponed to the following meeting.

THE SEVENTH MEETING of the Session was held in the Philosophical Society's Hall, on Wednesday, 31st March, 1858, the PRESIDENT in the chair.

The following paper was read:—

On the Expansion of Steam in Steam Engines. By Mr. J. G. LAWRIE.

BY the law of Boyle and Mariotte, the pressure or elasticity of saturated steam is proportional to its density, and the weight being given is inversely proportional to the volume. By this law, the pressure of saturated steam of a given weight and double volume, is one-half; of a quadruple volume, one-fourth; and so on in the same ratio, under the condition that the expression, $\frac{\text{Pressure} \times \text{Volume}}{\text{Weight}}$, is a constant quantity. Upon this law and these facts engineers have constructed the hypothesis, that when steam expands to twice its volume, the pressure is reduced to one-half; when it expands to four times its volume the pressure is one-fourth; to ten times its volume the pressure is one-tenth, or, in general terms, that the pressure is inversely proportional to the volume which contains the steam when expanded or compressed. On this principle the diagram, fig. 4, Plate XI., is constructed, showing that a volume of steam, represented by A B C D, expanded to fill A B E F, is reduced in pressure to one-half; that if it be expanded to fill A B G H the pressure is one-third; that if it be expanded to fill A B J K the pressure is one-fourth, and so on, reducing the pressure to one-tenth, when it fills the whole cylinder A B L M, which represents a volume ten times the original volume, A B C D.

On this principle the action of steam in steam engines has been investigated. Engineers and writers on the steam-engine have assumed it as the foundation of all their calculations concerning the quantity of steam and water employed in the cylinders and condensers of engines. On an analogous principle Carnot, the eminent French mathematician, based his dynamical theory of heat, and his exposition of the development of power in the steam-engine and other machines, the action of which depends on heat. On Carnot's principle, steam, in being expanded, loses no heat and gains none in being compressed.

According to the principle deduced by engineers from the law of Boyle and Mariotte, if the steam originally employed to fill the space A B C D, have its initial pressure doubled, and be expanded as before to fill the space A B L M, the power, as indicated by the diagram, will be considerably increased. If the initial pressure be quadrupled, as in diagram fig. 5, and expanded as before, the power is further increased; and by every increase in the initial pressure of the steam the power is augmented until, if the pressure be increased to an amount enormously large, say infinitely increased, the power is also enormously large; or, if the pressure be infinite, the power derived is also infinite.

On the principle which leads to this conclusion, namely, that the power or mechanical effect which can be derived from a given weight of steam, or, which is almost the same thing, from a given amount of heat, can be increased to be enormously great, by using steam of exceedingly high pressure; all the books written expressly for the steam-engine without, perhaps, a single exception, or rather with no other exception than a paper read by Professor Rankine before the Royal Society of Edinburgh, investigate the branch of the subject which relates to the operation of the steam.

The discoveries, however, of recent years—the discovery of James P. Joule of Manchester, proves this whole system to be completely erroneous. It proves that if heat, by means of steam, imparts power to the piston of a steam-engine, it cannot also remain as heat in the steam, or in the water of which the steam is composed. It proves that, for every horse power imparted to the piston, there is removed from the steam and utilized, a quantity of heat which is capable of heating a pound weight of water 423° Fah., or when steam is used in the engine of a pressure represented by 20 lbs. per square inch above the atmosphere; for every horse power imparted to the piston, a quantity of steam, amounting in weight to $\frac{1}{23}$ of a lb., which is somewhat greater than half a cubic foot, is condensed. That, with steam of 20 lbs. pressure for every 10 horses power given out by the engine, 5·2 cubic feet are condensed; for every 100 horses power, 52 cubic feet are condensed; and so on, reckoning $\frac{52}{100}$ of a cubic foot for every horse power, no matter how great or how small that power may be. That this condensation does not arise from radiation nor from a loss of heat, but from the fact that heat cannot, at the same time, give power to the piston of a steam-engine, and exist as heat either in the steam or in anything else. That no amount of clothing put on the cylinder would prevent this condensation, nor would a steam-case prevent it, although with a steam-case applied, the greater part of the condensation, or generally, the whole of it would take place, not in the interior of the cylinder, but in the interior of the steam-case. This law of the exact convertibility of heat and power, or mechanical effect, completely upsets all former calculations of the dynamical action of steam.

By the light of Mr. Joule's discovery, it is obvious that the diagrams in figs. 4 and 5, do not represent the action of steam in the steam-engine. As the steam issues from the boiler, and impels the piston from A B to C D, it is continually being condensed in the cylinder, and by the time when the piston reaches C D, at which point the steam valve is shut, the space, A B C D, is filled, not with steam alone, but is partly filled with water, the result of the condensation equivalent to the power developed, and the remaining space only is filled with steam. Again, as the piston progresses from C D, onward to L M, the steam is momentarily being condensed, while it is momentarily impelling the piston onward. The condensation takes place, as already stated, at a certain rate for every horse-power developed, but at a rate of bulk of steam which gradually increases as the pressure becomes less. When the piston is travelling from A B to C D, the communication with the boiler being open, the pressure is maintained, although condensation takes place by the influx of new steam; but when the piston travels from C D to L M, no additional steam is admitted, and as the condensation which takes place reduces the pressure, the diagrams, figs. 4 and 5, do not truly represent the pressure of the steam during the expansion. In figs. 6 and 7, diagrams are shown representing both the pressures, as in figs. 4 and 5, and also the reduction which takes place in these pressures due to the condensation of the steam by the development of power. In these, figs. 6 and 7, the spaces shaded with vertical lines show the pressures after condensation, and the spaces shaded with horizontal lines show the amount of condensation. The diagrams are divided into ten parts, and at each point of division along X x, is stated the fraction to which, by condensation, the pressure is reduced below the amount assigned by the mode founded upon the law of Boyle and Mariotte, which is noted along the curve; whilst at each point of division along Y y, is stated the rate of condensation for every 10 horses power developed. Thus, in fig. 6, the rate of condensation for every 10 horses power varies from 5·2 cubic feet, at the beginning of the diagram, to 54 cubic feet at the end; and in diagram 7 the rate of condensation varies from 8·8 cubic feet to 92 cubic feet.

These results are expressed without difficulty in the exact language of algebraic notation; but to do so is inappropriate in a paper of this character, and the subject has already been investigated analytically in an elaborate and philosophical manner by those whom Mr. Joule calls our illustrious townsmen, Professors Rankine and Thomson.

These eminent authors show that the power which can be obtained from a given weight of steam is not infinite, nor even enormously large, as would be the case if the hypothesis formerly assumed from the law of volume be true; but that it is limited to the number of horses power contained in the heat, of which the steam is deprived, reckoning a horse power of 33,000 lbs. 1 foot high, equal to a quantity of heat which would raise the temperature of 1 lb. of water 42⅓ degrees. They show that the heat of which the steam can be deprived so as to produce power cannot, or rather, has not in any case much exceeded one-sixth of the whole heat which it receives from the fire. They show further that, except in cases in which expansion has been largely and judiciously employed, this limit of power, equivalent to about one-sixth of the whole heat received from the fire, has not been approached, and cannot in any other way be approached.

The spaces shaded with vertical lines in the diagrams 6 and 7, show the pressure of the steam at the several parts of the stroke, on the supposition that the steam receives no heat from and gives no heat to the material of the cylinder; but in every working engine the steam, as it cools down in temperature by expansion, receives heat from the cylinder, which, again, during the early part of the following stroke, receives heat from the steam. Thus, when the cylinder is not provided with a steam-jacket, the twofold operation takes place of the material of the cylinder receiving heat during the early part of the stroke, which it transfers to the steam during the latter part of the stroke. If, in this twofold operation, the cylinder delivers up to the steam, with sufficient rapidity, during the latter part of the stroke, all the heat which it received during the early part of the stroke, no loss or gain is occasioned in the indicated power of the steam; but if less than the whole heat is delivered up, a loss arises to the extent of the difference; or if it be delivered up with insufficient rapidity, which there is reason to believe is the fact, a loss is occasioned to some amount.

The principles now explained afford a ready solution of the utility of the steam-jacket, an appendage which, though it has always been found highly useful in practice, has nearly, with the same uniformity, been pronounced useless by writers on the steam-engine. In the steam-cylinder water is produced principally from three causes:—

1st. By being carried in suspension in the steam from the boiler.

2nd. By condensation of the steam in the development of power.

3rd. By condensation of the steam in heating the material of the cylinder from the temperature to which it had been reduced in the previous stroke.

Each of these causes produces a considerable quantity of water, which, when the cylinder is unjacketed, is passed, together with the heat it contains, to the condenser, while in a jacketed cylinder, the water is produced, not in the cylinder, but in the jacket, and being passed, not to the condenser, but to the boiler, is economised. Even the heat contained in the water due to the first of the above causes is economised when a steam-jacket is employed, because, during the expansion part of the stroke, the water carried in suspension is converted into steam.

In practice, engines are constructed to work expansively in two ways. In one, two cylinders are employed, the steam from the boiler entering a small cylinder, where it is partially expanded, and passing to another of larger dimensions, where it is expanded to the limit intended. In the other way, one cylinder only is employed, in which the steam is admitted during a portion of the stroke and expanded during the remainder. In the engine constructed with two cylinders, the quantity of steam used per stroke of the engine is measured by the volume of the second or large cylinder added to the amount utilized due to the power developed; and in the engine constructed with one steam cylinder, the steam used per stroke for the same amount of expansion is the volume of the cylinder added in like manner to the amount due to the power developed. Therefore, on comparing the modes of expanding by the one plan and by the other, the comparison falls to be made between an engine having two cylinders and an engine having one only, in which engines the large cylinder of the one is of the same volume as the single cylinder of the other.

So far as my information goes, more minute and accurate experiments made with engines having only one cylinder are on record than are those made with engines having two cylinders. Indeed, I am not aware of any prominent experiments made to ascertain the consumption of fuel of engines having two cylinders being on record. In Lancashire, the association formed for the prevention of boiler explosions and the economy of steam, furnishes periodically a mass of information of great utility; but although that information establishes the fact, that a high rate of economy is obtained by engines constructed in either way, yet as the consumption of fuel by each of the 600 engines on the list of the association, is blended with the consumption necessary to heat buildings, or to perform other operations, no exact information is obtained from the reports, neither of the consumption of any individual engine, nor of any relative consumption of different engines, sufficient for a safe comparison.

The best engines on the list of this Association, both double and single cylinder engines, have a consumption of fuel of 3·1 lbs. per indicated horse power of 33,000 lbs.; but that consumption, including what is due to other operations besides that of the engines, furnishes no exact information beyond the fact that the consumption of the engines alone must be small.

The diagrams, figs. 8 and 9, were made by the engines called *Lion* and *Lioness*, the property of the New River Water Works, London, and constructed at Soho by Messrs. James Watt & Co. With these engines most accurate experiments have been made, in some of which the duty ranged as high as 107,000,000 lbs. 1 foot high per 112 lbs. of coal; and in one extending over a period of ten months, the duty of 112 lbs. of coal was in excess of 90,000,000 lbs. 1 foot high, being a result equal to 2·46 lbs. per horse power of 33,000 lbs. 1 foot high over and above the resistance due to the working of the engine. In contrasting the effect of fuel as measured in the steam-cylinder from the diagram, and as measured by the ultimate effect of the engine, in delivering water over a stand pipe, for example, the one result falls to be reduced by the resistances of the engine, whilst the other is clear of all deductions. Hence the result in the instance of the *Lion* and *Lioness* engines, which was measured by the delivery of water over a stand pipe, is a consumption of fuel per indicated horse power, measured in the cylinder, of $\frac{33000}{44000} \times 2·46$ lbs. $=$ 1·845 lbs.

I am not acquainted with any experiments made with any other engine of any construction, which show a result equal to this of the *Lion* and *Lioness*, taking into account the duration of the experiment.*

* A series of diagrams were exhibited at the reading of this paper, which were made by engines having an expansion-valve arranged on the author's plan, and capable of working with the utmost accuracy.

These diagrams showed the action of the steam when supplied to the cylinder during different portions of the stroke, varying by an inch from 3½ inches to 12 inches in a stroke of 81 inches, and an examination of them discloses the exceedingly remarkable fact, that in those diagrams in which expansion was not carried far, the final pressure of the steam was considerably less than the gaseous laws of expansion would assign, while in the diagrams in which expansion was carried farthest, the final pressure was considerably greater than the gaseous laws would assign. In the several diagrams, the final pressure was marked as given by a measurement of the diagrams, and also the pressure assigned by the gaseous laws of expansion. In these pressures a regular gradation of differences exists, and this remarkable fact plainly indicates the operation of an important influence, exercised partly by the alternate heating and cooling of the cylinder, and partly by the water suspended mechanically in the steam. This influence it is impossible to measure with precision, in any calculations of diagrams, to ascertain the consumption of steam or fuel due to these diagrams; and on that account, chiefly, I am of opinion that diagrams do not, in any instance, supply available information for an accurate measurement of the steam used.

In the calculation of the quantity of steam used in the series of diagrams, the part of it which was condensed in the development of the power, as defined by Joule's law, was separated from the part of it which passed to the condenser in the form of steam; and it appears that

But, whether the results obtained with the *Lion* and *Lioness* be surpassed or not by any other engines of either the double or single-cylinder arrangement, the comparative excellence of the two arrangements is not by that single fact decided. There are other elements, not elicited in the experiments with these engines, that fall to be taken into account. Against the single-cylinder arrangement it has been contended that, as the power of the engine becomes large, either by an increased diameter of the cylinder or by an increased pressure of the steam, a shock is incurred at the commencement of each stroke that is destructive to the smooth working of the engine; and it has also been contended that the double-cylinder arrangement, by dividing the power between two cylinders, diminishes the gross weight of the machine and the cost of construction. The first of these objections to the single-cylinder arrangement is by no means a new one, having been urged in the history of the steam-engine against each increase made to the diameter of the cylinder, and each increase in the pressure of the steam; yet locomotives, having cylinders of a diameter increased from 12 to 20 inches, run at speeds increased from 20 to 60 miles an hour, without shock of any kind; and marine engines, with cylinders of gradually increased diameter, worked by steam of gradually increased pressure, move without halt at a speed of 400 to 500 feet per minute. In the steam-ship *Australasian*, recently built by Messrs. J. & G. Thomson of Glasgow, the engines, which have cylinders 96 inches in diameter, turn the centre with the utmost smoothness, when worked with steam of 20 lbs., and moving at 400 feet per minute. The cylinders of this ship being 96 inches diameter, and the steam 20 lbs., the effect is the same as that of cylinders of 68 inches, with steam of 55 lbs., or as that of cylinders of 48 inches with steam of 125 lbs. The criterion, therefore, of the engines of the *Australasian*, is a sufficient reply to the objection of shock, until engines of greatly increased power become necessary.

But the practice of all engineers, with engines of moderate dimensions, is alone sufficient to establish the fact, independently of reference to such engines as those of the *Australasian*, that, provided the engines be of the requisite strength, without which no machine can operate satisfactorily, the severity of the shock depends not on the weight of moving mass, nor on the pressure of the steam, nor in any degree upon the length of the stroke of the engine, but upon the manner in which the steam is cushioned in the returning stroke. When that cushioning is adjusted so as to bring

when the engine was working with steam throughout the stroke, this quantity amounted to about 5½ per cent. of the gross quantity used, and when the steam was cut off at 8¼ inches from the commencement of the stroke, the quantity which was condensed amounted to about 14 per cent. of the whole.

up the pressure of the inclosed steam to an amount approaching that of the steam in the boiler, by the time the valve opens for the admission of fresh steam, no shock occurs, nor can occur. The second objection urged against the single-cylinder arrangement, of being more expensive and heavier than the double-cylinder kind is not so capable of precise argument, because, after any comparison that could be made of the weight and cost, the question would still, to a considerable extent, remain a matter of opinion, whether the weights and costs were calculated of the correct amounts. When it is considered, however, that for the same amount of expansion the large cylinder alone of the double-cylinder arrangement, is equal in volume to the single cylinder of the other kind, there is obviously a considerable margin in the small cylinder and appendages of the double-cylinder arrangement, to apply in the additional strength necessary for the single cylinder of the other kind. Another advantage in favour of the double cylinder has been urged in a supposed more uniform development of power; but, although that advantage does exist when single engines are employed, it does not exist when two engines at right angles are employed.

Having stated the chief arguments advanced in favour of combined cylinder engines, it now becomes desirable to consider what has been or may be advanced on the other side :—

1st, It is contended by those in favour of single-cylinder engines that they are of a lighter and cheaper construction.

2nd, That they have smaller surfaces to clothe in order to prevent radiation, and to encase in a steam-jacket.

3rd, That the alternate heating and cooling of the cylinder, which takes place more or less when steam is used expansively, exists to a less extent, and is spread over a smaller surface in the single than in the double-cylinder arrangement.

4th, That there is less friction, a smaller consumption of stores, and that considerably less attention is necessary with one cylinder than with two.

In drawing an inference from these arguments, Mr. Joule comes to our aid, by informing us that if the steam in the different arrangements is passed to the condenser at the same temperature, no difference in the indicated power derived exists, whether the expansion has taken place in one or in twenty cylinders ; and therefore the minor, or rather secondary elements of the question alone remain to guide the engineer to a selection.

In a consideration of the expansion of steam, it would be improper to omit a notice of certain statements made last session in the Institution of Civil Engineers in London. It was stated during a discussion of a paper by Mr. Armstrong, "On High Speed Navigation," that a record of the performances, for three or four years, of H.M. paddle-wheel steam-ship *Fury*, of 515 horses power, showed that, whilst working full power, 50 tons of coal were consumed per day of 24 hours, or 4·27 lbs. per horse power per hour. When working at the first grade of expansion, 40 tons of coal were consumed per day, or 4·65 lbs. per horse power per hour; and when working at the seventh grade of expansion, 15 tons of coal were consumed per day, or 12·3 lbs. per horse power per hour. Similar results were stated to have occurred in the *Desperate*, *Terrible*, and other vessels, and an opinion was expressed that in marine engines the attempts hitherto made to comply with the conditions necessary for realising the benefits to be derived from working expansively had not been attended with adequate success. The loss when working expansively was believed to arise in a great measure from the condensation, by means of the extended surfaces through which the steam passed, as only indifferent means were adopted for keeping up the temperature, and in that way there must necessarily have been a loss of mechanical effect.

Without knowing the details of the experiments referred to in these statements, it is impossible to account satisfactorily for the results obtained, nor to say whether they can be accounted for by the loss alone arising from the increased radiation of the extended surfaces; but no one who has witnessed the effect produced on judiciously-constructed engines by an increase in the steam cover of a valve, or who has travelled in a steamer in which the boilers are short of steam, and noticed the result of putting the expansion valve in action, or who has stood on a locomotive engine and tried the effect of modifying the action of the valve by the link motion, need be told that a better effect is not derived from steam worked expansively, even though by an imperfect manner of applying the principle, the benefit can be dissipated. The effects of expansion which occur in the instances I have quoted are manifest; and although they are not absolute demonstrations of the benefit of expansion alone, in consequence of the steam being used at a higher temperature when the pressure is increased, yet they furnish the data of demonstrations which are conclusive. It is to be regretted that the details of the experiments made in these Government steamers have not been published; because while they remain unexplained and not understood, they are calculated to produce an impression with regard to the use of steam which is injurious to the progress of economy.

Allied to the subject of expanding steam is the problem of obtaining steam. The steam upon which scientific experiments are usually made is raised slowly, and contains only the water of saturation, which is in chemical combination; but the steam with which engines are worked is raised in all the hurry inseparable from the small evaporating surface in a boiler, and contains considerable quantities of water in mechanical suspension, in addition to that in chemical combination. This water contains more than double the quantity of heat which the same bulk of 20 lbs. steam contains, and as it carries nearly the whole of that heat to the condenser, it causes first a large loss of heat, and also a further loss of power by burdening the condenser and air pump.

In some vessels means have recently been employed to superheat a part of the steam used, and a most satisfactory economy is reported to have been derived in every instance. There is no reason to doubt that this economy has been obtained. By converting the water which the steam contains into steam, an improvement must unavoidably be derived, and by superheating the whole mass, so as that it will continue uncondensed or unreduced to water, when its temperature is lowered during expansion, a further and considerable advantage will also be derived.

The idea of superheating steam is not by any means a new one, but its introduction has been materially retarded by a desire to superheat to an extravagant extent, which was and still is so difficult as to be practically inconvenient.

There does not appear, however, any difficulty in superheating to such an extent as to utilize all the water in the steam, and to prevent condensation during expansion.

The greatest improvement of which the steam-engine is, I believe, at present susceptible, is a judicious use of moderately-superheated steam in combination with expansion in a single-cylinder engine. In the marine engine and in the locomotive these desiderata can be carried out with facility, and in both economy of fuel is of the utmost importance.*

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* Formerly the water produced in the steam-cylinder was considered due principally to radiation, and to some considerable but undefined change in the specific heat of the steam during expansion. The experiments of Regnault, however, informs us that there is no change in the specific heat of the steam, of any moment, in considering the source of this water; while the experiments of Mr. Joule point out its true source. But it is remarkable that both Professors Thomson and Rankine, instead of eradicating the notion of a change in the specific heat of steam during expansion, adopt it. Professor Thomson, in a paper read before the Royal Society of Edinburgh, explains that, in his opinion, the quantity of heat necessary to evaporate a given weight of water is not constant, but may be infinitely varied, and lauds Professor Rankine for his discovery of "negative specific heat."

Specific heat, however, is essentially a relative measurement of the quantity of heat necessary to raise the temperature of the substance to which it relates, and as it would appear to be impossible that it can ever be so small as to be nothing. it cannot possibly

The following discussion took place on Mr. Lawrie's paper, and on Mr. Morton's, read at the preceding meeting:—

The PRESIDENT said, that amongst the authors mentioned in Mr. Lawrie's paper as having contributed to the development of the dynamical theory of heat, the name of Professor Clausius of Zurich had been omitted. The researches of Professor Clausius were contemporaneous with those made in this country, and he arrived at the same results, but by a process differing from that adopted here. In fact, when the paper was being read in Britain, in which he (the President) showed how a portion of the steam in an engine cylinder must condense when work was obtained from its expansion, Professor Clausius' paper on the same subject was being published in Germany, the authors being at the time unaware of each other's proceedings. It was right that Professor Clausius should have the share of credit due to him. On the subject of the expansive working of steam he would suggest, as a point for consideration, the fact, that the friction of the engine affected the limit of economy in expansive engines. In an engine working without friction the steam might be expanded down to the pressure at which it was to be exhausted. In an engine in which friction was to be overcome, the steam should only be expanded down to a pressure just balancing the friction; if it was expanded to a lower pressure than this, power would be wasted in working against friction. Probably some of the engineers present would know of facts bearing on this point. (The President illustrated his meaning by a diagram.)

Mr. J. BROWNLEE, referring to a statement in Mr. Lawrie's paper, to the effect, that the steam was partially condensed when working, both whilst the steam continued to be admitted into the cylinder and after it was cut off, said he did not think any condensation took place in consequence of the conversion of heat into power before the steam was cut off. As long as the cylinder was in communication with the boiler, the steam would be in the same condition in both; and although heat was converted into work, it did not follow that the steam in the cylinder must, on that account, partially condense, or lose any portion of its heat in giving motion to the piston. The steam in the cylinder acted simply as a medium for communicating to the piston force which the fire was imparting to the water in the boiler in the form of heat. In generating steam under pressure, part of the heat acted as mechanical force in making space for the new steam amongst that already generated, and when the boiler communicated with the cylinder the space required, or a part of it, was obtained by the movement of the piston, the mechanical force being communicated to it by the medium of the steam in the boiler, steampipe, and cylinder.

Mr. W. TAIT inquired if any of the members present had ever observed, whether the temperature of the steam in a steam-engine boiler was different when the engine was at

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become negative, or less than nothing. When heat is evolved by the compression of saturated vapours, it does not follow that there is any change of specific heat; and although in the case of saturated vapour of water there is a change of specific heat to the extent ascertained by Regnault, yet heat cooled is not due to that change, but arises from the quantity of mechanical effect converted into heat. It would appear that Dr. Thomson's illustration of the quantity of heat necessary to evaporate a quantity of water being infinitely variable, is not complete, if it excludes the power or mechanical effect involved in the operation: if this mechanical effect be introduced as an element, the heat ceases to be variable, and becomes what it ought to be, a constant quantity, with no variation but that pointed out by Regnault.

rest to what it was when the engine was working? It was well known that often when an engine had been standing, as during the meal hour, there was an excess of steam immediately after starting. It was also well known that most boiler explosions took place immediately after the starting of the engine which had previously been standing some time. It had occurred to him that these phenomena might arise from the steam getting partially superheated. When the engine was standing the damper would be shut, and the flues being, perhaps, as high as the surface of the water in the boiler, heat would be communicated directly to the steam, and so superheat it. On the engine being started the withdrawal of steam would cause the water, previously quiet, to boil up, and so mixing with the superheated steam instantaneously and enormously increase the volume of steam. He had been trying experiments for some days with the boiler at their works, but had not found any difference of temperature in the steam when the engine was at rest. The temperature was always that due to the pressure, as given in the tables in works on the subject.

The PRESIDENT remarked that in many cases there was an extraordinary difference between the pressure in the boiler and that in the cylinder. The pressure in the cylinder was often very much lower than that in the boiler, or, at any rate, than that on the safety valve. This was most noticeable in some Cornish pumping engines, and it might be owing to the fact that in these engines the steam was bottled up for a time in the boiler, and only let out during the fraction of a second. There was, at any rate, more in this than could be accounted for by throttling the steam on its way to the cylinder. Mr. Tait's experiments were of great importance, and he was sure the Institution would be glad to receive details of them.

Mr. WALTER NEILSON thought that Mr. Tait's experiments bore upon something more important than the diminution in the pressure of the steam when transferred from the boiler to the cylinder. It was a very common occurrence to find the pressure rising on an engine being started, at a time indeed when one would naturally expect more or less diminution in the pressure, on account of the cylinder beginning to use large quantities of steam. He would very gladly second the request for details of Mr. Tait's experiments. If the temperature of the steam in the boiler rose when the engine was standing, it would give a clue to the cause of most boiler explosions. He could mention that in the case of the explosion of a locomotive boiler, into which he had had to inquire, the pressure increased extraordinarily immediately before the explosion, which took place on the engine starting, after standing a short time. It was easy to conceive that if the water was low, the plates with which the steam was in contact would become heated beyond a proper amount, and that the steam would become superheated from them; at the same time the water would be quiet, the steam pressing down upon it with increasing force, and no ebullition taking place. The engine then being started, the consequent withdrawal of steam would, for a moment, reduce the pressure and permit the water to spring up in a state of violent ebullition, whilst the water mixing with the superheated steam, would instantly acquire a tremendous elastic force quite sufficient to account for the effects usually accompanying a boiler explosion.

Mr. D. MORE said he had been called upon to report on several boiler explosions, and could state that they had almost invariably taken place immediately after the engines were started. In most cases there was plenty of water in the boilers, and the valves and everything else about the boilers appeared to have been in perfect working order. He proposed that a committee should be named to investigate the subject during the recess. He thought Mr. Tait had suggested something very like the true explanation of the phenomena. When the engine was at rest and the valves all closed, the water in the boiler was quiescent, and the steam bore down upon it and restrained the ebullition; but on the feed pump throwing in a jet of water, motion was produced in the water in the boiler, and it immediately went into a state of violent ebullition. Some of the members present would probably remember the boiler explosion at Hamilton & Arthur's works. The engine was standing from 6 to 7 P.M., the water was at its proper level, and before starting at 7 P.M., the pressure was observed to be 25 lbs., the usual thing. Immediately after starting the boiler burst, doing enormous damage, and showing that there was some far greater element at work than a pressure of 25 lbs. to the square inch.

Mr. MACKAIN stated that he had observed an increased pressure on starting an engine with which he had something to do some years ago.

The PRESIDENT said an important suggestion had been made by Mr. More as to forming a committee to investigate the causes of steam boiler explosions. An association had been established at Manchester, and was now in active operation, for the prevention of boiler explosions, and generally for collecting facts in connection with steam-engines and boilers. Mr. More's suggestion, if carried out, would lead to the establishment of a similar body here, where their operations would, undoubtedly, be very useful. It would be desirable to consider the best means of setting on foot such an association. The Manchester association gave their attention, not only to boiler explosions and their prevention, but also to the collection and publication of facts bearing on the economy of fuel, and that body was proving itself of great utility.

Mr. MORE proposed that—

"The Council of the Institution be constituted a Committee to consider as to the best means of obtaining for Scotland the benefits of such an Institution as the Association for the Prevention of Boiler Explosions."

Mr. W. JOHNSTONE seconded Mr. More's proposal, which was adopted unanimously.

Mr. JAMES BROWNLEE said that, in some cases, water was heated much beyond the boiling point, particularly if the pressure on it was more than one atmosphere. In one experiment he had himself heated water up to 270° Fah. under atmospheric pressure. If any motion was imparted to the water in this condition, it immediately exploded, giving off the steam corresponding to its extra temperature, and its temperature fell at once to 212°. If a little oil is put on the surface of the water, or if its surface is kept quiet, it is easily heated to a higher temperature than that due to the pressure on it.—In answer to an inquiry, Mr. Brownlee said, that in the experiment referred to the water had been previously boiled to expel the air.

The PRESIDENT said it was thought that the presence of air in the water affected its boiling. If distilled water is boiled in a glass vessel, it boils by starts; its temperature appears to vary abruptly. Chemists are well aware of this fact, and are in the habit of causing the water to boil gently by placing in it angular pieces of metal, silver chains, or wire. The bubbles of steam form on the surfaces of the metal, and rise in continuous streams from salient points of the pieces of metal or wire.

Mr. WALTER NEILSON, referring to the indicator diagram (fig. 3, Plate VIII.) accompanying Mr. Morton's paper, inquired if it had been decided whether the oscillations shown were due to the indicating instrument, or to fluctuations in the steam pressure in the cylinder?

Mr. MORTON said he considered the oscillations in the figure to be caused partly by the indicator spring and partly by the steam. He had fixed the indicator at the lowest point to which it had previously descended, and the steam drove it still lower. The oscillations were less in cased cylinders. He had no difficulty in conceiving how the steam must oscillate or fluctuate. He had employed various indicators, the springs of which acted differently, and he had still found an oscillation in the figure, which could not be fully accounted for by the indicator spring.

The PRESIDENT said he concurred with Mr. Morton's views on this point. He thought his experiments proved that fluctuation must take place in the steam pressure; and he also thought that, on the whole, this was what might have been expected.

Mr. TAIT asked if Mr. Morton had, in his experiments, observed whether the governor had made any sudden changes? The oscillations might possibly have been due to such changes. He had often seen diagrams showing oscillations, but never so marked as in fig. 3. Or, if the speed was very great, a tremulous movement of the valves and piston might arise from the elasticity of the engine, and so cause the oscillations in the figure.

In reply to Mr. Tait, Mr. MORTON said no governor acted on the engine with which his experiments were made. The steam was cut off at about one-fourth of the stroke, whilst the figure showed oscillations throughout the entire stroke. As the speed of the engine was reduced, the oscillations also became correspondingly less. When the diagram, fig. 3, was got, the average speed of the piston was 350 feet per second.

The thanks of the meeting were passed to Messrs. Morton and Lawrie for their papers.

An abstract was then read of a paper containing—

An Account of some Original Experiments in Screw Propulsion prior to the general introduction thereof. By Mr. J. NICOL, and communicated by Mr. D. MACKAIN.

The Eighth and Last Meeting of the Session was held in the Philosophical Society's Hall, on Wednesday, 14th April, 1858, the President in the chair.

This was the Annual General Meeting for the Election of Office-Bearers for the Second Session, 1858-9.

The following paper was read:—

Notes on American Locomotive Engines. By Mr. Walter Neilson (of Hyde Park Foundry).

The fact that this country first gave birth to the railway and its engine, and brought this great system of locomotion to its present state of perfection, is apt to make us regard the like work of our followers with too much indifference. No doubt, the Americans have been accustomed to look to this country for all improvements connected with railroads and their attendant machines; but when we look at the United States, with their 21,440 miles of railroad against 8054 miles in this country, we may predict that the time is not far distant when we may look to our friends across the Atlantic with the expectation of learning something from them even in railway engineering.

In the American locomotive engine as at present constructed, we have a gay, jaunty-looking vehicle—very different from the sombre business-like machine of the old country. The extraordinary amount of bright brass and bright-painted ornamentation one is scarcely prepared for; yet the care with which all this gaudy decoration is kept clean, gains our admiration of, and interest in the machine, the effect being somewhat favoured by a generally clear and dry climate.

The ordinary form of locomotive engine used all over the States, has driving wheels before and behind the fire-box, coupled together; the fore part of the engine being carried on a swivel four-wheeled truck or boggie. It is worthy of remark that, in America, they seem, with a sort of common assent, to have agreed as to the best form of engine suitable for their purposes, whilst we, in this country, if we may judge from the variety of engines to be seen, would appear not yet to have arrived at this step towards perfection. The old "Bury" engine seems to be the type from which the American engine has come, as the combined truss-form of frame used in that engine is still closely adhered to in the United States.

The engines generally used for both goods and passengers have 15 in. to 16 in. cylinders, and eight wheels; coupled driving wheels of 5 ft. to 5 ft. 6 in. diameter, with truck wheels of 22 in. diameter. The driving wheels are placed close to each other, one pair before and the other close behind the fire-box, the springs being connected by compensating levers. The truck wheels, in the most cheaply-constructed engines for narrow gauges, are set about 3 to 3½ ft. from centre to centre of the axles; but there seems to be a feeling in favour of setting these wheels wider, for safety, say, up to 5 or 6 ft. from centre to centre of the axles. Compensating levers are sometimes put between the truck springs. This truck, with its framing, is almost the only thing about these engines in which much variety in form or construction is seen. They generally have only inside bearings, but many have both inside and outside bearings, from 3½ to 4½ in. in diameter. The framing of the trucks is of wrought iron—the simplest form consisting of two flat side bars, the ends of which are made to clasp the bushes of the axle bearing, whilst the centre part is made up of two plates rivetted above and under the side bars, with thimbles between them. A large inverted spring at each side, with its ends resting above the axle bearings, and the centre under the engine framing, bears the weight of the engine. This arrangement, however, does not admit of one wheel rising without raising the whole frame. The most improved truck frames have the action of the wheels independent of each other, the axle bearings running in ordinary sliding axle boxes, with a spring to each bearing or wheel. Many of these trucks exhibit ingenious applications of the truss-frame principle, adopted in order to obtain the greatest strength with the least weight. The bearing weight of the engine rests on the side frames of the truck, and not in the centre, as is the case with some truck engines made in this country. Safety chains from the engine are attached to each corner of the truck, to prevent its dropping down in the event of an axle breaking or a wheel coming off.

The truck wheels are cast solid, without arms, and are chilled on the rims. The driving wheels are also of cast iron, and remarkably light, being hooped with Bowling or Lowmoor tyres. Great care is taken in making these wheels, with the proper thickness of the parts, the quality of the iron, and the manner of casting them. The iron of this country—the Scotch iron—so much of which is imported into the States, is quite unfit for wheel making. In Messrs. Whitney's wheel factory at Philadelphia, a handsomely-built and well-arranged establishment, the casting house was about 460 ft. long by 60 ft. wide, lofty, and covered with a neat iron roof. Four large cupolas or melting furnaces, were arranged in the centre, and at the end four large annealing furnaces. A main road with rails ran down the centre of the building, and the floor on each side was covered with wheel moulding boxes, whilst light-framed four-wheeled trucks, with high light wheels, moved over the boxes on rails, spanning the whole width of the moulding floor on each side, carrying a jib crane at each end. A large ladle on a frame carriage, mounted with pouring gear, and capable of containing 15 tons of melted metal, moved down the rails of the centre road. Small ladles, suspended from the cranes above mentioned, and containing only as much metal as would cast one wheel, received the iron from the large ladle. As soon as the wheels were cast, they were lifted and carried down to the annealing surface by these same truck cranes, and piled up there, a cast-iron ring, about 4 in. deep, being put between each wheel. The top of the furnace was on a level with the floor, and having been previously heated to a clear red heat, as soon as it was filled, the covers were put on and luted, the dampers closed, and the fire door and ash-pit shut up; the whole was then left to cool. At the end of the fourth day the wheels were taken out, carefully examined, and cleaned. The car and truck wheels are cast in iron chills. On examining the pieces of the rims of wheels made there, it will be observed that the effect of the chilling penetrates about $\frac{5}{8}$ths of an inch into the iron. Four specimens were exhibited, two showing the section of car wheels annealed, or cooled slowly in four days, and two showing the section of wheel cast in chills in the ordinary manner without annealing. The effect of the chilling is shown in fig. 2, Plate XIV., which represents the broken surface of a wheel rim. In chilling wheels made of Scotch iron, the annealing is seldom observable more than $\frac{1}{8}$th of an inch under the skin, showing that there is some very remarkable difference between the two kinds of iron in this respect.

The boilers for locomotives are made very similar to those of British engines, except in the connection between the raised outer fire-box and the barrel, which consists of a straight taper instead of the square, formed by flanching or angle iron, as will be seen on referring to Plate XII., which is reduced from one of the numerous drawings exhibited when the paper was read.

The writer was much pleased with the excellent boiler work he saw in the States, both for marine and locomotive purposes. At the works of Messrs. Winans & Co., Philadelphia, he examined locomotive boilers drawn together for rivetting, and every hole appeared as if it had been bored and carefully rimelled. All the plates were marked for punching by a centre punch only, and the punches of the machine were turned in the lathe, leaving a small projecting pin or centre point, and no hole was punched by the machine until this point was felt in the centre punch mark on the plate.

In ordinary boilers for wood burning, the fire-box and tubes are of iron; but those of the best construction have a copper fire-box tube plate, and about No. 14 W. G. copper tubes. The writer was told the brass tubes used in this country would not do for wood burning engines, but could not get a satisfactory reason why. In some coal burning engines the fire-box is made of copper, a few inches above the top of the fire, the other part being iron.

In wood burning engines, the blast pipe for a 15 in. cylinder is sometimes reduced to 1¾ in. diameter, and for a 16 in. cylinder to 2 in. diameter. (In this country a 16 in. cylinder has blast pipe opening as large as 4 in. diameter.) Considerable obstruction to the blast is caused by the spark catcher over the chimney. This, to our eye rather unsightly appendage, is necessary to prevent the sparks from the wood being thrown out, to the great danger of fields of grain and forests during the hot season, and is simply a cap of light cast-iron—like an inverted cone—set above the chimney, the steam striking against it, and being turned back into the outer casing, where it deposits the sparks or burning wood. As a farther security, a piece of wire cloth is set over the whole.

There are a number of schemes and patents for spark catchers, having angular blades and spiral channels in which the sparks are arrested, but the kind described is that most in use.

The smoke-box is generally formed by a continuation of the barrel of the boiler—the smoke-box door, of an ornamental form, generally of cast iron, being put on with bolts, there being no ashes deposited, and the dust from the wood being carried into the spark catcher, whence it is withdrawn by a small door at the bottom.

The wood used in the engines is split into billets, from 2 to 3 ft. long, which are thrown into the fire-box by hand. Were it not for the great labour of constantly feeding the fire, wood makes a very cleanly and pleasant fuel for use. It is sold and reckoned by the "cord"—about 120 cubic feet piled, or 6000 lbs. weight. Passenger engines use about a "cord" of pine wood per 40 to 45 miles; or of oak per 50 miles. The American railroads generally pass through forests somewhere in their extent, and when the settlers clear the ground they split the timber and build it up alongside the track. The railway people lift it, and haul it to their stores, where it is sawn into lengths and stacked. The settlers get from 2 dols. to 3 dols. per cord for it, if at all near towns. About New

York it cost, when the writer was there, from 5 dols. to 7 dols. or more, in the tender.

In consequence of the high price of wood, considerable attention is now being turned towards engines constructed to use the coal of the country. It is proposed to notice these engines in a future paper on the subject of coal burning engines; but it may be remarked here, that in America, with such great coal fields, this question is about as important as it is in this country.

It will be observed that the American engines carry a large bell, which is used to give a signal of danger to the public, and all parties *not* connected with the railroad. It is constantly kept ringing when the engine moves along the streets in towns, or crosses roads, the driver being liable to a heavy fine should he fail to ring his bell on such occasions. The whistle is used to signal to employées on the road.

The sand-box is placed on the top of the boiler, within an ornamented casing, similar to the steam-chest, and a pipe on each side leads the sand down to the rails.

The cab on the foot-plate is quite peculiar to American engines, and is a source of great comfort to the men. It is generally found very neat and clean within, with a cushioned seat on each side. Egress to the platform-plates is obtained by small doors at the front.

The head lamp is a very clumsy affair, and does not give so much light as those of this country, in consequence of a simple reflector and plain glass front being used, instead of lenses of glass.

The cow-catchers in front, required to keep off cattle where the tracks are unfenced, are made of either wood or iron, and of forms shown in the drawings. These machines have been known to save lives, by knocking people off the track, instead of, as with our engines, knocking them down among the wheels.

As will be observed from the examples given of American engines in the illustrations before the meeting, the slide valve chest is usually outside above the cylinder, the motion to the valves being communicated through a rocking shaft; and, although most of the modern engines have the English link motion, many makers adhere to the old favourite American expansion system of one valve sliding on the back of the other, receiving its motion from a third eccentric, and all having the old gab or V connection. The amount of expansion is regulated by moving the end of the valve connecting rod in an arc, which forms the arm on the rocking shaft.

In many of the freight or mineral engines, the old hand gear is still used, and preferred for convenience in shunting, and starting on heavy gradients, or in snow storms.

Cast-iron is used for the eccentric hoops, piston-rod clutches, arms of the rocking shafts, and other parts, which are usually, but as the writer thinks, unnecessarily, made of wrought-iron or brass in this country. The number of bolts used to fix those parts, which required to be examined, or occasionally taken to pieces, is, in the American engine, reduced to a minimum. A gland with one screw fixes the two feed pump valve chest covers; four bolts the slide valve box cover, and so on.

Gauge glasses are not used on the boilers, and it would appear rather curiously, those tried have always broken so often that they have been abandoned altogether, and three gauge cocks used instead.

Cast-iron chilled tyres or hoops have recently been introduced on freight engines where the wheels are not large. They are made about 3 in. thick, and are fixed on the wheels by a number of keys sunk in the rim of the wheel, and slightly also in the tyre, having heads at one end, and nuts at the other, which when screwed up, bear both on the wheel and tyre, preventing it from slipping off.

The large eight coupled wheeled freight engine (represented in Fig. 1, Plate XIV.) by Winans of Baltimore, was made originally with cast-iron chilled wheels; but it being found troublesome and expensive to replace them, cast-iron tyres were successfully substituted, and are said to be much more desirable than wrought-iron ones. This engine is peculiar in its construction and appearance. The gratebar area is unusually large. The anthracite coal is put into the furnace by the hoppers, A, B, which are filled; the door, C, put down, and the slide doors, S, drawn—preventing the rush of cold air into the fire box, which takes place when firing in the usual mode. There are doors also at the end of the fire box by which the stoker can arrange and clean his fire. The valves are actuated by eccentric cams, and the old hand gear levers are used as before mentioned. The writer saw a great number of these engines at work on the Baltimore and Ohio railroad. The locomotive superintendent stated that they gave much satisfaction. In Messrs. Winans' factory, several of these engines were being made, but with the addition of a truck in front. This engine weighs above 32 tons; cylinders, 19 in. diameter; 22 in. stroke; wheels, 3 ft. 9 in. diameter; and it works over the summit of the Alleghany mountains, having 500 feet rise in a mile, taking, however, only one waggon of about 15½ tons weight. This part of the road is now tunnelled, but they still work 17 miles, with 117 feet rise to the mile, and in many places there is 85 feet rise to the mile. The usual load is 22 waggons, equal to 220 tons freight. The working speed does not exceed 12 miles an hour.

The American eight-wheeled truck engine is a beautifully balanced and steady machine, remarkably easy on a bad road, and much safer than an English engine under similar circumstances.

From the reported accidents on American railroads, it would appear that these engines keep the track well at the speeds they travel, which seldom, if ever, exceeds 40 miles an hour—the average running speeds of the express trains being generally from 30 to 35 miles, and that of freight trains about 15 miles an hour.

The great objection, and perhaps the only one to the American engine, is the difficulty of obtaining sufficient weight upon the driving wheels. With a 25 ton engine, seldom more than 15 tons can be got on the drivers, even by keeping the truck well forward.

There are several designs of freight engines used, those before the meeting give an idea of their leading peculiarities.

In Baldwin & Co.'s eight-wheeled coupled engine, four wheels are in a swivel truck, which arrangement, with spherical bearings in the couplings, the makers say, gives freedom on curves. This, however, appears doubtful. The only available relief seems to be in running the middle wheels without flanches, as done in Rogers, Ketchum, and Grosvenor's engine, and as is indeed the practice with the ordinary eight-wheeled engines.

An American Locomotive is represented in Plate XII., selected from the numerous drawings exhibited at the meeting.

An arrangement of engine on the American plan by Neilson & Co. of Glasgow is represented in Plate XIII., where the spring compensating levers are distinctly shown. This and one slightly different were made for British America, and are perhaps the first really American locomotive engines made in this country.

Mr. Neilson handed round some specimens of chilled cast-iron wheel rims, showing the penetration of the chilling action quite ⅝ths of an inch from the surface, as is represented in fig. 2, Plate XIV. He said the American cast-iron wheels were as light in appearance as wrought-iron wheels.

The President inquired if Acadian iron was ever used in making them, and said that some specimens of this iron exhibited a remarkable degree of toughness. He had seen pieces of Acadian cast-iron twisted about in a way which common cast-iron would not bear. The toughness might perhaps be attributable to the absence of sulphur.

Mr. J. R. Napier said that when he was in Boston, some eight or nine years ago, he saw some cast-iron guns made for the American navy, the metal of which was very like Stirling's toughened cast metal. He had also at the same time observed the fine quality of the iron used in the construction of boilers. The boilers were made with little or no angle iron, the edges being all flanged over.

The PRESIDENT believed the use of angle iron in the construction of boilers to be often objectionable. Boilers had been known to give way at the angle iron.

Mr. P. STIRLING thought angle iron would be much stronger than flanged plates.

Mr. NEILSON said that in the States, the holes in the tube plates of marine boilers were flanged inwards to receive tubes as small as 5 in. diameter, through which they were rivetted. In American wood-burning locomotives, the labour of firing was very great. It was the constant employment of the fireman to pitch the wood into the fire box.

The PRESIDENT had little doubt but that British cast-iron could be made of as good quality as any other if the proper means of working it were only known. From Professor Barlow's late experiments on beams, it appeared that the strength of the skin of bars of British cast-iron was about 2½ times greater than that of the interior. In the Acadian iron there was a greater uniformity in the strength of the skin and of the internal parts.

In reply to inquiries, Mr. NEILSON said the pressure used in American locomotives was about 80 lbs. per square inch. He could get no satisfactory replies to his inquiries as to the durability of the American locomotives, and the work or mileage done at a given cost. Captain Galton gave a general statement to the effect that there is 35 per cent. in favour of the durability of British locomotives. In the New England States, however, they were equal to British engines. In the south it was common to use cast-iron rocking shafts, chilled cast wheels, single springs acting on two axle boxes, and similar things which reduced the total cost, and rendered comparison difficult.

The PRESIDENT inquired whether any comparison had been made of the resistances of American and British engines; and how the friction was affected by the truck with its small wheels in front?

Mr. NEILSON said the swivelling of the truck avoided the friction of the flanges on the rails, but from the smallness of the wheels, the friction of the axles would be increased; on the whole, however, he thought the American locomotives had less frictional resistance than ours. The axle-journals of the 22 in. bogie wheels were 3½ to 4 in. in diameter, whilst the axle-journals of our leading trailing wheels were about 4½ in. in diameter. This gave the bogie axle-journal a very much greater surface velocity, but there was only half the weight bearing upon it.

Mr. TAIT thought the small wheels were objectionable, as they would sink into the concavity formed in the rail by the weight of the locomotive, and be constantly moving up a never-ending incline, the effect of which would be worse on the smaller wheel. He thought that many of the American locomotives, presenting a confused mass of stripes of paint and brass, were the flimsiest pieces of mechanism in existence; and that for work and durability, they were not half the worth of ours. He must, however, except the boilers from the charge of flimsiness. The workmanship of these was very excellent. They used larger and more ductile plates than we got here. He had in New York seen boiler plates 14 ft. by 7 ft. broad, intended for the upper part of the boiler.

Mr. NAPIER observed that the Americans covered their boilers with a kind of Russian iron like copper, and possessing a beautiful skin.

Mr. NEILSON said he envied the Americans the use of this iron, which they employed in great quantities. Its surface was of a blue colour like zinc. It never rusted, but always remained clean and pretty. It was very expensive, but the manner of its manufacture was still a secret. He had heard of two acute Yankees, living in Siberia for several years, endeavouring to find out the process, but in vain.

The PRESIDENT hoped they would ere long find out how to make it for themselves. He proposed a vote of thanks to Mr. NEILSON for his paper, and for the numerous and interesting drawings of American locomotives he had exhibited. The vote of thanks was unanimously passed.

The following paper was then read:—

On the Stability of Locomotives. By Mr. J. G. Lawrie.

The instability of locomotives arises from two causes—the internal disturbing action of the engine itself, and the unevenness of the permanent way. The control of these elements of instability is materially affected by the disposition of the axle bearings. These bearings in some engines are all of them outside the wheels; in some they are all inside; while in others, either the leading or the trailing axle, or both, have their bearings outside; and the driving axle inside.

A little reflection makes it appear that the merits of the several arrangements of the axle bearings are developed on considering the two forms, the one shown in fig. 3, Plate XIV., in which the leading axle alone has outside bearings, and the other shown in fig. 4, in which the trailing axle alone has outside bearings.

The internal disturbing action of the engine itself arises chiefly from the angular action of the connecting rods above and below a horizontal line, and from the momentum of the reciprocating parts. The disturbance from unevenness of the permanent way is caused by the curves, and by the state of repair in which the permanent way is. When an engine is well balanced, the instability or oscillation arising from the action of the connecting rods, and from the momentum of the reciprocating parts, is nearly removed, or at all events so nearly removed as to leave the disturbing action from unevenness of the road—of an importance by much the most material. The instability caused by unevenness of road arises either from inequality in the top and side surface of the rails—such as unfair butt joints, or from the difference of level of the rails in a curve, together with the difference in the length of the rails on the outside and inside of a curve. Of all the causes of instability, however, which an engine in good repair encounters on a line also in good order, that received when travelling at a high speed in a curve is the most important.

When an engine is in motion round a curve in the direction of the arrows, A, in figs. 3 and 4, all the parts of the engine resting upon the springs, tend, in consequence of their momentum, to move off the line in the direction of a tangent to the curve, whilst the wheels and axles are forced by the rails to follow the curve. Thus the parts of an engine upon which the springs bear, are forced to move in a direction forming some angle with the direction in which the parts supported by the springs tend to move, and that engine is the most stable which receives from the springs the greatest assistance in maintaining the entire structure in the shape and position it occupies when at rest. Suppose the arrows, A, represent the direction of a curve in a railway, and the arrows, B, the direction of a tangent to that curve, the question arises whether the arrangement of axle bearings in fig. 3, or that in fig. 4, contributes most to maintain the several parts of the engine in the position which they occupy when the engine is at rest. At C D are the bearings upon which the springs rest on the leading axle, and it is plain enough, with but little consideration, that the further apart these bearings are, the more effectually do the springs control the dislocation of the engine, and therefore the more stable is the locomotive. At E F are the spring bearings on the trailing axle, and it is equally apparent that the distance asunder of these bearings, though not by any means immaterial, is of very inferior importance in the stability of the engine to the width of the bearings on the leading axle.

It thus appears that wide bearings on the leading axle are of the highest importance in controlling the particular disturbance in the stability arising from a curve, and this is the most important element of instability; but the width of these bearings is of equal importance in controlling every other cause of instability. It has been contended, against outside leading axle bearings, that when the engine, so constructed as in fig. 3, travels over hollows in the permanent way, violent shocks are given by the springs acting with so much leverage from the centre of the engine. This argument, however, is of no moment, because those lines on which hollows so precipitate exist, are unfit for high speed; and the very fact of this argument being used against outside bearings, proves the efficacy of the arrangement in maintaining the stability of the engine.

Locomotives constructed with outside cylinders, and leading axles having outside bearings, possess the principal features of Locke's Crewe engine, and the admirable efficiency of that engine in these two particulars, seems to give it the highest position among existing locomotives.

I have stated, and experience has repeatedly proved, that in an engine properly balanced, no instability exists, which is caused by the angular action of the connecting rod, or by the momentum of the reciprocating parts; but those most familiar with locomotives know best that engines, generally, are far from being so carefully adjusted. No engineer now considers that he has altogether finished the construction of a stationary or marine engine until he has proved its correctness by the indicator, and to a much greater extent should the balancing of a locomotive be deemed a part of its construction. In those instances in which engines have been balanced with accuracy, the means employed have been of a temporary and somewhat imperfect description, but a suitable machine for regular use would not be by any means an expensive one. Fig. 5 represents one form in which it might be constructed. Two beams, A B, are carried by four rods, E, F, G, H, and suspended from a pivot, K. At L M are one or two wheels, as the case may be, upon which the driving wheels of the engine revolve, and friction straps, N, O, are provided for the purpose of grasping the driving wheels with an amount of force such that full steam may be applied to the engine. The point of suspension at K, is capable of being shifted so as to balance the entire weight. The wheels at L, are capable of being shifted to suit different engines. Such a machine would be by no means cumbrous or expensive, and would serve the purpose of balancing the moving parts of the engine much more effectually than can be done by any of the numerous modes of calculation extant. If to this machine another be added, for the purpose of loading the driving wheels equally in the case of coupled engines, locomotives would be balanced with an accuracy unknown in present practice.

Considering that the work performed on our several railways is similar, and in the case of all our principal ones the same, the variety of locomotives in use is much more apparent than advantageous. To the possessor of railway property this is a matter of no indifferent character, because upon the locomotive depends, to a large extent, the amount of his return. Yet all the information the railway proprietor possesses regarding his motive power is, that the engine employed on his own line is the one deemed by his own superintendent to be the best, and that this same engine is deemed by all other locomotive superintendents, or, at all events, by nine out of every ten, as very inferior indeed. This is surely not the condition in which our railway motive-power should stand.

I have already described a machine which is, in some measure, adapted to perfect the construction of the locomotive in certain respects, and I shall now describe an instrument which I confidently believe is fitted to bring about its more perfect construction, not only in those respects, but in others of vast importance, and capable also of leading to improvements in points in which it is not yet known that improvement is possible.

In 1829, when the competition with locomotives took place on the Liverpool and Manchester Railway, results were obtained wholly unanticipated, and a start forward was given to locomotive engineering which hastened the advancement of railways to an extent that cannot be overestimated.

In agricultural engineering what has been the result of repeated competition? The result has been that in no branch of the mechanical arts have strides so large or more successful been made.

In Lancashire, at the present moment, through the operation of the association formed for the prevention of steam boiler explosions, and for effecting economy in the raising and use of steam, a constant and accurate comparison is being made of upwards of 600 steam engines, and beyond a doubt one result of this association, perhaps the most important result will be, great improvement in the machinery which falls within its range. It is impossible that the accurate observations and tabulated records of that association can fail to raise, at all events, the inferior engines to the standard of the best, but its tendency also is to raise the best to a still higher standard.

In all machinery comparisons ought to be made. In most kinds of machinery comparisons can be successfully made; but in no machinery can they be made more fully, more easily, and with results more important than in locomotives.

The instrument, therefore, which I anticipate is capable of leading to results so beneficial in locomotives is the establishment of competitive trials, with premiums of considerable amount, open to every engineer who chooses to enter the lists. Such competitions would remove the contention of debatable ground, would sift and perfect all existing constructions of engines, and would bring forward improvements that are at present unthought of.

The benefits of these competitions would be reaped by every railway company in the kingdom. Manufacturing engineers also would share in them; they would receive instruction, and would derive employment from the demand for the improved form of engine. Indeed, from additional employment nothing would more conduce to the immediate profit of manufacturing engineers, as a body, than the invention of an improved construction.

An institution such as this which I now address, possessing, in its members, all the mechanical talent and status of the Clyde, or I may say of Scotland, if that comprehends more, is well fitted to carry forward such a measure as I have suggested, and in return would derive a dignity not unworthy of its aim and emulation.

Sources from which the funds necessary for this object would be derived are apparent enough, and in all probability very large premiums could be offered, which, together with the high position of being successful competitors, would afford inducements sufficiently tempting to arouse from indifference the most distinguished of our engineers.

In every path of human pursuit, in every art and in every science, no motive to exertion has yet been discovered so powerful as rivalry, and for the reason that the action of that motive is measured by the principle the strongest in human nature—ambition.

Mr. LAWRIE said that his views respecting the benefit of outside bearings on the leading wheels were corroborated in a rudimentary way by experimentally placing oneself horizontally, so as to rest on the toes, and on the elbows or arms, when it would be felt that in proportion to the distance asunder of the elbows, was the resistance to a capsize on a push being given forward and laterally, at an angle of say 45°, whilst increasing the width apart of the toes added comparatively little to that resistance.

Mr. P. STIRLING preferred that all the bearings should be inside, and did not agree with Mr. Lawrie that outside bearings would increase the stability. The stability depended on the width of base, which, in the locomotive, was 4 ft. 8½ in., the gauge of the wheels; the weight above should be kept as much within this base as possible; and the lateral spreading of the weight consequent on the use of outside bearings would be injurious rather than beneficial.

Mr. LAWRIE argued, that if Mr. Stirling's reasoning were correct, it would be best to put the bearings close together, or to use a single long one at the middle of the axle; but this arrangement would obviously involve great instability.

Mr. ALLAN said it was usual to suspend locomotives by chains 30 in. long at the four corners, for the purpose of testing and balancing them. Without balance weights there would, generally, be a slight oscillation, such as would describe an oval 1¼ to 1½ in. long, on a stationary card; but when the balance weights were applied, the locomotive was perfectly steady, describing an oval not more than $\frac{1}{16}$ in. long, when working at a speed corresponding to 50 miles per hour.

Mr. LAWRIE said that, according to his plan, the locomotive was suspended from a single point, instead of at the four corners; he did not, however, so much bring it forward as new, but because he thought its usefulness was not sufficiently recognized.

Mr. NEILSON doubted whether the proposed competitions would lead to any result; he thought engineers would not be got to agree to it.

On the motion of the PRESIDENT, a vote of thanks was unanimously passed to Mr. Lawrie for his paper.

The Secretary announced the reception of the following Works during the Session 1857–58.

"Rapport sur l'Exposition Universelle de 1855," par MM. Girardin, Cordier, and Burel. Presented by M. Burel.

"On the Composition of the Building Sandstones of Craigleith, Binnie, Gifnock, and Partick Bridge." Presented by the Author, Thomas Bloxam, assistant chemist, Industrial Museum, Edinburgh.

"The Illustrated Inventor." Nos. I. to XXIII. Presented by the Proprietors.

The thanks of the Institution were voted for these donations

The TREASURER presented his accounts and statements in accordance with Rule 15; and Messrs. HARVEY and WILKIE were appointed Auditors in accordance with Rule 17, to examine the same.

ABSTRACT OF TREASURER'S ACCOUNT—SESSION 1857–58.

Dr.				*Cr.*						
April 14, 1857.				April 14, 1857.						
To Subscriptions—				By paid to account of the Secretary's Salary,				£58	0	0
111 Members, at £8 8s.,	£849	18	0	Sundry accounts, as per vouchers, viz.—						
1 Associate, at £2 12s. 6d.,	2	12	6	Circulars, &c., connected with preliminary meetings,				7	11	6
8 Graduates, at £1 1s,	8	8	0	Advertising,	£6	1	9			
				Stationery,	6	9	6			
				Engraving and printing cards, and printing regulations,	5	16	0			
				Collecting a portion of the subscriptions,	1	2	0			
				Postages,	2	15	0			
				Report of President's address,	2	2	0			
								24		8
				Balance—						
				Cash in Union Bank, as per pass book,	270	0	0			
				Cash in Treasurer's hands,		15	9			
								270	15	9
	£860	18	6					£860	18	6

After their examination, the Auditors presented the following Report:—

"GLASGOW, *14th April*, 1858.—We have examined the above statement (made by the Treasurer), and compared it with the cash-book and vouchers, and we find it to be correct, the sum in the Union Bank being two hundred and seventy pounds (£270), and in the hands of the Treasurer 15s. 9d., making, in all, the sum to be carried to the credit of the Institution, two hundred and seventy pounds fifteen shillings and ninepence.

(Signed) GEORGE HARVEY, JOHN WILKIE, } *Auditors*."

The thanks of the meeting were voted to the Auditors.

The following gentlemen were duly elected Office-Bearers for the Second Session (1858–59) of the Institution, in accordance with Regulations 24, 35, 36, 37, and 38, which were read:—

President.

W. J. Macquorn Rankine, LL.D.

Vice-Presidents.

Walter Neilson, Esq.
James R. Napier, Esq.
William Tait, Esq.

Councillors.

John Elder, Esq.
William S. Dixon, Esq.
Neil Robson, Esq.
David Rowan, Esq.
Patrick Stirling, Esq.
Andrew M'Onie, Esq.
William Johnstone, Esq.
Robert B. Bell, Esq.
Benjamin Connor, Esq.
Alexander Allan, Esq.

Treasurer.

David More, Esq.

Secretary.

Edmund Hunt, Esq.

The proceedings were terminated by a few remarks from the President, touching on the successful completion of the first session of the Institution, and the commencement of a new session in the ensuing October.

List of Members, Associates, and Graduates of the INSTITUTION OF ENGINEERS IN SCOTLAND, *at the Termination of the First Session,* 1857–58.

MEMBERS.

John	Addison,	Maryport and Carlisle Railway.
William	Alexander,	Government Inspector of Mines.
Alexander	Allan,	Scottish Central Railway, Perth.
David	Auld,	124 Great Hamilton Street, Glasgow.
Hugh	Bartholomew,	Engineer to the Glasgow City and Suburban Gas Works.
Robert B.	Bell,	4 Bothwell Street, Glasgow.
Robert	Blackwood,	Kilmarnock.
Benjamin H.	Blyth,	135 George Street, Edinburgh.
Thomas	Brown,	Shotts Iron Works, near Motherwell.
James	Brownlee,	City Saw Mills, Port-Dundas.
James T.	Caird,	Greenock.
Duncan	Cameron,	Springfield Iron Works, M'Neil Street, Glasgow.
James	Campbell,	Elliot Works, Finnieston, Glasgow.
Alexander	Chaplin,	Cranston Hill Engine Works, Glasgow.
Benjamin	Connor,	Caledonian Railway.
Robert	Cook,	100 Commerce Street, Glasgow.
George	Crawhall,	Elliot Works, Finnieston, Glasgow.
William	Darling,	39 Union Street, Glasgow.
James	Denny,	Dumbarton.
William S.	Dixon,	1 Dixon Street, Glasgow.
John	Downie,	N. Woodside Iron Works, Garscube Road, Glasgow.
John	Duff,	Oakbank Engine Works, Garscube Road, Glasgow.
John	Elder,	Centre Street, Glasgow.
Robert	Faulds,	6 Parson Street, Glasgow.
A.	Ferber,	Hamburg.
James	Ferguson,	Auchinheath, Lesmahagow.
John	Finlay,	46 Buchanan Street, Glasgow.
Archibald	Finnie,	Kilmarnock.
William	Forrest,	9 Canal Street, Glasgow.

John	Galloway,	Kilmarnock.
George	Graham,	Caledonian Railway.
Robert	Gunn,	Proprietor of the *North British Daily Mail.*
John	Hamilton,	8 Exchange Square, Glasgow.
George	Harvey,	Albion Engine Works, 40 M'Neil Street, Glasgow.
James	Henderson,	7 Exchange Place, Glasgow.
James	Hendry,	8 Dixon Street, Glasgow.
John	Houldsworth,	124 St. Vincent Street, Glasgow.
James	Howden,	25 Robertson Street, Glasgow.
William	Howie,	45 Union Street, Glasgow.
Edmund	Hunt,	28 St. Enoch Square, Glasgow.
John	Hunter,	Dalmellington Iron Works, near Ayr.
John	Inglis,	60 Warroch Street, Glasgow.
William	Jack,	Carnbroe Iron Works, Coatbridge.
William	Johnson,	166 Buchanan Street, Glasgow.
James	Johnstone,	Larchhill House, by Moffat.
Ronald	Johnstone,	204 West George Street, Glasgow.
William	Johnstone,	Glasgow and South Western Railway.
David	Kirkaldy,	Vulcan Foundry, Glasgow.
David	Laidlaw,	Alliance Foundry, Glasgow.
William	Lancaster,	Portland Iron Works, near Kilmarnock.
J. G.	Lawrie,	Whiteinch.
John	Lawson,	Mountain Blue Works, Camlachie.
David	M'Call,	Glasgow.
Hugh H.	Maclure,	65 Sauchiehall Street, Glasgow.
James I.	M'Dermont,	Winton Buildings, Ayr.
Walter	M'Farlane,	Saracen Foundry, Glasgow.
James	M'Ilwham,	Anderston Foundry, Glasgow.
Daniel	Mackain,	Engineer to the Glasgow Corporation Water Works.
John	Mackenzie,	Dundyvan.
John	M'Kinnell,	Secretary to the Athenæum, Glasgow.
William	Macnab,	Greenock.
Andrew	M'Onie,	Scotland Street, Tradeston, Glasgow.

James	Milne	Engineer to the Forth and Clyde Canal.
James B.	Mirrlees,	2 Scotland Street, Glasgow.
John	Moffat,	Ardrossan.
David	More,	33 Montrose Street, Glasgow.
Matthew A.	Muir,	Anderston Foundry, Glasgow
James	Murdoch,	Lancefield Forge, Glasgow.
James R.	Napier,	26 Newton Place, Glasgow.
John	Napier,	10 Woodside Crescent, Glasgow.
Robert	Napier,	West Shandon.
James B.	Neilson,	Queen's Hill, Kirkcudbright.
Walter	Neilson,	Hyde Park Foundry, Glasgow.
Walter	Neilson,	Summerlee Iron Works.
William	Neilson,	Mossend Iron Works, Bellshill.
Robert	Nicholson,	Edin., Perth, & Dundee Railway, Burntisland.
Charles	O'Neill,	40 Abbotsford Place, Glasgow.
William	Paton,	Edinburgh and Glasgow Railway.
William	Ramsay,	37 West George Street, Glasgow.
W. J. Macquorn	Rankine,	59 St. Vincent Street, Glasgow.
James	Reid,	Hyde Park Foundry, Glasgow.
James	Robertson,	Ardrossan.
Hazelton R.	Robson,	9 Rutland Place, Glasgow.
Neil	Robson,	180 West George Street, Glasgow.
Robert C.	Ross,	Springvale.
David	Rowan,	Greenock.
James	Russell,	N. Woodside Iron Works, Garscube Road, Glasgow.
John	Scott,	Cartsdyke, Greenock.
John	Scott, junr.,	Greenock.
Thomas	Shanks,	Johnstone.
James	Shearer,	Ardrossan.
George	Simpson,	52 Renfield Street, Glasgow.
Alexander	Smith,	Eglinton Engine Works, Cook Street, Glasgow.
David	Smith,	37 West George Street, Glasgow.
David	Smith,	St. James' Foundry, Anderston Quay, Glasgow.
William	Smith,	Eglinton Engine Works, Cook Street, Glasgow.
Robert	Steel, junr.,	Greenock.
William	Stephen,	50 Duke Street, Glasgow.

Patrick	Stirling,	Glasgow & South Western Railway, Kilmarnock.
Peter	Sturrock,	Kilmarnock.
A.	Swan,	Greenock.
William	Tait,	2 Scotland Street, Glasgow.
George	Thomson,	Clyde Bank Foundry, Finnieston, Glasgow.
James	Thomson,	82 West Nile Street, Glasgow.
John	Thomson,	East Indian Railway, Mirzapore, India.
John M.	Thomson,	Carfin Colliery, Motherwell.
Thomas	Thorburn,	Borough Surveyor, Derby.
David	Tod,	Clyde Foundry, Anderston Quay, Glasgow.
William	Tod,	Clyde Foundry, Anderston Quay, Glasgow.
John	Tulloch,	Dumbarton.
Matthew	Waddell,	8 Rutland Place, Glasgow.
John	Watson, junr.,	30 Tureen Street, Glasgow.
William	Weir,	Eglinton Iron Works, Kilwinning.
Alexander	Whitelaw,	Gartsherrie House, Coatbridge.
Isaac	Whitesmith,	29 Govan Street, Glasgow.
John	Wilkie,	33 Renfield Street, Glasgow.
Thomas	Wingate, junr.,	Whiteinch.
R.	Young,	Caledonian & Dumbartonshire Railway, Bowling.

ASSOCIATE.

William	Hall,	Kirkgate, Irvine.

GRADUATES.

Thomas	Aitken.	John	M'Donald.
José Maria da	Conceiçaõ.	Thomas	Roberts.
John	Hall.	Alexander M.	Strathern.
William	Inglis.	J. Millar	Ure.

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THE GREAT — WEST —

Fig. 1.

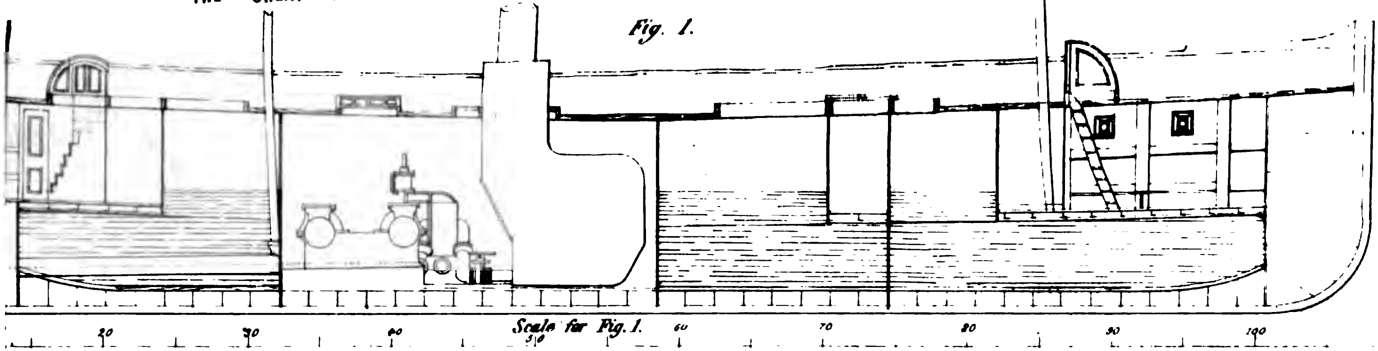


Fig. 2.

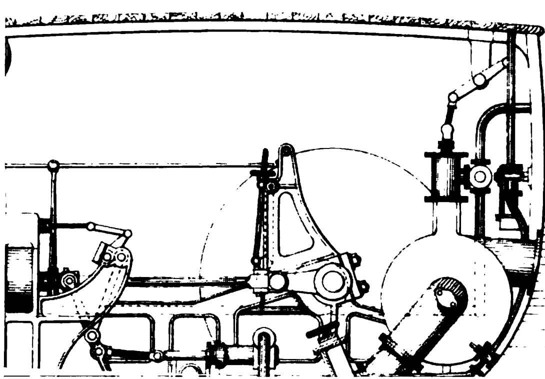
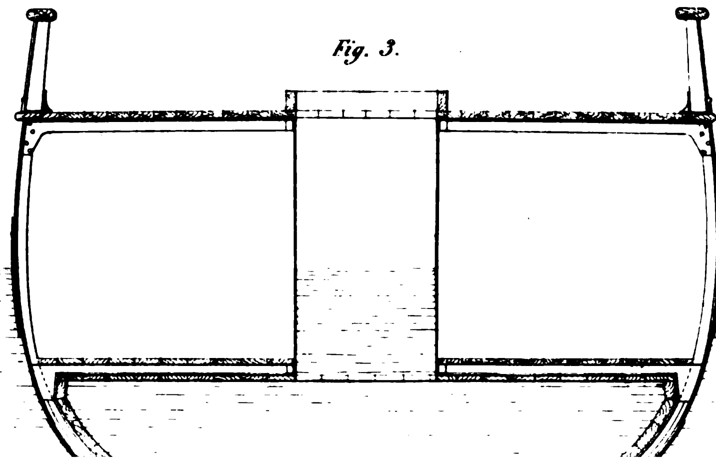
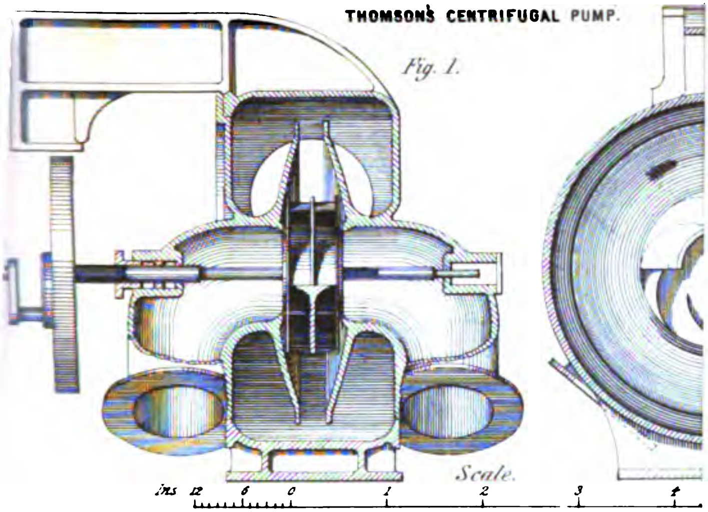


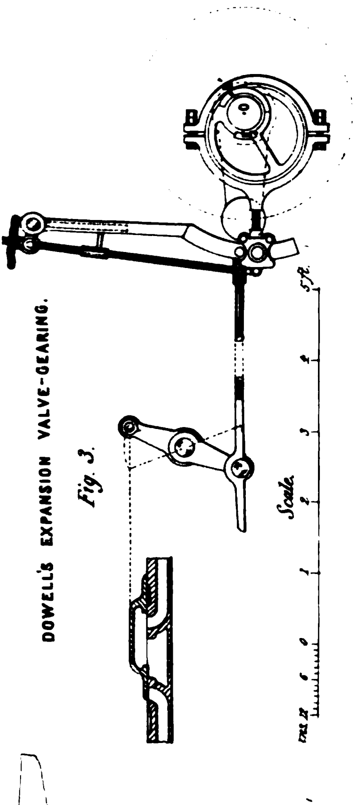
Fig. 3.



THOMSON'S CENTRIFUGAL PUMP.



DOWELL'S EXPANSION VALVE-GEARING.



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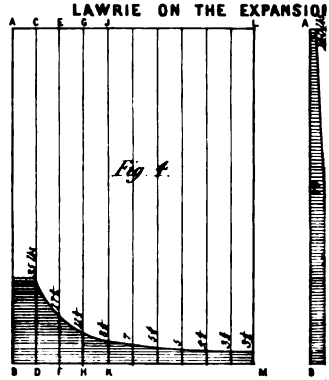

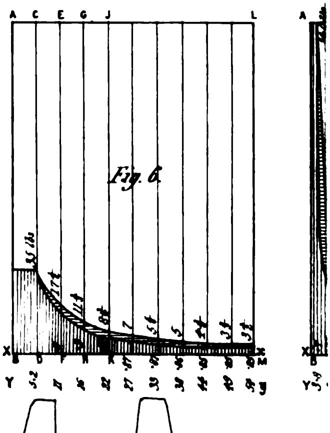

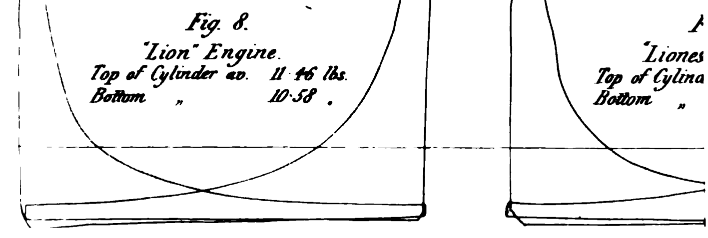

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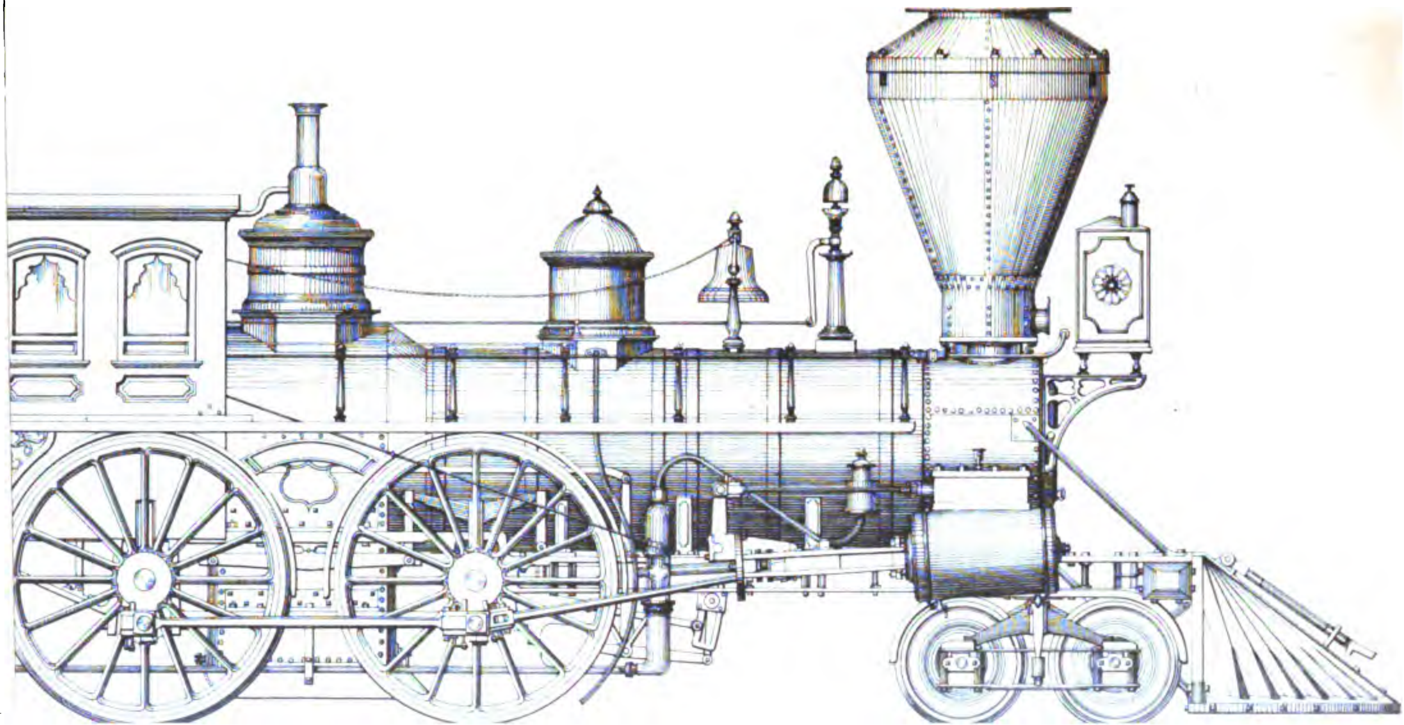
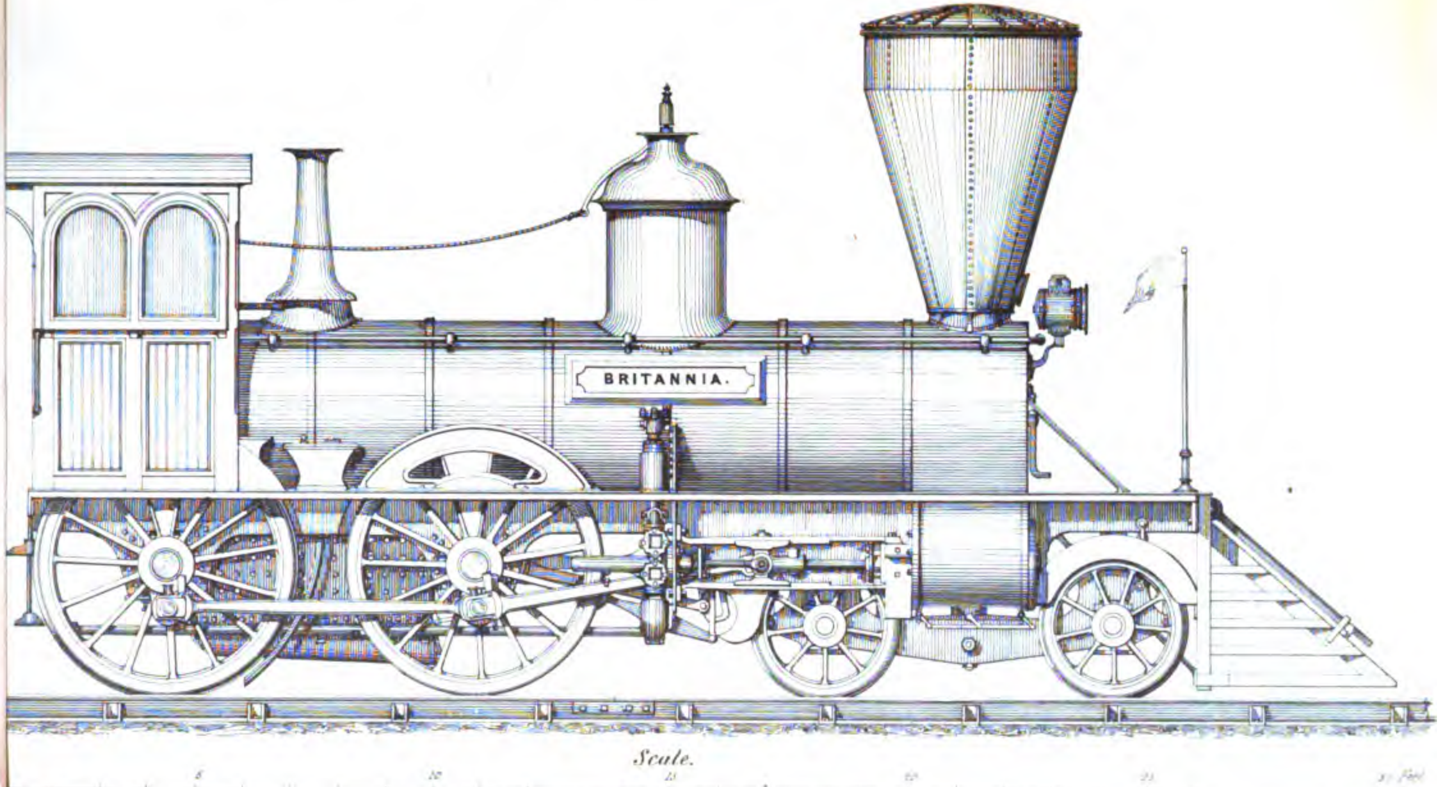
PASSENGER ENGINE, BUILT AT SCHENECTADY, NEW YORK.



GOODS ENGINE BUILT BY MESSRS NEILSON & Co, GLASGOW.



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FREIGHT ENGINE ON THE BALTIMORE & OHIO RAILWAY.

Fig. 1.

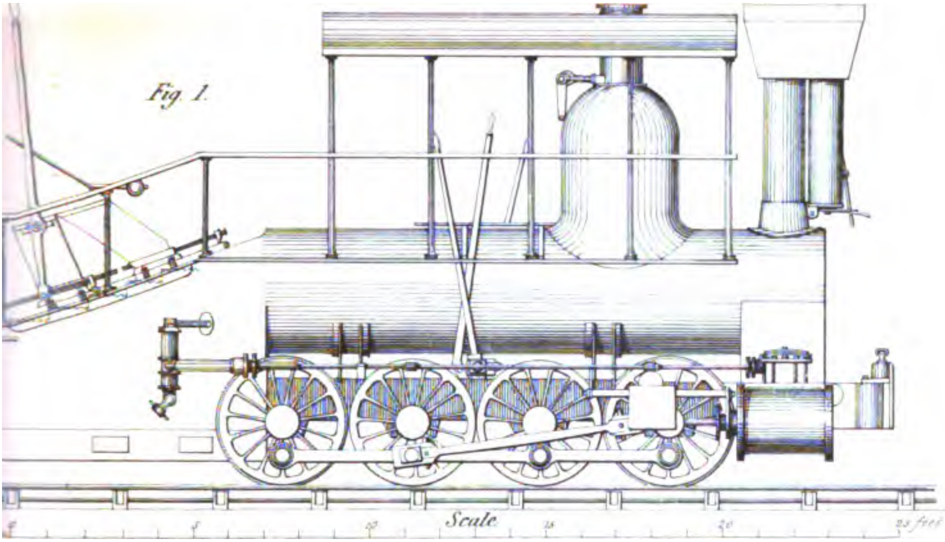


Fig. 2.

AMERICAN CHILLED WHEEL-RIM

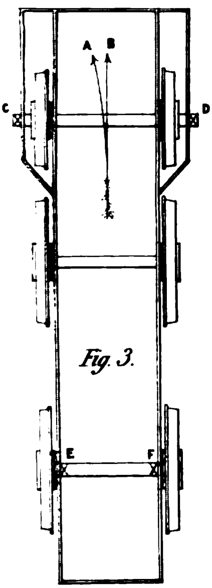


Fig. 3.

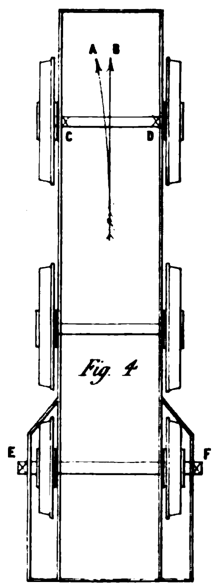
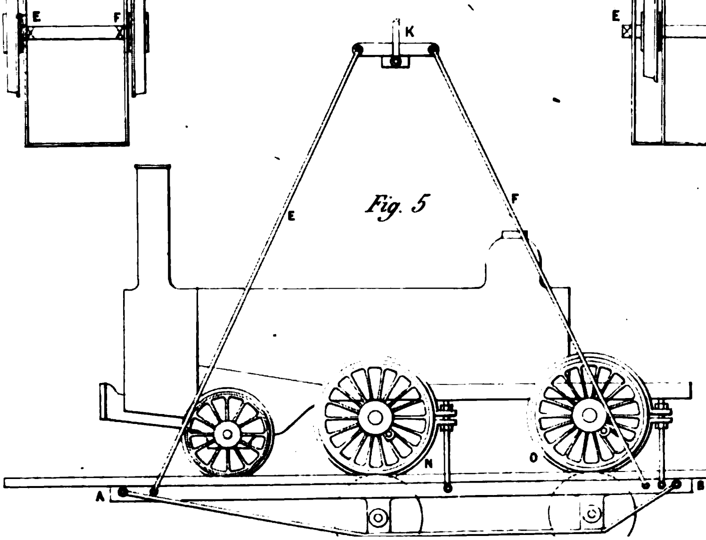


Fig. 4

LOCOMOTIVE STABILITY.

Fig. 5



TRANSACTIONS

OF THE

INSTITUTION OF ENGINEERS

IN SCOTLAND.

VOLUME II.

SECOND SESSION, 1858-59.

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OF THE

INSTITUTION OF ENGINEERS

IN SCOTLAND.

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GLASGOW:
WILLIAM MACKENZIE, 45 & 47 HOWARD STREET.
1859.

GLASGOW: WILLIAM MACKENZIE, 45 & 47 HOWARD STREET.

OFFICE-BEARERS.

Elected 14th April, 1858.

SECOND SESSION, 1858-59.

President.

W. J. MACQUORN RANKINE, LL.D.

Vice-Presidents.

WALTER NEILSON, Esq. | JAMES R. NAPIER, Esq.
WILLIAM TAIT, Esq.

Councillors.

JOHN ELDER, Esq.
WILLIAM S. DIXON, Esq.
NEIL ROBSON, Esq.
DAVID ROWAN, Esq.
PATRICK STIRLING, Esq.
ANDREW M'ONIE, Esq.
WILLIAM JOHNSTONE, Esq.
R. BRUCE BELL, Esq.
BENJAMIN CONNOR, Esq.
ALEXANDER ALLAN, Esq.

Treasurer.

DAVID MORE, Esq.

Secretary.

EDMUND HUNT, Esq., 28 St. Enoch Square, Glasgow.

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SECOND SESSION, 1858-59.

SEVENTH MEETING, 16th MARCH, 1859.

EIGHTH MEETING, 13th APRIL, 1859.

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 IN SCOTLAND.

SESSION 1858-59.

The First Meeting of the Session was held in the Philosophical Society's Hall, Andersonian Buildings, George Street, Glasgow, on Wednesday, 27th October, 1858—W. J. Macquorn Rankine, C.E., LL.D., F.R.S.S.L. & E., President, in the chair.

The President delivered the following Introductory Address:—

Gentlemen,—When, at the first regular meeting of our first Session, almost exactly a year ago, I had the honour to deliver to you an introductory address on the nature and objects of our Institution, I ventured to indulge in anticipations of success, founded on the character of engineering industry and skill in this city, and in Scotland generally. I have now to congratulate you on the fact that those anticipations have not only been realized, but exceeded. The time of each of our meetings has been fully occupied by papers and discussions of great interest and practical value. Those papers and discussions, copiously illustrated by drawings, have been published in a volume which may be left to speak for itself. The number of our members has greatly increased, and goes on increasing at each successive meeting; and our financial position is perfectly satisfactory.

I shall now address to you some remarks on the present condition of the branches of practical science which we cultivate; on the extent to which, during the past year, they have been advanced, by our own labours and those of others; and on some of the many questions which they still present for solution. In so doing, I shall not have to enter into a detailed analysis of the papers read here last Session, or the discussions on them, seeing that they have been printed in the volume of Transactions which you possess, and that a summary of their subjects, prepared by our secretary, is contained in the Report of the Council which has recently been distributed.

The subject of decimal measures was brought before us by the papers of Mr. Neilson and Mr. Holland, and discussed at three meetings. With reference to Mr. Neilson's proposal, that the French system of measures should be adopted at once, and as a whole, I may remind you that doubts had been entertained whether so great and sweeping a change could easily be introduced amongst workmen, and that various members mentioned instances of the ready adoption by workmen of French measures, tending to remove that doubt. I am happy to be able now to refer to additional facts of the same character, tending to prove that amongst intelligent artisans (and no others are fit for engineering work), no difficulty whatsoever would be met with in the introduction of the metrical scale. I had recently the satisfaction, in common with other members of the British Association, of visiting the locomotive works of an eminent engineering firm at Leeds—Messrs. Kitson, Thompson, and Hewitson; and there we found several engines in progress for foreign railways. All those engines were made to French measures, of which the workmen, with the utmost willingness, had learned the use in a few minutes. It appears, in short, that the metrical system is being introduced by degrees into practice, without the aid either of legislation or of the action of societies. There is a close connection between the subject of standards of measure, and that of engineering tools. In connection with the latter subject, we had, last Session, only one paper; that of Mr. M'Cormick on his screwing machine, illustrated by the machine itself. Papers on this branch of mechanics are much to be desired, and would prove both interesting and useful.

The papers by Mr. Morton and Mr. Lawrie, on the expansive working of steam, and the discussions on them, have tended to elucidate and to establish the principle, that in order to realize the economy properly due to expansion, means must be taken, by steam-jackets or otherwise, to prevent that condensation which always takes place in saturated steam when it performs work by expansion, without being supplied with heat from an external source. It is not that such condensation constitutes of itself a loss of power, but that the liquid water produced by that condensation, by its presence in the cylinder, acts as a conductor, diffuser, and equalizer of heat, and tends to cool the steam at the beginning and warm it at the end of the stroke, and thus to lower the initial pressure and injure the vacuum, to reduce the work of the engine below that which is properly due to the expansion, and to make it approximate to that of a full-pressure engine, working at some pressure intermediate between that of the admission and that of the exhaust. By the use of the steam-jacket, the condensation of a certain quantity of steam is not prevented; but, instead of taking place in the cylinder, it is made to take place in the jacket, where the liquid water produced is not injurious. The liquefaction of a portion of the steam which performs work by expansion was deduced from the mechanical theory of heat in 1849. Prior to that time, the whole of the water found in the cylinders of engines without jackets, was supposed to have been carried over from the boiler by priming.

I am happy to recognize in the papers and discussions to which I have referred, as well as in papers which have been read to other societies, or which have appeared in the mechanical journals, evidence that the true principles of the mechanical action of heat, founded on the idea that heat is not a substance, but a form of energy, are making their way amongst practical men, and are being usefully applied by them.

As a means of facilitating that progress, by putting the expression of those principles into a shape more familiar to practical engineers than their present form, it was recently suggested by Mr. Stephenson, that, instead of the unit of heat commonly employed in scientific treatises—viz., so much heat as one pound of water requires in order to raise its temperature by one degree—quantities of heat should be expressed in terms of an unit which practical men oftener have occasion to think of, viz., so much heat as one pound of water at 212° of Fahrenheit requires, in order to convert it into steam at the same temperature; or what is commonly called, "the latent heat of one pound of steam at 212° of Fahrenheit;" being, in fact, the unit of heat now commonly employed in comparing the effects of different kinds of fuel, and different forms of furnace. This suggestion of Mr. Stephenson appears to be well worthy of consideration and discussion.

The following is a comparison of different units of quantity of heat, British and French, reduced to their equivalents in units of mechanical energy, as a common standard of comparison based on the experiments of Joule.

COMPARISON OF UNITS OF HEAT.

BRITISH UNITS.

	Equivalent energy in foot-pounds.
One degree of Fahrenheit's scale in a pound of water,	772
One degree of the centigrade scale in a pound of water,	1390
Latent heat of one pound of atmospheric steam,	745750

FRENCH UNITS.

	Equivalent energy in kilogrammètres.
One degree of the centigrade scale in a kilogramme of water,	423·7
Latent heat of one kilogramme of atmospheric steam,	22730

One kilogrammètre = 7·23314 foot-pounds.
One foot-pound = 0·138253 kilogrammètres.

Besides the proper management of the expansive working of steam, we have another means of improving the economy of power in the cylinder of the steam-engine, by using steam heated to a temperature higher than the boiling point corresponding to its pressure, or as it is commonly called, "superheated steam." The efficiency of any engine moved by the mechanical action of heat in any fluid, is the greater, the greater the difference between the temperature at which the fluid performs its work, and that at which it is either rejected or condensed, as the case may be; and the use of superheated steam enables us to work at a high temperature, without producing a dangerous pressure. Although the practical use of superheated steam has made considerable progress of late, there is still a scarcity of data for precise calculation on the subject; the only experiments on the laws of expansion of superheated steam, being those of Mr. Siemens, which are of too limited extent.

The instances which practice has lately afforded of improvements in the economical working of steam, are so numerous, that it would be impossible, within reasonable limits, to give even a condensed view of them all; and if I now select one case as an example, it is simply because the economy in that case was ascertained by experiments conducted under my own inspection. It is that of the engines furnished by Messrs. Randolph & Elder to Mr. James R. Napier for the steamer *Admiral*, which he lately built for a Russian company. The engineers guaranteed to the builder that the consumption of coal should not exceed three pounds per indicated horse-power per hour, and the actual consumption, as ascertained by me, was two pounds and nineteen-twentieths.*

The steamer which I have now mentioned is an example of progress in naval architecture, as regards the precision with which the power required to propel a ship of a given size and shape at a given speed, can be computed beforehand—a point of the highest importance, both to the purchaser and to the builder. In the present instance, the builder, Mr. James R. Napier, in his contract with the purchasers, bound himself under heavy penalties to fulfil conditions as to draught of water, cargo, speed, power, and consumption of coal, which he could not possibly assure himself of fulfilling, except by being able to compute beforehand the resistance and propelling

* Displacement of the *Admiral*,	820 tons.
Length,	210 feet.
Breadth,	32 "
Draught of water,	7½ "
Midship section,	214 square feet.
Speed,	12 knots.
Indicated horse-power, including friction,	744
Coal burned per hour,	2206 lbs.

power of the ship at any required speed, *from the drawing of her lines*, with very great precision: and in this he was perfectly successful. In such calculations as these, an error in excess is as fatal as an error in defect; for if, in order to make sure of fulfilling the contract as to speed, the engines are made too powerful, they become also too bulky and heavy, and the conditions as to cargo and consumption of fuel are violated. It is true that by the common method of calculation, that is, by making the indicated horse-power proportional to the square of the lineal dimensions multiplied by the cube of the speed, the power required by a proposed new ship may be computed with tolerable exactness, from the results of a previous experiment on an existing ship of similar, or nearly similar figure and proportions; but if no such experiment has been made or recorded, and especially if the proposed vessel has anything new and unusual in her proportions and shape, that method totally fails. It is to be hoped that a great body of useful experimental data on the subject of the propulsion of ships, whether by steam or by sails, will be collected by the committee appointed for that purpose by the British Association during their meeting at Leeds. It may be regarded as certain, that experiments on the resistance of models are almost worthless for the purpose of determining the propelling power required by ships of figures similar to those of the models. The forces which constitute the principal part of the resistance to the model and to the ship respectively, are of different kinds, and follow different laws: in short, to determine the laws of the resistance of real ships, we require experiments on real ships, and such are the experiments which the committee in question propose to collect and arrange.

I must not quit the subjects of ship-building and marine engineering without referring to the *Great Eastern;* and I am sure that all the members of this Institution will concur with me in regretting that that unparalleled work of Mr. Brunel and Mr. Scott Russell is still unfinished. Independently of her great size, the *Great Eastern* is a most beautiful example of good figure and proportions, and the finest specimen now existing of the application of the true principles of strength to naval construction. Her intended speed, I believe, has not yet been announced by authority; but with eleven thousand indicated horse-power, which is understood to be the intended power of her engines under ordinary circumstances, it will probably be between fifteen and sixteen knots when loaded, and may, of course, be increased by working the engines up to a higher power, and by the aid of sails.

It is gratifying to observe, that the improvement of propulsion on canals, which the sudden advancement of railways at one time caused to be neglected, is now employing much skill and ingenuity.

Mr. Robson and Mr. Milne gave this Institution last Session some interesting information as to steam propulsion on the Forth and Clyde canal, showing a good economic result. Recent experiments on the Aire and Calder navigation (as stated by Mr. Bartholomew to the British Association), have shown that by the use of steam-tugs for the conveyance of minerals, the cost of locomotive power has been reduced to between one-tenth and one-twelfth of a penny per ton per mile—the usual cost of horse-power being one-eighth of a penny. It is still much to be desired that a practical trial should be made of Mr. Liddell's mode of propulsion on canals, to which I referred on a former occasion—viz., by means of fixed steam engines and endless wire ropes.

The subject of the use of steam-power in pumping water to supply a town, or to drain mines, was brought before us by Mr. Mackain and Mr. Neilson, in connection more especially with the performance of direct-acting engines, in which a considerable saving of cost and resistance is effected by the comparative simplicity of the mechanism. The raising of solid material from mines has also engaged our attention, in connection with the application to mine-hoists of Mr. Robertson's frictional gearing.

The subject of mining in general is one of very great importance; and I think we have had fewer papers upon it than might reasonably have been expected in a locality where mining is carried on so extensively, and with so much success. I hope that this defect will be filled up in the present and future sessions.

I am sure that all the members of this Institution will rejoice at the recent opening of a field of ironstone in the outskirts of the city of Glasgow—an event which must contribute not only to the prosperity of this neighbourhood, but to that of the whole country. It is a remark not the less true for being commonplace, that coal and iron are the roots of the material greatness of Britain. At the recent meeting of the British Association, nothing gave greater satisfaction to the multitude assembled, than the announcement by Professor Phillips that the lately-opened ironstone field of the north-east of Yorkshire is likely to last two thousand years.

Mr. Johnstone's description of a very simple and efficient joint-chair last Session, led to a discussion on the permanent way of railways—a subject that ought always to occupy much of our attention, especially when we can obtain the results of the practical use of different systems.

As regards railway carriages, the tendency of the present day is to increase their length and capacity in imitation of those used in America. Those large carriages are cheap and convenient; but it is worth consideration whether their length and weight do not increase the danger to passengers in the event of a collision—their weight, as increasing the momentum of each separate carriage; and their length, as diminishing the compressibility which the train derives from the buffer-springs. Much remains still to be done towards increasing the comfort of railway carriages, which is a matter not merely of ease, but of economy; for a passenger who arrives at the end of a long journey in a condition of fatigue from an uncomfortable carriage, is less able to attend to business than he ought to be, and sustains a loss of time, which is equivalent to a loss of money.

The interesting work of Mr. Colburn and Mr. Holley on European Railways, has furnished abundant evidence of the fact that the light and cheap mode of construction which is common in America, and which, from motives of economy in first cost, has been of late partially introduced into this country, not only fails to produce any real economy, but is absolutely ruinous in working expenses.

The manufacture of locomotive engines is making great progress, through improvements in rapidity and exactness of workmanship. The peculiarities of the American locomotives, which were last Session very fully explained to us by Mr. Neilson, are attracting attention in this country, from the good adaptation of those engines to steep gradients and sharp curves. The question of the balancing of locomotives was brought before us by Mr. Lawrie, and we received interesting information respecting it from Mr. Allan.

The use of coal instead of coke as fuel for locomotives, is rapidly spreading, with most beneficial results. The advantage of coal over coke, in point of cheapness, is so well known as to need no comment; and many members of this Institution must have had occasion to observe the great superiority of coal over coke in raising and maintaining a high pressure of steam; the effect of which is, that the same engine which, with coal as fuel, can be worked expansively, so as to economize the heat to the best advantage, requires, when coke is used, to be worked at full pressure; so that even independently of the higher price of coke, the steam works less economically.

Several forms of locomotive fire-box, specially adapted for burning coal, have lately been invented. I have seen it burned in the ordinary fire-box without the production of any smoke whatsoever, the coal gas being entirely consumed before the flame entered the tubes; but this required careful adjustment of the opening of the fire-door on the part of the engine-driver and stoker, so as to admit just enough of air above the fuel and no more.

The prevention of smoke, besides its great natural importance, has of late acquired considerable artificial importance, by having been made the subject of a law. It is well known that the prevention of smoke is accomplished by producing a complete combustion of all the constituents of the fuel; that if this is done without admitting more air into the furnace than is necessary for complete combustion, it promotes economy of fuel; and that there are a great number of inventions, patented and unpatented, any one of which will accomplish that object if properly managed. The fundamental principle of all the successful inventions for preventing smoke is the same, viz:—to introduce enough of air above the fuel to burn the coal-gas, and enough of air below to burn the fixed carbon, or coke. The number of those inventions has become so great, that I cannot attempt to enumerate or arrange them; but it may be interesting to the members of this Institution to hear, that one of the most convenient and useful of these contrivances, the introduction of air through tubes perforated with small holes, near and behind the bridge, was successfully used forty years ago at Govan, by Mr. Morris Pollok.

The most perfect example of the prevention of smoke which I have lately seen, is at some reverberatory furnaces into which blasts of air are blown by a fan, both above and below the fuel. Before this system was adopted, those furnaces produced smoke almost unequalled for thickness, blackness, and volume; and now there is no smoke whatsoever emitted at any time, and there is a great saving of fuel. The blasts are regulated at the discretion of the workmen who attend to the furnaces. By stopping the upper blast, volumes of black smoke in the old style can be reproduced at any moment; but the re-admission of the blast instantly converts that smoke into flame.

In the administration of the law for the prevention of smoke, the thing chiefly to be avoided is, the giving a preference to some particular method of prevention, and the enforcing it in all cases, without considering whether it is suitable to each particular case. Considering how many different contrivances are available, every furnace-owner ought to be left as far as possible to adopt that contrivance which appears to his own judgment to be the most convenient and suitable. It is not a grievance, that the owners of boiler furnaces, and furnaces of a few other classes, should be prevented from making smoke, if there are parties to whom smoke is a nuisance; but it is a grievance that any particular method of preventing smoke should be forced upon them.

The same principle is true with respect to the application of the law to all branches of practical mechanics. Let every engineer, every manufacturer, every shipowner, every person who makes or uses anything which can cause nuisance, damage, or danger to others, be fully responsible for all the nuisance, damage, and danger that his structures or machines may occasion; but let the means of preventing those evils be left to his own judgment. Any other course lessens his feeling of responsibility, and tends not only to retard the progress of improvement, but to produce the very evils which it is designed to prevent; and such is the effect of all regulation by authority of such matters as the thickness of a boiler, the thickness of the plates of a ship, or the construction of her frame.

Nothing can tend more effectually to prevent vexatious interference of the legislature with engineering and manufactures, than the belief on the part of the nation that the engineers and manufacturers are willing and ready to exert themselves, in order to render their works free from annoyance and danger to the public. That belief ought to be strengthened, and I have no doubt is strengthened, by the fact of the existence of such voluntary associations for promoting safety and economy in the use of steam, as that which has for three years been successfully in operation in and near Manchester, and that which is now being founded in Glasgow. Independently of their advantages in promoting safety, such associations are of most essential service to engineers, by collecting, recording, and arranging facts as to the efficiency and economy of furnaces and engines; which facts, in their isolated condition, are of little or no value, but, being collected and arranged, lead to useful practical and scientific conclusions.

A contribution of almost unequalled importance has lately been made to our knowledge of the laws of the strength of boilers, by Mr. Fairbairn's experiments on the resistance of thin tubes to collapse. In my introductory address last year, I referred to a preliminary report on those experiments, which had been read to the British Association in Dublin. Since the close of our last Session, the detailed account of those experiments has been laid before the Royal Society, and will probably be published in the Philosophical Transactions for 1858; and an abstract of their results has been read to the British Association. Mr. Fairbairn finds, that the intensity of the pressure required to make a flue or other thin tube collapse, is directly as the square of the thickness nearly, inversely as the diameter, and inversely as the length. The diminution of the strength of a flue, as the length increases, is a law never before suspected. For computing the pressure in pounds on the square inch, which makes a wrought-iron flue collapse, the following rule is sufficiently near the truth for practical purposes:—*Multiply the constant factor*, 806,000, *by the square of the thickness in inches, and divide by the product of the length in feet, and diameter in inches.* It is of great importance to strength that the flue should be exactly cylindrical; and as a flue with lapped joints cannot be exactly cylindrical, Mr. Fairbairn recommends that flues should be made with butt-joints and covering-strips.

Upon applying the law thus discovered to the internal flues of existing boilers, it appears that they are almost all too weak, being in general only one-third of the strength of the outer shell, instead of being equally strong, as they ought to be. This explains much of the mystery which formerly hung over the cause of steam-boiler explosions. So far from the number of such explosions being a matter for wonder, the marvel is, that any boilers with internal flues have escaped. As a remedy for that weakness, Mr. Fairbairn proposes to strengthen long flues at intervals, by means of hoops or rings of T-iron; his experiments having proved that a long flue so hooped is as strong as a shorter flue, whose length is equal to the distance between two adjacent rings. This strengthening of flues by means of rings is not absolutely new in practice; but the principles on which it depends, and the rules according to which it ought to be executed, are undoubtedly the discovery of Mr. Fairbairn.

I may now call your attention to an obvious limitation of the exactness of Mr. Fairbairn's formula. It cannot be true, that by indefinitely lengthening a tube, its resistance to collapse is indefinitely diminished; neither can it be true, that by indefinitely shortening a tube, its resistance to collapse is indefinitely increased. Mr. Fairbairn's formula, therefore, cannot be applicable to tubes which are either very long or very short, as compared with their thickness; although, for such intermediate lengths as occur in boiler-flues, it is sensibly quite accurate.

Another important experimental inquiry into the laws of the strength of materials, is that of Mr. William Henry Barlow, on the resistance of beams to breaking across. I mentioned in my introductory address last year, the general nature of the result of Mr. Barlow's first series of experiments; and I have now only to state, that his second series of experiments on the same subject has appeared in the Philosophical Transactions for 1857. In the same volume also is contained an important series of experiments by M. Hodgkinson, on the strength of pillars.

Important progress has of late been made, in the adoption by practical men of correct principles as to the action of the particles of a beam in resisting fracture; the knowledge of which principles had formerly been confined to a few mathematicians. They relate chiefly to the action of the *shearing force*, and its combination with that of the *bending force*, which latter was at one time the only circumstance considered. One of their results is, that the *neutral axis* of a beam, as it is called, is not, as it used to be described, a place of no strain whatsoever on the particles; but is truly a place where, although the strain in a horizontal direction due to the bending force is nothing, the strain due to the shearing force is a maximum, and consists in a tension in one diagonal direction and a compression in another, each making an angle of forty-five degrees with the horizon. Mr. Stephenson lately, while referring to this fact, proposed a very ingenious method of verifying it experimentally. On the side of an unloaded beam, a series of small circles are to be drawn. When the beam is loaded, each of those circles will become an ellipse, whose dimensions are to be measured. It will be found, that near the upper side of the beam, each ellipse has its longer axis vertical and its shorter axis horizontal; that near the lower side, each ellipse has its shorter axis vertical, and its longer axis horizontal; that at the neutral axis, each ellipse has its longer and shorter axes sloping at angles of forty-five degrees, and that ellipses in intermediate positions have intermediate figures and obliquities.

The construction of iron bridges of great size still continues to be one of the leading features of the engineering of the time. The forms of bridge which have been practically tested may be divided into five classes —the arch, the suspension bridge, the tubular girder, the lattice girder, and the bowstring girder—of each of which I shall cite one recent example:—the arch, exemplified by Mr. Page's Westminster bridge, which has the broadest roadway in the world; the suspension bridge, by the bridge of the same engineer at Chelsea; the tubular girder, by Mr. Stephenson's enormous viaduct across the St. Lawrence at Montreal; the lattice girder, exemplified, in the form invented by Captain Warren, by the Crumlin viaduct, which—constructed by Messrs. Liddell and Gordon as engineers, and Mr. Kennard as contractor—crosses the vale of the Taff at the height of two hundred and twenty feet; and the bowstring girder, exemplified, in a novel and singular form, and on a gigantic scale, by Mr. Brunel's viaduct at Saltash, in which the string of the bow, which in the original form of the bowstring girder was a straight tie, is made to take a curved, or rather a polygonal form, and to act as a suspension chain. The great works which I have cited as recent examples of viaducts, are interesting in other respects besides the superstructure. The piers of the Crumlin viaduct, which I understand to have been designed by Mr. Kennard, consist of a skeleton framework of iron, being excellently adapted to the purpose of attaining an immense height at a moderate expense. The bases of the piers of the new Westminster bridge, may be briefly described as consisting mainly of cast-iron boxes filled with concrete. Those of the Victoria bridge at Montreal are of massive granite masonry, remarkable for the cost which has been incurred in order to enable the piers to withstand the floating ice of the river. The central pier of the Saltash viaduct is founded by a process originally practised at the new Rochester bridge, but never before carried out on so great a scale, consisting in the sinking of vertical iron cylinders filled with compressed air, inside of which the excavators and masons work.

The completion of those great structures will furnish important data for settling the question as to the most economic mode of crossing wide valleys at great heights, and of founding heavy structures under difficulties of various kinds.

A sixth class of bridge, which I mention apart, because it has not yet been practically tested, its probable success having been inferred from theoretical calculations verified by experiments on a reduced scale, is the suspension bridge, adapted to the passage of railway trains by a stiffening framework, of dimensions greater than those hitherto employed, and sufficient to make the bridge as stiff as a tubular or a lattice bridge of the same strength. This is the design of Mr. P. W. Barlow's bridge at Londonderry, to which I referred in my address last year. Should that bridge answer its purpose of safely carrying trains at considerable speed, it will probably be found to be the cheapest mode of crossing spans which lie between certain limits.

A very happy adaptation of the suspension bridge is its use to carry canals. When used for that purpose, the suspension bridge requires no stiffening framework, and is subject to no undulations, except such as may be caused by the wind; for as each boat displaces its own weight of water, the load is always uniformly distributed. This invention of Mr. Roebling has been employed with success in America, but has not yet been introduced into Britain. It is probable that it might be found an easy and cheap method of carrying aqueducts for the supply of towns, or of water-mills, across deep valleys.

In connection with the storing and conveyance of water for such purposes, I shall now refer to an important improvement in the gauging of the flow of streams of water by means of weirs or "notch-boards," which has recently been introduced by Professor James Thomson of Belfast. Hitherto it has been the practice to gauge such streams by causing them to flow through rectangular notches in vertical boards or weirs, and observing the height at which the still water behind the weir stands above the lower edge of the notch. The mean velocity of the stream of water which falls over that edge in the form of a cascade, bears a certain proportion to the velocity which a heavy body would acquire by falling through the height already mentioned. The sectional area of the same stream is found by multiplying the product of the same height and of the breadth of the notch, by a factor called the "coefficient of contraction." The product of the mean velocity of the stream into its sectional area, gives the volume of water discharged in a second.

A serious imperfection in this method consists in the uncertainty and variability of the "coefficient of contraction," which is different for different heights, and also for every different proportion of the height to the breadth of the notch, and is consequently variable for the same stream flowing through the same notch, when the volume of the flow varies. Its variation has not been reduced to any general law; and the value to be assigned to it in each particular case, has to be taken from voluminous tables of experiments by Poncelet and Lesbros. Engineers are consequently often compelled, sometimes by the want of those tables and sometimes by want of time for their use, to employ an approximate average coefficient of contraction, and thus to compute the flow from sources of water in a rough and inaccurate way.

This evil obviously arises mainly from the fact, that the section of the stream flowing through a rectangular notch is not a similar figure when the flow is large and when it is small; and Mr. Thomson has therefore adopted a form of notch in which the section of the stream is always of similar figure; that is to say, a triangle with the apex turned downwards. For such a notch, the coefficient of contraction is either constant, or very nearly so.

Mr. Thomson's experiments, which are made at the expense of the British Association, are not yet complete; but they are sufficiently advanced to have enabled him to publish a formula applicable to cases in which the velocity of the stream in the pond behind the weir is insensible. The great utility of that formula induces me to state it now, though in terms differing a little from those in which Mr. Thomson has expressed it.

For the mean velocity of the stream, take eight-fifteenths of the velocity due to the height of fall from the surface of the pond to the apex of the notch. For the area of the contracted stream, take five-eighths of the area of the triangle bounded by the top-water level and the edges of the notch. In other words, the volume of the flow is the area of that triangle, multiplied by one-third of the velocity due to the height before mentioned.

Mr. Thomson's improvement in the measurement of sources of water comes at a good time; for the economic use of those sources is becoming every day of greater importance. The subject of the water-supply of large towns has of late been so fully discussed that I shall not now enlarge upon it, especially as we may, perhaps, hope at a future period to have it before us in a most interesting shape, when the works now in progress for the supply of Glasgow shall be completed. Another important and very ancient use of sources of water is for the obtaining of motive-power; and that is a use which no degree of abundance or cheapness of coal ought to induce us to neglect; for every horse-power obtained on land by the proper application of streams of water, sets free a certain quantity of coal to be employed at sea or in locomotive engines. It is well known that when rivers are left in their natural condition, their flow is so irregular, from the alternation of floods and droughts, that a small fraction only, such as a third or a fourth of the whole volume of water which flows down, can be made available for water-power. The remainder, being the surplus water which comes down during floods, usually does much damage, and effects no useful purpose except sweeping away deposits in an uncertain manner and at irregular intervals. The remedy for that evil is the well-known and obvious one of forming store reservoirs in suitable sites on the course of each stream, in order to store up the surplus waters of floods, and to let them down by degrees so as to increase the ordinary flow available for motive-power and other useful purposes.

That remedy has been extensively applied to small streams, such as the Allander and the White Cart in this neighbourhood, the Shaws water near Greenock, and others; but the larger rivers are left nearly, if not altogether, in their natural irregular condition. It was long ago pointed out by Mr. Adam, that the valley of the Clyde, above the Falls, presents a site where a large quantity of water could be stored at a moderate cost, to be used for motive-power and other purposes. A similar scheme was, at a later period, proposed by Mr. Thomas Kyle, for the water-supply of Glasgow; and a few weeks ago, Mr. Hill of Barlanerk proposed its revival, with a view more especially to the use which might be made of the water-power so obtained for the removal of sewerage.

There can be little doubt that the storing and equalizing, to a certain extent, of the flow of the Clyde, might be rendered remunerative; for, if the probable demand for the additional water-power which would be rendered available were first ascertained, the magnitude of the storage works could be adjusted to that demand. With respect to the sewerage of Glasgow, there is one benefit which would obviously arise from a partial equalizing of the flow of the Clyde, even under the present system of drainage. It appears from the experiments reported by Dr. Anderson and Mr. Bateman, that sewerage which flows into the Clyde at Glasgow, when the river is low, takes a month to reach Dumbarton; so that it travels at the rate of about half a mile a day. Were the flood-waters of the Clyde stored, even to a moderate extent, and let out by degrees, the fresh-water current would never fall to that extreme sluggishness which has been proved by those experiments, and the sewerage could be carried away with a greatly increased velocity.

I have now been led by degrees to the most perplexing problem ever submitted to engineers—that of the drainage of large towns; complicated as it is with chemical, physiological, agricultural, commercial, and social questions; of which almost all that can be said is, that if much labour and thought have been expended on them, much more are still required. The opinion of many competent judges appears to be, that if physical circumstances were to be alone considered, the best method for the cleansing of cities would be to remove as much of their refuse as possible in the solid form, combined with dry deodorizing substances; but against that plan there has been urged the objection, in a social point of view, that the change of customs which its adoption would involve is impracticable in Britain. If, then, the refuse of cities is to be removed altogether in the form of liquid sewerage, any means of rendering that sewerage harmless, at a moderate cost, whether it is to be discharged into the sea or into a river, or used for the irrigation of land, must be most valuable. According to the report of Dr. Anderson and Mr. Bateman, such means are afforded by an invention of Dr. Angus Smith and Mr. M'Dougall, consisting in the addition of sulphurous acid and carbolic acid to the liquid sewerage. The use of certain substances distilled from coal for that purpose, was some time ago proposed by Mr. John Tennent, manager of St. Rollox Chemical Works. It would be foreign to the province of this Institution to enter into chemical questions in detail. The mechanical branch of the subject will probably be soon brought before us again.

From sanitary engineering the transition is natural to the art of defence against human enemies, of which we had an example last Session in the improved rifle-sight of Mr. Lawrie. Many experiments on that art are in progress in different parts of the world, especially on artillery and the strengthening of ships. The most curious contrivance in the art of war which has recently been published is that of Mr. Mackintosh, for suffocating an enemy by the smoke of naphtha and sulphuret of carbon.

In harbour and dock engineering the limited time now remaining only permits me to refer to those excellent examples which exist in our immediate neighbourhood, and to hope that the engineers of those works may be induced to give a description of them to this Institution.

The last subject to which I shall refer is that of submarine telegraphs. With respect to the Atlantic telegraph, it must be admitted that even in the event of its being found impossible to repair the fault in the existing cable, the experiment which has been made will have answered the purpose of proving the practicability of the undertaking, and of furnishing its promoters with that experimental knowledge of its difficulties and dangers which will enable them afterwards to avoid or overcome those obstacles, so as to insure the permanent efficiency of the next cable that shall be laid. The great improvements lately made by Professor William Thomson in apparatus for transmitting and receiving electric signals, will much facilitate the use of all telegraphic lines of great length; having in fact enabled intelligible messages to be sent through the Atlantic Cable, when other means had failed. The Red Sea cable will probably be laid with the success which has hitherto attended the operations of Messrs. Newall & Co. There will soon be a submarine telegraph across Bass's Straits, to connect Australia with Tasmania.

Thus far I have endeavoured to fulfil one of the duties of the President of this Institution, by giving an outline of the recent progress and present state of some at least of the many branches of the vast subject of engineering and mechanics. In conclusion, I again congratulate the members of this Institution on the extent to which it has contributed to that progress, and on the prospect which it enjoys of continuing that good work with success and honour.

The Secretary then read the following Report:—

REPORT OF THE COUNCIL OF THE INSTITUTION OF ENGINEERS IN SCOTLAND.

October 27, 1858.

The council have the following particulars to add to the statements already submitted to the Institution in the prospectus issued in August last.

Of the 118 members, 1 associate, and 8 graduates, forming the Institution at the termination of the First Session in April last, 32 members, 1 associate, and 6 graduates, or nearly one-third of the whole joined it during the Session; and it is hoped that members will exert themselves to obtain an equal, if not a greater increase of members, during the ensuing Session.

The whole of the expenses connected with the First Session having now been ascertained, a more complete view of the financial condition of the Institution can be given than was possible in April last. From the statement submitted by the treasurer, it appears that the subscriptions received during the Session amounted to £360. 13s. 6d. In making a comparison of the receipts and expenditure appertaining exclusively to that Session, it will be well to divide this amount into two sums, namely, £117. 12s. the "Entrance Fees," or extra portions of the subscriptions payable the first year only; and £243. 1s. 6d., the amount of the regular portions of the subscriptions payable annually. From the first amount, which may be termed the entrance fund, there fall to be deducted the expenses connected with the establishment of the Institution incurred prior to the commencement of the Session, amounting to £24. 6s., and leaving a balance of £93. 6s.

The expenses exclusively appertaining to the First Session, are as follows :—

Secretary's Salary,	£80	0	0
Fee to the Officer of the Philosophical Society,	5	0	0
Circulars for Meetings, Stationery, collecting a portion of Subscriptions, Postages, &c.,	20	6	0
Printing the Transactions (300 Copies),	69	2	0
In all,	174	8	0
Which, deducted from the amount of the regular Subscriptions,	243	1	6
Leaves a balance of	£68	13	6

This balance, added to the entrance fund balance, makes a total of

£161. 19s. 6d. at the credit of the Institution. This state of financial matters is very satisfactory.

It is understood that the Philosophical Society will require a payment of about £15 for the use of the hall during the ensuing Session. The council believe that this hall is in every respect the best in Glasgow for their meetings, and they have no doubt the Institution will authorize them to engage it from the Philosophical Society.

The council having been appointed by the Institution to consider as to the best means of obtaining for Scotland the benefits of such an Institution as the Manchester Association for the Prevention of Boiler Explosions, have held several meetings for that purpose. Their deliberations resulted in the calling of a public meeting of users of steam residing in and near Glasgow, to ascertain the feeling on the subject of those most interested in it. To lay before that meeting they prepared a draft code of rules for the constitution and government of an association, the establishment of which they recommended. The public meeting was held on the 1st September last, when a resolution was unanimously passed to the effect, that there should be established in Glasgow an Association for Promoting Safety, Economy, and the Absence of Smoke in the raising and use of Steam; and a committee of influential gentlemen was appointed to take the necessary steps for the establishment of the proposed association. A meeting of that committee was, by circular, called for to-day; but a quorum not being present, the meeting was adjourned.

Some expense has necessarily been incurred by the council in the steps taken by them for the establishment of the proposed Boiler Association, which will be repaid by the association when it is organized; but the authorization of the Institution is requested for the advancement, in the meantime, of a sum not exceeding £10, to cover it.

The council were last Session appointed to consider and report on the subject of Decimal Divisions; they have not, however, been able to take this matter up as yet, the time at all their meetings having been wholly occupied by the affairs of the Institution, and by the consideration of the proposed Boiler Association. The council have not yet received the report of the committee appointed to investigate and report upon the subject of Blowing Fans.

In conclusion, the council wish to call the attention of members to the list of subjects for papers given in the prospectus referred to. The experience of last Session affords sufficient indication that the members of the Institution can furnish an ample supply of valuable papers, but there is a tendency to bring these forward at the end, rather than at the commencement of a Session; the council have therefore to urge upon members the desirableness of giving early notice of papers proposed to be read. Attention to this will undoubtedly render the arrangements for the meetings more satisfactory, and make the Institution generally more efficient and useful.

The report having been read, the PRESIDENT moved that it be approved of, and that the payments for the rent of the Hall, and for the Boiler Association, be authorized.

This motion was seconded by Mr. Walter Neilson, and unanimously agreed to.

The following paper was then read:—

On a Centrifugal Pump with Exterior Whirlpool, constructed for Draining Land. By Professor JAMES THOMSON, of Belfast.

THE centrifugal pump which forms the subject of the present communication has been designed and constructed in the course of this year, for Messrs. James Ewing & Co. of Glasgow, for the drainage of lands belonging to them in Demerara.

The cultivated district of Demerara in which the lands referred to are situated, forms a narrow strip or belt of low ground extending along the sea-coast. It is about four or five miles wide, as measured from the sea back towards the interior. It lies generally below the level of high tide; and is protected in front against the waters of the sea, and in rear against the waters of the Savannahs, or inland swamps, by embankments. The district was originally embanked and reclaimed by the Dutch, and was taken from them by the English in 1796, along with other parts of what now forms British Guiana. The drainage is ordinarily effected by valves or *kokers*, as they are designated, which discharge to the sea when the tide is low, but hinder the entrance of the tidal water when it rises. Of late years banks of soft and shifting mud, or slob, have been gathering and increasing for great distances out to sea, for miles perhaps, in front of some of the estates. These banks, by stopping the drainage outlets to the sea, have caused several estates to be swamped, and have been threatening like destruction to others. Some estates, it is understood, have been saved, mainly by the employment of centrifugal pumps driven by steam power, which keep up the drainage when the slob rises so high as to stop the ordinary flow to the sea by gravitation through the valves or *kokers*; and which, by keeping up a run of water over the slob, tend, as is believed, in a material degree, to keep open the outlet channels through the slob, or to open them again when choked up by the shifting of the mud banks. Some of the estates of Messrs. James Ewing & Co., after having been seriously threatened for several years by the approach of mud banks to their front, were last year partially injured by deficient drainage; and thus the proprietors were led to determine on speedily procuring a centrifugal pump, to be driven by a steam-engine already existing on their land, as the driving power for one of their sugar mills. They engaged the writer to prepare the designs according to an improved arrangement, which had been devised by him for increasing the work done by a given power, the main feature of which is the employment of an exterior whirlpool round the circumference of the pump wheel. The exterior whirlpool had been previously introduced in a centrifugal pump designed by him in 1853, for Messrs. James Ewing & Co., for drainage of lands on an estate of theirs in Jamaica, and constructed by Messrs. W. & A. M'Onie & Co. of Glasgow. It had also more recently been introduced in a centrifugal pump constructed according to his designs by Messrs. Robert Napier & Sons, for a steamer for the Great West of Scotland Fishery Company.* The nature of this modification in centrifugal pumps, consisting of the introduction of the exterior whirlpool may be understood from the following explanations:—

In centrifugal pumps for water, or fans for air, when doing actual work in lifting the fluid, or in forcing it against a pressure, the fluid has necessarily a considerable tangential velocity on leaving the circumference of the wheel. This velocity in wheels in which the vanes or blades are straight and radial, is the same as that of the circumference of the wheel; in others, in which the vanes are curved backwards in receding from the centre, it is somewhat less; but in all cases it is so great that the water on leaving the wheel carries away, in its energy of motion, a large and important part of the work applied to the wheel by the steam-engine, or other prime mover. This energy of motion in centrifugal pumps and fans, as ordinarily constructed, is mainly consumed in friction and eddies in the discharge pipe, which receives the water or air directly from the circumference of the wheel. The object of the introduction of the exterior whirlpool is to prevent this waste, and to apply usefully, towards increasing the pumping power, the energy of the motion inherent in the fluid on its leaving the circumference of the wheel. For this purpose there is provided, round the circumference of the wheel, an exterior chamber, in which the fluid is left free to revolve, in virtue of the motion it had on leaving the wheel. This chamber may be called the *exterior whirlpool chamber*, and its diameter is ordinarily made about double that of the wheel. The fluid revolving in it assumes the condition of a vortex or whirlpool, which has been designated by the writer as the Vortex or Whirlpool of free mobility. The principles of the motion of this kind of whirlpool, and of its application in improving the action of centrifugal pumps and blowing fans, was first brought forward at the Belfast meeting of the British Association in 1852, in a paper read in the mechanical section, of which an abstract is to be found in the report of the meeting. The chief properties for which this whirlpool is remarkable, are, that its particles move with velocities inversely proportional to their distances from the centre or axis of rotation, and that each particle composing it is free to move to any position within the whirlpool, without interfering with the general motion of the other

* See *Transactions of the Institution of Engineers in Scotland*, vol. i. p. 90.

particles, as each one in moving towards or from the centre assumes of itself, subject simply to the laws of motion under a central force, the velocity due to its position in the whirlpool. It is also a property of this whirlpool, that, for any equal particles, in whatever situations in it they may momentarily be, the sum of the energies corresponding to velocity, to pressure, and to height, is constant. Thus it arises that, in the exterior whirlpool in the pump for raising water, as each particle of the water, in moving from the centre, gives up its velocity according to the law of motion already stated, it either actually ascends or becomes subject to a pressure capable of causing it to ascend, through a height corresponding to the energy deducted from its motion. It follows, therefore, that through the medium of the exterior whirlpool a decided increase in the working efficiency of centrifugal pumps is attainable; the work contained in the rapid motion of the water leaving the wheel, which in centrifugal pumps as ordinarily constructed is wasted, being, according to the new arrangement, usefully employed in increasing the pumping power of the machine.

To arrive by a simpler method, than that just given, at a general idea of the mode of action of the exterior whirlpool in improving the efficiency of the centrifugal pump, it is only necessary to consider that the mass of water revolving in the whirlpool chamber, round the circumference of the wheel, must necessarily exert a centrifugal force, and that this centrifugal force may readily be supposed to add itself to the outward force generated within the wheel; or, in other words, to go to increase the pumping power of the wheel. The outward force generated within the wheel is to be understood as being produced entirely by the medium of centrifugal force, if the vanes of the wheel be straight and radial; but if they be curved, as is more commonly the case, the outward force is partly produced through the medium of centrifugal force, and partly applied by the vanes to the water, as a radial component of the oblique pressure, which, in consequence of their obliquity to the radius, they apply to the water as it moves outwards along them. On this subject it is well to observe, that while the quantity of water made to pass through a given pump with curved vanes is perfectly variable at pleasure, the smaller the quantity becomes the more nearly will the force generated within the wheel for impelling the water outwards, become purely centrifugal force, and the more nearly will the pump become what the name ordinarily given to it would seem to indicate—a purely centrifugal pump. When, however, a centrifugal pump with vanes curved backwards in such forms as are ordinarily used in well-constructed examples of the machine, is driven at a speed considerably above that requisite merely to overcome the pressure of the water, and cause lifting or propulsion to commence, the radial component of the force applied to the water by the vanes will become considerable, and the water leaving the circumference of the wheel will have a velocity less than that of the circumference of the wheel, in a degree having some real importance in practice. It has, indeed, been promulgated in respect to some centrifugal pumps with curved vanes brought into use in the last six or eight years, that they are capable of propelling the water from the centre to the circumference, along the line of a stationary radius, and of discharging the water at the circumference without rotatory velocity. This supposition needs only to be mentioned as being fallacious. A motion approximately along a stationary radius may no doubt have been attained when the pump was made to impel a fluid against no resistance; but when a pump is actually doing work in raising water, the rotatory motion of the water on leaving the circumference of the wheel is unavoidable. In practice it involves, in ordinary pumps, an important loss, the loss being commonly about as much as the entire power usefully applied in overcoming the gravitation of the water; and the efficiency of the pump comes out, therefore, when friction and other farther losses are taken into account, in ordinary circumstances, considerably less than fifty per cent. of the applied power.

From calculations relative to the various sources of loss occurring in centrifugal pumps of the improved kind with the exterior whirlpool, according to the design carried out for Messrs. James Ewing & Co.—the writer thinks the efficiency of such pumps may be fairly estimated at about seventy per cent. Now the steam-engine, already existing on the estate, for which the pump forming the special subject of the present paper was required, is estimated as being capable of applying 25 horses power (of 33,000 foot-pounds per minute) to the driving of the pump. The lift of the water is intended to be variable, according to the state of the weather, and is to range ordinarily from 2½ feet to 5 feet. Then for a 2½ feet lift, and an assumed efficiency of the pump of seventy per cent., the quantity of water lifted comes to be 3700 cubic feet per minute. And for a lift of 5 feet, the quantity would be about half as much, or, say 1850 cubic feet per minute.

The details of the constructive arrangements of the centrifugal pump are shown in Plate I., prepared from drawings supplied to the Institution by Messrs. W. & A. M'Onie & Co., the engineers by whom the execution of the work has been carried out. In reference to them, the writer here wishes to recognize the very efficient aid they afforded him during the progress of the work in arranging many of the practical details of the construction. The work was required to be designed and executed in great haste, and their ready co-operation tended very materially to facilitate the business of the undertaking. Fig. 1, Plate I, is an elevation, and fig. 2

is a plan of the pump—one half of each figure being in section—fig. 1 as through the line *a b* in fig. 2, and fig. 2 as through the line *c d* in fig. 1. In addition to the description already given of the principles and mode of action of pumps of this kind, attention may be directed to the helical outlet chamber, B C, which is arranged for receiving the water from all parts of the circumference of the whirlpool chamber, except the part from which an immediate outlet into the discharge pipe is available. This helical chamber has a gradually increasing area to meet the regular accessions of water which it receives from its commencement at its smaller extremity, B, forward to its termination at C in the outlet pipe. This helical outlet chamber is arranged with a large part of its capacity lying nearer to the axis of rotation than the edge of the whirlpool chamber cover, D. This arrangement is made with the special object in view of preventing eddying water that will exist in the outlet pipe at times when the pump is raising a small quantity of water through a high lift, from being able to return to the circumference of the whirlpool, with the risk of breaking through the water of the whirlpool, and, as it were, falling in towards the centre in consequence of having less rotatory motion, and, therefore, less centrifugal force than the water of the whirlpool. If any such return water were to penetrate into the whirlpool, it would very materially damage the action of the whirlpool, by disturbing its motion, and introducing impacts of quickly moving against slowly moving water. The helical chamber, as may readily be seen by consideration of the figures, is adapted for receiving any such eddying water, and hindering it from getting access to the whirlpool; as the most rapidly moving water coming direct from the whirlpool, will tend always to fly outwards, and will occupy the outer parts of the helical chamber, leaving the inner parts of the same chamber for the dead or eddying water, when from any of the varying circumstances of the height of lift and power applied, such eddying or dead water exists.

The writer would farther direct attention to the peculiar adaptation of the forms selected for the various parts of the case for the attainment of a high degree of stiffness for preventing the top and bottom of the case from changing their distance apart under varying circumstances of the internal water pressure. It is to be observed, on this point, that no tie bolts through the case for holding the top and bottom together are admissible, as any such tie bolts would interrupt the revolving motion of the water. Yet, at the same time, there ought to be as close a fit as possible, without rubbing, between the joint rings of the wheel and case at the central orifices, in order to prevent leakage and waste of the water pumped. The conical forms of the bottom, E, and top, D, of the whirlpool chamber, and the cylindrical vertical walls, G, with the somewhat conical form of the roof, H, of the helical chamber, all taken together, and, in conjunction with rivetted boiler-plate as the material, form a shell of peculiar stiffness. The chief difficulty connected with this undertaking has had reference to the transmission by sea and land of so bulky a thing as the boiler-plate casing, which is 16 feet in diameter, and which could not well be sent in parts, to be put together at the site where the pump is to work. The casing was, of course, sent separate from the *boat*, K, or large conduit for leading to the water the lower central orifice, L, and the casing was shipped on deck, being too large to enter the hold of the vessel by which it was transmitted. Accounts have been received of the safe landing in the colony of these bulky parts; and news is soon expected of farther progress having been made towards their erection at the site where they are intended to operate.

It may be mentioned that the pivot, M, on which the wheel, A, turns, is made of lignumvitæ. It is fixed standing upright in the bottom of the boat, K; and in the bottom of the shaft, Q, there is fixed a brass socket, P, which turns on the pivot. Arrangements are made for spreading an ample supply of water over the rubbing surfaces of the wood and brass, for lubrication. Bearings of lignumvitæ have of late years been found to be much superior in durability, when working under water, to any kinds of metallic pivots. Lignumvitæ, from this reason, has recently come much into use for the bearings of propeller shafts, where the shafts pass through the sterns of steamers. Lignumvitæ pivots have likewise come much into use for turbines in America, and the writer is now in the habit of introducing them in his vortex turbines, in preference to all other kinds of pivots.

In conclusion, the writer considers centrifugal pumps, constructed on the principles which have been described, to be capable of affording the best available means of raising large quantities of water through low lifts, or through lifts of such moderate height as may not require the wheel to revolve at an inconveniently high speed. For drainage of fens, and for raising the sewerage of towns through moderate lifts, they are peculiarly suitable. They are much less liable than common pumps to be choked or injured by the entrance of solid materials; and, having no working valves or pistons, they are remarkably free from injury by wearing; whilst, as regards economy of power in the applications referred to, they will, the writer believes, be found decidedly superior to pumps of the ordinary kinds, constructed with valves and pistons or plungers.

Mr. M'ONIE exhibited a model of the pump, and explained the drawings, showing the details of its construction. In reply to inquiries, he stated that the pump was prevented by a timber framing from being shifted by the floating action of the water in which it was immersed. The wheel, A, was upon a vertical shaft, and the water had access to it both above and below, finding its way to the top central aperture over the casing of the helical discharge duct, and to the bottom central aperture by the boat, K, which formed a channel for it through the mud. The wheel was made with 36 blades, which were about 6 inches apart at the circumference, and 1¾ inches at the central opening; the whole being flush-rivetted together, in order that the frictional resistance to the passage of the water should be as little as possible. The pump was intended to work at the rate of about 80 revolutions per minute, but the speed would vary with the lift.

The PRESIDENT thought that a pump of this kind would be very suitable for removing the sewerage of towns where, from the lowness of situation, it was necessary to lift the sewerage in order to get rid of it.

Mr. HILL of Barlanerk, who was introduced by the President, said he had had much pleasure in listening to the President's address, and to Professor Thomson's paper. He thought that in places like Glasgow, where one part of the town was much more elevated than another, the sewerage of the higher part might, by its descent to a mean level, be made to raise to that level the sewerage of the lower part. Professor Thomson's pump would be extremely well adapted for working out this plan. He also thought it probable that a portion of the Loch Katrine water might be devoted to the same purpose.

The PRESIDENT remarked that the number and closeness of the blades in the wheel might seem likely to cause more friction than was desirable; but he believed that Professor Thomson had carefully calculated the amount of friction, and that he had proportioned each part, so as to obtain from the whole a maximum result. This particular form of pump was suitable for low lifts, and in the present instance the pump had been designed for a lift of from 2½ to 5 feet only. For higher lifts the size would have to be reduced, and the velocity increased, for the application of the same power. He proposed that the thanks of the meeting be awarded to Professor Thomson for his paper, and to Mr. M'Onie for his drawings and model.

The thanks of the meeting were unanimously awarded accordingly.

Mr. NEIL ROBSON hoped, that before separating, those present would give a hearty vote of thanks to their President for his very excellent address. They all knew that the success of an Institution like their own depended, in a great measure, on having a president capable of ably conducting the proceedings, and possessing a complete acquaintance with the varied subjects coming before them, so as to guide the discussions in a satisfactory manner; and they would all acknowledge that Dr. Rankine possessed these qualifications in an eminent degree.

Mr. R. Bruce Bell seconded the motion, and it was unanimously and cordially adopted.

The Second Meeting of the Session was held in the Philosophical Society's Hall, on Wednesday, 24th November, 1858, the President in the chair.

The following paper was read:—

On Frictional Engaging and Disengaging Gear. By Mr. David More.

In bringing this subject under the notice of the members of this Institution, the writer desires, in the first place, to state distinctly that he does not claim any share in the invention of the apparatus which he is about to describe, but merely presents a simple statement of his own experience of the manufacture of it in various forms.

The object to be attained by appliances such as that forming the subject of the present paper, is the transmission of power, without shock or violence, to some kind of machinery, the arrangement being in every case such, that the prime mover is not interfered with.

In factories where a great quantity of heavy machinery is required, such as bleaching, calendering, calico-printing, and similar establishments, the introduction of frictional engaging gear has been found of the greatest benefit, as it completely puts an end to the annoyance and expense previously occasioned by frequent breakages of the gearing attached to such machines. One illustration will suffice to show the superiority of the new arrangements. Under the old system a glazing calender, consisting of three paper and two iron rollers—one or two of which, as the case might be, were geared in such a manner as to produce a rubbing motion upon each other, whilst at the same time the whole machine was working under a pressure of not less than ten tons—was set in motion by a simple clutch, moved by a powerful lever which often required the utmost efforts of the workmen to bring it into the proper position. The suddenness with which the gearing in motion and the machine at rest were thus brought into connection, was very destructive, and the cause of grievous and oft-recurring stoppages. But now, with new arrangements embodying the simple element of friction, the same machines can be set in motion or brought to rest with little or no exertion, without damage to the driving gearing, and with the greatest facility and exactitude.

Amongst the first of the many contrivances for obviating the defects just mentioned, was the application of a malleable iron friction strap to the clutch; but this was liable to a serious objection, in so far that there was considerable difficulty in tightening it accurately to the proper pitch, a single turn more or less of the nuts on the bolts rendering it too slack for transmitting the power required, or making it so tight that it was as bad as if it had been rigidly attached.

Another arrangement, and the one which it is believed gave the first idea from which have resulted the many improvements that have taken place of late, was that known as the friction-cone connection. In this arrangement, an internal cone, either cast or bolted on the driving wheel, but running loose upon the shaft, was brought into contact with an external cone sliding upon a feather on the same shaft. This contrivance was very efficient, but had one serious fault in that at times it could not be disengaged, owing to the rubbing surfaces getting locked together by ridges being raised upon them while running; and so firmly were they sometimes united, that the writer has known cases in which the whole gearing had to be stopped before the parts could be taken asunder.

To obviate the defects of the friction cone, and at the same time take advantage of its great benefits, has for a long period occupied the endeavours of those who are interested in its application, and various plans have been devised for the attainment of this result. One plan which has been very extensively, and, until lately, almost exclusively used, comprehends a drum or case of a size proportionate to the amount of power to be transmitted. This case, which is turned smooth on its internal surface, is attached to the driving wheel, and runs loose upon the shaft. Inside of the case, and keyed firmly on the shaft, is a plate with studs on it, carrying arms or "flights" curved to exactly fit the inside of the case, and these flights are covered with strong leather secured to them by wooden pins. Spiral springs sufficiently strong to keep the flights, when the machine is at rest, from coming into contact with the case, are attached to them and the flight plate; whilst sliding on a feather on the shaft is a movable block with tapered projections corresponding to the number of arms or flights, and this block being moved forward by a lever, forces them outwards, and so produces the amount of friction required to drive the machine to which the apparatus is attached.

Great, however, as were the advantages resulting from this invention, there was still room for farther improvement. Owing to the space taken up with the joints on which the arms moved, there was nearly one-sixth of the frictional surface of the case from which no benefit was derived; consequently the case had to be made much larger and heavier than would have been necessary if a plan could be devised in which nearly the whole of the surface was taken advantage of. To this end various arrangements have been proposed; but, without stopping to enumerate them, the present paper may now be brought to a conclusion by briefly describing the construction of a kind of engaging and disengaging gear which has been found very successful, and which is illustrated in detail in Figs. 1 and 2, Plate II. The friction box, marked A, is bolted or cast on the wheel, B, the inside of the box being turned perfectly smooth and cylindrical, and being fitted with two cast-iron rings, C, similar to the packing rings of a steam-engine piston. These rings are bolted together by bosses and arms, H, stretching across nearly the whole diameter, and keyed upon the shaft, J; and in sockets formed in these arms are placed wedge-shaped sliders, D, which, on being pushed outwards, expand the rings so as to bring them into close contact with the internal surface of the friction box, A. Small levers, E, work on pins in the arms, H, of the rings, C, and actuate the sliders, D. The levers, E, carry small friction wheels, I, running on studs fixed with adjusting screws, whilst a tapered sliding block, G, is fitted loose on the shaft, J, and when moved forward by the starting bar, acts upon the levers, E, through the medium of the friction wheels, I The shaft, J, is driven continuously by the prime mover, and the friction box, A, and wheel, B, being fitted loosely upon it, are turned by it, or not, accordingly as the rings, C, are expanded or contracted.

Mr. MOKE exhibited a brass working model of the improved frictional coupling, and explained a contrivance applied to the starting bar of the model, by means of which its leverage or power could be increased or lessened as might be required. He did not bring the gear forward as being in any way novel; but having had some experience in the construction of apparatus of this kind, he thought half an hour would not be unprofitably taken up in giving his fellow-engineers the benefit of that experience, and in discussing the subject. In order that the coupling might be as efficient as possible for a given size, it was desirable that as much as possible of the circumferential surface of the rings should be in contact with the internal surface of the friction box. To this end the rings had to be shaped with great accuracy, and he had found that the best way to proceed was to spring out the rings to their extreme size, and then turn them down to the exact size of the friction box. On the wedge sliders being afterwards released, the rings contracted, so as to free themselves from the case.

In reply to inquiries, Mr. MOKE stated that for transmission of a power of five horses, the shaft making 35 revolutions per minute, he usually made the friction box 20 inches in diameter. With this coupling the machinery could be started gradually, and without the slightest shock. With respect to the friction-cone coupling, when the parts exactly fitted each other, it did very well; but ridges were apt to be formed on the surfaces, and these prevented their separation. He had tried the friction-cone coupling with various degrees of taper, and had found a taper of about 14½° to be the best. The largest coupling of the improved kind which he had made, had a friction box 6 feet in diameter, the frictional surface being 10 inches broad, whilst the power to be transmitted was 25 horses. He thought the improved coupling would be very suitable for lathes, where it would save cross belts and other complications. It would also be advantageously applicable to numerous other machines.

The PRESIDENT inquired whether frictional coupling surfaces had been made of the form known as Schiele's curve, which was said to possess the property of uniformity of wear.

Mr. P. STIRLING remarked that Schiele's curve was termed the "anti-friction curve," and he thought it would consequently be the worst kind of curve for the purpose of forming a coupling where it was wanted to increase rather than to reduce the friction.

The PRESIDENT thought that from there being uniform wear, there would be less liability to stick. One property possessed by surfaces formed to this curve, was their having the same friction as cylindrical surfaces of the same length.

An inquiry being made as to whether a modification of the improved frictional appliances would be suitable for a railway brake, Mr. WALTER NEILSON, of Hyde-park foundry, said he did not think any advantage would arise from such an application. What was wanted for stopping railway trains was not a contrivance to hold the wheels, but something to prevent the wearing of the wheels on the rails when so held. The present brake was cheap in first cost and easily repaired, whilst it was efficient as far as it went. As to the frictional clutch, as adapted for engaging and disengaging machinery, they all knew what annoyance had been experienced for want of a suitable contrivance of the kind. The old plan of friction cone had its defects; the engagement took place by a jamming together of the parts, and the grip took effect all at once. The improved plan described by Mr. More was the right thing, and just what was wanted. He only feared it was rather expensive, but then breakages and other annoyances arising from the want of a good clutch, were also very expensive.

Mr. MORE remarked that, as regarded cost, the coupling he had described was comparatively cheap. He understood that thirty pounds was charged for a recently-patented coupling, whilst the one he had described was superior, and could be made for about fifteen shillings per inch of diameter (3 inches corresponding to 1 horse power at 35 revolutions per minute). In reply to inquiries, Mr. More said that the breadth of the rings, and the proportions of the other parts, depended conjointly on the power to be transmitted and on the speed. A coupling of a given diameter could be made suitable for transmitting more or less force, by adopting an appropriate circumferential width. The smallest couplings he had made were 12 to 16 inches in diameter.

The President observed, that although the arrangement might not be suitable for a railway brake, it might, perhaps, be advantageously applied to apparatus for paying out submarine telegraph cables, on account of the delicacy with which it could be adjusted, and the readiness with which it could be slackened or tightened.

Mr. Stirling thought there would be as much liability of the surfaces wearing into grooves with the improved arrangement as with the old friction cone. If the surfaces rubbed or slipped upon each other, as in a railway brake, great wear and tear would arise; whilst, if the surfaces were oiled, the friction would be lessened.

Mr. More said the cording of the surfaces might occur with the improved coupling, but it would not prevent the separation of the surfaces, which were drawn apart as it were, whilst in the cone the separation was effected by a longitudinal motion, which was prevented by the cords or ridges. It might, indeed, be an improvement to groove the surfaces in the improved coupling, like Mr. Robertson's frictional gearing.

The President, remarking that Mr. More had given them much practical information on a subject of great importance, proposed a vote of thanks to him, which was unanimously passed.

A paper was then read entitled—

On the Proportions of Anchors and Cables supplied to various classes of Ships. By Mr. James R. Napier.

[The publication of this paper is deferred, with the concurrence of the Author.]

A discussion followed the reading of Mr. Napier's paper, and a vote of thanks was passed to him for it, after which:—

The President said that, in consequence of the unexpected but unavoidable postponement of a paper by Mr. Elder, which was to have been read that evening, there was still some time before their usual hour of separation, which might be advantageously occupied by their discussing some subject of interest. He would call upon any gentleman to propose a subject for discussion.

Mr. Walter Neilson believed it was generally understood that some great advances had recently been made in economizing the expenditure of fuel in steamers. A consumption of 5 lbs. of coal per indicated horse power per hour was hitherto considered very economical, but he had heard of some recent cases in which only 3 lbs., 2½ lbs., and of one in which only 1 lb. had been consumed. Information on this subject would doubtless be most gladly received by the Meeting, and the subject would form a most important one for discussion.

The President said that, having been present when some of the results referred to were obtained, he could state the particulars, for which purpose he would vacate the chair.

The chair having been taken by Mr. Walter Neilson, the President said that the experiments, the results of which he was about to state, were made with a steamer belonging to Mr. J. M. Rowan, of the Atlas Works, Glasgow. He had at one time hoped that Mr. Rowan, who had that evening been elected one of their members, would himself have given them a paper describing his engines in detail, with the experiments and their results; but further improvements were contemplated, and Mr. Rowan proposed deferring his paper until those improvements were completed, and further trials made. A trial of the vessel, which was a screw steamer, had taken place on the previous Saturday, The steamer was out about two and a half hours. The experiment respecting the fuel was made during one hour,* the pressure of steam and the vessel's speed being kept up for half an hour before the experimental hour, and for half an hour after it. The average pressure during the hour was 115 lbs. above the atmosphere, the fluctuation being between 125 lbs. and 112 lbs. Every precaution was taken to obtain accuracy in the record of coal consumed, and of the results derived. For example, as at the commencement of the experimental hour the fires appeared to be rather high, a fresh supply of coal was added to them immediately before concluding the experiment, so as to bring them as nearly as possible to their original condition, this last supply being included in the calculation of the results. Indicator diagrams were frequently taken, and carefully calculated. The result of the hour's trial was as follows:—

$$\frac{\text{Coal consumed 230 lbs.}}{\text{Indicated H.P. 226}} = 1{\cdot}018 \text{ lb. coal per indicated horse power.}$$

The indicated horses power varied between 231 and 221, the average

* The shortness of this experiment was caused by the commencement of a fog, which made it unsafe to continue at full speed.—W. J. M. R.

being 226. The vacuum was maintained at an average of 13 lbs. The steam was expanded nearly fifteen times.

Mr. James R. Napier said he had been present at an earlier trial of the vessel, but this last experiment was much superior. The results were most extraordinary. He had heard Mr. Scott Russell state, at the Dublin meeting of the British Association, that the steamship *Great Eastern* was the smallest vessel that could be built to carry the coal for the service for which she was intended, but his calculations were based on a consumption of 4 lbs. of coal per indicated horse power. Of course, if the same work could be done with one pound of coal, that vessel had been made very much too large, and instead of building vessels still larger than the *Great Eastern*, as had been expected, it was unlikely that another would be built as large. He understood that Mr. Rowan's results were partly owing to the use of a surface condenser, and to the boilers being in consequence continually supplied with fresh water. The coal consumed on the trial at which he was present, was 1·88 lbs. per indicated horse power per hour. In the steamer *Admiral*, built by himself, the consumption on the trial was 2·95 lbs. per indicated horse power per hour. Both results were obtained at trial trips in the Clyde, and were therefore comparable, and one showed a saving of nearly half the fuel.

The President stated that at the earlier trial the steam was expanded only eight times, and the pressure varied between 110 lbs. and 65 lbs. The pressure was unsteady, and the speed of the vessel also, and the experiment was generally imperfect. At the later experiment, however, the steam was expanded nearly fifteen times, and it was kept at a pressure varying within narrower limits. He ascribed the improved result to the increased extent of the expansion, and to the greater steadiness of the pressure. As another example bearing on the subject before them, he might mention that at the trial of the steamer *Callao*, engined by Messrs. Randolph, Elder, & Co., the consumption of fuel was 2·66 lbs. per indicated horse power per hour.

In reply to Mr. Milne and other members, the President stated that the boiler primed a good deal in the earlier experiment. The boiler was of peculiar construction, but it would be as well to leave a description of its details to Mr. Rowan. The engine worked very smoothly; it was of the double-cylinder expansive class—the large cylinders having four times the capacity of the smaller ones. The vacuum was maintained very uniformly at 13 lbs.

Mr. H. R. Robson mentioned that the boiler had been proved with cold water to a pressure of 240 lbs. per square inch. He had been present at the trial, with which he was much pleased. In reply to an inquiry, he said the pressure was indicated by a Bourdon's gauge.

The CHAIRMAN (Mr. Walter Neilson) said, that something like the results said to have just been obtained, had long been looked forward to. He thought they could not expect anything like perfection in marine engines without using a high pressure of steam. Nothing less than 100 lbs. would do; but the working with such steam power was impracticable with sea-water, and along with it they must adopt surface condensation to enable them to use fresh water in the boilers. It was a matter in which the engineers of Glasgow should take special interest. The reduction of the consumption of fuel to 1 lb. per indicated horse power per hour was an enormous advance. It was, in fact, somewhat difficult to believe—it was almost "too good to be true." One hour's trial was scarcely sufficient; a ten hour's run would have been more satisfactory. A short time back the statement that the consumption had been reduced to 1 lb. would have been laughed at; however, he thought that they now had some reason to at least hope for the realization of such a saving. How many pounds of coal were contained in the furnaces at one time? A very small mistake in judging of the condition of the fires would cause a great error in calculating the results.

Mr. H. R. ROBSON said the furnaces were very small, and that an experimenter was not likely to go astray in judging of the condition of the fires at different times.

Mr. J. M. ROWAN, who had entered a few minutes before, said that in his opinion more favourable results would have been recorded, if the experiment of which the results had been given had been continued an hour longer.

A vote of thanks was passed to the President for the particulars furnished, and a wish was expressed that Mr. J. M. Rowan would bring forward a paper on the subject at an early Meeting.

The THIRD MEETING of the Session was held in the Philosophical Society's Hall, on Wednesday, 22nd December, 1858, the PRESIDENT in the chair.

A paper was read entitled—

On Marine Steam Engines. By Mr. JOHN ELDER.

[The publication of this paper is deferred, with the concurrence of the Author.]

A discussion followed the reading of Mr. Elder's paper, and a vote of thanks was passed to him for it, after which the following paper was read:—

On Patent Slip Docks. By Mr. R. BRUCE BELL.

Prior to the invention of the slip dock, ships requiring examination or repair had either to be taken into a dry dock, beached upon a soft bottom and repaired by tide work, heaved down on their beam ends whilst afloat, or hauled out of the water by sheer force upon greased ways laid under their bilges.

With the exception of the dry dock, these means of getting at a vessel for repair could only be considered as expedients, and no serious repairs could be executed except in the case when they were hauled upon dry land. In the other cases nothing but temporary repairs or caulking could be effected; so that virtually, for the purpose of effecting repairs, there were only two modes of getting at vessels:—viz., by dry dock, or by hauling up on greased ways.

The expense attending the construction of dry docks, more particularly in situations having small rise of tide, limited their existence to the larger ports and naval stations, where they were constructed either by government, by corporations or companies, or by wealthy private shipbuilders, so that ship-repairing became a monopoly, and a very lucrative one.

In the early part of the present century the late Mr. Thomas Morton, then carrying on business in Leith as a shipbuilder, found that he was not able to compete in repairing with his more wealthy neighbours who had the use of dry docks. Mr. Morton at that time resorted to the process of hauling up on greased ways; and his means being too limited to allow him to construct a dry dock, he set his mind to work to find out some means of lessening the expense of the operation, as the cost of laying ways, rigging purchases, and the time and labour expended in hauling up, absorbed a great part of the profit derived from repairs; and besides, in the case of a weak ship, this was a dangerous process, as the vessel had to be hung on her bilges—an operation which many old vessels could not stand; and the purchase being attached to a bolt passed through the fore-foot of the ship, the vessels were by this usage much strained, in some cases the fore-foot being actually torn out of them.

Mr. Morton's scheming resulted in the invention of the slip dock, of which he erected the first in his building-yard in Leith in the year 1818; and by the advice and with the assistance of his brother, the late Mr. Samuel Morton, he took out a patent in 1819. This patent was successfully worked by Mr. Morton, and by the representatives of the patentee, the present firm of Messrs. S. & H. Morton of Leith.

Although at first these slips were not intended for vessels over 200 tons register, they were afterwards improved and strengthened in their design to such a degree, that slips are now made of power sufficient to haul up vessels of 3000 tons.

The inventor lived to see his patent carried into very general use, and appreciated as an invention of great national importance; in proof of which a committee of the House of Commons awarded him a sum of £2500 for the great advantage it had been of to the shipping interests of this country. Mr. Thomas Morton died at Leith in December, 1832.

The original slip for vessels of small tonnage was formed in this manner: —The ground was cut out to a regular incline from dry land into deep water, and if sufficiently firm to require no artificial foundation, three longitudinal ways or beams of timber were laid upon cross sleepers, a main beam in the centre to lie under the keel, and two side beams to lie under the bilges. Upon these ways were laid malleable iron rails—heavy rails for the keel beam, and lighter rails for the sides. This formed the slip-way; the upper end being dry at all times of the tide, whilst the lower end was submerged at high water.

Upon these ways was erected a rolling carriage, consisting of a keel-beam as long as the keel of the longest ship intended to be taken up, and two bilge-beams. Upon this keel-beam carriages containing double sets of rollers were fixed, fitting the rails of the centre ways, and palls were attached to some of the carriages falling into ratchets laid along the centre of the entire length of the midway of the slip. The bilge-beams were, in a like manner, fitted with rollers in carriages, but single and fewer in number. Resting upon the bilge-beams, and fixed to the centre beam, were placed cross arms with sliding bilge-cods, upon which blocks were fitted to suit the shape of the vessel to be hauled up, and strong cross beams at the lower end of the cradle connected the three beams together. A line of blocks was laid along the centre beam at regular distances, to take the keel of the vessel, and ropes, attached to the sliding bilge-cods, were passed over the keel-beam to the other side of the cradle, and coiled on the tops of iron supporting-rods standing up from the cradle, so as to be accessible either from the vessel's side or from the slip gangway.

When the keel-blocks were all set and the bilge-blocks adjusted, the bilge-cods were pushed out to the extreme end of the cradle-arms, and the ropes all arranged upon their supports. The palls, which were also attached to ropes so as to be accessible from the vessel, were then hauled up and fixed, and the purchase-chain attached to the connecting bar of the cradle, this connecting bar being a long iron bar with a strong eye bound into the woodwork of the main beam of the cradle. The last pall was then lifted, and the cradle being let go, by its own gravity descended to the extremity of the slip. The vessel to be docked was then floated over the blocks of the keel-beam until her forefoot touched the foreblock, and set exactly in the centre line of the cradle, and a rope from her bow secured to the purchase-chain.

The purchase consisted of an ordinary capstan and chain cable. This chain was used as a single chain for light vessels, and was passed through a sheave, and used as a double or runner chain for heavy vessels, as shown in Fig. 3, Plate II. When the vessel was set fairly in the centre, the purchase was set to work, and the cradle and ship hauled up until the vessel began to settle on the blocks; the purchase was then stopped, and the bilge-cods hauled in until the blocks caught the vessel's bilges, when the ship was all secure. The purchase was then set on and kept moving until the vessel was hauled up high and dry, and the operation was completed. To remove the cradle the ship could be blocked up, and the arms removed, and the main beam allowed to roll from under her, to be used to haul up another vessel astern.

Such was the first slip; and although since that time many details and improvements have been added to it, the main features of the slip continue the same.

The first improvements effected by Mr. Morton were, the substitution of cast-iron for malleable-iron rails—the centre double rail with its ratchet being all cast in one breadth, in lengths of about ten feet; and the substitution of traction-rods connected by pins and eyes, and of a pitch chain in place of the cable chain; and also of a powerful wheel purchase in place of the capstan. This purchase consisted of a system of wheels and pinions driven by a shaft, with connections either for manual, horse, or steam-power, the power being gradually increased up to the main shaft, upon which was fixed a pitch-wheel, through which the power was transferred into a dead pull on the pitch chain.

The traction-rods consisted of round bars about twenty feet in length, having eyed ends connected one to another, either with forked eyes, or links, as shown in Fig. 4, Plate II. The rod nearest to the cradle was attached to the connecting-bar of the cradle by a pin and forked eye, or links, in the same manner; and in like manner the top bar, A, was attached to the pitch-chain, B. The pitch-chain was made rather longer than two lengths of traction-bars, the upper end of the pitch-chain passing over the top of the pitch-wheel, C, and the open links catching upon the teeth, whilst the tail end of the pitch-chain was attached to a small messenger-chain, D, led down the side of the centre way to a snatch-block, or sheeve, and having its end secured to the traction-rods.

The manner of working the purchase was this:—The power being set on, the pitch-chain, B, was dragged over the pitch-wheel, C, the tail end as it came off the teeth being dragged down the slip again by the messenger chain, D, so that when the pitch-chain was expended, two lengths of traction-rods, A, had been hauled up. The engine was then stopped, and the palls of the cradle having by this time been let fall, the cradle could hold itself; the rods were then removed, and the lower end of the pitch-chain, B, which had now been hauled up to the purchase, was attached to the pitch-wheel, C, by a pin; the engine was again set in motion, until it had reversed the end of the chain upon the wheel, and was then ready for a fresh start. The other end of the pitch-chain had, during the operation of hauling up the rods, been dragged down by the messenger chain, and was in its turn connected to the traction-rods. The operation was then repeated, the next set of rods removed, and the connections again made, the pitch-chain being by this means each time reversed end for end. These operations were repeated until the whole line of traction-rods and the cradle and ship had been dragged to the head of the slip.

An improvement was proposed upon this purchase, about ten years ago, by Mr. Leslie of Edinburgh, which consisted in substituting an endless pitch-chain, E, fig. 5, revolving round two wheels, C, F, in place of the two-ended chain and messenger. This was adopted by Mr. Morton upon the Granton slip, which was erected for his Grace the Duke of Buccleuch in the year 1852. This improvement made a considerable reduction in the time occupied in fleeting, as it is called; that is, in changing the rods, rewinding the pitch-chain, and taking a fresh hold. With the endless chain, the engine had merely to be stopped, the rods removed, and a new hold taken, and the dragging operation again continued.

Further than in strengthening the slip-ways, and in modifying and adapting the cradle and ironwork for the large class of vessels for which slips have lately been made, no alteration of moment has been made upon the cradle or mainway of the slip. Certain modifications and additions, which will afterwards be referred to, have, however, been made, which adapt the slips for situations where it could not otherwise have been available.

It may be as well to notice at this stage, a plan which was patented about the year 1831, as an improvement upon Morton's patent slip, by the late Sir Samuel Brown.

This plan consisted in the addition of a transverse carriage set upon lateral ways, upon which the main carriage and ship could be removed to the sides of the slip, and thus give more accommodation on the mainway. A slip on this principle was laid down at the government arsenal at Deptford, but was made of too light material and design, and gave way on the first trial. There is no reason, however, why it should not be again tried, as it would no doubt give more accommodation. At the same time, the great expense attendant on the additional cradle, and the great number of lateral ways required, cause altogether so much additional expense, that in but few cases could it be made an available improvement.

The progress of improvement on the slip-docks has thus been traced from the time it left Mr. Morton's hands until its improvement by the introduction of the endless pitch-chain—the principle of the slip and purchase having remained the same throughout; and from the date of the construction of the first slip in 1818, until the year 1852, slips, varying in size from those for vessels of 200 tons, to those for vessels of 1200 tons, were constructed in all parts of the world—in England, Scotland, and Ireland, and on the continents of Europe and America; the great recommendation being the comparative lowness of cost, and the ease and despatch with which vessels could be taken up and examined, and repaired and launched again.

In the year 1848 the attention of Mr. Miller, the writer's partner, was turned to the hauling power of the slip. The great increase in the size of slips having rendered it necessary to employ enormous wheels for the gearing of the purchase, and there being a prospect of a demand for slips of an even still larger size for men-of-war, and for the largest class of merchant steam-ships; it appeared that some modification must be made in the design of the purchase, otherwise the number of working parts, and the great weight of wheels, involving a great amount of friction, would act seriously against the introduction of slips on the large scale contemplated. The result was, the production of a purchase on an entirely different principle; toothed gearing being entirely done away with, and a direct pull by hydraulic pressure substituted.

A patent was taken out for this purchase in 1849, and the first slip constructed on this principle was the Kelvinhaugh slip on the Clyde, the property of Robert Black, Esq., constructed in 1850–51.

This slip was intended for ships of 800 tons register, and was designed and laid down by the writer and his partner.

Shortly after the completion of the Kelvinhaugh slip, another slip was constructed on this principle for vessels of 1500 tons. This slip was also designed by the writer and his partner, and is now at work in Melbourne, being the property of the government. The purchase for this slip was made by Messrs. More of Glasgow.

At the present time, slips of a still larger size are in course of construction, Messrs. Morton of Leith having nearly completed one for vessels of 2000 tons for the Mauritius, and one capable of taking up vessels of 3000 tons for the war ships of the Egyptian navy, which is in course of being laid down at Alexandria. The writer and his partner are at present engaged with the plans for another slip of 3000 tons for the West Indies, to take up the largest steamship of the Royal Mail Steam Packet Company, and government frigates. From the simplicity of this improved purchase, the small number of the working parts, and the unlimited power which can be commanded, there is now no limit to the size of vessels which it can be made to take up. In figs. 3 and 4, Plate III., are shown an elevation and a plan of one of the forms in which the hydraulic purchase has been constructed.

The main feature of the purchase is a cylinder, a solid iron casting fitted and firmly bolted down to a frame, and to a foundation, which, in this example, is shown as of timber. The ram or piston works from the upper end through the neck of the cylinder, which is kept water-tight by means of cupped leathers. Two side rods, fixed into a cross head, secured to the head of the ram, pass down one on each side of the cylinder, and are united at the foot by a cross-tail. In fig. 4 the clutch is shown adjusted on the cross-tail for one set of rods, a saddle being used to equalize the strain upon the side rods, when two sets of rods are used. The rods are connected to the purchase by means of pins.

A set of pumps—in this case three in number, whilst in some of the larger purchases as many as five are used—are worked beneath the purchase by a cranked shaft driven from the steam-engine, which, at other times, is used to drive the machinery connected with shipbuilding operations. The pumps are set in a cast-iron box, which forms the cistern for containing the water supply. The cranked shaft is placed above the pumps, passing beneath the cylinder, and works the pumps by means of connecting rods. The pumps are brass, with brass plungers, and connected to one supply pipe, which is fitted with weighted safety valves to let off the water when the pressure exceeds safe bounds—this supply pipe being led directly into the purchase cylinder without the intervention of any cock or valve. A discharge pipe of a large bore allows of the exit of the water from the cylinder back into the cistern, and upon this discharge pipe there is fixed a strong equilibrium cock, worked by a lever. A counterweight for drawing back the ram after it has completed its stroke, is attached to the top of the ram by a chain doubled round a sheave to shorten the length of descent, the weight descending into a well in the foundation. A barrel, worked by wheels from the engine-shaft, is used as a quick purchase for hauling up the empty cradle, by means of a common cable chain.

The action of the purchase is as follows:—The ram being full down in the cylinder, the pump shaft is set in gear with the steam-engine, and the pumps commence working, and do not require to stop until the work is completed and the ship hauled to the top of the slip. At starting the discharge cock is open, and the water only passes through the cylinder back into the cistern. The traction rods are connected directly from the purchase to the cradle upon which the slip lies, and when all is ready, the discharge cock is shut and the ram moves steadily out of the cylinder, hauling up along with it the side rods and tail plate, and so drawing up the traction rods with the cradled ship as shown in fig. 1, Plate III. When the ram arrives at the top of its stroke the discharge cock is opened partially, and the ram is brought to a dead stand; the connecting pins of the first length of traction rods are then driven out, and the rods removed, and the discharge cock opened full. There being no resistance, the counterbalance immediately reverses the ram's stroke, and draws it back into the cylinder ready for another stroke. The rods are again connected, and the operation repeated as before. The operation of fleeting, or taking off one set of rods, reversing the ram, and again connecting, is simple and expeditious, as by partially opening or shutting the discharge cock, the action of the ram backwards or forwards, or in stopping, can be regulated with the greatest precision and ease, and the whole apparatus kept under complete control—a matter of great moment in handling a heavy ship. The usual mode of connecting the rods is by pins, which are driven out as each rod is hauled up, or they can be connected by a self-acting claw, which does away with the necessity of again connecting by driving in a pin.

The largest purchase which has yet been made on this principle, is one which has just been completed by Messrs. S. & H. Morton of Leith, for the pacha of Egypt. This purchase has been proved to a pressure of nearly three tons on the square inch, and is capable of hauling up a vessel of 3000 tons dead weight, on an incline of 1 in 20.

Some idea may be formed of the magnitude of this machine from the following particulars:—the stroke is 15 feet; the ram is 18 inches diameter; the weight of the cylinder is 17 tons; that of the ram 5 tons; and the side rods are each 5 inches diameter.

This purchase is worked by five powerful brass pumps, driven overhead by a three-throw and a two-throw shaft, worked by a fifty horse-power condensing engine.

The usual speed for hauling up heavy ships by these purchases is, including stoppages for fleeting, four feet per minute; this is sufficiently speedy for any ordinary purchases, but still greater speed can be obtained by working with two purchases and self-acting claws, thus saving the time lost in fleeting. The time gained, however, would not compensate for the extra outlay, and it must be borne in mind that the utmost simplicity is a prime requisite in a machine of this kind. The time gained by having two cylinders would be but trifling; as with one cylinder the largest ship could be taken up in three and a half hours, and with two, there would only be the gain of about half an hour.

The length of slip-way which requires to be submerged, in order to obtain sufficient draught of water, has acted as a drawback to the introduction of the slip in some situations where the property is of limited length. This drawback has been got over by a plan proposed by the writer many years ago, but which was not carried into execution until the year 1855. This plan consists in the adoption of half-tide gates or caissons, which, having but a small head of water against them, can be made of an inexpensive description. By placing these gates half-way down the submerged portion of the slip-way, a considerable portion of the ground is reclaimed, and made available for repairing upon. Another improvement, which is likewise the invention of the writer, consists in laying the slip-way in a hollow curved incline, with the object of saving excavation at the lower end of the slip. In the channels of muddy rivers like the Thames, subject to great deposit, this is the means of saving the lower part of the slip from being silted up, which, in many situations, would be a matter of certainty if the end of the slip-way was excavated deeper than the surface of the river bed.

As both of these improvements were carried into execution at the same time, upon a slip constructed at Rotherhithe on the Thames, it may not be out of place to give a short description of the slip.

The Nelson graving slip-dock—the one referred to—was designed by the writer and his partner, and constructed under their superintendence in the year 1855–56. The piece of ground upon which it was proposed to erect this slip, possessed features which rendered it impossible to erect a slip of the ordinary construction, as the whole extent of ground available, exclusive of what was allowed to be projected into the river, was only 196 feet, and inclusive of the projection into the river the total length for a slip-way was only 356 feet. To get a sufficient draught of water this brought the surface of the water at the top of spring-tide up to the very head of the slip. Another feature was, that with an ordinary incline, the lower end of the slip would require to have been carried to a lower level than the bed of the river; and any one who has witnessed the fearful deposit of mud left in any hollow at this part of the Thames, will understand the annoyance that would have been sustained in working the slip.

To overcome the first difficulty, the engineers proposed the introduction of the writer's plan of gates placed across the slip, in the line of the river frontage, so as to secure dry ground over all the property which the proprietors held in their own right.

The difficulty of keeping free from too deep excavation was overcome by substituting the writer's plan of a curved incline in place of a straight plane. Both of these expedients were approved of by the proprietors, Messrs. Bilbe & Co., and carried successfully into execution. Fig. 1, Plate III., is a longitudinal vertical section of the slip, showing the curve and the position of the gates, with the curved cradle and ship upon it. Fig. 2 is a plan, partly in section, of the foundations, ways, &c.

The curve was made to a radius of 286 feet, commencing from the purchase and dipping so as to give a depth of 12¼ feet on the slip at the fore-end of the cradle, and, at the same time, only 19 feet of water on the slip at its extremity.

The ground consisted of a treacherous foundation of mud, and had to be piled and concreted over the entire extent of the slip, the piles being driven to reach the gravel overlying the London clay; every part of the foundation and ways was made of timber, and the concrete merely composed of chalk and clay. The gates were also made of timber, with iron sluices and rollers.

The generality of the London graving docks are completely made of timber; they are leaky and dirty, and require constant pumping. This slip is free from these drawbacks, as, by opening the gates at low water and washing down the floor with water from a hose, the mud brought in when a vessel is docked is swept down the incline without farther trouble; the gates are then shut and kept closed until the vessel is repaired. Owing to the incline of the slip any leakage lies at the lower end without spreading over the floor, as is the case in the Thames docks, and this water can be let off at low water without requiring to pump.

Notwithstanding the steepness of the upper part of the incline, the strain, as exhibited on the indicator of the purchase, is not greater than might have been expected with a regular incline, which, in this case, would have been one in eighteen. In drawing up a ship equal to about 600 tons dead-weight, the indicator has never shown a greater strain than 45 tons.

This slip must not be taken as a model of what a slip might be made under favourable circumstances; but merely as an instance of what can be effected in a very unfavourable locality, by planning the works to suit the place. Plans for a more complete graving slip on this principle, but without the curved incline, and having a caisson in place of gates, have just been completed by the same engineers, to be erected on the river Oder in Prussia.

Slip-docks were, on their first introduction, looked upon more as a substitute for dry docks, where means were not obtainable for the construction of the latter; but they have now, in consequence of the improvements which have been made upon them, become of a more important character: and from their comparative cheapness, and from the ease and expedition with which they can be constructed, where the situation is favourable, they have now acquired a position more nearly equal to that of dry docks, and in some points will even compete with the latter in advantages.

In reply to inquiries, Mr. Bell said the curve of the slip was of the same radius throughout its length. It was an arc of a circle drawn through three points—that of the fore end, that of the after end, and that of the bottom of the half-tide gates or caissons.

Mr. J. R. Napier asked if there was any reason why the curve should not always be adopted. For the Clyde, where so little space was available, it would be a very good plan, notwithstanding that a little more hauling power might be required as a ship approached the upper and steeper end of the incline. He believed Mr. Wood of Port-Glasgow had used curved launching-ways for newly-built ships.

Mr. Bell thought there could be very little objection to the general adoption of the curved slip. It was true that with it the hauling strain was greatest as the ship neared the upper end, and very great care and nicety was required in laying down the rails in the true curve, whilst unequal settlement of the foundation was very injurious. This had, however, to be provided against with equal care when a straight incline was adopted.

Mr. N. Robson inquired what was the comparative cost of the slip dock and of Mr. Edwin Clark's new system. He understood the latter was accompanied by a saving of 25 per cent. on the old system.

Mr. Bell said, that as far as he understood the matter, Mr. Clark's system must be very expensive, owing to the immense extent of ground required, and the costliness of the apparatus, independent of the foundations. He understood that the principle was to float the vessel into what was called a submerged saucer, or in other words, a floating dock similar to those in use on the Tyne and the Tay. The float was then lifted by hydraulic lifts with the ship in it, and the water allowed to flow out. It was then closed against the water, and the ships floated off in the saucer to be repaired. The whole weight being suspended, ships float, and part of the water must make the weight lifted greater than that in the case of slips. A slip would cost from one-half to one-third less than a graving-dock, according to the situation. A floating dock of iron, something on the principle of the American floating docks, would cost about £30,000. The cost of slips depended very much on the foundations required.

Mr. R. Napier understood that with Clark's system the various ship-builders could have saucers of their own, and each have a vessel raised at the lift, and take it away on the saucer to any convenient spot. The system might require great outlay at first, but very great accommodation was given by it. He was not aware what was the cost of the saucers.

The President said Mr. Bell's paper was on a most important class of works, and it was a great advantage to have such a paper from one who, like Mr. Bell, had had so great a share in their improvement. He proposed a cordial vote of thanks to Mr. Bell, which was unanimously awarded.

The FOURTH MEETING of the Session was held in the Philosophical Society's Hall, on Wednesday, 19th January, 1859, the PRESIDENT in the chair.

The PRESIDENT, in the name of the council, proposed the following gentlemen for election as Honorary Members:—

The Right Honourable the Earl of Dundonald, G.C.B., Admiral of the Red, Rear-Admiral of the Fleet.

James Walker, Esq., C.E., LL.D., F.R.SS.L. & E., Past-President of the Institution of Civil Engineers, Consulting Engineer to the Trustees of the Clyde Navigation.

James Prescott Joule, Esq., LL.D., F.R.S.

Charles Piazzi Smyth, Esq., F.R.SS.L. & E., Astronomer-Royal for Scotland.

The following paper was then read:—

Account of some Practical Experiments on the Economic Use of Steam in Steam-Engines. By Mr. PETER CARMICHAEL of the Dens Works, Dundee.

Having an engine of forty nominal horses power, working with a very uniform load, driving flax-spinning machinery, it occurred to the writer that a few experiments on different methods of using the steam, cut off sooner and later, and with different pressures in the boilers, might be of use.

For the purpose of obtaining accuracy, each experiment was made on a whole week's work of 60 hours. The following particulars were noted and recorded, and care was taken to insure the greatest amount of uniformity of conditions in the different experiments:—

The coals were accurately weighed, including every pound used, from the getting up of the steam on Monday morning until stopping-time on Saturday; and to check the quality of the coal, the whole clinkers and ashes made for the week were also carefully weighed. The quality of the coals used was as nearly as possible the same in all the experiments, being a mixture of Lochgelly (in Fife) and South Hetton, both small coals.

The water supplied to the boilers was measured by one of Kennedy's water meters, and no water was blown through, nor steam blown off, during the time the experiments lasted. The temperature of the feed water was noted daily, as also the height of the water in the boilers, at the beginning and end of the experiment. The injection water supplied to the condenser was made as uniform as possible, the injection cock having a two-inch bored hole, which was kept full open during all the experiments. The temperature of the injection and discharged water was noted daily, to show the amount of heat imparted to the water. Diagrams of both top and bottom of the engine were taken daily, and the horses power calculated, so as to obtain a correct average for the week. The number of strokes made by the engine for the week was recorded by the speed clock, and the overtime counted in the work performed.

The Boilers.—The engine was supplied with steam by two round boilers, each 7 feet in diameter, and 24 feet long, with two flue tubes through each in the common form, with a furnace in the mouth of each tube; the furnace part of the tube being 33 inches in diameter, and coned down to 29 inches. The furnace bars are five feet long, by 33 inches wide, and the dumb plate 16 inches broad.

The Engine.—The cylinder is 35¼ inches in diameter, the length of stroke being 4½ feet. The rate of working was 37 strokes, or 333 feet per minute travelled by the piston, but the engine by the speed clock made from 30 to 40 minutes per day overtime. The actual power was calculated from diagrams made by a M'Naught's indicator in the usual way, thus—

$$\frac{\text{Area of cylinder} \times \text{feet travelled per minute} \times \text{effective pressure}}{33{,}000} = \text{H.P.}$$

In each experiment six diagrams above and below the piston were taken and calculated, so as to form a fair average. The valves, both steam and eduction, are conical and balanced, and the steam wipers were changed in the different experiments, so as to shut off the steam at the time required in each.

One diagram, made during each experiment, is shown in Plate 4, illustrative of the lines, and showing the mode of calculating the effective pressure.

The following are the results obtained in the several experiments:—

First Experiment, from the 8th to the 13th November, 1858, *inclusive.*

Pressure of steam in boilers, ... 30 lbs.

Steam cut off at *one-fifth* of the stroke.

Coals consumed for the week, . . 272½ cwt. = 30,520 lbs.

Clinkers made for the week, 1040 lbs.

Ashes made for the week, 476 "

In all, 1516 lbs., or 5 per cent. of the coals used.

Total water supplied to boilers, ... 22,500 gals.
being 13·3 cubic feet of water evaporated per cwt. of coals.
Average heat of feed water supplied to boilers, . . 112°
Do. of injection water, ... 82°
Do. of discharged water, ... 112°
Heat imparted to water in condensing, ... 30°
Average horses power by diagrams, ... 135½
Time made by the engine for the week, . . . 63 hours, 12 min.
Coals consumed per horse power per hour, . . . 3·56 lbs.

Second Experiment, from the 15*th to the* 20*th November*, 1858, *inclusive.*

Pressure of steam in boilers, ... 30 lbs.
Steam cut off at *one-half* of the stroke.
Coals consumed for the week, . 296 cwt., 21 lbs., = 33,173 lbs.
Clinkers made for the week, 1743 lbs.
Ashes made for the week, 364 „

In all, . . 2107 lbs., or 6·3 per cent. of the coals used.

Total water supplied to boilers, ... 25,800 gals.
being 14·01 cubic feet of water evaporated per cwt of coals.
Average heat of feed water supplied to boilers, . . 112°
Do. of injection water, ... 79°
Do. of discharged water, ... 112°
Heat imparted to water in condensing, ... 33°
Average horses power by diagrams, ... 130½
Time made by the engine for the week, . . . 64 hours, 3 min.
Coals consumed per horse power per hour, . . . 3·97 lbs.

Third Experiment, from the 22*d to the* 27*th November*, 1858, *inclusive.*

Pressure of steam in boilers, ... 15 lbs.
Steam cut off at *three-fourths* of the stroke.
Coals consumed for the week, . . . 369½ cwt., = 41,356 lbs.
Clinkers made for the week, 1736 lbs.
Ashes made for the week, 518 "

In all, . . 2254 lbs., or 5·4 per cent. of the coals used.

Total water supplied to boilers, ... 30,600 gals.
being 13.3 cubic feet of water evaporated per cwt. of coals.
Average heat of feed water supplied to boilers, . . 119°
Do. of injection water, ... 76°
Do. of discharged water, ... 119°
Heat imparted to water in condensing, ... 43°
Average horses power by diagrams, ... 133
Time made by the engine for the week, . . . 63 hours, 14 min.
Coals consumed per horse power per hour, . . . 4·91 lbs.

TABLE FOR COMPARISON.

No. of Exper.	Press. in Boilrs.	Steam cut off.	Consumption of Coal For Week.	Ashes and Clinkrs.	Water Evaporated.	Water Evaporated Per cwt. Coals.	Horses Power.	Time For Week	Heating of Injc. Wat.	Coals per H. P per hour
	lbs.		lbs.	per 100.	gallons.	cubic feet.		H. M.		lbs
1 *a*	30	$\frac{1}{5}$	30,520	5	22,500	13·3	135½	63 12	30°	3·56
2	30	$\frac{1}{3}$	33,178	6·3	25,300	14·01	130½	64 3	33°	3·97
3	15	$\frac{3}{4}$	41,356	5·4	30,600	13·3	133	63 14	43°	4·91

The above shows a consumption of coal on No. 2 of 11·5 per cent. more than No. 1; and, on No. 3, of 37·9 per cent. more than No. 1. Or—reversing the calculation—there is a saving of 19·1 per cent. on No. 2 as compared with No. 3; and a saving of 27·5 per cent. on No. 1 as compared with No. 3.

In all these experiments there was a little loss in the economy of the coals from the following causes:—

1st, The boilers were not covered or felted on the top, the room above them being used for drying yarn.

2nd, The quality of the coal was inferior, as shown by the large percentage of clinkers and ashes, which was not only a direct loss, but also spoiled the economic working of the fires.

3rd, The heat of the injection water was rather against the perfection of the vacuum in the condenser, but this could not be avoided, as the water required to be returned and used over again on account of the supply being scanty.

4th, The cubic feet of water evaporated by one cwt. of coals is below the ordinary standard. It must, however, be borne in mind that the experiments were continuous from week to week—commencing with the getting up of the steam on Monday morning, the 8th November, and continuing until Saturday, 27th November, and included every pound of coals consumed during the three weeks, whilst there was a certain loss from the stoppages at meal hours, and from the getting up of the steam in the mornings.

To make certain that Experiment No. 1, which gave the best result, was correct—after the three experiments were completed, which occupied, as already stated, three weeks—the steam wipers were changed to the same as No. 1, that is, to cut off the steam at one-fifth of the stroke. This was continued for a whole week, from the 29th of November to the 4th of December, 1858, inclusive, and the results were as under-noted:—

Pressure of steam in boilers, 30 lbs.
Steam cut off at *one-fifth* of the stroke.
Coals consumed for the week, . 262 cwt. 3 qrs. 21 lbs. = 29,449 lbs.
Clinkers made for the week, 1288 lbs.
Ashes made for the week, 406 "

In all, . . 1694 lbs., or 5·7 per cent. of the coals used.
Total water supplied to the boilers, 21,800 gallons, being 13·36 cubic feet of water evaporated per cwt. of coals.
Average heat of feed water supplied to boilers, 96°.

Do.	of injection water, ...	69°
Do.	of discharged water, ...	96°
Heat imparted to water in condensing,	. . . . . .	27°

Average horses power by diagrams, 130·5.
Time made by the engine for the week, . . . 63 hours, 26 min.
Coals consumed per horse power per hour, . . . 3·55 lbs.
Thus confirming the correctness of No. 1 Experiment.

It also occurred to the writer that the reduction of the pressure of the steam in the boilers in No. 3 Experiment to 15 lbs. on the inch, instead of 30 lbs. in the other two experiments, might have some effect in increasing the consumption of coals; and to ascertain this, the steam wipers were changed to the same as No. 3, to cut off the steam at three-fourths of the length of the stroke, with 30 lbs. pressure of steam in the boilers. This experiment was only continued for three days, from 6th to 8th December, 1858, inclusive; but the results seemed so nearly to agree with the No. 3 as recorded, that the writer did not think the difference of the pressure of the steam in the boilers made any difference in the economy.

The injection cock for supplying the water for condensation was a 2-inch round hole, and was kept full open in all the experiments, and is 12 inches below the level of the water in the pond, so that one foot has to be added to the head of water, as indicated by the diagrams:—

No. 1.

Average vacuum, 12·11 lbs. × 2·3 ft., + 1 foot = 28·85 ft. head of water.

No. 2.

Average vacuum, 11·59 lbs. × 2·3 ft., + 1 foot = 27·65 ft. head of water.

No. 3.

Average vacuum, 11·47 lbs. × 2·3 ft., + 1 foot = 27·38 ft. head of water.

The injection pipes are of large size—six inch bore; the only contraction is at the injection cock, all the other parts allowing a free flow to the water. From this can be calculated the quantity of injection water supplied per stroke, or per minute, in the different experiments. The steam cylinder has a jacket, and is, in addition, carefully covered with felt and cased. The steam-pipes leading from the boiler-house to the engine are also well covered; but they are uncovered in the boiler-house, the heat from them, as well as from the top of the boilers, being utilized for drying purposes.

Various experiments were made to ascertain the heat of the products of combustion escaping from the boilers. They were performed as follows: —A number of thin slips of metal, fusible at different temperatures, were prepared, and hung by small wires in the flue leading from the boilers to the chimney. The metals tried were—zinc, which melts at about 700°; lead, which melts at about 600°; bismuth, which melts at about 500°; tin, which melts at about 440°; and an alloy containing three parts tin, and one part lead, which melts at about 367°. The three last-named melted at once; the lead (600°) sometimes remained for a few minutes without melting, but if the fires were stirred it melted immediately. In all the experiments the zinc (700°) remained unmelted. These experiments were repeated so often with the same results, that the writer came to the conclusion that the escaping heat was between 600° and 700°.

The chimney into which the flues are led is situated on an eminence at a considerable distance from the furnaces, and the flues from 14 boilers, each having two furnaces, are led into it. To get some more information respecting the state of the conducting flue, a hole was opened into it at a distance of 200 feet from the boilers, and exactly the same results were again obtained, the lead (600°) very soon melting, and the zinc (700°) remaining intact.

This great loss of heat has, in all cases tried, been so uniform that it appears to follow some law in the kind of furnaces and boilers used.

In conclusion, it remains only to say, that in all these statements the writer's aim has been to record results as carefully and correctly as possible, without attempting to draw any conclusions having; no bias towards any view of the subject, and seeking only the most economical results. He is aware that there are statements of engines doing their work with a much smaller consumption of coals, per horse power per hour, than the best here recorded; but they are chiefly pumping engines. In most cases there is a great want of minute information to show where or how the saving is effected, such as would enable a practical man to copy the best examples, and it is beyond all doubt that there is an enormous amount of fuel wasted for want of such information.

If these statements have the effect of inducing others, who have better results than those here recorded, to come forward and make them public, they will have answered the purpose of the writer.

The PRESIDENT said, the account of the experiments of Mr. Carmichael was so intelligible that he thought much explanation on the subject would not be required. He would be glad if the members present would make any observations that occurred to them.

Mr. ELDER said, that 7½ lbs. of water per lb of coal was about the usual average evaporation if the boilers were in good condition. He thought the engine referred to in the paper was a first-rate example of a good factory engine, and he would like to find many engines of a similar kind. The engine of his own firm burned 4½ lbs.; but it was an expansive engine, and had lately been brought to consume only 3½ lbs. The figures, as regarded it, were very like those arrived at by the writer of the paper, which certainly showed that there was some benefit in expansion. The other day he had a letter from a person in London, calling in question the advantage of carrying expansion beyond half-stroke, and stating that it was contrary to experience to do so. Now, he thought that the facts stated in the paper very clearly showed that there was advantage.

The SECRETARY, in reply to the President, stated that the cylinder of Mr. Carmichael's engine had a steam jacket round it. He also said, in reply to a member, that the pressure given in the paper was the pressure above the atmosphere, and not the absolute pressure. The valves used were common equilibrium valves, worked by wipers. There was no expansion valve used in the experiments.

Mr. W. NEILSON considered the consumption of fuel rather high. Six or eight years ago it was quite common for people getting engines made in England, to stipulate that the engine should not consume more than 2½ lbs. per horse power; but these were double cylinder engines with steam jacket. As regarded consumption of fuel, imperfection in the boilers would counterbalance the good performance of the engines.

Mr. Brownlee observed that Mr. Carmichael had to use the same injection water over again, and that his engine had the disadvantage of a bad vacuum.

Mr. Elder thought that the average, which was 12 lbs., could not be called a bad vacuum.

The President observed, that from the diagram it appeared that in Experiment No. 1—that in which there was most expansion—the vacuum was 11·8; in Experiment No. 2 it was 11·59; and in Experiment No. 3 it was 11·25—a fact that verified the common observation, that with great expansion the vacuum in the cylinder became better. The best vacuum obtained was 11·8, the worst 11·25, and the average was 11·5 lbs.

Mr. Lawrie called attention to the fact, that the boilers being uncovered would have an effect in causing a variation of the pressure.

Mr. Napier said, that some years ago he made a number of experiments respecting the economy of fuel by comparing diagrams. By measuring the length of the steam-line at atmospheric pressure he obtained the quantity of steam, and the area of the diagram gave the power. On comparing these he was led to the conviction that in many cases there was no saving at all to be got from expansion. He could not positively assert this; for it was a theoretical conclusion to regard the length of the atmospheric line as representing the quantity of steam; besides, the quantity of fuel was not weighed, though the coals were measured, but he had no faith in that mode of ascertaining their exact quantity. He thought that in working on the expansion principle with ordinary engines, no saving could be made. The results he obtained from the steamer *Islesman* showed no saving; for the consumption was double that mentioned in the paper. However, the experiments made by Mr. Carmichael showed that there was an advantage in working expansively in a proper manner. Mr. Elder stated at last meeting, he thought, that in working his engine expansively, when he did not use a steam-jacket, he had to stop it every half hour in order to let out the water that was condensed in the cylinder.

Mr. Elder remarked that a large steam-jacket was better than a small one. He considered that large cylinder capacity with steam jackets, not only round the cylinder, but also at top and bottom, the best means of reducing the consumption of fuel.

The President read a note of an experiment he had made with a pair of double cylinder engines, which showed a consumption of 3lbs. of coal per H.P. The circumstances were—steam expanded, $4\frac{1}{8}$ times on one side, and $6\frac{1}{4}$ times on the other side of the piston, giving an average of 5 times: net evaporation $7\frac{1}{4}$lbs. of water to 1lb. of coal.

Mr. Neilson remarked that, in Mr. Carmichael's experiment, the quantity of coal mentioned was used for getting up steam, as well as for the time the engine was actually working—a fact that should be borne in mind when comparing the results of these experiments with others.

Mr. NAPIER said he found that in cutting off steam at less than half stroke, there was no advantage to be gained. In the *Islesman* he found that more coal was burned when the steam was cut off at two-tenths, than when at four-tenths, and no additional power was gained. He never found that the vessel went faster when he used the expansion valve; and on trying to beat other boats by using expansion, he failed. His opinion was borne out by a French writer, and also by a writer in the *Mechanic's Magazine.*

Mr. NEILSON thought that was probably because the boilers were too small.

Mr. BROWNLEE held that there was nothing to be gained from expansion without a steam jacket; and he found that the admission of steam during a considerable part of the stroke was an advantage. On the river Mississippi, where steam was used at a pressure of from 100 lb. to 150 lb., it was cut off at half stroke.

Mr. ELDER referred to the loss of power arising from friction in engines, which was a subject well worthy of the attention of engineers. He thought they should be able to calculate the amount of power so lost; for he had himself tried in one or two cases to do so, and succeeded pretty well in ascertaining what the amount of the friction was, and the power usually absorbed by it. It was not a very large quantity. In some engines there was, however, a difference of 40 per cent. in the friction.

The PRESIDENT expressed a hope that Mr. Elder would favour the Institution with some experimental results as to loss of power in engines from friction.

Mr. NEILSON said he was surprised to find Mr. Napier still wavering in his faith in the advantages of expansion; for he had expected that he would have admitted at once that expansion was theoretically correct, and proved by figures and diagrams. Of course, in applying the principle in engines not constructed with the care that was necessary to insure economy, the advantages might not be obtained; but theoretically it was quite apparent. Mr. Neilson, after illustrating the theory of expansion, with the aid of a diagram, went on to say that, as a very slight change in temperature produced a great change in pressure, it was plain that with cold cylinders, and without jackets, there must be a loss of power that would almost lead one to deny the benefit of expansion altogether, were it not proved that, when properly applied, the principle was most advantageous. It was to be hoped that the time would soon come when marine engines would be made with care, when the boilers would be properly protected, and when engine-rooms would no longer be found hot enough to roast one, nor heated air be wastefully allowed to escape through every crevice of the deck. It was well worth the while of engineers to exert themselves to promote economy in every small point. Take the marvellous result recently obtained of a consumption of only 1 lb. of coal per indicated horse power per hour, and compare it with the consumption of some of the fast vessels of most of our large steam navigation companies, and see what a vast sum of money wasted by them could be saved, were the same economical principles applied to their engines! In future increased attention would undoubtedly be given to the consumption of fuel by marine engines.

Mr. NAPIER, being asked what was the consumption of fuel in the case of the *Islesman*, said he hoped in time to reduce it to 1 lb. per indicated horse power per hour.

Mr. BROWNLEE alluded to the circumstance, that frequently about *half* the steam going into a cylinder was condensed on entering it, and called attention to Watt's plan for preventing this. A mistake sometimes made in using steam-jackets was the not having the steam in the casing at the full pressure in the boiler; and unless this was done, the pressure in the cylinder would not equal that in the boiler.

Mr. LAWRIE remarked that he had it on the authority of Mr. Robert Stephenson, that an experiment was made in which a flue was carried round a cylinder, and it was found that one cwt. of coal burned in it, gave a result equal to three cwt. burned in the boiler furnace.

Mr. NEILSON said it was a well-known fact, that the more within certain limits heat was added to steam as it expanded, the greater were the results obtained. This arose, not from any law of latent heat, but from the expansion of the gases.

Mr. NAPIER said, in case his views might be misunderstood, he must explain that he did not mean there was no gain from using expansion, but that when the expansion was pushed beyond a certain point—to cutting off at one-fifth of the stroke, for example—you gain nothing.

Mr. NEILSON said it could be proved from diagrams that there was a gain.

Mr. NAPIER placed no trust in diagrams.

Mr. NEILSON admitted that there was no economy to be found in cutting off steam, unless when used at a pressure of at least 100 lbs.

The PRESIDENT said the extent to which expansion could be carried with practical benefit, depended on the initial pressure of the steam. He had seen an engine in which the steam was expanded from 14 to 16 times. Useful work was performed during the whole of that expansion, because the absolute initial pressure was 110 lbs., or 95 lbs. above the atmosphere; so that the pressure at the end of the expansion was still sufficient to overcome the back pressure and friction. The vacuum was 11½lbs., and the back pressure 3½lbs. The steam on one side of the piston was expanded 14, and on the other 16 times. The engine was a double-cylinder one: one cylinder was jackete, dthe other unjacketed.

Mr. LAWRIE said it was important in connection with the subject to remark, that the speed of the piston should be taken into account; for with slowly-moving pistons there was time allowed for the cooling of the cylinder. The cause here indicated might possibly have prevented gain in the case of the *Islesman*.

Mr. NAPIER said there were few faster working engines than the *Islesman*. With a 3 feet stroke the engine made 70 revolutions a minute. The speed had lately been reduced, and all who worked the engine agreed that the consumption of fuel was less than before.

Mr. LAWRIE said he recently offered a steam ship company to supply the engine of one of their vessels, at his own expense, with an apparatus for heating the steam, but he found it already patented. He had often found a great difference of pressure between boilers and engines, which was more in some cases than in others; and it increased when the engine was worked expansively, especially if without a steam-jacket. The reduction of the pressure in these cases was no doubt owing to the rapid condensation of the steam on entering the cylinder, and to counteract it either superheated steam or steam-jackets must be used.

The PRESIDENT said, that in the Cornish engines the pressure in the cylinder was often less than one-half that in the boiler.

Mr. BROWNLEE ascribed the reduction of pressure in Cornish engines to the small size of the valves, and also to the fact that it was considered unsafe to admit the full boiler pressure to the cylinders.

Mr. LAWRIE considered that if the passages were large enough, and the heat kept up, the pressure of the steam in the cylinder should be the same as in the boiler.

Mr. NAPIER remarked that the valves in the *Islesman* were 12 inches, which he thought large enough for the engine.

Mr. LAWRIE said he understood Mr. Inglis had particulars of an engine which burned less coal than the *Islesman's*.

Mr. NAPIER asked if the coals were weighed in the case referred to.

Mr. INGLIS had the statement from the engineer, who said, that whilst on a voyage the engine was worked expansively, and the consumption of coal reduced from 5·5 lbs. to 4·6 lbs.

Mr. NAPIER held that the smallness of the cylinder and the amount of surface it presented in the case of the *Islesman*, had something to do with the quantity of coal the engine consumed. It was also to be recollected that the cylinder of the *Islesman* was placed on the top of the condenser.

The PRESIDENT said, that in expansive engines, where condensation was prevented, the results obtained from experiments agreed with theory, within 2 per cent., or some such small difference.

Mr. MORTON having called attention to Wetherhed's apparatus for superheating steam,

The PRESIDENT remarked, that he believed the apparatus introduced the superheated steam near the ports of the cylinder to mix with steam that was not superheated, and that the mixed steam was thus superheated to a less degree. He never heard a reason assigned for this mode of superheating being better than the direct superheating of the whole of the steam.

Mr. MORTON said, he understood that by mixing superheated steam with the other steam there was an advantage of nearly 30 per cent. There was an experiment made with combined steams, and the best result obtained was a consumption of 2·7 lbs. of coal per horse power per hour. The valves in that trial were not altered; but he was not aware whether the engine worked expansively or not.

The PRESIDENT observed that that was about equal to some of the results got with ordinary engines when worked expansively.

Mr. LAWRIE mentioned an experiment made on the steamer *Dee*, when only a third of the steam was superheated, but without any saving.

The PRESIDENT said, he believed that was what was called the "combined steam" system.

Mr. NAPIER thought that experiments had shown that, to heat the entire steam supplied to the cylinder, was the same in point of effect as to heat only a portion of it; and whatever saving was observable from the experiments with combined steams, probably arose from a different cause than what was supposed. Many boilers sent more than steam into the engine. What old engineers called "dry steam" was just what modern engineers called "superheated steam," or steam without water. Now, if a boiler sent over water along with the steam, and if superheating were applied, of course the effect of an additional boiler would be produced. From French experiments he found that the amount of "priming" varied from 5 to 25 per cent.

The PRESIDENT asked if these experiments distinguished between actual priming from the boiler and condensation in the cylinder?

Mr. NAPIER said, the experiment referred to the water coming over with the steam from the boiler; but he did not know exactly whether the distinction was made.

The PRESIDENT observed that an ingeniously-contrived apparatus, intended to prevent "priming," had been tried in the neighbourhood of Glasgow, which was on the principle of a centrifugal fan, to scatter the drops of water brought over by the steam, and send them back again to the boiler. It had not, however, the effect of attaining the object desired —of preventing water from collecting in the cylinder—for it was found that what was supposed to be "priming," was really water produced in the cylinder by condensation. This fact, of course, rendered the experiments of Pambour, and a number of others, upon the priming of locomotives inconclusive; for these experimentalists were not aware of that condensation taking place when they set down all the water in the cylinder as occasioned by priming from the boiler. Some had estimated the amount of priming at 40 per cent.; but it was impossible to say what the real amount was, and it was probably much less than 40 per cent. It appeared to him that there was reason to suspect that the friction of moist steam in passing through pipes was greater than that of dry steam; and when a boiler primed, there was a much greater loss of pressure to the steam than when it came over in a dry state, and that loss of pressure was probably owing to the friction of the cloudy steam. What confirmed him in this belief was, that with cloudy steam there was an electrical action produced. Dr. Faraday had made experiments on letting jets of steam issue from a boiler, and he found that if the steam was dry no electricity was manifested, and that it was necessary, in order to produce electricity, that powder or drops of water should be carried with the steam so as to cause friction.

Mr. Lawrie said, that the experiment on priming, to which the President had referred, was made on the Caledonian Railway. He differed from the President in opinion; for he did not think that the experiment at all proved that water did not come from the boiler along with the steam.

The President did not wish to be understood as saying that it proved that no water came over from the boiler; all he meant was, that the experiment showed that there was other water produced in the cylinder besides what might come over with the steam.

Mr. Neilson thought the Institution would be glad to have a paper from Mr. Rowan, explaining how economy in the consumption of fuel could be brought to the low figure of only 1 lb. of coal per horse power.

Mr. Rowan said he would be happy to lay a paper before the Institution as soon as he had completed some further experiments he proposed making.

A vote of thanks to Mr. Carmichael for his paper was cordially adopted.

The Fifth Meeting of the Session was held in the Philosophical Society's Hall, on Wednesday, 16th February, 1859—the President in the chair.

The President, in the name of the Council, proposed the election of the following gentlemen as Honorary Members:—

William Fairbairn, Esq., C.E., F.R.S., F.G.S.

William Thomson, Esq., A.M., LL.D., F.R.SS. L. & E., Professor of Natural Philosophy at the University of Glasgow.

The meeting unanimously elected as Honorary Members the four gentlemen proposed at the last meeting.

A donation was laid on the table from Mr. Fairbairn consisting of the following works by that gentleman:—

On Canal Navigation. 1831.

Observations on Improvements of the Town of Manchester. 1836.

Account of the Construction of the Britannia and Conway Tubular Bridges. 1849.

Useful Information for Engineers. 1856.

On Tubular Wrought-iron Cranes (from Transactions of the Institution of Mechanical Engineers). 1857.

On the Sliding Caisson at Keyham Dockyard (from Transactions of the Institution of Civil Engineers). 1857.

On the Tensile Strength of Wrought-iron (from the Report of the British Association for 1856). 1857.

On the Application of Cast and Wrought-iron to Building Purposes. 1857, 1858.

On a Floating Steam Corn Mill and Bakery (from Transactions of the Institution of Mechanical Engineers). 1858.

On the Resistance of Tubes to Collapse, 1858, (from the Philosophical Transactions, and also from the Engineer's and Contractor's Pocket-Book for 1859.)

Notice Extraite du Panthéon Biographique. 1859.

A vote of thanks was passed for this donation.

Before proceeding to read the papers for the evening,

The PRESIDENT said, they were all aware that since their last meeting the Institution, and the engineering profession generally, had sustained a heavy loss in the death of two of their members—Mr. DAVID TOD, the eminent iron shipbuilder, and Mr. DANIEL MACKAIN, who, he said, was one of the heads of the profession of water-engineering in Scotland. The Council of the Institution had considered how they could most appropriately express the Institution's deep sense of the loss sustained by the death of those two members; and they had come to the conclusion that the best thing they could do was to direct the Secretary to prepare notices of the lives and professional careers of both gentlemen, to be published in the Transactions of the Institution. He hoped, therefore, that any member who could give any information upon the subject would furnish it to the Secretary.

Memoir of Mr. DAVID TOD.

MR. DAVID TOD was the architect of his own fortunes, having been born of humble but respectable parents at a village in the parish of Scone, Perthshire. He commenced his professional career as apprentice to a country millwright, and after in this capacity proving himself to be a first-class workman, he came to Glasgow in search of work, first obtaining it at Shettleston. He subsequently entered the workshop of Mr. David Napier at Camlachie, where he may be said to have first entered upon the special branch of engineering to which the chief part of his life was devoted, and where also he met with the late Mr. John M'Gregor, who was eventually to be his partner. Mr. Tod's talent and practical mechanical skill insured him a gradual but sure and certain rise in position; during which it was ever his aim to obtain experience in everything connected with his business, not only in the workshop but also in the engine-rooms and stoke-holes of steamers in regular work. He was engineer to the *Rob Roy*—the first sea-going steamer, and which plied between Glasgow and Belfast—and he subsequently acted as chief engineer of various other and larger steamers. Conjointly with Mr. M'Gregor, he commenced iron-shipbuilding and engine-making on his own account, under the firm of Tod and M'Gregor, whose name is now to be found impressed upon upwards of one hundred successful sea-going steamers, besides many river steamers. They began in a small place in Carrick Street, Glasgow, where trade flowed in so rapidly upon them that they soon saw it was necessary to have larger premises. Accordingly a large piece of ground was feued at Anderston quay, and a splendid shop erected thereon, to which, as is always the case with rising firms, large additions and improvements have from time to time been made, and which is now considered one of the finest and best-arranged workshops in the kingdom. Messrs. Tod and M'Gregor were the first to make iron-shipbuilding a trade. The first steamer they built for this country was for the Dumbarton Company; and, as a proof of the foresight of Mr. Tod, he offered to make the ship fifteen feet longer than their model without any extra charge, being convinced the extra length would give much greater speed, with the same power. The owners would not accept this offer, as they thought she would not take the turns in the river quickly enough. Now, however, the river steamers are much longer than even he at that time contemplated. The next step was to suggest the building of sea-going steamers of iron, and, after a great deal of trouble, a company was formed to sail steamers between Glasgow and Liverpool. Two vessels were built, called the *Royal Sovereign* and *Royal George*, which kept their ground against a strong opposition and many predictions of failure. The owners then ordered another steamer, and gave Mr. Tod a *carte blanche* as to dimensions, power, &c., on which terms he engaged to beat anything afloat. The result was the splendid steamer, the first *Princess Royal*, which at once put an end to all opposition, the other company's steamers having no chance.

They next built the screw steamer *City of Glasgow* for the Atlantic trade, which vessel made three or four trips to New York, proving beyond a doubt that such vessels would pay in the trade. Companies were immediately formed both in Liverpool and Glasgow, which have turned out eminently succesful. Messrs. Tod & M'Gregor built also many of the finest ships of the splendid fleet belonging to the Peninsular and Oriental Steam Navigation Company. No single firm has contributed more than they to the present extended and extending use of the screw as a propeller for steamships, and perhaps a higher indication of sagacity could not be exhibited than that given by them in leading the van in the application and improvement of this instrument. Altogether there have been built by this enterprising firm about 60,000 tons of shipping, and they have supplied engines to the extent of 19,500 horses power.

This brief notice of Mr. Tod's career would be very incomplete without a mention of the noble graving-docks which have recently been constructed for his firm at the confluence of the Kelvin with the Clyde. Their construction affords another instance of Mr. Tod's far-sighted sagacity, and of his liberal and enlightened disposition. The representatives of his firm cannot fail, sooner or later, to reap an income from these works proportionate to the immense outlay invested in them; but the direct and indirect advantages they confer on such a port as that of Glasgow, are of incomparably greater importance.

Mr. Tod was a man of the clearest judgment and a first-rate calculator, notwithstanding the slightness of his early education. He was exceedingly liberal in his views and conduct, and a man of the strictest honour and integrity. During the twenty-five years that he was in business the firm never had a lawsuit, a case of reference, nor a disputed account, and every contract taken was completed by, and in many instances before, the stipulated time.

Mr. Tod was one of the original members of the Institution of Engineers in Scotland, but his advanced age, together with the distance of his residence and his engrossing occupations, have doubtless prevented his taking an active part in the proceedings.

Mr. Tod died at his residence at Partick on the 24th January, 1859, aged sixty-three years.

Memoir of Mr. Daniel Mackain.

Mr. Daniel Mackain was born at Fortrose, Ross-shire. He appears to have commenced his career as civil engineer in some important situations at Leith. In 1830 he was appointed engineer and manager of the Cranstonhill Water Company of Glasgow. He exhibited talents peculiarly suited for his position, and he greatly benefited the company by whom he was employed; so much, indeed, was thought of his abilities, that on the amalgamation of the Cranstonhill Water Company with the Glasgow Water Company in 1838, he was appointed chief engineer to the combined concern. After that time Mr. Mackain retained the post of chief engineer of the more important portion, and latterly of the whole of the works for supplying Glasgow with water. Mr. Mackain's ability showed itself not merely in matters strictly confined to the civil-engineering department, but also and with equal success in parliamentary proceedings connected with the various successive modifications of the arrangements for supplying water to Glasgow, called for by the rapidly-increasing wants of the city. Some sixteen or seventeen years ago, Mr. Mackain executed one of the most extensive explorations ever made, to ascertain from what sources a sufficient supply of water might be obtained for Glasgow. In the course of this he gauged every loch and watercourse, and estimated every rain-shed in the West Highlands, and his observations resulted in the Loch Lubnaig scheme, for which an act of parliament was obtained in 1846, but which was not carried out on account of the difficulty of raising capital for it. About three years ago Mr. Mackain went to Portugal, to examine into the means of supplying Oporto with water, and it is understood that the plan recommended by him will be carried into effect when funds can be obtained.

Mr. Mackain was long a member of the Institution of Civil Engineers: he was one of the original members of the Institution of Engineers in Scotland, and a member of its first council. He also formed one of the committee by whom the regulations of this Institution were drawn up, and many of the best features of those regulations are due to his excellent suggestions and advice. He read a paper at the second meeting of the first Session, being a "Description of a Steam Pumping-Engine constructed for the Glasgow Water Commissioners at their Reservoir in Drygate Street."* This engine was constructed from Mr. Mackain's own designs, and showed him to be as good a mechanical as he was a civil and hydraulic engineer.

Mr. Mackain died on Tuesday the 8th February, 1859, aged fifty-eight years.

The following paper was read:—

* *Transactions of Institution of Engineers in Scotland*, vol. i., p. 30.

On Coal-Burning Locomotive Engines. By Mr. Patrick Stirling.

In bringing this subject before the notice of this Institution, it is not the intention of the writer to enumerate or describe the many attempts that have been made to substitute the use of coal for that of coke in locomotive engines, but to give a short account of some of the most successful arrangements of fire-box and boiler that have been made for this purpose.

It must be evident to every one who has paid any attention to the subject, that great economy in locomotive working must result from the use of coal instead of coke, more particularly if it is considered that about one and a half tons of Newcastle coal are required to produce one ton of coke; whilst it has been ascertained from experiments made with great accuracy, that the steam-producing power of coke is inferior to that of the coal from which it was made, weight for weight. In some cases known to the writer, the cost of good Scotch splint coal is not one-third the cost of Newcastle coke, and if pretty nearly the same duty can be obtained from it that can be got from coke, there can be no doubt of its greatly superior economy. The importance of this subject will be more fully appreciated, perhaps, if we consider that the gain to some railway companies would be equal to one-fourth or one-half per cent. on their dividends.

The great objection to the use of coal hitherto, has been the nuisance arising from unconsumed smoke escaping from the funnels of the engines, and many have been the attempts of engineers to devise means whereby such smoke might be prevented, or burned and utilized before leaving the boiler. The most successful plan that has come under the observation of the writer, is that of Mr. Beattie's patent coal-burning engines, one of which has been in use on the Glasgow and South Western railway for nearly a year, and has given the greatest satisfaction.

Mr. Beattie's engine does not differ in any essential respect from engines of the ordinary construction, except in the boiler and apparatus for heating the feed-water on its passage from the tender to the boiler. Fig. 1, Plate V., represents the boiler in longitudinal vertical section. The fire-box is divided into two distinct furnaces by a slanting midfeather or water-space, A, and each of these furnaces is provided with a fire-door of its own, so that the one can be fired without interfering with the other. From the crown of the fire-box there is a hanging bridge or deflector—shown at B—for the purpose of throwing the products of the outer fire down upon the other, so that they may either be consumed themselves, or aid in consuming the products of the inner one. The fire-box is continued into the boiler a distance of five feet, in the form of a flue, called a mixing chamber, a transverse vertical section of which is given in fig. 2. The flat top of this flue is supported by the water-space G. The tube plate is rivetted into the end of this flue, and is pierced to receive 375 tubes, five feet six inches long, and of one and one-eight inches outside diameter.

In working the fires, care is taken that they are supplied with fuel at different times, so that there shall always be one of them burning clear, whilst the other is throwing off the blackest of the smoke, and in this way there is generally sufficient heat communicated to the partially unconsumed gases to cause them to ignite, and pass off in flame instead of smoke. This method of firing two furnaces alternately has long been known as favourable to smoke burning, and has now been successfully applied to locomotive engines by Mr. Beattie.

To make the consumption of smoke still more perfect, however, and to provide against any sudden fall of temperature in the fire-box or boiler, there are a considerable number of fire-bricks of different forms introduced. Those shown at D and E are slabs three inches thick, set on edge, with open spaces one and a-half inches wide between them. At F there is a simple arch of bricks, chiefly for the purpose of carrying the fire-brick slabs shown at E, whilst part of the combustion chamber (fig. 2) is filled with hollow tiles, fifteen inches long. These tiles are so arranged that all the products of the furnaces must pass through the open spaces, and in this position they very soon become red-hot, and are able to give out sufficient heat to ignite the volatile particles of carbon and gas, when supplied with a sufficient quantity of air. The supply of air is regulated by sluices in the fire-doors, and by a series of small tubes, shown at G.

The feed-water heating apparatus is another important source of economy, and is shown in section in fig. 1. The principle of this apparatus consists in condensing and abstracting the heat from a portion of the exhaust steam, and thereby affording the great advantage of being able to feed at all times without lowering the temperature of the boiler so much as when cold water is used. This is particularly valuable when ascending long gradients, where the resources of the boiler are taxed to the utmost to keep up the pressure of the steam. The communication between the exhaust-pipe and warming apparatus is made by means of a copper tube inside the smoke-box, attached to a brass knee outside the smoke-box. Into this knee is fixed the pipe which conducts the steam along to the condenser, shown at H, underneath the footplate, where it comes in contact with the cold water from the tender. The water is allowed to flow into a copper vessel, the flat bottom of which is perforated with small holes, from which it falls in a shower, whilst the steam is blown amongst it at every exhaust of the cylinders. The steam-conducting pipe, which is $2\frac{1}{2}$ inches outside diameter, passes within a pipe 4 inches in diameter on its way to the condenser, and the large pipe is made water-tight at each end by means of a stuffing-box, as shown in the drawing. There is in this way a narrow waterspace left between the two pipes through which all the feed-water passes on its way to the boiler. The quantity of water admitted to the condenser is regulated by a float, I, which shuts a valve and never allows the condenser to get full. In feeding the boiler the water is drawn from the condenser, H, where it is partially heated; and, being forced through the passage between the two pipes already described, becomes gradually hotter by abstracting heat from the exhaust steam rushing through the inner pipe, and it can be forced into the boiler at a temperature of 200°.

The following are the general dimensions of the engine under consideration:—

Cylinders, 16 inches diameter, 22 inches stroke.
Four wheels, 5 feet diameter, coupled.

Heating surface of fire-box,	. . . .	120 sq. ft.
" " of combustion chamber,	.	66 "
" " of tubes,	. . . .	628 "
Total heating surface,	. . .	814 sq. ft.

The engine has run 25,000 miles with trains averaging from 200 to 250 tons gross, and has consumed on the average 37·5 lbs. per train mile of Ayrshire splint coal, costing 4s. 2d. per ton, which gives $\frac{84}{100}$ of a penny per train mile as the cost for fuel. To this must be added the expense of renewing bricks, which item increases the cost of fuel to $\frac{98}{100}$ of a penny per train mile.

A coke-burning engine doing the work, and using coke at 17s. per ton, costs $3\frac{20}{100}$ pence per train mile, giving a clear advantage of $2\frac{22}{100}$ pence in favour of Beattie's engine.

For the purpose of testing what amount of economy was due to the heating apparatus, the quantity of water evaporated per lb. of coal was taken accurately for several days, and was found to be 6·5 lbs. with the apparatus in use, and when the water was pumped direct from the tender without being heated, the quantity evaporated was 5·75 lbs., showing a gain of $\frac{3}{4}$ lb., or 11 per cent., in favour of heating the water. It was observed, when working without heating the water, that the quantity of fuel consumed was increased 13 per cent., which may be accounted for, if we consider that in the one case the whole of the exhaust steam was forced through the outlet orifice of the blast-pipe, whilst, on the other, a large portion of the steam found its way back to the condenser, and in this way the fuel seems to have been burned faster to keep up the pressure of the steam.

The writer regrets he has no accurate means of ascertaining what quantity of the exhaust steam is condensed, but believes it will amount to one-fourth of the whole; and if this be the case, the quantity of water evaporated will be 8 lbs. by 1 lb. of coal, as the boiler has to convert all that is condensed into steam again without getting credit for it by measurement. This seems to be a very favourable result to be obtained from Ayrshire coal, which is estimated to contain not more than 70 per cent of carbon, and it will be found not inferior to the best performance of many boilers where coke is used.

The consumption of smoke in Mr. Beattie's boiler is absolutely perfect, and with ordinary attention the engine can never emit smoke that could be considered a nuisance.

In Plate V. are represented two very simple and tolerably efficient arrangements for burning coal without smoke, and they possess the great advantage of being readily applied to locomotive boilers already constructed, at a very trifling cost. The arrangement shown in fig. 3 is the invention of Mr. Lees of the East Lancashire Railway. There is a brick arch thrown across the tube plate; and the furnace-door is so constructed, that the air admitted through it is thrown down upon the burning fuel, which causes the fire to burn clear above as well as below. The brick arch seems to throw out a counter-current of hot air, and prevents any unconsumed smoke from getting away through the tubes of the boiler. The following experiments were tried upon a goods engine, and will show the amount of duty obtained from coal used in both ways. Total heating surface of the boiler 1121 square feet. Fitted with Lees' smoke-burning apparatus 1 lb. of coal evaporated 5·5 lbs. of water. Without burning the smoke, 1 lb. of coal evaporated 5·83 lbs. of water, the result being rather against smoke-burning by this plan. Fig. 4 illustrates the invention of Mr. Jenkins of the Lancashire and Yorkshire Railway, and is very similar to the other in principle. There is a baffling plate of cast-iron stretched across the whole width of the fire-box, and air is admitted below it by three rows of hollow stays. The air is projected outwards in the direction of the fire-door, and is in this way thoroughly mixed with the gases as they rise from the coal; and if the fire is well worked, the fire-box seems to be constantly filled with clear burning flame. Neither of these are equal to Mr. Beattie's as smoke-consumers; but in careful hands they can be used without much nuisance, and their simplicity is a great recommendation to them.

In concluding this short notice the writer would express his hopes that the importance of the subject may recommend it to some of the members present, and may elicit opinions as to improvements that may be made upon locomotive engine furnaces and boilers, so that coal may be as freely used as coke.

The following paper was then read:—

On the Combustion of Coal; with Description of an Improved System of conducting such Combustion. By Mr. William Gorman.

In the early part of the year 1854 an opportunity occurred of trying an improved mode of working a steam-boiler furnace, by means of a fan blowing into a closed ashpit. On each side of the furnace door were chambers communicating with the interior of the furnace above the fuel, and with the ashpit or atmosphere when the ashpit was not closed. In the bottom part of the chambers opening to the ashpit were fitted valves of the nature of ventilating valves, vibrating on knife edges, and made as sensitive to variations of pressure as possible. On air being blown into the closed ashpit by the fan, the passage through the grate bars being obstructed by the fuel lying thereon, it inclined to pass through the valve chambers to the interior of the furnace, the valves being weighted, so that the pressure of the air through the fuel, when the gases were just about burned off, would only balance them. They would thus close altogether when the fuel burned thinner, or offered less obstruction to the air. Again, when a fresh charge was put on, the layer of coals, being thicker and denser, would offer more resistance to the air, which, acting on the valves, would open them, and admit air to the gases, and of course they would shut again when the gases were burned off. One valve in a case fire-door, with suitable air passages, would have answered the purpose quite as well; but the fan and closed ashpit were adopted, as it was intended to heat the air for combustion by the heat which usually produces draught in the chimney, according to a plan patented by the writer in 1852. The air was admitted into the furnace through a number of three-quarter inch holes, in order to effect its proper mixing with the coal gas.

Had it been possible to effect complete combustion by simply supplying air to the gases over the fuel, the above arrangements would have answered; but the coal used was unusually rich in bituminous or volatile matter, and no amount of air let in to the gases seemed to have any mitigating effect on the dense, black volume of smoke produced.

The furnace was about 12 square feet in area; the grate bars were rather wide; and the coals burned down, leaving very little solid coke. The openings for admitting air to the gases were collectively about 50 square inches in area.

From experiments with this furnace, the writer was led to the conclusions, that no amount of air admitted to the gases over the fuel would effect their combustion, unless air were prevented from getting through the fuel; and that the practice of letting in air over the fuel to the gases, in sufficient quantity to prevent smoke, was erroneous, there being no connection between the quantity of air necessary to burn the gas, and the quantity necessary to prevent smoke.

Towards the end of last century it was well known that smoke from furnaces could be prevented, by simply lifting the door about an inch, more or less, until smoke disappeared; and in 1825 we had a last century man condemning the introduction of a practice which had been thrown aside as worse than useless 27 years before; and it remains to be proved that there is a better, simpler, or more economical mode of preventing smoke, than the plan referred to.

Ordinary pit coal, which is in general use for raising steam and other purposes, may be said to consist of 82 per cent. carbon, and 5½ per cent. hydrogen; the remaining 12½ being ashes and other unimportant matter. When coal is submitted to a sufficiently high temperature, carburetted hydrogen gas is evolved—the gas in ordinary use for illuminating purposes—in a crude state. This gas is composed of two atoms of hydrogen, and one atom of carbon, the carbon being three times the weight of the hydrogen. When the volatile gases are expelled from coal, the residue is coke, charcoal, or solid carbon. The hydrogen in 100lbs. of coal weighing 5½ lbs., the carbon contained in the gas will, therefore, weigh 16½ lbs., which, added to 5½, makes 22 lbs. of gaseous combustible matter, and this subtracted from 87½ lbs., leaves 65½ lbs. of coke or solid carbon; the gaseous matter is, therefore, fully one-third of the weight of the solid carbon.

The volatile parts being combined in a solid state in coal, require to be converted into gas, which operation absorbs and renders heat latent; we may assume 10 per cent. of the solid carbon as being necessary to expel the gases from the coal, the available solid carbon being reduced to 55½ per cent. The value of the volatile parts of coal is enhanced by the heating power of the hydrogen gas, this power being four times that of carbon; so that 5½ per cent. of hydrogen is equal to 22 per cent. of carbon, which, added to 16½, makes 38½ per cent. heat due to the volatile products of coal.

The available heating power, therefore, of the volatile and fixed portions of coal stand in the relation of 55½ for the coke, and 38½ for the gaseous parts. The bicarburetted hydrogen gas, amounting to about 10 per cent., the writer has not allowed for; so that these figures do not overstate the value of the volatile gases.

If these data are correct, the solid coke or carbon being set down at 100, the volatile or gaseous parts require to be set down at 69·34.

This slight glance at the component parts of coal shows such a decided gain to be realized by the proper combustion of the gaseous portion thereof, that it is no wonder that so many hundreds of schemes have been from time to time brought forward for this purpose; but, unfortunately for science and society, too many of these schemes have turned on the mere matter of preventing or consuming smoke.

The appearance of smoke is a standing evidence that combustion is not complete; but the non-appearance of smoke is no evidence of complete or economical combustion. A far higher criterion is necessary before practically perfect combustion can be obtained, than the mere consideration of the appearance or non-appearance of smoke.

The smoke nuisance has, however, grown so formidable that society has almost resolved to put it down, whatever it may cost to do so; and it is painful to witness the expensive expedients resorted to, in order to meet the requirements of law.

It would be easy to fill a volume with the ingenious contrivances which have been from time to time brought forward to burn or prevent smoke. "Many of the plans are exceedingly complicated. Some have sets of fire-bars made to rise and fall; in some the coked coals are raised bodily up, and the cold coals introduced beneath; others are encumbered with a complex system of racks and pinions, fans, hoppers, revolving grates, and the like contrivances, requiring large outlay in the first instance, and much labour and constant attention afterwards."

Plans for merely calcining or burning smoke are evidently proposed through ignorance of the whole subject of combustion, and may, therefore, be passed over without remark.

The plans proposed by C. W. Williams and Mr. T. Symes Prideaux, are worthy of attention, in so far as they stand most prominently forward in that class of smoke-preventatives, which have for their object the complete combustion of the gaseous portion of coal.

These gentlemen have also written in the same cause, and, although differing in some conclusions, yet they both agree generally as to the combining equivalents which result in complete combustion. Unfortunately, however, for the cause in which they are engaged, they have given no chemical analysis, so far as is known to the writer, of the products of combustion as found in the flues or chimneys of furnaces in practical operation. Such analysis would at once show whether the air supplied to the gases had been in excess or otherwise, and without such an analysis there is no evidence to show in what proportion the air is supplied for the combustion of the gases.

It is well known to those who understand the subject, that in usual practice double the quantity of air which would supply oxygen sufficient for the complete saturation of the fuel, passes through the furnace; and a greater quantity must pass when air is admitted directly to the gases for their combustion without requiring to pass through the fuel. Let us suppose that 100lbs. of pit coal is to undergo combustion. It was stated that the coal selected for consideration was composed of 82 per cent. of carbon and 5½ of hydrogen; that the 5½ hydrogen, when expelled from the coal, united with three times its weight of carbon, forming carburetted hydrogen gas composed of 5½ hydrogen and 16½ carbon—22lbs., carbonic acid gas being the product of the combustion of carbon, with its equivalent of oxygen, in the proportion of 1 atom of carbon to 2 atoms of oxygen, or 6 parts by weight of carbon, and 16 parts by weight of oxygen. The product of the combustion of hydrogen, with its equivalent of oxygen, is steam, or water vapour, composed of 1 atom of hydrogen and 1 atom of oxygen, or 1 part by weight of hydrogen, and 8 by weight of oxygen.

The following will, therefore, be the chemical combinations when coals are burned without admitting air to burn the gases:—

Carbon.		Oxygen.		Carbonic Acid.
65·5 lbs.	unite with	174·66 lbs.	forming	240·16 lbs.

leaving 611·33 lbs. uncombined nitrogen, and 22 lbs. coal gas not consumed.

When the *coal gas* is consumed—

Carbon.		Oxygen.		Carbonic Acid.
16·5 lbs.	unite with	44 lbs.	forming	60·5 lbs.
Hydrogen.		**Oxygen.**		**Steam or Water.**
5·5 lbs.	unite with	44 lbs.	forming	49·5 lbs.

Nitrogen.
leaving 154 lbs. nitrogen in each case = 308 lbs.

The products of combustion are therefore—

From coke,.....	240·16	lbs.	carbonic acid.
	611·33	"	nitrogen.
	851·49	"	incombustible gases.
From coal-gas,	60·50	"	carbonic acid.
	49·50	"	steam or water.
	308·00	"	nitrogen.

1269·49 lbs. total incombustible gases, from the combustion of 100 lbs. of coal, deducting ashes, &c.

All the carbon being burned to carbonic acid, and all the hydrogen to steam, the escaping products, which pass up the chimney, must be taken at double this quantity, nearly, as the best practical combustion requires twice the quantity of air indicated by theory, to supply the equivalent of oxygen; in which case the figures will be 2451·48 lbs., nearly.

It will be seen from the foregoing figures that 65·5 lbs. coke, when supplied with oxygen, will yield 240·16 lbs. carbonic acid, and 611·33 lbs. nitrogen. If we suppose that the coal gas is expelled in the third part of the time of a charge, there will be 80 lbs. carbonic acid, and 203 lbs. nitrogen, produced in the same time. These incombustible gases rising and mingling with the coal gas must render its combustion impossible, as 3½ lbs. carbonic acid, mixed with 22 lbs. coal gas, would prevent combustion; whereas, there are 283 lbs. of gases, which are more antagonistic to flame than water, to mix with 22 lbs. of coal gas in the usual mode of working furnaces; so that, notwithstanding whatever changes it may experience, the coal gas cannot be consumed when mixed with the products of coke undergoing combustion.

Seeing that the laws of chemical union declare the impossibility of igniting the gases produced when fresh coals are supplied to a furnace, it may be asked how Williams and Prideaux, and the last century stokers, could, by admitting air to the gases, produce bright flame instead of black smoke? The answer is simply this, that by making a large opening into the furnace, above or beyond the fuel, or between the fuel and the chimney, the draught through the grate bars is weakened so much that carbonic acid is evolved in such limited quantity that partial combustion of the coal gas is permitted.

The united area of the apertures for admitting air to gases, is set down by Williams at from 4 to 6 square inches for each foot of grate surface, and this would be on an average for a grate of 18 square feet, equal to an opening of 9 by 10 inches. Now, were it not that there is a great deal of heat got from the partial combustion of the coal gas, it would be vain to attempt to raise steam under the circumstances; and the fact that, when properly managed, a gain rather than a loss is sustained, may show how much profit may be expected when the gases are properly consumed without letting in a superfluous quantity of air for their combustion.

No doubt good results have been obtained by many of the plans proposed for consuming the gases of coal, but equally good results have been realized from judicious alterations of the furnace or flue of a boiler which had not been properly built or arranged originally.

A saving of even 10 per cent. in fuel would not be disregarded if it could be relied upon; but the conditions are so fluctuating on which success depends, that it seems difficult by any fixed arrangement to obtain permanently good results.

Even the stoker would not object to adopt a system whereby he could manage his furnace, and procure steam more easily; but no stoker would ever think of opening his fire-door to improve his steam. And yet the proposal that, "if there be not enough room in the fire-door to admit a sufficient number of half-inch or even three-quarter-inch holes, then a perforated plate is to be inserted in the bridge" to admit the requisite quantity of air, amounts to something like opening the fire-door; and the writer knows it to be a regular practice amongst stokers to open the fire-door a little when the steam gets too strong, in order to lower its pressure.

Mr. Prideaux asserts that double the quantity of air is necessary for the furnace when a fresh charge is put on. If so, a double quantity of steam should be produced; but in practice the reverse occurs. Unless more steam or heat is produced when more air is admitted to a furnace, the system is wrong, and the sooner it is abandoned the better.

The report of the committee at the late competition at Newcastle-on-Tyne, may be taken as a fair account of what advance has taken place in the combustion of coal, as they give a standard of the value of 1lb. of coal, burned in the usual smoky manner; from which it appears that the successful competitor had realized fully 12 per cent. of saving in fuel with no smoke. Now, the alternate mode of firing adopted by him is quite sufficient to account for a saving of 12 per cent., without laying anything to the credit of combustion of the coal gas. An analysis of the escaping products of those experiments would show that the coal gas was unconsumed; at least, analyses can be referred to from several different boiler furnaces, where combustion is carried to a degree of perfection and economy rarely attained, and where no smoke is to be seen issuing from the chimneys, and yet the coal gas found in the flues and chimney is not sensibly diminished in quantity from what is due to the kind of coal employed.

Having thus endeavoured to show that very little profit has hitherto been derived from the gas of coal, as compared with the great per-centage of heating power it has been found to possess; the writer will now endeavour to show how coal gas may be consumed with certainty and due economy.

It was previously shown that when a fresh charge of coal was laid on a bed of incandescent coke, coal gas was evolved, the same as what is used for lighting, but in a crude state; and that when air was permitted to ascend through the grate bars and fuel, the coal gas was poisoned by the carbonic acid gas rising and mixing with it; and that no amount of heat or air would consume such a mixture. Now, if air is prevented from getting through the grate bars the coke will lie unconsumed, and give out its heat to expel the gas from a charge of fresh coal laid thereon. Air being supplied to the gases, they will ignite and produce available heat for raising steam or for other purposes. When the coal gas is burned, the air supplied for its combustion may be withheld, and air supplied to the coke or solid part of the coal until it is sufficiently consumed, when a fresh charge of coal may be supplied; and so on *alternately, consuming the gas and coke at different intervals of time.* The simplest way of carrying out this system is to have a door in the ashpit to prevent air from getting through the grate bars while the gases are being consumed. The fire-door is provided with directing passages, suitable for distributing the air into the furnace for the combustion of the coal gas, and also a valve to shut or open, and so permit or prevent the admission of air above the fuel. The ashpit door may be used as a valve, or a valve may be provided to supply the air as required, or prevent it from passing through the fuel on the grate bars. In applying the new system of combustion the usual furnace arrangements are not altered, and there is no difference in the mode of working the furnace; the simplest and easiest mode of firing being the most suitable for obtaining the greatest economy. The valves for supplying the air are connected so that one movement adjusts them both, and they require no more attention on the part of the stoker than is implied in a single movement of a lever or handle, or they may, in a simple manner, be arranged to dispense with any interference on the part of the stoker.

Many furnaces are constructed at present with doors on the ashpit, and even valves on the door of the ashpit, and also furnaces are constructed with valves in the fire-door; but the new system of combustion consists in supplying air to consume the *coke* and the *coal gas* alternately, by means of valves worked in connection with each charge of coal.

It appears strange that literature, professing to treat of the combustion of coal, should not have given a prominent place to the well-known fact —that when a furnace is in active operation the principal product of combustion is carbonic acid gas, and that coal gas, mixed with a very small part of this gas, becomes incombustible.

Seeing that experimenting on boiler furnaces on a large scale would involve considerable time and expense, it was deemed advisable to fit up a small boiler, the fire grate of which was about 13½ × 12 inches. The results obtained were highly satisfactory—indeed results as high as 33 per cent., over the usual method of firing, were obtained; the coals being carefully weighed, and the water evaporated carefully measured.

In Plate VI. fig. 1, are shown the arrangements as used on the occasion referred to. The furnace is not altered in any way from that in common use, and it is worked in the usual manner; and although the apparatus for regulating the supply of air to the gas and coke may appear a little peculiar, it is not more difficult to work than arrangements which are already in constant use.

The furnace of the boiler consists of a fire-box, A, and flue, B; the fire-box is 18 inches from the fire-door, C, to the flue, and the flue is 2 feet 8 inches long, by about 5¾ inches internal diameter; the fire-box is 15 inches wide, and 13 inches from the grate to the roof.

The arrangement for supplying air to the coke through the ashpit, D, and to the gases through the door of the furnace, is shown in section, and will be easily understood.

The furnace door does not differ materially from many that are in use; it consists of the usual outside door, C, having an inside plate, E, about 2½ inches apart, forming a double door. In the inside plate, E, are inclined holes for directing jets of air down upon the fire, and to as many different points and as far asunder as possible.

The dead-plate, F, is cast with oblong apertures like a grating, through which the air ascends to the space between the outer and inner door plates, C, E, to burn the gases. A valve, G, is hinged below the dead-plate and covers these apertures, as also the passage, H, for admitting air to the ashpit; one movement of the valve either admitting or shutting off the air to the gases or coke as desired.

It may be necessary to state again, that what is here meant by coke is the part of coal left on the grate bars after the volatile part has been expelled, the volatile part being coal gas. When a fresh charge of coals is put on the fire, the under valve is shut or nearly so; and the same movement opens the upper or gas air-valve. The gases of the coal are now being consumed, as seen in the drawing. When the gas has been all burned the valve is reversed, and the air is supplied for the combustion of the coke, and, of course, shut off from above.

After a few preliminary experiments in working the furnace, to ascertain the proper mode of burning the gas, 28 pounds of slack were carefully weighed to be used in the ordinary manner, and the same quantity for the new system; the fire was burned off, after being cleaned, until about an inch and a half of clear charred cinders lay on the grate bars in each case. The water was raised to the boiling point, and kept at the same height in the boiler during each experiment; the fire being completely surrounded with water, and there being no mass of brickwork to absorb heat, there could be no error on that account.

The firing was as regular and perfect as possible, so as to bring out the full duty from the coal; but the boiler being so small, and the slack purposely taken out of the middle of the heap, only a comparative result was expected from the experiment.

In the first experiment, with coals burned in the usual manner with smoke, 28 pounds of slack were burned in an hour; and evaporated 93 pounds water from about 45°; the water left being at 212°.

In a second experiment, in which the gas was consumed, 28 pounds were burned in an hour and ten minutes, evaporating 110 pounds water; the same conditions as to water being observed in each case.

In the last experiment, the united area of the holes for admitting air to the gas was about 3 inches. They were stopped up until their area was reduced to 2 inches, when the above experiments were carefully repeated.

There was no perceptible difference in the experiment with coals burned in the usual way, proving the accuracy of the arrangements; indeed the writer has scarcely ever seen experiments so satisfactory on a small scale.

The fourth experiment was with the gas burned. The fuel lasted 83 minutes and evaporated 123 pounds of water, showing a duty of 35 per cent. more from 28 pounds slack than the same quantity burned carefully in the usual manner. There is a difference in the time of doing the work of about 7 per cent., but this does not necessarily accompany the system, and the above gain is clearly from the superior mode of burning the gas. The flue being only 2 feet 8 inches long, and only 4 superficial feet in area, the flame was projected with such force from the flue that it was necessary to restrict the combustion, in order to prevent the great consequent waste of heat. Had there been sufficient length of flue to allow the flame to expend itself therein, higher results than the above would have been obtained, and in less time than by the ordinary mode of firing. It has been shown that a duty amounting to 50 per cent. is due to the gas of coal; and when there is a means of burning the gas with a proper quantity of air, the full duty should be obtained from it as well as from the coke.

The furnace was provided with sight holes at the front and also at the end of the flue, so that the effect of opening or shutting the air valves could be seen at every period of the charge.

The grate bars were made thin—about half an inch thick—with openings of about three-eights of an inch; and the fire was kept thin, so that the combustion might be as complete as possible.

In experimenting with the furnace fire, after the gas had been all burned, the writer was surprised to observe a copious production of flame from the glowing coke, as with so thin a fire there was no reason to expect carbonic oxide would be formed. This flame was produced by shutting the ashpit door and letting air in by the door valve; but when the ashpit door was opened the flame disappeared, although the air was still let in at the furnace door. From these experiments and other observations, it would appear that a certain velocity or force of impact is necessary for producing carbonic acid gas; and that with slow or restricted currents of air, when coke is the combustible, it is only half burned, and forms carbonic oxide. Until he had made this discovery the writer had little hopes of being able to apply his system of combustion to the ordinary purposes of raising steam without a forced blast; as a fresh charge of coal puts down the fire so much, and thereby causes the gas to be produced so slowly, that very different arrangements would be required to obtain the heat of the gas.

This power of transferring the great part of the combustion of the coal from the grate to the body of the furnace, together with complete combustion of the coal gas, promises to be of great use in the manufacture and working of iron.

Well-constructed furnaces will always produce carbonic acid when the fire-door is kept close, and air allowed free access through the grate bars; but if a large opening be made above the fuel into the furnace or flues, so as to prevent a sufficiently strong current of air passing through the grate bars to the coke, then carbonic oxide will be formed.

There exists no better means, and perhaps a better means could not be devised for the complete combustion of coke, than the usual grate bars, if they and the furnace be properly proportioned, and perhaps the proper conditions are best carried out in the locomotive; but just in proportion as a furnace is perfect for the combustion of coke, is it opposed to the combustion of coal gas. In order that gas be produced fit for combustion it must be expelled from the coal by heat, without the admixture of incombustible gases, but as if it were heated on a red-hot plate or in a gas retort.

When a furnace is in active operation, supposing the gas to be expelled in the half of the period, between two charges every pound of coal gas will be mixed with 5½ pounds of carbonic acid gas, as stated previously. This mixture is incombustible, since 2½ ounces would poison 1 pound of coal gas.

As it is impossible to consume the products of a furnace in active operation, or rather the coal gas mixed therein, the draught through the grate bars must be prevented; and whereas the usual means resorted to for this purpose is to admit an enormous volume of air over the fuel into the furnace or flues, robbing the furnace of heat in proportion as it is in excess of the requirements of the gas; the writer accomplishes the same object by shutting out all air from the furnace, except what is necessary for expelling and consuming the coal gas, and thereby obtains the full benefit of the heat due to the gas.

In conclusion the writer would remark—

1st. That no amount of air or heat will consume the gas contained in coal when it is mixed with the products of furnaces in active operation.

2nd. That the practice of letting air into a furnace to consume such a mixture is opposed to science, and failure is the immediate result.

3rd. That before the gas can be consumed the activity of the furnace draught, through the grate bars or coke, must be destroyed.

4th. That the practice of letting in air over the fuel for consuming the gas, has the effect of destroying the draught through the coke, and thus permits the gas to be burned.

5th. That the quantity of air required for this purpose does not depend on the wants of the gas, but on the conditions and proportions of the furnace and on the coals.

6th. That the quantity of air in general required for this purpose, to prevent smoke, is so large as to carry away more heat from the furnace than what is due to the gas.

7th. That the new process of combustion produces the coal gas as combustible as if it were made in a gas retort, and what will at once distinguish the gas produced in this furnace from that produced in any other furnace, is, that it may be lighted at the top of the chimney, after having passed through the flues.

Mr. DAVID ROWAN, referring to the last experiment mentioned in Mr. Gorman's paper, asked if the gain of 33 per cent. in economy was obtained from the use of the fan-blast.

Mr. GORMAN said, in the small experiment referred to, the fan-blast was not used; it was a draught-blast.

The following paper was then read:—

On the Combustion of Fuel. By Mr. J. G. LAWRIE.

IMPERFECT combustion of fuel involves a loss of heat; and the most apparent evidence of the imperfect combustion of coal, is the production of smoke. To avoid a loss of heat, from the source of which smoke is a witness, has long been a pursuit of those interested in the economy of fuel, and the plans invented for that purpose have been both ingenious and numerous.

The desire for sanitary improvement—a dominant feature of this age—has, within a recent period, introduced a new reason for the avoidance of smoke; and, notwithstanding the high importance of effecting the utmost possible economy in the consumption of fuel, there are grounds to believe that this new incentive will produce more instant and beneficial results in abolishing smoke, than would have arisen during a long time from the labours of those seeking economy only.

In economizing fuel, and also in the prevention of smoke, excellent results have been derived from slow combustion, as practised in Cornwall. Instead of the dense black atmosphere which usually clouds the chief seats of our manufactures, it is no uncommon thing there to witness a cluster of chimneys, of large dimensions, with an atmosphere over them as clear and transparent as if the fires at the bottom did not exist. It may be that the coal used in these instances is less bituminous than that of this neighbourhood; but the satisfactory result obtained is undoubtedly, in some measure, attributable to the method of slow combustion, according to which, the fires are charged with fresh coal not oftener than at intervals of from one to three or four hours. To practise, however, this extremely slow combustion, it is necessary that the boilers and fires should be of larger dimensions than are admissible in marine or locomotive machinery, or even in a very considerable portion of land engines. In these cases, therefore, other means for obtaining economy of fuel and preventing smoke require to be employed; and an annual crop of about eighty patents on this subject is obtained with the intention of supplying them.

Of these numerous schemes, the contrivances which are attended with success can be divided into two classes. In the first class, of which the object is to render smoke colourless, or to consume it after it has been produced, are comprised all the schemes, with the exception of one; and in the other class, of which the object is to burn the coal without the production of smoke, is comprised the remaining one only.

To render smoke colourless after it has been produced, which is the object of the first of these classes, has been attempted and accomplished in a variety of ways; but, through every series of intermediate steps by which success has been attained, all the methods coincide in mixing with the smoke a certain quantity of atmospheric air before the smoke is reduced in temperature below a certain degree. The consumption of smoke in this way was successfully accomplished upwards of twenty years ago by Mr. Charles Wye Williams, who, in a treatise of considerable value, entered minutely into the subject, and explained in a scientific manner the principles upon which the method rests.

Fig. 2, Plate VI., shows one of the arrangements adopted by Mr. Williams. At A B is the fire-grate; at B C the bridge built double, or with two walls, E F, and an intermediate air space, G, between them. At H, I, K, L, &c., are a number of apertures for the passage of the smoke through the bridge. An air passage connects the space, G, with the atmosphere, and a regulator, O, serves for altering the amount of air admitted to the space, G, and to the smoke in the apertures, H, I, K, L, as it passes through the bridge. When the coal is newly placed on the fire, and is evolving smoke, the regulator, O, is opened to permit the passage of air through the narrow openings, P, into the smoke; and when this regulator is adjusted to modify the quantity of air admitted in proportion to the necessity for it, the smoke is effectually consumed.

Since the days when Mr. Williams, who has received a far less than sufficient acknowledgment of his merit, first brought this subject prominently forward, a variety of changes has been proposed in the mechanical arrangements by which he sought to attain his object; but to no one of these changes with which the writer is acquainted, belongs any merit of original conception; and it is not by any means clear that any of them are more convenient when applied to boilers, for which the plans of Mr. Williams have been contrived. Mr. Williams, in his treatise, explains various forms of apparatus fitted to carry out his views, and the arrangement shown in fig. 2, which is one of them, is adapted for application to the greater number of both land and marine boilers, and for these boilers no better arrangement has, the writer thinks, been proposed. The regulator, O, Mr. Williams contemplated, should be adjusted by hand; but instead of this, a mechanical regulator, similar to that of Prideaux, could be used, and probably with advantage. This regulator should be constructed to admit the greatest quantity of air when the coal is newly placed on the fire, and to gradually diminish the quantity as the coal becomes incandescent.

Locomotive boilers did not, however, receive much attention from Mr. Williams, and none of the arrangements that he used or explained can be judiciously employed to carry out his principles in them. To Mr. Beattie, the locomotive superintendent of the London and South-Western Railway, belongs the principal share of the merit due for carrying out the consumption of smoke produced from the use of coal in this class of engines. Mr. Beattie prosecuted the subject for a number of years, and has at length effected most important improvement in the cost of working these engines. The earlier arrangements of his means for this purpose, as described in several patents, were of a somewhat, or rather were of an exceedingly crude description; but, with an unfaltering industry and by a successful perseverance unparalleled in the history of locomotive improvement, he surmounted the numerous obstacles that occurred, and now points with satisfaction to the results he has obtained. In the first six months of 1857, Mr. Beattie found the total cost of the whole fuel, including coal and coke, was 2·9 pence per train mile, being a decrease of nearly one-fourth of a penny, or fully nine per cent., as compared with the corresponding period of 1856; and again, in the six months ending with the 31st December last, the cost per train mile was 2·43 pence, while, for the same six months of the previous year, it was 2·68 pence, showing another decrease of one-fourth of a penny, or nearly ten per cent. Mr. Beattie has now so far extended the use of coal, that he burns three tons of coal to one of coke.

To Mr. Beattie belongs the signal merit of leading the way in this improvement in locomotives; but the object is so important, and his progress has been so marked, that he no longer occupies the path alone. He is followed by several engineers, by whom a variety of plans have been suggested for the same purpose, and of these, one made by Mr. Neilson, a vice-president of this Institution, appears to me to possess, in a remarkable degree, simplicity and effectiveness.

Figs. 3 and 4, Plate VI., show this arrangement, in which a water space, A, is formed across the fire-box—a number of bricks or tiles, B, being placed in parallel positions. At C there is a row of small air tubes, of which one opens into each space between the tiles, B, and one into the air passage shown in dotted lines in the body of each of the tiles. The other parts are a man-hole door, D, a funnel-shaped mouthpiece, E, connected with, and for the supply of the air tubes, C; a hinged valve, F, or adjustable mouthpiece, or other contrivance for regulating the amount of air admitted through the air tubes; a reciprocating hopper, G, actuated by an eccentric on the trailing-wheel shaft, for the purpose of maintaining the fire with a uniform addition of fresh coal, and a common fire-box door, H. In this arrangement, the manhole door, D, affords sufficient and easy access to the ends of the tubes for the purpose of repairing or replacing them; and the air channels, C, very effectively and evenly mix together the atmospheric air and the smoke before they are exposed to the high temperature of the tiles. Every part of this arrangement seems to be perfectly accessible for every necessary purpose, and the tiles, which are the only damageable part, are not only conveniently out of the reach of injury, but can be replaced with the utmost facility, as it involves little more labour to remove and replace the whole of them, than to draw the fire, and replace the fire-bars.

So far as consuming the smoke is concerned, the contrivances shown in figs. 2, 3, and 4 appear to be judiciously adapted for the descriptions of boilers to which they are applicable. These plans not only provide for the admixture of the necessary quantity of air to consume the smoke, but they also provide for its intimate mixture with the smoke, and Mr. C. W. Williams admirably explains, in his treatise on combustion, that to succeed in consuming smoke, the mixture must be thorough, and ought to be atomic.

For the purposes of sanitary improvement, all the plans which provide reasonably for an admixture of atmospheric air with the smoke, and for the mixture being subjected to the necessary temperature, are practically successful to the extent required by the acts of parliament, which do not necessitate a total consumption of smoke. So established is this now considered, that in London, where the prosecutions are conducted at the expense of the Crown, and where, therefore, no undue lenity is practised; in those instances where smoke is produced, and where means are provided for the admixture of air, and for the necessary temperature, the proprietors of the establishment are held free of responsibility, and the attendant on the machinery is fined or imprisoned.

To effect, however, an economy in the coal consumed, more is necessary than the consumption of smoke. It is necessary that the quantity of air admitted should not be much, or rather not at all in excess, of the quantity required to complete the combustion of the smoke; and all the plans which the writer has explained or referred to, and which are comprised in the first of the two classes, fail in the important particular of furnishing means by which the quantity of air required can be known, or can, with any accuracy, be measured into the furnace. There is not only, with these arrangements, the practical impossibility of effecting the thorough and atomic mixture of the air and smoke which the chemistry of the subject requires, and consequently, when the smoke is consumed, an excess of air has been admitted; but there is besides the impossibility of limiting the admixture of air to the quantity sufficient to effect such a mixture as the means of subdivision provides for. On account of the practical impossibility—by any of the means already used or proposed—of so admitting the air as to meet with accuracy the demands of the smoke, no economy has, in the writer's opinion, yet been effected by consuming smoke, or which is attributable to that cause only. Commonly enough great economy is stated to have been derived from this source; but in those instances the comparison has, the writer believes, been made, not with the result obtained from a carefully attended common fire, but with the results of one carelessly attended; and, inasmuch as the admission of air through another channel than through the fire bars, introduces an unknown and unmeasured element of loss, the writer is convinced that, with the ordinary attention which furnaces have hitherto received from firemen, and when the careful watching and occasional cooking practised in experiments have been discontinued, a loss of effect has, in every instance, been occasioned by the use of smoke consumption. In locomotives, where undoubtedly great advantage has been derived from the use of coal, the economy has arisen, not directly from the consumption of smoke, but from the use of coal, which is cheaper than coke, and which is admissible in these engines only when the smoke is abolished.

The single plan, comprised in the second class to which the writer has already referred, and of which the object is to burn the coal without the production of smoke, is the contrivance of Dr. March, a surgeon, now or lately practising in Barnstaple. Fig. 5, Plate VI., shows this arrangement, comprising a box, A, containing coal; a series of tubes, B, through which air is blown down upon the coal; and a movable table, C, to be raised as the coal is consumed. This simple contrivance effects an absolutely perfect combustion of the fuel. There is not in the fire itself, nor in any part of the flues, nor at the top of the chimney, the slightest indication of smoke. Our President in his opening address this Session referred to a furnace he had seen, of which his description agreed in some respects with this one, and the writer has no doubt, if it was this furnace which he saw, that he considers its operation one of the most beautiful facts in chemistry. In this furnace there is no unknown or unmeasured element of loss introduced. All the air is brought into atomic contact with incandescent fuel, and therefore consumed; yet in a series of experiments which the writer conducted with it twelve years ago, the economy obtained was only about 11 to 12 per cent. beyond the result obtained with a carefully attended common fire. Being aware that with this furnace, in which perfect combustion is effected in a manner entirely beyond the control of the attendant, so small an economy was attained, the writer is confirmed in the belief that the large economy so often reported as arising from the consumption of smoke in cases where perfect combustion is not effected, is entirely fabulous, and has been supposed to exist from the fact that the smoke-consuming furnace, which, during the reported experiments, was carefully nursed, had been compared with other furnaces of the ordinary construction, which received no such attention.

If it be the fact, as the writer believes, that no considerable economy of fuel or of heat is to be derived, either from the consumption of smoke or from the combustion of coal without the production of smoke, as hitherto conducted, whence is further economy to be obtained? Mr. J. P. Joule informs us that with the best-constructed engines in the country, and with ordinary furnaces of the best construction, the amount of effect obtained in power is not greater than $\frac{1}{10}$ or, at the very utmost, $\frac{1}{6}$ of that due to the heat of perfect combustion of the coal. A considerable part of this deficiency of $\frac{9}{10}$ is caused, no doubt, as Mr. Joule and Dr. Rankine point out, by using saturated steam in steam-engines instead of superheated steam, with which a much better effect is obtained; but, although the subject is not entirely within reach of analysis, there are some reasons to believe that not less than $\frac{2 \cdot 6}{9}$ of the deficiency, or $\frac{1}{4}$ part of the entire heat due to perfect combustion of the coal, or about double the quantity of heat which is utilized, is lost from the careless manner in which this combustion is effected, and is, in part at all events, recoverable by various means. Considerable efforts have been made to improve the steam-engine and to nurse the steam, but comparatively nothing has been done to improve the method of treating the fuel. Coal is the raw material with which heat is manufactured, and is the original source of the power; yet there is no other instance, in the whole breadth of manufactures, in which raw material is treated with similar inattention. There is no other instance with which the writer is acquainted, in which the raw material of any manufacture furnishes so small an amount of the manufactured produce as $\frac{1}{6}$ of that due to a perfect treatment of that raw material.

But if, in the combustion of coal for the manufacture of power by means of the steam-engine, the result obtained is an inadequate one, much more is the result deficient in the use of coal made in other manufactures. In smelting furnaces, and especially in furnaces such as are used in large forges, it would appear that a lavish waste was rather a virtue than a loss. In the combustion of fuel connected with smelting furnaces important improvements have been made; the introduction of the hot blast produced a revolution in the quantity of the coal used in smelting; but reverberatory furnaces, such as are used at forges, have, notwithstanding some feeble efforts at improvement, remained practically unchanged for upwards of half a century. The great cost and risk of experiments in these larger manufacturing operations are sufficient to render improvement exceedingly slow; but whilst vast strides have been made in improvement of the machinery for which these furnaces are required, it is remarkable that they alone would appear to be incapable of beneficial change.

For some years attention has been diverted from the improvement in the combustion of coal for the production of power, by an anticipation that the combustion of zinc in a galvanic battery for the same purpose was about to supersede the steam-engine. The discoveries of Mr. Joule, however, as explained by the President at last meeting, when proposing Mr. Joule's admission as an honorary member of this Institution, not only furnish the means of comparing the amount of power which can be obtained from different descriptions of coal, but they also afford the grounds of a comparison between an electro-magnetic engine and a steam-engine. Mr. Joule finds, that the power derived from the use of one pound of coal in a furnace, is equal in effect to the consumption of nine pounds of zinc in a galvanic battery, and therefore until zinc costs only one-ninth part of the price of coal, or until some new method of producing galvanic action at a cheaper cost is discovered, it is utterly impossible that an electro-magnetic engine can supersede one actuated by steam.

Besides electricity no other agent at present known promises to compete with steam, and it will, therefore, be well to direct attention to the improvement of the combustion of coal. With a loss of heat amounting, in the manufacture of power, to double the quantity utilized, and with an aggregate quantity of coal consumed, in this country alone, exceeding 65,000,000 of tons, of the value of £40,000,000 sterling, the scope would appear to be sufficiently extensive to enlist the best efforts of those most competent to deal with such a subject.

The problem of smoke consumption is substantially solved, but no solid advance has been made in improving or economizing the combustion of coal for the production of power, or for other large manufacturing operations.

Mr. Walter Neilson, vice-president, having taken the chair, the following statement was made:—

On the working of certain Furnaces at Messrs. Charles Tennant & Co.'s Chemical Works, St. Rollox. By W. J. Macquorn Rankine, C.E., LL.D.

Professor Rankine said he had wished that a paper on this subject should be prepared; but owing to want of leisure on the part of Messrs. Tennant & Company, that was found to be impossible; and besides, the most numerous class of the furnaces had been described in Knapp's treatise *On Chemistry applied to the Arts.* These furnaces prevented the production of smoke, with an appreciable, though not a great saving of fuel. The statement which he had to make was merely from notes of the information furnished to him by Messrs. Tennant & Company, and especially by their manager, Mr. John Tennent. The first class of furnaces to which he would refer, was one that was applied to a great many steam boilers, which were placed in almost every situation. Fig. 1, Plate VII., was a transverse vertical section of one of these boilers and its flues, internal and external; fig. 2 was a transverse vertical section, and fig. 3 a horizontal section, of the furnace, which was outside of the boiler. The furnace had two entrances, A, A, and two sets of grate bars, B, B; but within the entrance the central division, C, did not rise above the grate bars. The two sides of the furnace were fired alternately, and their gaseous products mingled. The walls and arched roof of the furnace were formed with air spaces, D, to reduce the loss of heat through them. At the back of the grate bars the furnace was tapered gradually to the size of the internal flue, E, of the boiler, fig. 1. At the back end of the boiler this central flue, E, communicated with two lateral external return flues, F, F, and these last communicated at their forward ends with a single flue, G, running back beneath the boiler to the chimney. These furnaces were introduced by Mr. John Tennent, and were improved by the late Mr. Charles Tennant Dunlop. Most of the furnaces had a cast-iron mouthpiece, with an arched top perforated with half-inch holes. The mouthpiece, which was represented in front elevation in fig. 4, and in longitudinal vertical section in fig. 5, was 12 inches high at the outer end, and tapered down at the inner end to 9 inches. Some of these mouth-pieces had doors; in others the place of a door was supplied by a heap of dross on the dead plate. When the doors were shut the air entered the furnace by the ashpit, and through the holes in the arched top of the mouth-piece. Some furnaces had brick ovens without mouth-pieces, and some mouth-pieces without ovens. The effect of the brick ovens was to produce a very high temperature, which caused a complete combustion of the products of the fuel, and thereby prevented smoke. The actual evaporation was 5·97lbs. of water per lb. of Scotch dross in furnaces with mouth-pieces and no oven; and with ovens and no mouth-piece, 6·13lbs. to a lb. of Scotch dross. From this it appeared that a slight saving was obtained by the use of the oven. The President then referred to the reverberatory furnaces used at the St. Rollox works. Every one knew that in reverberatory furnaces there was a horizontal hearth of brick on which the substances to be heated were placed, and this was roofed over by an arch against which the flame was driven, before it could get round into the chimney. This description of furnace, as formerly constructed, produced a great deal of smoke. A system was adopted of blowing them with fans; and it was due to Mr. Prideaux to say, that he was one of the first who recommended that system. Each of these furnaces was blown through two rows of holes—one above, and one below the grate bars. The air for burning the coke entered below the grate bars; the air for burning the coal-gas, wholly or chiefly above them. The regulation of the blast was left to the discretion of the workmen in charge of the furnaces; and they had learned by experience to admit the blast, during the ordinary working of the furnaces, alternately above and below the grate—above, after throwing on fresh coal, so as to consume the gas; and below, after the expulsion of the gas, so as to consume the coke. If the blast was cut off above, when fresh coal was on the grate, a great deal of thick black smoke was produced; but the instant the blast above the fuel was admitted, the smoke disappeared, and was succeeded by bright flame. There were six of these furnaces, and they were blown by a high-pressure engine of about 6 or 7 horse power, which drove a fan of 42 inches diameter by 12 inches breadth, which he had described at the first meeting of the Institution.* There was a saving in these reverberatory furnaces of 17 per cent. of the coal formerly used; but the coal so saved was at present all expended to drive the high-pressure engine. The engine, however, was capable of blowing six other furnaces, and in that case there would be a saving of fuel on the whole; and a still greater saving could be effected if, instead of driving the fan by a separate engine, a portion of the power of a larger condensing engine were applied to drive it. The President concluded by expressing his sense of the kindness of Messrs. Tennant & Co., and Mr. John Tennent, in furnishing him with the data from which he made the above statement, and drew the sketches.

Mr. Gorman asked if the smoke was prevented when the air was let in both above and below the fuel in the furnaces. It was his opinion that if the air was so admitted, the smoke would not be sensibly abated.

* *Transactions of Institution of Engineers in Scotland*, vol. i., p, 25.

The PRESIDENT said, the ordinary practice of the workmen at St. Rollox was to shut off the air below when they let it in above.

Mr. FAULDS remarked that on starting the furnaces on Monday mornings, they had to admit the air both above and below at the same time.

Mr. WALTER NEILSON, before leaving the chair, said, the information which Dr. Rankine had given the Institution was very important, especially as it referred to experiments made at the St. Rollox Chemical Works, where experiments were always made with the greatest care and in the most liberal manner. He hoped Dr. Rankine would furnish the Secretary with the measurements, so that the plans of the furnaces might be drawn to a scale for the benefit of the Institution.

The PRESIDENT, having resumed the chair, said that, in consequence of the lateness of the hour, the discussion of the papers which had been read would be adjourned to a Special Meeting fixed for Wednesday, 2nd March.

THE SIXTH MEETING of the Session was held in the Philosophical Society's Hall, on Wednesday, 2d March, 1859—the PRESIDENT in the chair.

The President, in the name of the council, proposed the following gentlemen for election as honorary members:—

ROBERT STEPHENSON, Esq., M.P.
Professor R. CLAUSIUS of Zurich.

The meeting unanimously elected as honorary members the two gentlemen proposed at the last meeting.

The following donations of books were laid on the table:—

Naval Services in Chili, Peru, and Brazil, from the author, the Earl of Dundonald.

Experiments on Mixtures of Cast-iron and Nickel, from the author, William Fairbairn, Esq.

A vote of thanks was passed for these donations.

The meeting proceeded to discuss the subject of

The Combustion of Coal,

in connection with the papers read at the preceding meeting—a few notes, supplementary to Mr. Gorman's paper, and incorporated in the paper as already given, having been first read—

Mr. D. K. CLARK described a plan applied for the prevention of smoke in locomotives. It was based on the principle that there must be plenty of air to burn the gases, which was to be introduced above the fuel and thoroughly intermixed with the gases. Such intermixture was of the greatest importance, and formed the essence of all successful plans for burning smoke. His arrangement consisted in the use of openings along the two sides of the furnace, as close as possible to the level of the fuel, by which openings the air entered in horizontal lines at right angles to the ascending gases, with which it was forcibly mixed by means of jets of steam of one-sixteenth of an inch in diameter. The jets of steam were used principally when the engine was standing, with the aid of a moderate draft from a ring jet in the chimney to carry off the products of combustion. They could be shut off when not required. He recommended that the grate-bars should be placed close together, with narrow air-spaces, and that the ash-pan and damper should be tightly fitted; whilst the level of the fuel should, at all times, be below the air-tubes. Fig. 6, Plate VII., was a horizontal section through a locomotive fire-box, taken at the level of the air-tubes. Fig. 7 was an enlarged section showing the construction of one of the air-tubes and its steam jet. This plan was successfully adopted on the South-Eastern and Eastern Counties Railways, and the result obtained was, a consumption of only 27 lb. of coke to the mile, and 29½ lb. of coal. The water evaporated by a pound of coal was 7½ lbs., and 7¾ lbs. to a pound of coke; but he ascribed the lowness of these figures to the circumstance that the fire-box to which the plan had been applied was too large.

Mr. Walter Neilson said he had to submit some very good results obtained by Mr. Yarrow of Arbroath. His arrangements were shown in figs. 1 and 2, Plate VIII., which were respectively a longitudinal and a transverse vertical section of a locomotive fire-box. The fire-box was crossed by a brickwork arch or mid feather, A, which was made perfectly tight, and which rose in an inclined direction from beneath the tubes at the front of the fire-box, towards the furnace door, B. Eight studs were screwed into each side of the fire-box to act as abutments to the arch. Air was admitted through a number of bars, C, arranged with a slight inclination at the front lower part of the fire-box, and resting on a cross-plate rivetted to the fire-bar frame bearer. The air entered to the bars, C, by an opening, D, which might have a valve adapted to it. With these arrangements, the fire gases were retained in the furnace a much longer time than in ordinary furnaces, because the fuel as it was put in was thrown forward beneath the arch, A, and the gases being unable to escape directly to the tubes because of the arch, were compelled to first pass towards the fire-door, B, and then forward over the top of the arch, A. In this way a complete and smokeless combustion was obtained.

Tabular Statement of Experiments with Engines belonging to the Scottish North-Eastern Railway Company, showing the result of a few trips over that Railway.

The greatest altitude attained on this line was 340½ feet above the level of the terminal station, and of this, 234¼ feet had to be surmounted in 7 miles, and the heaviest gradient on this part of the line was 1 in 91.

There were various other heavy gradients on the line; for instance, on another portion, 171½ feet had to be surmounted in a distance of 3½ miles. Mr. Yarrow considered the mode indicated by the table of testing the saving properties of a particular form of fire-box, and the steaming qualities of any particular kind of fuel, as compared with another, as the most correct which could be instituted; since, when the several experiments were all conducted with the same engine, it mattered not so much in what particular order that engine was, as regarded its valves, pistons, &c., the true value of the experiment consisting not so much in the result shown as regarded the consumption of fuel per mile, as in the amount of water evaporated by a given quantity of fuel.

No. 4 ENGINE.

From	To	Miles.	Total Fuel Consumed.			Water Evaporated.	Lbs. of Fuel to Evap. a Cubic ft. of Water	Lbs. of Water Evaprtd. by a lb. of Fuel.	Load.	Lbs. of Fuel per Mile.	Cubic ft. in Fire-box at end of Journey.	Kind of Coal.
			tns.	cwt	qrs.	lbs.						
Arbroath	Aberdeen	57¾	..	9	2	·897	7·38	8·43	3·00	18·66	·87	Wellwood.
Aberdeen	Perth....	90¼	..	18	0	1·901	6·60	9·42	6·67	22·40	2·84	Drumclair.
Perth....	Aberdeen	90¼	1	2	1	1·991	7·79	7·98	9·98	27·68	3·06	
Aberdeen	Perth....	90¼	1	3	2	1·907	8·59	7·24	9·26	29·24	1·96	Watson's.
Perth....	Aberdeen	90¼	1	4	0	1·947	8·60	7·24	9·16	29·86	1·53	
Aberdeen	Perth....	90¼	1	4	2	1·981	8·62	7·21	7·25	30·48	2·62	
Perth....	Aberdeen	90¼	1	5	3	1·845	8·73	6·39	9·11	32·04	1·64	

No. 9 ENGINE.

From	To	Miles.	Total Fuel Consumed.			Lbs. of Fuel to Evap. a Cubic ft. of Water	Water Evaporated.	Lbs. of Water Evaprtd. by a lb. of Fuel.	Load.	Lbs. of Fuel per Mile.	Cubic ft. in Fire-box at end of Journey.	Kind of Fuel.
			tns.	cwts	qrs.							
Arbroath	Aberdeen	57¾	..	14	0	10·90	·891	5·68	4·69	27·50	2·18	Watson's.
Aberdeen	Perth ...	90¼	1	7	0	8·81	2·138	7·07	10·61	33·60	0·87	
Perth....	Aberdeen	90¼	1	3	0	8·85	1·813	7·03	6·62	28·62	2·18	Drumclair & Cuttlebill
Aberdeen	Perth ...	90¼	1	2	2	7·99	1·963	7·78	9·20	28·00	2·18	
Perth ...	Aberdeen	90¼	1	2	0	8·24	1·871	7·59	8.16	27·37	2·40	Watson's.
Aberdeen	Arbroath	57¾	..	18	0	9·82	1·278	6·33	7·67	35·36	1·09	
Arbroath	Aberdeen	57¾	..	11	2	10·02	·784	6·08	3·00	22·59	2·18	
Aberdeen	Perth ...	90¼	1	4	0	7·95	2·105	7·83	9·51	29·86	1·09	
Perth ...	Aberdeen	90¼	1	0	1	7·41	1·906	8·40	6·82	25·20	4·37	Drumclair.
Aberdeen	Perth ...	90¼	1	2	0	..	..	..	9·64	27·37	2·18	
Perth ...	Aberdeen	90¼	1	0	0	7·64	1·825	8·14	8·65	24·88	1·96	
Aberdeen	Arbroath	57¾	..	11	0	6·65	1·154	9·36	4·59	21·61	1·09	
Arbroath	Aberdeen	57¾	..	10	1	6·40	1·116	9·72	7·23	20·14	1·09	Coke.
Aberdeen	Perth ...	90¼	..	19	2	7·89	1·724	7·89	7·30	24·26	2·07	
Perth ...	Aberdeen	90¼	1	0	0	8·06	1·731	7·72	6·62	24·88	1·31	
Aberdeen	Perth ...	90¼	1	1	0	8·01	1·829	7·77	8·75	26·13	1·31	

Mr. DEWRANCE remarked, that it was of great importance to be able to burn coal, and particularly the Scotch coal, in locomotive engines, as the white-ash coal was considerably less injurious to the fire-box than coke.

Mr. Stirling, referring to Mr. Gorman's plan, fig. 1, Plate VI, observed, that he feared that unless a considerable quantity of air were admitted through the ash-pit, the fire would go out.

Mr. Clark, in reply to the President, said he had no doubt that it was easier to keep up steam with coal than with coke.

Mr. Lawrie feared that the introduction of the surplus air and steam in Mr. Clark's plan must have the effect of reducing the heat. By this plan flame would be produced from the smoke, and this he took to be a strong proof of imperfect combustion.

Mr. J. R. Napier said he would be glad to know whether any of the gentlemen present had ever found a saving of steam or fuel from burning smoke.

Mr. Clark said he found a saving, inasmuch as coal would go as far as coke if properly burned.

Mr. Napier remarked that in marine engines he never found the advantage of burning smoke. With regard to Mr. Gorman's plan, he mentioned that Dr. Arnot had one in which the air had no access from below, and the fire did not go out as Mr. Stirling feared.

Mr. Lawrie was satisfied that there was no saving to be derived from the consumption of smoke.

Mr. B. Connor said that, in the engines of the Caledonian Railway Company, the use of coke had been given up, and that of Wishaw coal adopted, the consumption of which was 18½ lbs. per mile; and he found that steam was not only got up more quickly with coal than with coke, but also that it could be maintained at a high pressure with greater ease. He was having a locomotive altered for the purpose of trying Mr. Clark's plan.

Mr. D. More explained a simple plan for smoke consumption which he had adopted. Air was admitted below the fire bars through three tubes of three inches' diameter, extending back some distance beneath the bars, and in the intermediate spaces were placed smaller tubes. The furnace door was perforated and covered with wire gauze. The furnace was always open below, and a little air admitted at the top.

Mr. Napier said there was no difficulty in burning smoke, the only question being, could it be done economically.

Mr. More said he found from a register of his engine, which was of 20 horses power, from 1854 to 1857, that it formerly consumed nearly 20 cwt. of coal a day, whilst, since he adopted the plan referred to, the consumption was reduced to 17½ cwt.

Mr. M'Farlane said it had occurred to him that a great waste of heat arose from admitting air below the fire, and that if he could prevent that, smoke would be prevented. In order to try this, he made the floor of the grate of fire-bricks, and admitted only one current of air to the fire, and the effect was what he had anticipated.

The PRESIDENT remarked that good results had been obtained at Campsie and St. Rollox works from the use of a fire-brick hearth, and the only objection was the difficulty of removing the cinders; but great advantage was derived from making two-thirds of the furnace floor of brick, and one-third of bars.

Mr. STIRLING, referring to figs. 1 and 2, Plate VIII., asked what was the difference between the arrangement and effect of the brick arch in it and in Mr. Beattie's plan. For his part he could see no difference.

Mr. D. ROWAN said that, in Mr. Beattie's plan, it would appear that a copious supply of air was not sufficient to burn the smoke, without the use of a heating apparatus—such as the bricks—otherwise the water-spaces, A. would have a cooling effect; whereas, in Mr. Yarrow's plan, the case was different. He remarked also that smoke was produced more from the want of sufficient heat than from the want of a sufficient supply of air. The water-spaces in Mr. Beattie's plan would circulate the gases; but without the brick-heating apparatus there would not be enough heat in the furnace to consume them and prevent smoke, and they did not burn until they impinged upon the hot bricks.

Mr. STIRLING contended that Mr. Beattie's plan was superior to Mr. Yarrow's, inasmuch as if the bricks were taken out of the latter's furnace, smoke would be produced; whilst, if they were removed from the former's, the effect would be to only slightly reduce the smoke-consuming power of the furnace, which would still, owing to the circulation of the gases by the water-spaces, be a smoke-burning furnace.

Mr. D. MORE thought the same might be said of Mr. Yarrow's plan if the arch was removed.

Mr. STIRLING knew from experience the advantage of Mr. Beattie's plan. Even if the furnace was used without the bricks, it had the advantage of being capable of alternate firing on account of the water-spaces which reduced the production of smoke very much. If used with the bricks, there was no smoke at all from it.

Mr. D. K. CLARK said that he found from experiments made a few years ago, that the introduction of the bricks entirely prevented smoke. He explained that the jets represented in his plan were not to be used continuously, but only when it was found that the fire required them. They were usually turned on when steam was shut off as the engine approached a station. He did not think that the use of the jets occasioned any loss of heat.

Mr. GORMAN observed that it was a new theory to him that flame in a furnace was an evidence of imperfect combustion, except in the case of coke. He found the expedient of leaving the fire door about an inch open, as effectual a plan for consuming smoke as all the bricks and other contrivances patented for the purpose. In reply to Mr. Stirling, he explained that, in the plan he suggested, there was a very small supply of air admitted below the fire, in order to allow of the production of combustible gases.

Mr. W. Neilson said it would be interesting to see a calculation of the saving that could be effected in a year by the use of coal instead of coke in locomotive engines. He also thought there must be economy in consuming smoke, if properly managed. In order to consume smoke economically, he would recommend the adoption of larger boilers than those now in use.

Mr. Dewrance said he had tried Williams' smoke-consuming plan in Liverpool. The ash-pit door was shut, and the furnace door perforated and fitted with valves. The result was a saving of 25 per cent. of fuel, or 25 per cent. more work done if the full quantity of fuel were used. In another experiment made on a larger boiler, the saving was about 50 per cent. He found from experiment on an engine on the Liverpool and Manchester line that, weight for weight, coal and coke did the same amount of work, but the coal was much less injurious to the fire-box than the coke—the loss in wear and tear on fire-boxes from the use of the latter being exactly 25 per cent. On testing the ashes or deposit of the coke, he found a large deposit of copper, but could discover no trace of it in the deposit of the white-ash coal.

Mr. D. More referred to the recent endeavours of the Institution to induce manufacturers, and persons using steam power in Glasgow, to form an association for improving their boilers, and for the prevention of smoke. He regretted that they had not been so successful in their undertaking as the Manchester Society had been, but hoped that the matter would yet, and very soon, be taken up by the manufacturing classes.

The President remarked that the Manchester Society had been very successful in their operations; but the manufacturers of Glasgow did not yet seem to be alive to the importance of the subject.

The thanks of the meeting were voted to the authors of the papers read, and to those gentlemen who had supplied additional information.

THE SEVENTH MEETING of the Session was held in the Philosophical Society's Hall, on Wednesday, 16th March, 1859—the PRESIDENT in the chair.

The meeting unanimously elected as honorary members the two gentlemen proposed at last meeting.

The following paper was read:—

On Patent-Law Reform. By EDMUND HUNT.

THE object of the present remarks is simply to introduce the subject of Patent-Law Reform for discussion by the members of this Institution. When the subject was first proposed, it seemed desirable that it should be discussed at the present time, because it was generally understood that the Government contemplated introducing a measure to amend the patent laws during the present session of Parliament. A question has since been put in the House of Commons to ascertain the intentions of the Government in this respect; and it has been stated that there is no intention of bringing forward such a measure this session. Notwithstanding this, however, the want of some amendment in the patent laws seems to be so generally felt, that the writer considers it far from unlikely that a measure may still be introduced this session; and if not so soon, at any rate early next session. In any case, we cannot discuss the subject at too early a date if we wish to give the results of our deliberations a chance of embodiment in any new law that may be passed.

No section of the inhabitants of these realms can be more interested in the subject than that having Glasgow for its centre—and of such section, none more than the engineering portion—whilst the proportion of patent taxes contributed from this district entitles the contributors to expect a proper respect for, and consideration of any suggestions they may offer. By no body or society, however, in this district, can the matter be more appropriately taken up than by this Institution—the members of which cannot but be qualified to give valuable suggestions towards the obtainment of really beneficial enactments, seeing that every individual of them has, directly or indirectly, experienced something of the working of the existing patent laws. Many of them are themselves patentees, and more would undoubtedly be so under an amended state of the laws; whilst such as are neither patentees nor inventors, are the customers of patentees, and may represent the public interest as opposed to that of patentees.

As you are probably aware, the subject is now being discussed in other parts of the kingdom, and in the engineering press. At Manchester a public meeting has been held, at which there was adopted a petition to Parliament embodying several suggestions of amendment in the laws, and prepared by the Manchester branch of the Patent-Law Reform Association. These suggestions can be discussed by you, and if you approve of them, you can assist in impressing upon the legislature the desirableness of adopting them. The writer hopes, however, that you will do more than this; for there are many points of importance about which the Manchester petition is silent.

The Manchester suggestions relate—1, To the taxes payable to Government for patent rights; 2, To the use of the surplus funds formed by the excess of the taxes over the expenses of the Government patent office; 3, To the appointment of additional commissioners; 4, To the formation of a special court for trying patent cases; 5, To the imposition of a penalty on all persons selling goods as patented which are not so; and, 6, To the simplification of the modes of obtaining patents in, or extending them to the colonies.

Before detailing the suggestions relating to taxes, it may be well to make a short statement of the present state of matters in that respect:—Before 1852, it cost about £500, including all expenses, to obtain three patents together extending over the United Kingdom; now, a single patent, extending over the United Kingdom, costs, in Government taxes, £175, if kept up for fourteen years; and, in agents' charges, from £16 to £40, or £50 in extreme cases. Of the £175 Government taxes, £25 is paid in various separate sums upon the application for a patent being made, and within six months after it; £50 is paid at the end of the third year; and £100 at the end of the seventh year. As the last two payments are expected to be provided for out of the profits of the invention, and need not be paid if the patentee does not care to keep up the patent, it is usual to consider the cost of a patent as being £25—the taxes payable during the first six months, *plus* the agents' charges for the preparation of documents, drawings, &c.—say in all, forty to fifty guineas in ordinary cases. Now, the Manchester petitioners wish to make the taxes payable during the first six months £15 instead of £25; that is, to reduce the cost by £10, or from 20 to 25 per cent. Instead of the taxes now payable at the ends of the third and seventh years, they propose to substitute a tax of £25, payable at the end of the fifth year, that is, to deduct 83 per cent. from the taxes for keeping the patent in force.

This question of the taxes is evidently the first we ought to consider, as being the most important. What will, in all probability, be the effect of the proposed reduction? At the last reduction of taxes, the annual crop of patents increased from 523 in 1850, and 454 in 1851, to an average of 3000 since 1852, and we may expect a further increase on the taxes being again reduced. The reduction in 1852 opened the door to a great number of perfectly worthless inventions (in the first two or three years there were annually ten to twenty mechanical "perpetual-motion" schemes; during the last year, the writer has not observed so many, although they are occasionally to be met with); but, perhaps, the worst evil arising from the increased facility in obtaining patents consists in the patenting (or, in most cases, the merely provisionally protecting) of numerous really valuable inventions by parties not in positions to work out their ideas to practical and useful results—some of such parties wanting the requisite funds, and others, to whom the writer more particularly refers, being engaged in business pursuits of a nature totally dissimilar from that of their inventions.

An evil arising from the great number of patents, is the difficulty of ascertaining what is, and what is not patented. It was extremely fortunate that when, in 1852, the act was passed, which resulted in the enormous increase in the number of patents already referred to, steps were at the same time taken by the Government to mitigate this evil by printing and distributing the specifications. Notwithstanding this, however, the evil referred to must increase with the addition to the existing stock of each succeeding patent, whilst a further reduction of taxes must notably *enlarge the rate* of such increase.

There can be no doubt that the reduction of the patent taxes will be a boon to inventors, and through them to the public generally; but the value of the boon will be considerably enhanced if a measure can at the same time be devised which shall have the effect of reducing the number of patents for valueless and abortive inventions. The writer has long thought of a measure which would, he hopes, have such an effect, besides doing away with some other evils attending the present system. The proposed measure is extremely simple, and on its first mention it may not meet with the approval of many—with that of patent agents generally it certainly will not, and lawyers will probably raise many objections to it. A lengthened study and consideration of it, however, has given it some importance in the writer's eyes, and he trusts it may be impartially discussed.

One remarkable result of the working of the Patent-Law Amendment Act of 1852, is the enormous revenue yielded in excess of the expenses attending the Government patent office. This has accumulated since 1st October, 1852, and now amounts to nearly £100,000. If, at the present time, this revenue were derived from what would be openly called lotteries, the Government would be exposed to perfect storms of condemnation from all quarters; and yet, in the writer's opinion, there is as much ground for censure as regards this patent revenue. It is true, the Government has been asked, and there is some reason to hope it will consent, to use this revenue for the benefit of the patentees who have contributed to it, in which case, of course, it will not be chargeable with the possession of revenue improperly obtained. If the patent laws are not amended, however, patentees will, with few exceptions, continue to be little better than lottery gamblers. The laws, as they now stand, force them to be so. It may be said that, in a vague sense, every occupation of life has something of the lottery about it, but more than this is meant in the present case.

As the laws now stand, there are very few cases, indeed, in which an inventor can assure himself of the mechanical feasibility, let alone the practical or commercial success of his invention, before spending money in obtaining a patent. In obtaining such assurance he must, in very many cases, *publish* his invention more or less; but the law says the patent is invalid if such publication takes place before the patent is applied for; in other words, the inventor must purchase a provisional protection lottery ticket, and take his *chance* of a prize with the rest. Some years' experience in these matters has convinced the writer that nothing tends so much to swell the lists of patents as this one little lottery regulation—"Apply for your patent before proceeding to ascertain the value of your invention."

But this little regulation is productive of more extended evil than at first appears. We all know how prone we are to throw good money after bad, vainly hoping thereby to recover all. Many an inventor, who if he had been able to test his invention before investing in a patent, would soon have relinquished it, his purse very little the lighter—now persists in a vain pursuit simply because of the amount he has so invested; and not liking to lose this, ends by losing much more. There are a few cases where such persistence results in success—another exemplification of lottery-like character. Again, when an inventor first applies for his patent, he must produce a provisional specification or description of his invention. It is not to be expected that at this stage, when his invention is but a crude embryo, he, or the best agent he may employ, can make this document altogether what it should be; and yet it is required by law expressly to prevent the patentee from afterwards adding to his patent any important improvements that may occur to him during its six months' progress to completion. It very frequently happens that the most valuable part of an invention only acquires value in the inventor's eyes from experiment or practical trial after the patent is applied for, and that it is not sufficiently explained in the provisional specification to afford ground for a valid claim in the final specification. At present such a defect can only be remedied by taking out a new patent for the part in question; but rather than go to the extra expense of this step, many an inventor enters the claim he wants in the final specification of his original patent, and runs the risk of its invalidity being discovered. It is true, this arrangement is supposed to prevent a patentee from incorporating in his final specification the inventions or improvements of others; but surely a better measure could be devised to prevent a man from stealing, than one which denies him the use of his own property. Altogether the practical effect of this arrangement as to the provisional specification combined with the "lottery regulation" requiring an inventor to apply for a patent before he well knows what his invention is, is to make a great proportion of existing patents invalid, by reason of there being claims in the final specifications for which the provisional specifications contain no sufficient grounds.

Patent rights or monopolies have more of the commercial than any other character. The inventions which are most meritorious in a scientific sense, are generally not the most successful commercially. Viewed commercially, successful inventors receive, through the action of the patent laws, a recompense more justly proportioned to their respective merits than could be given them in any other way. The law says—only the patentee shall make and sell—but the law cannot force the public to use or buy; each invention must do that itself, according to its value. The granting of a mere nominal patent right has nothing whatever to do with the commercial success or failure of the invention, whilst the cost of the patent must be regarded as a tax on the profits derivable from the invention; the patent laws obviously implying that the inventor deserves these profits as a reward. As long as we pay taxes at all, we cannot expect to be exempt from taxes on such profits; but it is hard to be called upon to pay them so long before enjoying the profits upon which they are charged; and it is harder still, for those not fond of lottery gambling, to pay them without some solid grounds for counting on such enjoyment. As just mentioned the patent laws imply that an inventor deserves reward, and they give him the patent simply as an expedient for securing that reward. Why make the security so uncertain as it practically is at present? What harm can possibly result from the inventor's ascertaining practically if his invention merits reward, before spending money for a mere nominal title? Indeed, if practicable, it would not be very much out of the way for the Government to ascertain the actual merit or practical value of inventions before taking steps to secure rewards to the inventors. One would expect caution to lead them in that direction rather than in the very opposite one, as is the case.

It may be said that the proper remedy for the defect complained of lies in the inventor's hands. Let him consider his invention more carefully before rushing into the patent list. This is, however, very much more easily said than done. The very process of invention renders the inventor less capable than before of carefully considering the invention, which places itself before him as the offspring of his own brain in the most glowing sunlight; and a lengthened study of it but brings out more beauties in his eyes. Besides, every inventor will tell you it is impossible to consider the matter more carefully than he has done.

Before proposing a measure for doing away with the present lottery-like character of patents, it will be well to inquire if there is any benefit to any one in the arrangement which imparts this character. It is true, it increases the number of patents, and in consequence the patent revenue; but this argument would not avail much in the case of an ordinary lottery revenue. The lawyers will say, that something of the kind is necessary to fix the date of the invention. If it can be proved that an invention was publicly known or used before a certain date—at present the date at which the patent is applied for—the patent is invalid. What harm can it possibly do to make this date a few months later or a few months earlier than the nominal date of the patent? The evidence at patent trials must still be the same, only the date to which it refers will be different. A patent is never sealed until some time after the first application for it. Under the old law—before 1852—the date of sealing was the date to which everything connected with the patent was referred. If a person on inventing anything immediately applied for a patent, but did not get it sealed, say, for four months, there was a possibility of his invention being published during those four months, so as to render his patent invalid. One of the greatest improvements of the Patent-Law Amendment Act of 1852 was to make the patent date back to the date of the original application for it, notwithstanding that it might not be sealed for nearly six months afterwards. The writer refers to this to show that there is a precedent for making a patent refer to a date prior to that on which it is in reality granted.

This brings us to the proposed measure. Let it be declared in any new act relating to the patent laws that—

"Any publication of an invention by the inventor for a certain time—six months, for example—before he applies for a patent, shall not invalidate such patent. The actual use during that period by another party not authorized by the inventor, shall invalidate the patent. The publication, during that period, of a description of the invention, shall not affect the patent, excepting in so far as it may bear upon the patentee's claim to be an original inventor." *

* Three days after this paper was read, there received Her Majesty's Royal Sanction an act for INDIA, entitled "An Act for granting exclusive privileges to Inventors," and con-

At present parties may take two courses in obtaining a patent. They may lodge a provisional specification, and six months afterwards a final complete specification; time being thus afforded them to complete their plans, though, as before mentioned, not to introduce any improvements of importance. Or they may lodge a complete specification on first applying for the patent, having, of course, no opportunity of afterwards remodelling this document. It will be well, in case the proposed measure is adopted, to make it applicable only where a complete specification is lodged on making first application; the law remaining unaltered as regards those who wish to take the six months for the preparation of their complete specifications.

The proposed measure may be expected to reduce the number of applicants for patents; for many inventors will put their inventions in practice before spending money on a patent, and in many cases, finding no practical improvement on previous plans to result, will abandon them. In most cases, the schemes thus tried and abandoned will be better out of the patent lists. In some cases valuable inventions may be lost for want of the perseverance which the fact of having invested money in a patent would otherwise have given their authors; but these cases will be few, as inventors are generally too sanguine to give up, as long as an invention exhibits a spark of promise.

The number of patents thus taken out of the lists will, however, be partly at least replaced by patents for inventions of value, which, under the existing state of things, do not get patented. And here we shall have a very valuable result of the working of the proposed measure. It is well known that many valuable inventions have never been patented; they have been devised in the ordinary course of business, perhaps, and not

taining the following remarkable clause, showing that our Indian legislature is in advance of that at home.—E. H.

"An invention shall be deemed a new invention within the meaning of this Act if it shall not, before the time of applying for leave to file the specification, have been publicly used in India or in any part of the United Kingdom of Great Britain and Ireland, or been made publicly known in any part of India or of the United Kingdom by means of a publication, either printed or written, or partly printed and partly written. The public use or knowledge of an invention, prior to the application for leave to file a specification, shall not be deemed a public use or knowledge within the meaning of this section, if the knowledge shall have been obtained surreptitiously, or in fraud of the inventor, or shall have been communicated to the public in fraud of the inventor or in breach of confidence: provided the inventor shall, within six calendar months after the commencement of such public use, apply for leave to file his specification, and shall not previously have acquiesced in such public use: provided also, that the use of an invention in public by the inventor thereof, or by his servants or agents, or by any other person by his licence in writing, for a period not exceeding one year prior to the date of his petition, shall not be deemed a public use thereof within the meaning of this Act."

been much thought of at the time; or the inventor has had an objection to a patent, or wanted funds, or has been without sufficient faith in the commercial success of the invention. In a few months the invention has proved itself worthy of a better fate; and the inventor, encouraged, at once consults a patent agent. He is then cruelly told he cannot get a valid patent, because he has already published his invention. The term "publish," in connection with patents, signifies "publishing in a book or periodical, using in a public manner, putting others in the way of being able to use," &c. The writer's own experience proves, that there are more cases of this kind than is generally supposed. And in addition to inventions failing to be patented in this way, many invalid patents are taken out at the risk of the prior publication being afterwards proved. The proposed measure would remedy all this.

Of course the inventor must run the risk of his invention being used by others in consequence of his publishing, but he will doubtless publish it cautiously, and not more than is necessary. Besides, when he has got his invention to such a condition of perfection or success as he fears may induce other parties to adopt it, he immediately secures his patent.

If it should be found that there are insurmountable objections to the proposed measure, there is an alternative measure meeting some of the evils complained of. Thus, it might be enacted that, if an inventor finds, after lodging his provisional specification, that it does not cover some important points which have turned up in working out his invention, he may make a valid claim for these in his final specification; such claim, however, being subject to be declared void, not only if it shall be proved that the matter claimed shall have been published before the date of original application, but also if it shall have been published before the filing of the final specification, or if it be described in the provisional specification of any other party lodged before the filing of the final specification.

This measure might also be adopted along with the first one mentioned.

In proceeding to discuss in detail the Manchester suggestions as to the reduction of taxes, we find they propose to retain the £5 tax on the application for a patent, taking the reduction entirely off the subsequent taxes. Were the writer's measure to become law, it would not matter much to those availing themselves of it in what separate sums the taxes were payable; but, in the absence of such a measure, the question is worth considering. Is not the first payment as much felt as, if not more felt than any, seeing that then the value of the invention is more uncertain than at any other time? Again, with the first payment there is necessarily required a larger proportionate payment to the agent than at any other stages except the final one. Would it not be better, therefore, to reduce this first payment, rather than those accompanied by smaller proportionate agency fees. A common reason urged for reducing patent taxes, is to enable poor but meritorious inventors to obtain patents, or rather to protect themselves so as to render their inventions marketable. The usual plan is, for a poor inventor, to purchase provisional protection, and then sell the whole or a portion of his invention to the capitalist, who pays the remaining taxes required to complete the patent. According to the Manchester suggestion, the poor inventor is to be saved nothing, whilst the capitalist is to derive all the benefit of the reduction. Altogether, the first payment should at least participate in any reduction that may be made. The Manchester suggestion reads very much as though compiled by a class able to risk a £5 note now and then, but who never considered those with less money to spend.

With reference to the Manchester proposal to substitute for the £50 tax at the end of the third year, and the £100 tax at the end of the seventh year, a single one of £25 only; it may be said that, to a certain extent, it has the same fault as the other proposed reductions. If taxes are to be paid on the profits arising from inventions, it is surely better that the larger portion, if not the whole, should be paid when the profits are being reaped. It is said, and with truth, that the majority of important patents do not commence to yield profits until the fifth, sixth, or seventh years of their duration. If this is the case, make the present £50 tax payable at the end of the fifth year, and the £100 tax payable at the end of the tenth year. But if these taxes are to be reduced, let the earlier expenses share to a greater extent in the reduction. A sound principle on which to adjust the patent taxes, would consist in making the taxes which are payable during the first six months barely sufficient to cover the expenses of the Government patent office; and in levying extra taxes, at a period not earlier than the average at which patents ordinarily commence paying, on the profits, of receiving which there is then some probability.

In the case of French, Belgic, and some other continental patents, an annual tax is payed, and it has been proposed to adopt something of the same kind here; but there are objections to it, chiefly arising from the machinery (if that term may be used) involved in collecting it. If it were to be adopted, the annual tax should be as small as possible at first, and gradually larger as the profits arising from the invention may be supposed to increase.

The Manchester petitioners suggest that the surplus funds arising from patent taxes, in excess of the Government patent office expenses, be set aside to be expended in promoting the progress of invention and science. This is all very well, but it will be very generous on the part of the Government to give up this revenue. When the system of patents is properly regulated, this patent revenue is as much a tax on commercial profits as any other existing tax, and the Government has as much right to impose it. It is, indeed, less objectionable than many other taxes. The party who actually pays the tax, gets in return what he may convert into a valuable consideration, and the public are not losers in consequence of the monopoly, because, without the reward thereby held out to the inventor, they would be without very many of the improvements the inventor is induced by that reward to produce.

The third proposal of the Manchester petitioners is to appoint scientific commissioners to assist at the granting of patents—what for, is beyond the writer's comprehension. It is impossible that any scientific examination, before granting a patent, can do anything but injury. All the examination necessary is, to see that the documents lodged are formal. It is far the fairest way for the inventor to take the risk as regards the novelty of his invention and the validity of his claims.

The fourth of the Manchester proposals is, to provide a special court for trying patent cases, at which neutral scientific persons are to act as jurors, their services being paid out of the surplus fund. This question is worthy of much more consideration than the writer can possibly give it in the present paper. Suffice it to say, that there is unquestionably great need for simplifying the existing modes of trying patent cases, particularly in Scotland.

The fifth of the Manchester proposals is, to impose a penalty on all persons selling goods as patented which are not so. It is remarkable, that whilst there is a penalty for using the word "registered" without due authority, there is none for similarly using the term "patented." Of course, if a price is obtained for an article partly on the ground of its being patented when it is not so, a deduction can be enforced in paying the account, and the party using the designation can be put to considerable inconvenience otherwise. However, a simple penalty will be far better, and its imposition will tend to give a higher character to patent property generally. There can scarcely be any objection to this proposal.

The sixth and last of the Manchester proposals is likewise a useful one, and one which can scarcely be objected to. It is to this effect, "That some simple means be devised to secure patents for her Majesty's colonies." The writer would merely suggest a slight alteration in the wording—say, "That some simple means be devised for extending British patent rights to her Majesty's colonies."

Mr. W. Neilson thought the members were scarcely prepared to take up the subject at present. For his own part he must confess considerable ignorance of it; still he really must say that he did not think the present charges much too high, and he would be very much disinclined to deprive the Government of the good revenue they derived from the patent taxes. At the same time he thought that that revenue should be applied to the advancement of the arts and manufactures, and to the encouragement of inventors. As the matter was rather important, and the Session about to close, he would suggest that it be taken up at the first meeting of next Session, by which time, if Mr. Hunt's paper was published, the members would be much better prepared than they now were to follow him in it.

Mr. J. R. NAPIER saw no reason why the Government should not derive a revenue from patents. Many persons took out patents who should not have done so, and it was only right that they should pay for it.

Mr. LAWRIE said Mr. Scott Russell would make a bonfire of patents and patent laws together.

Mr. J. R. NAPIER was convinced that, if the members had an opportunity of reading the paper in print, they would be better able to form an opinion, and come to a proper determination of the question.

Mr. HUNT feared that if nothing were done in the matter during the present Session nothing would be done at all; for it was generally expected that if the Government did not introduce a bill this Session some other parties would bring one forward.

Mr. W. NEILSON thought that extremely doubtful.

Mr. J. R. NAPIER did not feel himself aggrieved by the law as it stood, or affected with any great sympathy for the subject.

Mr. W. NEILSON said there could be no doubt that it would be of the greatest importance to get a revenue of £100,000 applied to scientific purposes.

Mr. HUNT observed that there were other points for discussion besides those referred to in his paper, which was intended to merely introduce the subject. He had suggested to the council that the subject should be brought before the Institution, and he had been requested to throw together a few remarks by way of introduction.

The PRESIDENT said there were a certain number of definite points to be considered in reference to the subject, and he thought the best way of discussing these was to consider in succession the six heads into which the subject was divided by the Manchester Association. The first point was regarding the fees levied. Now it would require consideration whether, as a matter of principle, it was right that a tax should be levied by the Government for any process carried on by them more than was sufficient to pay the expense attendant upon carrying it on. Then there were, of course, collateral questions as to the practical effect of the taxes. There was next to be considered the application of the surplus fees, which involved the question whether there ought to be any surplus at all. A considerable portion of the patent revenue had been applied in printing the specifications of patents, and he did not think money expended in that way was thrown away. The third point referred to the appointment of scientific commissioners to assist the present-law officers in considering patents beforehand, and this was a question open to a great deal of discussion as to how such a plan would work. This was the system in Prussia, where it was complained that there was a body of scientific commissioners to consider inventions proposed to be patented, who were so thoroughly acquainted with every subject that nothing seemed new to them; and the result was that if they found any invention submitted to them to bear a resemblance to something they had met with, perhaps in the corner of some old book, they would pronounce that invention not new. As to the appointment of a special court, consisting of persons acquainted with the subjects brought before them, for the consideration of patent questions—he thought that every one who saw how ordinary juries treated such cases, must admit that their decisions had generally very little accordance with the true merits of the question before them. This point should therefore be fully considered. With respect to the proposal that a penalty should be inflicted upon persons using the word "patent" upon articles not patented, he thought there could be very little objection to it, for, in point of fact, such a penalty was against an act of fraud and falsehood. The next point had reference to the patenting of British inventions in colonies, which was a subject beset with great difficulties; for many had legislatures of their own, and it would be impossible to adopt any measure on the subject without acting in concert with them, which would require something like a treaty. But if it was worth while to take such a course, no doubt it would be followed. He then came to Mr. Hunt's proposal for improving the existing state of things, especially as regarded the system of provisional protection—which required every one to make and incur the expense of an application for a patent before he could ascertain the feasibility or commercial value of his invention. The proposal was to give him a sort of protection, without the necessity of applying for a patent in the first instance. As matters stood at present the grant of a patent was not for making an invention, but for publishing it. There seemed to be good reason for believing that Mr. Hunt's proposal would prevent inventors running into needless expense, and diminish the number of patents on the list. It appeared that at present upwards of 1000 patents a year, out of 3000 applications, were not proceeded with, the expense attending these 1000 having, therefore, been uselessly incurred; whilst, under Mr. Hunt's proposal, the inventors would have made experiments on their inventions, and, finding them useless, would not have applied for patents, and would therefore have saved such unprofitable expense. This observation would apply also to several cases, in which inventors having gone to a certain expense without any good result, were induced to spend more money in the hope of perfecting their inventions.* It was a question whether calling for fresh payments at the end of the third year was not too soon, and did not occasion the lapsing, at the third year, of five-sixths of the number of patents applied for; for it was well known that even the very best inventions did not begin to pay often until the end of six or seven years. Watt's invention was unproductive for the first seven years, and nothing like an adequate profit was derived from it until very long after that period. He was therefore of opinion, that the time for the first additional payment should be fixed at the seventh instead of the third year after the granting of the patent. Without attempting to lay down any definite principle upon all the doubtful points which the subject involved, he had only endeavoured to show what some of the principal questions were; and, considering the vast number of persons holding patents in Glasgow, or who were in some respect interested in the patent laws, he thought it desirable that the subject should as soon as possible be very fully gone into. The Manchester people would probably put forward a measure of their own upon the subject, and as Parliament was occupied with very important public business it was quite possible that such a measure would be gone through in a hurried manner, and passed without much consideration. It was therefore desirable that the Engineers of Scotland should give their anxious attention to the subject, and see how far the alterations recommended in Manchester were desirable, or what other alterations could be substituted for or added to them.

Mr. D. More moved that it be remitted to the council to consider the propriety of calling a special meeting to consider the subject of patent-law reform.

Mr. N. Robson seconded the motion.

Mr. W. Neilson suggested that the public be invited to attend the meeting which the council should appoint—and the motion, embodying this suggestion, was unanimously carried.

A vote of thanks was then passed to Mr. Hunt for his paper.

The following paper was then read:—

* See foot note at page 102.

On the Effect of a Third Cylinder in the "Clyde" Screw Engine. By Mr. J. G. Lawrie.

When two engines work in connection with the cranks at right angles, as in marine machinery and in locomotives, several causes combine to produce irregularity in the speed of the crank shaft. Of these the two most important are the unbalanced weight of pistons, piston rods, connecting rods, &c., and the varying amount of friction on the journals of the shaft.

To follow the operation of these causes of irregularity, let in the annexed diagram A represent the crank shaft of an ordinary inverted screw engine; A B, A C, the two cranks at right angles; D E, F G, horizontal and vertical lines respectively; and G D, D F, F E, E G, four equal parts into which the entire revolution of the shaft is divided.

The disturbance in the speed of the crank shaft, due to the unbalanced weight of the pistons, piston rods, connecting rods, &c., varies in different parts of the revolution. In the part represented by the crank, A C, passing over G D, the speed is retarded by the total weight of the unbalanced parts of both engines; in the part, D F, the cranks being on different sides of the vertical line, the effect is varied from retardation at D to acceleration at F; in the part, F E, the effect is an acceleration of speed; and in E G it is varied from acceleration at E to retardation at G. Thus, on the ascending side of the shaft the speed is retarded by the unbalanced weights, and on the descending side it is accelerated.

The disturbance due to the friction of the journals of the shaft is also different at different parts of the revolution. In the part, G D, as before, the total pressure of the steam on both pistons presses the shaft on the upper side of the bearings; in the part, D F, the cranks being on different sides of the vertical line, the shaft is in equilibrio; in the part, F E, the shaft is pressed on the under side of the bearings with the total pressure of the steam on both pistons; and in E G the shaft is again in equilibrio. The friction, therefore, is greatest when the cranks are both on one side of the vertical line, and smallest when they are on different sides.

The effect due to the unbalanced weights has been mitigated, both in marine engines and in locomotives, by the use of weighted discs instead of cranks; but although engines may, while at rest, be balanced by means of weights attached to wheels or discs, it is utterly impossible to effect a balance in that way which shall be correct when the engines are in motion. When the engines are in motion the momentum of the heavy side of the weighted discs in no respect meets or counteracts that of the unbalanced reciprocating parts; and although for moderate speeds and light machinery, a practically sufficient balance by means of these discs is attainable, the plan is wholly inefficient and inadmissible in heavy machinery working at high speeds, and would produce in such engines injury rather than improvement. To diminish the effect of the friction due to the pressure of the shaft on the bearings, an increased length of journal has been used in order to lessen the pressure on each inch of surface, so as to render unnecessary the use of appliances to prevent heating, which, when frequently resorted to, are always injurious to the permanence of the machinery.

Thus it appears, that when two engines are working in connection, the speed of the crank shaft is alternately retarded and accelerated by the unbalanced parts of the engines, and that the disturbance due to these weights is not removed by the use of weighted discs. It also appears that the friction arising from the pressure of the shaft on the journals, produces a varied amount of retardation, as well as an injury to the shaft, which is only mitigated by the use of long bearings.

When three engines work in connection, having the cranks placed to form equal angles, the unbalanced parts of the individual engines are exactly balanced by the combination; and the amount of friction arising from the pressure on the top and bottom of the bearings, is never more than that due to one-third of the total pressure of the steam on the three pistons.

To show this, let A be the crank shaft; A B, A C, A D, the three cranks, forming equal angles; E F, G H, horizontal and vertical lines respectively; and B J, C K, D L will represent the leverage of the weights resting on the several crank pins to turn the shaft, A.

Put the angle, $BAG = \theta$; then $CAH = 180° - (120° + \theta) = 60° - \theta$; $HAD = 120° - (60° - \theta) = 60° + \theta$; also $BJ = \sin\theta$; $CK = \sin(60° - \theta)$; $DL = \sin(60° + \theta)$. Put $BJ + CK - DL = a$; or $\sin\theta + \sin(60° - \theta) - \sin(60° + \theta) = a$; which by resolution gives, $\sin\theta\,(1 - 2\cos. 60°) = a$; but $2\cos. 60° = 1 \therefore a = o$. Hence $BJ + CK = DL$; and if W = weight of unbalanced parts resting on each crank pin, it follows that $W \times BJ + W \times CK = W \times DL$ $\therefore$ The unbalanced parts of the several engines are at every part of the revolution of the crank shaft exactly balanced in the combination.

Plainly, the crank shaft is pressed on the upper side of the bearings by the pressure due to one piston only, when two cranks are on the ascending side of the shaft; and is pressed against the lower side of the bearings by the same pressure when two cranks are on the descending side. Thus, with three engines working in connection, no irregularity is caused in the speed of the shaft by the unbalanced parts of each engine; and the pressure against the bearings of the shaft at no time exceeds that due to one-third of the total amount of the steam pressure on the three pistons.

The superiority in these respects possessed by a combination of three engines over one of two, is very important, and, in large machinery especially, places the one arrangement beyond all question above the other. A short time ago the *Tasmanian* screw steamer was fitted by the Messrs. Inglis with three trunk engines having steam cylinders 71 inches in diameter; and that steamer has not only performed in every respect in a most satisfactory manner, but is one of the fastest, if not the very fastest screw vessel afloat. If the power of these engines had been exerted by a combination of two trunk engines, the pressure on the top and bottom side of the bearings—or more correctly, the pressure on the shaft upwards and downwards—would have been 150 tons instead of 50 tons, as in the *Tasmanian;* and trunk engines having heavier unbalanced parts than most other forms of engines, the retardation and acceleration of the speed of the crank shaft would have been very considerable. For these reasons the writer doubts exceedingly whether it is possible to exert in a satisfactory manner, with two trunk engines, the amount of power which in the *Tasmanian* is so effectually employed in three. Every engineer acquainted with screw engines is aware, that to be free from hot journals, and to have no necessity for the appliances commonly used to cool them when hot, is a property as rare as it is valuable; and, manifestly, to reduce the pressure of the shaft on the bearings, in the proportion of 3 to 1, is conducive to the attainment of a cool working shaft.

It may be that screw machinery with three cylinders is more expensive than with two; but, when the power is large, it appears impossible to doubt that the arrangement with three cylinders possesses a very considerable advantage in lessening the consumption of stores, in the permanence of the engines, and in the speed of the ship.

In the preceding investigation, the angular position of the connecting rod, and the effect due to the pressure of the shaft journals on a curved, instead of a flat surface, are neglected, as they do not materially affect the matter under consideration.

Note.—In the foregoing it has been shown that a mechanism, consisting of three steam engines working in combination with the cranks placed to form equal angles, possesses the following properties:—1st, That the unbalanced parts of pistons, piston rods, connecting rods, &c., of the several engines exactly balance each other. 2nd, That the force of torsion exerted upon the shaft is exactly equal on the two sides; that the force exerted to pull the one side of the shaft upwards, is exactly equal to the force exerted to push the other side downwards. But the writer finds that these properties are not confined to a combination consisting of three steam-engines; and that a mechanism consisting of any number of engines greater than one, possesses them both, if the cranks are placed to form equal angles.

To prove this in general terms, let n be the number of steam engines working in combination, θ the angle which one of the cranks forms with a vertical line; and as the sine of the angle which each crank forms with the vertical line represents the leverage of the crank, it follows that the sum of the sines will be the sum of the leverages. Hence the sum of the leverages

$$= \sin\theta + \sin\left(\theta + \frac{360^\circ}{n}\right) + \sin\left(\theta + 2 \times \frac{360}{n}\right) \ldots + \sin\left(\theta + [n-1] \times \frac{360}{n}\right)$$

which put $= a$; and by development

$$a = \sin\theta \left\{ 1 + \cos.\frac{360}{n} + \cos.\,2 \times \frac{360}{n} + \cos.\,3 \times \frac{360}{n} \ldots + \cos.(n-1) \times \frac{360}{n} \right\}$$

$$+ \cos.\,\theta \left\{ \sin\frac{360}{n} + \sin 2 \times \frac{360}{n} + \sin 3 \times \frac{360}{n} \ldots\ldots + \sin(n-1) \times \frac{360}{n} \right\}$$

By a summation of these two series

$$a = \sin\theta \left\{ 1 + \frac{\sin\frac{1}{2}(2\,n - 1)\frac{360}{n} - \sin\frac{1}{2} \times \frac{360}{n}}{2 \sin\frac{1}{2} \times \frac{360}{n}} \right\} +$$

$$\cos.\,\theta \times \frac{\sin\frac{1}{2}(n-1)\frac{360}{n} \times \sin\frac{1}{2}\,n \times \frac{360}{n}}{\sin\frac{1}{2} \times \frac{360}{n}}$$

and by reduction, $a = \sin\theta\,(1-1) + \cos.\,\theta \times o \qquad \therefore a = o.$

Hence the sum of the sines on the one side of the perpendicular line is equal to the sum of the sines on the other side; and therefore, as explained in the text, the two properties above stated are possessed by this mechanism.

When two engines only work in combination, the cranks are placed, not to form equal angles, but at right angles to each other; and on that account such a combination does not possess the properties of equal action.

Mr. J. R. Napier thought it might be desirable that the motion of an engine should be uniform, but he did not know how much it was worth.

Unless there was a loss of power from the want of a uniform motion, there was no material damage from it.

Mr. Lawrie said that in a steam vessel, unless the motion of the engine was uniform, the vessel would sometimes outrun the machinery, and at others the machinery outrun the vessel.

Mr. J. R. Napier said, that might be the case in screw steamers, but did not take place in paddle steamers. The vessel could never outrun the machinery. He would like to know if there is any loss from an engine going slow at one time and fast at another.

The President thought that it occasioned the great vibration which was observed in vessels with single cylinders.

Mr. J. R. Napier said one might sometimes feel the vessel driven forward from that cause, but he did not know that the want of a uniform motion caused loss of speed.

Mr. W. Neilson held that if an engine went irregularly, it would sometimes go faster and sometimes slower than the vessel, and there certainly would be a loss from that.

Mr. J. R. Napier said the engine could never go slower than the vessel, for the vessel could never drive the engine.

Mr. W. Neilson said if it did not go slower than the vessel there would be a certain point at which it would exert no power, except from the momentum of the wheel, if the motion was not uniform.

Mr. P. Stirling thought that, if it was necessary to have a uniform action, he supposed it would have been before this time adopted at the great rowing matches at Oxford and Cambridge, the rowers taking stroke at different times instead of all at once as was the practice.

Three cylinder locomotives had been tried; but he thought the advantages derived from them were not equivalent to the cost of the additional machinery.

Mr. D. More said he found that pumps driven by three cranks or five, were more effective than those driven by two or four, or any other even number.

Mr. Lawrie said, that with any number of engines or pumps a balance was obtained, if the circle was equally divided by the cranks, and that a uniform motion was necessary for an economical result; because, at the time when the motion of the vessel was above the mean, a resistance proportioned to the square of the increased speed was encountered; and also because one proportion of slip of the propelling instrument, whether screw or paddle, was more economical than any other proportion of slip, and, therefore, the speed could be varied without loss.

Mr. W. Neilson thought, that in the case referred to by Mr. More, the valves might have been the cause of the improvement rather than the cranks.

The PRESIDENT remarked, that in the case of the pumps with three or five cranks, only one piston reversed its motion at a time, whilst with an even number of cranks two pistons would be reversed together. Thus, with three cranks the reversals took place at the same periods as with six cranks, and with five at the same periods as with ten.

A vote of thanks was passed to Mr. Lawrie for his paper.

Mr. DAVID MORE then exhibited and described

A Combined Engine-Counter and Clock. By Mr. A. MITCHELL.

This apparatus is contrived to record the periods at which each successive thousand, or other convenient number of strokes of the engine, are completed. It comprises a clock and a counter which may both be of ordinary construction—the former marking the time, and the latter indicating the total number of strokes made. In addition, the clock is made to draw or move regularly onwards a suitable surface to receive recording marks, which are made by the counter at every thousandth or other stroke of the engine. In the instrument shown, the clock was made to draw regularly forward a riband of paper marked with hour and minute divisions—this riband passing under a pin which was struck by a hammer actuated by the counter at every thousandth stroke of the engine. Perforations were thus made in the paper riband at intervals, the space between each perforation corresponding to, and indicating the time occupied by, each thousand strokes. In the same way a second pin was contrived to perforate the paper riband at every ten-thousandth stroke, so that every tenth mark comprised two perforations. In another modification of the instrument, the recording marks are made upon a drum, either the drum or the pin and hammer being made to move longitudinally, so that the marks follow a helical direction. With this arrangement, the marks may be continued several times round the drum without interfering with each other; or the marks might be received on a paper riband wound helically round the drum.

An ordinary engine-counter merely shows the total number of strokes made between any two periods of observation, from which the *average* rate for the whole time can be deduced; but gives no indication of any irregularities that may have occurred. With Mr. Mitchell's instrument, however, it is as though observations were noted at the short intervals occupied by each successive thousand or other number of strokes; and in this way irregularities are prominently brought out, since where they occur the time indicated by the space between each mark will be greater or less accordingly.

In reply to an inquiry Mr. MITCHELL stated, that the instrument would cost from £12 to £15.

The subject of

Indicator Connections

was then discussed. A set of such connections as usually supplied by Mr. Wm. M'Naught were exhibited. In the course of the discussion it was laid down as very desirable, that a uniform size of connection should be fitted upon the cylinders of every steam-engine, in order that any indicator might be applied in any case without loss of time.

A committee was appointed, consisting of Messrs. H. R. Robson, J. Inglis, and D. Rowan, to ascertain and report what size of indicator connections would be the most convenient for all parties, in order that the adoption of such size might be recommended by the Institution. It was suggested that the size selected should be one in Whitworth's scale.

Mr. J. M. ROWAN exhibited models of his improved Marine engines and Boilers.

Mr. WALTER NEILSON presented to the Institution, in the name of Messrs. Ross & Beanes of Havana, a valuable model of the *Plymouth Rock*, one of the finest of the American river steamers.

The SECRETARY was directed to transmit to Messrs. Ross & Beanes the cordial thanks of the Institution for this donation.

The Eighth and Last Meeting of the Session was held in the Philosophical Society's Hall on Wednesday, 13th April, 1859, the President in the chair.

This was the Annual General Meeting for the election of office-bearers for the Third Session, 1859–60.

The following notes were read:—

On American River Steamers, with more particular reference to the model presented to the Institution. By Mr. Walter Neilson.

(Illustrated by interesting drawings of several American River Steamers.)

In offering a few remarks on the American river steamers, such as the one represented by the model presented to our Institution at the last meeting, the writer proposes to take a general view of the vessel, as fitted out for the Hudson river traffic. This traffic consists, for the most part, of passengers, and we therefore find the accommodations of the vessel designed for their comfort and convenience. We enter on the main deck, and find the steam-engine in the centre of the vessel, occupying a very little space in width, and leaving a wide passage on each side, fore and aft, with the paddle-shaft over-head. On this deck are the booking office, baggage office, kitchen, engine-room, boiler-rooms, and other departments appertaining to the conduct of the vessel. Farther off is the ladies' saloon, reserved exclusively for the use of the fair sex, to whom so great a preference is shown in travelling in the United States. Ascending by a wide flight of steps, we next enter the principal saloon, or as it is sometimes called, the State-room hall. The roof is some 15 or 20 feet high, and the length extending fore and aft the vessel, with only the interruption of the narrow engine-house in the centre. The floor of this hall is covered with the richest carpet; and the furniture—chairs, sofas, couches, &c.—are after the most fashionable drawing-room models of elegance and ease—mostly in white and gold woodwork, to correspond with the sides and roof. Suspended from the roof are magnificent crystal gasaliers, which at night give the whole a brilliant and dazzling appearance; whilst white marble tables, and pure iced water flowing from silver fountains, impart a refreshing coolness to the whole. Around this hall, overhead, runs a gallery, with an ornamental balustrade in front, which gives access to the state-rooms, each containing two beds; whilst there are also generally one or two bridal rooms—these latter having each a handsome posted and curtained bed—and provided with basin-stands, chairs, and rich carpet, all handsomely got up. The steamer *New World*, which the writer has more particularly in view in this description, and of which a lithograph was exhibited at last meeting, had 347 of these state-rooms, containing in all 680 berths. The gentlemen's saloon and dining-room is under the main deck; also the washing-saloon, and hair-dressing and shaving shop. The promenade deck is forward of and abaft the saloon, and on the sides.

The engine-room, entering from the main deck, is situated before the nozzles of the engine, and has placed in it a comfortable mahogany hair-stuffed sofa. The engineer is very unlike our greasy shirt-sleeved men. He sits comfortably on his sofa—the stopping and starting of his 15-feet-stroke, and 76-inches-cylinder engine, requiring little more than the power of a child. As he stands in front of the nozzles, and cannot see the crank or the beam overhead, a small pointer revolves in the engine-room to show the motion of the crank. The boilers, generally one on each side, are carried on the wings or guards; and opposite them are the blowers, with their engines, in separate rooms. The paddle wheels, sometimes as large as 45 feet in diameter, and 12 feet in width, have their arms of wood fixed into cast-iron centres. The general form of the American marine steam-engine is familiar to all engineers, so that the writer need not now enter into a minute description of it, but may simply draw attention to its extraordinary lightness.* The short skeleton main beam, the skeleton or trussed connecting-rod, and crank, all show distinctly the desire to obtain the very lightest structure consistent with the necessary strength. The whole bed or foundation of the engine is formed generally of white-pine timber capped with oak, and the gallows frame which supports the working beam is of yellow pine, all firmly fixed with wood knees, and securely bolted together.

The engines are worked at a pressure varying from 25 lbs. to 45 lbs. per square inch; and the system of double-beat or equilibrium valves used, brings the largest engine most completely under the control of the engineer. The valves are lifted by "toes," as they are named, or curved levers on a rocking shaft—the steam valves by an eccentric on one side, and the eduction valves by an eccentric on the other side. The motion given to the valves by these levers is very beautiful—first gently moving the valve, then suddenly lifting it, and as suddenly dropping it through a portion of its fall, then gently letting it down to its seat.

* Mr. Neilson here pointed out various peculiarities of construction upon a large drawing of an American Beam Marine Engine.

The hull of the vessel is a long flat boat, of itself evidently insufficient in strength to support the machinery and superstructure; but we find an immense girder, composed of frames fixed one in each side, and bound across to each other. This gives strength to the fabric fore and aft, whilst the great weight of the boilers and paddles on the wings is supported by tension-rods from the five great masts or struts bearing on the keel of the vessel. We find the same principle of truss or tie rod combined in the strengthening of the vessel, as we observed in the structure of the engine, the great object throughout being obviously lightness; and this we notice most particularly in the extraordinary light material used in the construction of the passenger accomodations built on the vessel.

The river steamers on the Clyde and on the American rivers cannot justly be compared with each other. No doubt they are both intended to carry passengers, bound on business or on pleasure; but here their necessary similarity ends. The climate is different; the rivers are different; and the voyages are different. In this country we may be said to have no inland river navigation. Our steamers, although running over a few miles of protected waters, must be able to face the rough weather of our estuaries, where, indeed, is the principal part of their navigation. It must be admitted, however, that these circumstances offer no excuse for the dirty and slovenly manner in which many of our Clyde river steamers are kept—a complaint too frequently heard from the strangers who periodically visit our locality, and particularly those who have witnessed the beautiful and orderly manner in which the floating palaces of the American rivers are conducted.

It has been for many years a matter of surprise to the writer that some improvement has not been made upon our river steamers, in order to give more comfort to the passengers. The hull of one of our steamers forms a sort of box girder, strengthened at the centre to carry the machinery. One would think a very much lighter vessel might be built, by adopting something of the American system of truss and tie binding; a considerable weight of iron would be saved by keeping the vessel lower, and the deck near the level of the water, whilst a very light cabin built on deck would permit of ventilation, and allow the cabin passengers the much desired privilege of seeing around them. Such a vessel would not cost more money to build, would draw less water, and be more easily propelled. It might not be considered suitable for a winter boat to ply to the outposts of our firth, but it would be sufficiently safe for our ordinary sea-coast traffic, and add immeasurably to the comfort of the passengers.

Being desirous of forming a comparison between this model of the steamer *Plymouth Rock*, as an example of American mould, and those of our best river steamers, the writer endeavoured to obtain some figure presenting the type or character of the vessel; and following Peake's mode of curves of vertical section, deduced from the form of the model a curve in which the axis represents the length of the vessel, and the ordinates the areas of the immersed vertical sections, at the respective intervals of the length. Messrs. J. & G. Thomson in the most liberal manner gave the requisite data from their draft of the steamer *Iona*, and Messrs. Tod & Macgregor in like manner those of the steamer *Spunkie*. A scale was selected to give the same length as in the figure of the *Plymouth Rock*, and ordinates were formed, from similar vertical sections, giving curves for these two vessels. In like manner curves of horizontal sections were formed, the axis representing the depth, and the ordinates the areas of the horizontal sections at the respective intervals. With these two curves, or, perhaps, with some combination of them, a means might be afforded of comparing the types of different vessels, and the writer would urge on the members of this Institution to give what information they may possess in the shape of examples (whether successful or unsuccessful—the one being as valuable as the other), to increase the number of comparisons and to add weight to the deductions from them. The writer is indebted to Mr. J. G. Lawrie for making the requisite calculations in the case of the three steamers named, and he will no doubt be glad to give any one willing to assist in this matter any information required.

The diagram referred to by Mr. Neilson was exhibited at the meeting, and will be published in the Transactions when it can be accompanied by the corresponding diagrams of a large number of vessels, so as to render the comparisons and deductions the more useful and valuable. It may, however, be mentioned here that in the diagrams shown, the steamers *Iona* and *Spunkie* appear to be fuller abaft the centre, and slightly leaner forward, than the *Plymouth Rock*.

Description of the American Steamer "Plymouth Rock."

Length on deck 340 ft. Breadth of beam 40 ft. Depth of hold 12½ ft.

The vessel has a single beam engine with cylinder of 76 inches diameter and 12 feet stroke. Diameter of wheels 36 feet 10 inches, with 30 floats in each wheel, each float being 10 feet long and 2½ feet wide. Dip of the wheel 3 feet 10 inches when the boat is loaded, and drawing 8 feet water. There are two boilers of the return-flue kind 38 feet long, round shell 10½ feet diameter, front 12½ feet wide, steam dome 8½ feet high, 2 furnaces in each boiler 5 feet 8 inches and 8 feet long.

The engine cuts off at half stroke, and burns 1⅝ tons of coal per hour, with an average pressure of 25 lbs. The boilers are placed on the guards forward of the wheels.

The vessel has a single deck extending over the whole length and guards; the dining hall is below this deck, and is about 120 feet long, 32 feet wide, and capable of seating 200 persons. There are 254 sleeping berths, which extend, on both sides, the whole length of the vessel.

On the main deck, abaft the engine, is the ladies' saloon, with 72 berths, and 2 bridal rooms with 1 berth each. The promenade deck extends from extreme stern to within 60 feet of the bows, and has 31 state-rooms on each side with 2 berths each, besides a state-room hall some 25 feet in width. The whole number of passenger sleeping berths is 452. The vessel has a double frame sided 7 inches each, and moulded at centre 18 inches, at bilge 10, at top 6½ inches, and placed 2 feet from centre to centre of frame. There are 7 rows of keelsons extending the entire length, of yellow pine timber, with yellow pine bilge streaks and clamps. The vessel is diagonally strapped with iron the whole length, and there is a suspension frame in each side extending within 30 feet of either end, commencing from the deck and rising 18 feet above the deck in the centre being secured with posts, straps, and rods to the hull of the vessel. In addition there are also for support five marts, fitted at equal distance, apart, with rods and chains extending to the keelsons and guards. The average speed of the vessel is 18 miles per hour.

Whole cost of vessel complete 240,000 dollars.

For comparison particulars of three Hudson river steamers are added:—

	EMPIRE STATE.	ISAAC NEWTON.	NEW WORLD.
Length on deck, ...	304 ft.	338 ft.	371 ft. Over all, 380 ft.
Breadth of beam,..........	39 ft.	40 ft.	50 ft. " 85 ft.
Depth of hold,............	13 ft.	11 ft.	11 ft.
Draft of water,............	8 ft.	5 ft.	5 ft. 6 in.
Diameter of cylinder, ...	6 ft. 4 in.	6 ft. 9 in.	6 ft. 4 in.
Length of stroke,..........	12 ft.	12 ft.	15 ft.
Diameter of paddle wheels,..	38 ft.	39 ft.	45 ft.
Length of paddles, ...	10 ft. 3 in.	12 ft.	12 ft.
Number in each wheel, ...	30	32 double paddles,	38
Dip of wheel, ...	3 ft. 6 in.	4 ft.	3 ft. 4 in.
Average No. of revolutions,	18	17	17
Average pressure of steam,..	25 lbs.	35 lbs.	45 lbs.
Cutting off at............	6 ft.	6 ft.	8 ft.
Whole amount of fire surface	4160 square ft.	4540 square ft.	5338 square ft.
" " grate "	166 square ft.	161 square ft.	212 square ft.
Consumption of anthracite coal per hour...........	6500 lbs.	8000 lbs.	9000 lbs.
Water evaporated by 1 lb of coal,...................	$5\frac{82}{100}$ lbs.	$6\frac{2}{10}$ lbs.	7 lbs.
Coal per hour to a square foot of grate,...........	$39\frac{1}{10}$ lbs.	50 lbs.	$42\frac{5}{10}$ lbs.
Tonnage,................	1551 tons.	1454 tons.	1418 tons.
State-rooms,..............			347.
Berths, ...			680.

In reply to a remark of the President's, Mr. DOWNIE said, his reason for bringing his paper in reference to steam-vessels before the Philosophical Society, rather than the Institution of Engineers in Scotland, was, that he did not consider it definite or practical enough in its character for the latter society; while, through the medium of the Philosophical Society, he was enabled to bring an important subject under public notice, with a view to its discussion, and to ascertain the general feeling with reference to it, prior to entering upon the practical development of his plans.

Mr. NEILSON—in answer to a gentleman who doubted whether a steamboat, built on the plan described in his paper, would stand the rough weather common on the Clyde—said, that the American river boats were often exposed to the waves and winds of the Atlantic, which they bore without any damage.

Mr. Neilson then explained the construction and working of Mr. Chaplin's steering apparatus, several models of which were exhibited. The improved steering apparatus is more particularly designed for flat-bottomed boats of light draught for shallow waters. The steering is effected by means of vertical plates disposed obliquely at either end, or at both ends, of the vessel, in the manner shown in figs. 6 and 7, Plate VIII, which are respectively an elevation and a plan of the stern of a boat fitted with the plates. There are two steering plates, A, one on each side of the vessel; and they work in vertical casings, the positions of which are indicated by dotted lines at B in the plan, fig. 7. Each plate, A, turns on a joint at its front end, and, when not required to turn the vessel to the side it is on, is drawn up within its casing. Independently of their peculiar suitableness for flat-bottomed boats, these plates have a greater control, and act more quickly, than the ordinary rudder, from their being placed on each side of the centre line of the vessel. A pair of the plates at one end is sufficient for ordinary requirements, whilst for intricate navigation a pair at each end may be used, to be actuated either simultaneously or separately.

Mr. DOWNIE asked, at what angle the steering plates were set, and whether it had ever been practically tried; and, if so, with what result.

Mr. CHAPLIN said that, whilst various angles might be adopted, he preferred that of 37° from the line of the keel. The plates had been successfully tried. He understood that seventeen boats were being or about to be built in England with steering plates on the same plan as that described, being chiefly for the Government. On trying the steering plates in a small boat, it was found that when plates were acting on the same side at both ends, the boat turned round on a radius equal to its length. Another modification had been applied to a vessel built by his firm and sent to Java, consisting of a simple conical shell oscillating on an axis, a piece being cut out of the cone, and one side or other being made to project as required; but this was only suitable for small vessels, where the apparatus was not to project through the deck. The vessels which he mentioned as in course of building were to draw 2 feet water, to carry 1000 men, and coals for a voyage of 50 miles. They were 220 to 240 feet long, and 35 to 40 feet beam, and almost perfectly flat. They were, he understood, intended for the navigation of the Ganges and other rivers of India. The steering apparatus was adapted as well for deep sea vessels as for those of shallow draught: and for screw vessels it was peculiarly fitted; for the screw could be placed between the plates. In the event of any injury being sustained by one of the plates, it could be hoisted on deck without trouble, and repaired.

Mr. Downie said it appeared to be generally thought that there was considerable top weight in vessels constructed on the American plan. He, however, thought otherwise; the centre of gravity was really lower than in our own river boats, because of the comparatively lower position of the main deck.

Mr. Neilson said there could be no objection to the American construction on the ground of the position of the centre of gravity of the vessel itself, but there was, on account of the double tier of passengers, the weight of whom, if they were on one side, might cause the vessel to overbalance.

Mr. Downie observed that the double tier was so arranged that one of the flats or decks was a good way below the water level, and there was little danger of the passengers above running to one side, as the arrangement of the upper deck prevented them.

Mr. D. More said that the diagrams of the ships' lines exhibited by Mr. Neilson showed the fault committed by Clyde shipbuilders, in making the river steamers too full aft, which they did in order to give plenty of room for passengers. If this were avoided there was no doubt that greater speed would be obtained.

Mr. D. Rowan did not consider that the lines exhibited by Mr. Neilson were sufficient *data* to found any definite conclusion upon, for he thought the draught and other details should also be taken into consideration.

The President said he did not think the greater fullness aft than forward, to which Mr. More referred, was given so much for passenger accommodation as from its being considered the best figure to adopt: it was a characteristic of the figure adopted by Mr. Scott Russell. He doubted, however, whether the principle was correct, and the American model was an instance of a contrary character.

Mr. D. Rowan remarked that it was often difficult to get the Clyde steamers alongside the piers, from the wind catching them and drifting them off.

Mr. Chaplin said that if his steering plates were projected one at each end of the vessel on opposite sides, and so as to be parallel to each other, the vessel would move in a lateral direction, and be easily brought alongside of a pier.

Mr. D. Rowan said that he did not allude to the difficulty of bringing alongside so much as to that of keeping alongside until the mooring rope was attached on shore. Very often if the man on shore missed the rope when it was thrown to him, the vessel would drift off. This happened to vessels of 3 feet or 3 feet 6 inches draught. In alluding to the constructing of vessels of light materials, he might mention that some time ago the Messrs. Caird & Co. of Greenock contemplated building vessels entirely of steel; but they were at the time obliged to renounce the plan, because the Board of Trade would not sanction it at all, although it was known that steel was doubly as strong as iron.

The President said he hoped that the experiments which were being made by Messrs. R. Napier & Sons on the strength of iron and steel, would throw some valuable light on the subject.

Mr. D. Smith thought, that if Mr. Chaplin's steering apparatus would remove the difficulty vessels had in touching at piers and starting from them, it ought to be generally adopted.

Mr. Chaplin observed that one great cause of vessels drifting off from piers was the running of the passengers to one side, as their weight caused the vessel's side to strike the pier, and the blow generally drove it off.

Mr. Neilson, in reply to a question as to how the American vessels touched and left the piers, said he never observed that there was any difficulty attending their doing so.

A vote of thanks was passed to Messrs. Neilson and Chaplin.

Mr. Neilson having taken the chair the following paper was then read—

On a Method of Estimating the probable Evaporative Power of Fuel and Efficiency of Boilers. By W. J. MACQUORN RANKINE, C.E., LL.D., F.R.SS. L. and E.

The following formulæ are, of course, not intended to supersede experiments and practical trials, nor to furnish results as accurate and satisfactory as such experiments and trials. They have been deduced from existing experimental data, and chiefly from those of the recent experiments on Welsh and North of England coal, of Mr. D. K. Clark's experiments on locomotive boilers, of a few experiments by the author, and of Messrs. Favre and Silbermann's experiments on the total heat of combustion of the chemical elements of fuel, in order to furnish a convenient means of estimating approximately the evaporative power of fuel in proposed boilers, and the comparative efficiency of different boilers.

The formulæ are framed on the supposition, that the admission of air and the management of the fire are such, that no appreciable loss occurs, either from imperfect combustion or from excess of air; the construction and proportions of the furnace, and the mode of using it, being the best possible for each kind of coal.*

The *Evaporative Power* is stated in *pounds* of *water supplied and evaporated at* 212° by each pound of fuel; and when the temperature of the feed-water and the boiling point differ from 212°, the actual evaporation is to be reduced to the *equivalent evaporation from* 212°, by multiplying by the following factor:—

$$1+\frac{0{\cdot}3\,(T_1-212^\circ)+(212^\circ-T_2)}{966}$$

where T_1 is the actual boiling point, and T_2 the initial temperature of the feed-water.

* The loss of heating power from imperfect combustion of coal may be roughly estimated as follows, when the proportion of hydrogen in its composition is about 5 per cent:—

When the supply of air is insufficient but the firing good, so that the whole or part of the hydrogen is wasted, but none of the carbon, ... from 20 per cent. downwards.

When the supply of air is very insufficient and the firing bad, so that more or less of the carbon is wasted along with the hydrogen, ... 33 to 50 per cent.

General Formula for Evaporative Power E′.*

$$(1.) \quad . \quad . \quad . \quad E' = E \frac{B\,S}{S + A\,F}.$$

Explanations.

E denotes the *theoretical* evaporative power due to the chemical composition, and may be thus calculated—

Let C, H, and O, be the fractions of one pound of the fuel, which consist respectively of carbon, hydrogen, and oxygen; the remainder being nitrogen, ash, and other impurities. Then—

$$(2.) \quad . \quad . \quad . \quad E = 15 \left\{ C + 4{\cdot}28 \left(H - \frac{O}{8} \right) \right\}.$$

The following are some of the results of this formula—

	E
Finest qualities of North of England and Welsh coal,	15 to 16
Coke, with 6 per cent. of ash, ...	14·1
Coke, with 12 per cent. of ash, ...	13·2
Coke, with 18 per cent. of ash, ...	12·3

S denotes the number of square feet of total heating surface per square foot of grate, including the surface of the feed-water heater if any.

F denotes the number of pounds of fuel burned per square foot of grate per hour.

B and A are two constants, which have the following values for the four following classes of boiler furnaces:—

	B	A
Class I.—The conveyance of heat from the flame to the water taking place in the best manner, either by introducing the water at the coolest part of the boiler, and making it travel gradually to the hottest, or by heating the feed-water in a set of tubes in the uptake—the draught produced by a chimney, ...	1	0·5
II.—The conveyance of heat taking place in the ordinary manner—the draught produced by a chimney, ...	$\frac{11}{12}$	0·5
III.—Conveyance of heat in the best manner—the draught produced by a blast or fan, . .	1	0·3
IV.—Conveyance of heat in the ordinary manner—the draught produced by a blast or fan, . .	$\frac{11}{12}$	0·3

* The theoretical considerations by which this formula was suggested, are given in a work, now in the press, "On the Steam Engine and other Prime Movers."

The *efficiency of the boiler* is the factor by which E is multiplied in formula 1, viz.:—

$$\frac{E'}{E} = \frac{B\,S}{S + A\,F}.$$

The following are examples of efficiency, $\frac{E'}{E}$.

$\frac{S}{F}$	For Class of Boilers. I.	II.	III.	IV.
0·1	0·17	0·15	0·25	0·22
0·25	0·33	0·31	0·45	0·43
0·5	0·50	0·46	0·62	0·59
0·75	0·60	0·55	0·71	0·68
1·0	0·67	0·61	0·77	0·73
1·25	0·71	0·65	0·81	0·77
1·5	0·75	0·69	0·83	0·79
2·0	0·80	0·73	0·87	0·83
2·5	0·83	0·76	0·89	0·85
3·0	0·86	0·79	0·91	0·86
6·0	0·92	0·84	0·95	0·90
9·0	0·95	0·87	0·97	0·92

The following are particular cases:—

I.—Hartley coal, $E = 15{\cdot}5$. $S = \frac{1075}{22} = 48$; $F = 24$; boiler with feed-water heater and chimney draught, or Class I. $E' = 15{\cdot}5 \times 0{\cdot}8 = 12{\cdot}4$.

This agrees closely with the results of the experiments at Newcastle on fresh coal, both by the Newcastle committee and by the Admiralty reporters.

II.—Same coal, same boiler, without heater, Class II. $S = \frac{755}{22} = 35$; $F = 27$. $E' = 15{\cdot}5 \times 0{\cdot}66 = 10{\cdot}23$.

This nearly agrees with an experiment made at Newcastle by the Admiralty reporters, in which the result was 10·54.

III.—Same coal; $S = 25$; $F = 25$; no heater. Boiler Class II. $E' = 15{\cdot}5 \times 0{\cdot}61 = 9{\cdot}4$.

This applies to many ordinary marine boilers, and agrees with practical experience.

IV.—Locomotive boiler, Class IV. Coke, E = 14·1; S = 60; F = 56. E′ = 14·1 × ·74 = 10·43 from 212°. Equivalent evaporation, from 62° at 329°, $\frac{10·43}{1·2}$ = 8·69.

The above proportions of S and F are computed from a formula of Mr. D. K. Clark as being suitable to insure an evaporative power of 9 from 62° at 329°. The difference is only $\frac{1}{30}$.

V.—Locomotive boiler, Class IV. (Mean of Mr. Clark's experiments, Nos. 38, 39, 40, 41, 42). E = say 14·1; S = 83; F = 65½. E′ = 14·1 × ·77 = 10·86 from 212°.

Equivalent evaporation, from 62° at 319°, $\frac{10·86}{1·2}$ =	9.05
Mean result of experiments, ...	8·72
Difference, ...	0·33

VI.—Locomotive boiler, Class IV. (Mean of Mr. Clark's experiments, Nos. 48, 49, 50, 51, 53). E = say 14·1; S = 66·4; F = 56·2. E′ = 14·1 × ·76 = 10·72 from 212°.

Equivalent evaporation, from 62° at 329°, $\frac{10·72}{1·2}$ =	8·93
Mean result of experiments, ...	8·75
Difference, ...	0·18

VII.—Locomotive boiler, Class IV. (Mr. Clark's experiment, No. 55, mean of 10 trips). E = say 14·1; S = 57; F = 44. E′ = 14·1 × ·77 = 10·86 from 212°.

Equivalent evaporation from 62° at 329°, $\frac{10·86}{1·2}$ =	9·05
Result of experiments, ...	9·00
Difference, ...	0·05

VIII.—Locomotive boiler, Class IV. (Mr. Clark's experiment, No. 61, mean of 8 trips). E = say 14·1; S = 60; F = 87. E′ = 14·1 × ·66 = 9·3 from 212°.

Equivalent evaporation, from 62° at 329°, $\frac{9·3}{1·2}$ =	7·75
Result of experiments, ...	7·2
Difference, ...	0·55

Note.—The only principle followed in selecting experiments from Mr. Clark's table, is that of giving the preference to those cases in which a mean can be obtained from the results of a large number of experiments under similar or nearly similar circumstances.

The general conclusion to be drawn from the preceding comparisons is, that the formula agrees closely with the results of experiment up to a rate of consumption of about 60 lb. per square foot of grate; and that above that rate of consumption, although there is still an approximate agreement, the results of experiment fall somewhat short of those given by the formula. It is probable, however, that for those high rates of consumption, the combustion is not so complete as at lower rates, and that some heat is consequently wasted.

IX.—Boiler, Class II. E = about 15½; S = 60, nearly; F = 6·4.

E = 15½ × 0·87 = ...	13·48
Result of experiment, . . .	13·56
Difference, ...	0·08

The above is the result of an experiment of the author's.

X.—The Earl of Dundonald's boiler. This boiler is considered as belonging to Class I., because of the feed-water being introduced at the part where the gas from the furnace is coolest.

E = about 16? (for handpicked Llangennech coal). S = 3·35; F = 10·17.

E′ = 16 × 0·87 = ...	13·92
Mean result of two experiments with the feed-water at 50, 12·14 × factor of evaporation, 1·17, .	14·20
Difference, ...	0·28

A vote of thanks was passed to Dr. Rankine for his paper.

It was announced that the Council had thought it desirable to postpone, until the commencement of the next Session, the discussion of the

Tabulated results of Experiments on the Comparative Strength, &c., of Steel and Wrought Iron, by Messrs. Robert Napier & Sons.

Time would thus be afforded to include the results of numerous additional experiments, and as the Tables would be printed in the volume of the Transactions for the present Session, the Members would have them in a convenient form for reference and examination.

The Secretary announced the reception of the following Works during the Session 1858–59:—

"A Manual of Applied Mechanics," and "On the Conservation of Energy." Presented by the Author, W. J. Macquorn Rankine, LL.D., C.E., F.R.SS.L. & E., &c.

"Steam Ship Capability," and "On Marine-Engine Construction and Classification." Presented by the Author, Charles Atherton, Mem. Inst. C.E., Chief Engineer Royal Dockyard, Woolwich.

"Proceedings of the Institution of Mechanical Engineers" for January 28, April 28, July 28, and August 24 and 25, 1858. Presented by the Institution of Mechanical Engineers.

The thanks of the Institution were voted for these donations

The Treasurer presented his accounts and statements in accordance with Rule 15; and Messrs. Downie and Ramsay were appointed Auditors in accordance with Rule 17, to examine the same.

Abstract of Treasurer's Accounts—Session 1858–59.

Dr.

	£	s.	d.	£	s.	d.
April 14, 1858.						
To Balance from Session 1857—58.						
Cash in Union Bank,............	£270	0	0			
Cash in Treasurer's hands,.......		15	9			
				270	15	9
April 13, 1859.						
To Subscriptions—						
96 Members, at £2 2s.,........	201	12	0			
20 New Members, at £3 3s.,....	63	0	0			
1 Associate, at £1 11s. 6d.,..	1	11	6			
8 Graduates, at £1 1s.,........	8	8	0			
				274	11	6
To Cash for 16 copies of the Transactions, Vol. I., at 5s.,...				4	0	0
				£549	7	3

Cr.

	£	s.	d.	£	s.	d.
April 13, 1859.						
By Balance of Secretary's Salary for Session 1857–58,............				£22	0	0
By payment to account of Secretary's Salary for Session 1858–59,........................				75	0	0
By fee to Officer,....................				5	0	0
By cost of 300 copies of the Transactions, Vol. I.,............				69	2	0
By cost of large box for drawings,				1	3	9
By expenses of the Session, as per vouchers, viz.—						
Circulars, Stationery, &c.,............	£9	15	6			
Postage, Porterage, &c.,..................	5	0	0			
Reporter, payment to account,..........	2	2	0			
				16	17	6
By expenses incurred on account of proposed Boiler Association, as per vouchers,..................				8	5	0
Balance—						
Cash in Union Bank, as per pass book,..............	346	0	0			
Cash in Treasurer's hands,.........	5	19	0			
				351	19	0
				£549	7	3

After their examination, the Auditors presented the following Report:—

"Glasgow, 13*th April*, 1859.—We have examined the above statement and compared it with the cash-book and vouchers, and find it correct, the sum in the Union Bank being Three hundred and forty-six pounds, and in the hands of the Treasurer, Five pounds nineteen shillings, making, in all, the sum to be carried to the credit of the Institution, Three hundred and fifty-one pounds nineteen shillings.

(Signed) John Downie, William Ramsay, } *Auditors.*

The thanks of the meeting were voted to the Auditors.

The following gentlemen were duly elected Office-Bearers for the Third Session (1859–60) of the Institution, in accordance with Regulations 24, 35, 36, 37, and 38, which were read:—

President.

WALTER NEILSON, Esq.

Vice-Presidents.

WILLIAM TAIT, Esq.
NEIL ROBSON, Esq.
WILLIAM JOHNSTONE, Esq.

Councillors.

W. J. M. RANKINE, Esq., LL.D.
JAMES R. NAPIER, Esq.
JAMES G. LAWRIE, Esq.
DAVID Y. STEWART, Esq.
WILLIAM ALEXANDER, Esq.
JOHN ELDER, Esq.
WILLIAM S. DIXON, Esq.
DAVID ROWAN, Esq.
PATRICK STIRLING, Esq.
ANDREW M'ONIE, Esq.

Treasurer.

DAVID MORE, Esq.

Secretary.

EDMUND HUNT, Esq.

Mr. WALTER NEILSON, being in the chair, drew the attention of the meeting to the valuable services which Professor Rankine had rendered to the Institution during the two years for which he had held the office of its President. They could not, he thought, separate on the present occasion, without tendering him a special and cordial vote of thanks for his close attention to the interests of the Institution. He had given them much valuable information; and the success attending their meetings was undoubtedly, in a great measure, due to the excellent manner in which he had conducted the proceedings. They would all, in this instance, regret that the Rules of the Institution prevented his longer continuance in office at the present time, and that his place must be occupied by others not nearly so well qualified to fill it.

Professor THOMSON cordially seconded the motion, which was unanimously and enthusiastically agreed to.

Professor RANKINE said it was most gratifying to him, at the termination of his tenure of office as President, to receive so great a testimonial of the Society's appreciation of his services. He was sure that, under their new President, they would find no falling off in the manner in which the duties of chairman would be performed; but rather that in Mr. Neilson they had a great acquisition.

Description of Experiments on the Comparative Strength, &c., of Steel and Wrought Iron, by Messrs. Robert Napier and Sons.

The object sought in instituting the series of experiments about to be described, was to ascertain the comparative strength of various kinds of Steel and Wrought Iron when subjected to a tensile strain, with the view of substituting Homogeneous metal or Steel for Wrought Iron in the construction of machinery, boilers, steam-ships, &c. For this purpose it was considered decidedly preferable to take the specimens that were to be tested from bars and plates, as produced for the market, instead of applying to the various makers for samples, which might or might not be superior to those usually turned out. It is therefore to be understood that all the specimens tested were indiscriminately collected from engineers' or merchants' stores, except those marked *samples* which were obtained from the makers, owing to their not being found in stock at the time; in some instances, however, specimens of the same make were afterwards obtained from stores, and consequently both sets appear in the accompanying Tables. Nothing was taken as to the origin of which the least doubt existed; and, in most cases, the plates and bars bore the makers' brands. The trial specimens were severally cut from four or more different bars or plates to obtain an average, whilst from each plate a piece was cut off lengthways, and another crossways, and correspondingly marked, L and C. All the trial specimens were duly registered, and when and from whom received, and were distinguished by numbers or marks. In many cases, the makers' names or brands were concealed from the experimenter at his own request, until after the specimens were tested and the results communicated to the parties from whom they were obtained; such specimens being sent ready for testing, with private marks for subsequent identification. In order that the series of experiments might be strictly comparative, care was taken that, as far as was possible, all the specimens should be similarly prepared, or when otherwise, the difference noted.

Testing Apparatus.—The testing apparatus employed in the experiments is fully delineated in Plate IX.; fig. 1, being a longitudinal sectional elevation of the entire arrangements; fig. 2, a corresponding end elevation; and figs. 3 to 6, representing details drawn to a larger scale. A large cast-iron base plate, A, resting on wooden sleepers, *b*, forms a rigid foundation for the two upright standards, C, which support the cross-bar, *d*, passing through the eyebolt, *e*, of the large wrought-iron steelyard, F. Shackles, *g*, connect the steelyard's eyebolt, *h*, to the specimen, *k*, to be tested; the lower end of the specimen being connected by the shackles, *g'*, to the adjusting screw, *l*, which works in a nut fastened to the underside of the foundation-plate, A. A platform, M, supports the men, who apply the weights, N, by separate hooks to chains hanging from the end of the steelyard, F. An adjustable platform, O, receives the falling weights, whilst the block, P, sustains the steelyard, when it drops at the breaking of the specimen. A rope-sling, *r*, attached to the chain-hook of a derrick crane, is employed for elevating the steelyard into the position indicated by dotted lines, at the commencement of each experiment; the amount of elevation varying with the specimen to be tested. Figs. 3 and 4 represent the forms of the plate specimens; the thinner plates tested having side pieces riveted on, as shown in fig. 4, to give longer bearings to the steel pins, whilst the plates, fig. 3, of a thickness of four-tenths and upwards did not require any. Fig. 5 exhibits the form of the bar specimens with full details of their receiving shackles; two different sets being used to suit the larger and smaller sizes tested. Fig. 6 refers to the screw-bolt-and-nut experiments. Marks were made with a centre-punch for receiving the points of a large pair of compasses, and used for measuring the gradual elongation of the specimens, as the weights were applied to the steelyard, as shown in the various figures. In order to ascertain the length of the parts actually stretched, a number of the specimens had the space between the punch marks divided into spaces of $\frac{1}{4}$ or $\frac{1}{2}$ inch, previous to applying the weights. The necks of the bolts were slightly tapered, as shown in fig. 5, to insure the fracture taking place somewhere in the central part or body of the bolt, instead of at the neck or shoulder; the heads of the Iron bolts were formed by welding on rings, and those of the Steel by staving down the solid bar. Several attempts were made to weld rings on the latter; but, in most instances, the rings failed at the trial, and consequently other specimens had to be substituted. On referring to the accompanying Tables, A and B, in the description column will be found the terms, "rolled bars," signifying that the central portion or part to be drawn asunder had not been operated upon by the smith; "forged," that they were reduced to the given size by the smith; and "planed," that the rolled bar had been reduced in the planing machine to find if its relative strength was thereby affected; whilst other pieces are noted as "turned" down in the lathe for a similar purpose.

Mode of Conducting the Experiments.—Each bolt, with the bearing part of its heads turned true, was first carefully gauged, and the distance between the inside edges of the heads measured by an accurately-divided ivory scale by Elliot of London, and the same duly recorded. The bolt was then fastened in the shackles and placed in position, the steelyard having been raised to the required elevation by means of the crane. The connection having been completed by means of two steel pins, the crane chain and sling were lowered so as to clear the steelyard, and the attendants applied the weights in succession, beginning with weights of 56 lbs., and gradually reducing to weights of 28 lbs., 14 lbs., 7 lbs., 4 lbs., as the breaking point was approached. The descent of the steelyard was observed by sighting it with the brick-work of a neighbouring wall; additional weights were not applied until the motion caused by the preceding weights ceased to be apparent. In the hard, brittle, and coarser kinds of Iron little or no indication was given of the approaching rupture, by the gradual descent of the steelyard; on the contrary, it dropped suddenly on the breaking of the specimen: this remark also applies to the hard classes of Steel. In such cases the lighter were repeatedly changed for heavier weights, until the limit of the specimen's tenacity was reached.

Fracture Illustrations—Plates X. XI. & XII.—These Plates contain full-size delineations of fractured specimens selected as representatives of the various kinds of fractures. In Plate X. are shown the bar specimens, the hardest class of Steel tested being marked **A**; the softest and most ductile, **J**; the softest and most ductile of the various kinds of Wrought Iron embraced in the bar experiments, **K**; and the hardest and least ductile, **Z**. In Plate XI., specimen, **A**, is the hardest, and specimen, **H**, the softest of the Cast Steel rolled plates; whilst specimens **I** to **L** are Puddled or Wrought Steel rolled plates. Plate XII. contains the fractures of the Wrought Iron rolled plates, specimen, **M**, being the most ductile of the fine-fibred class; specimen, **Q**, being of the finely crystalline and fibrous class; specimen, **T**, of the coarsely crystallized and least ductile variety; specimens, **U**, **V**, and **W**, of the coarser kinds of fibrous-laminated plates; and specimen, **X**, unlaminated. The outside dotted lines indicate the original sizes of the specimens, or the sizes previous to the application of the weights; the inner full lines showing the reduced sizes at the fractures caused by the sudden contraction of the bar when weights equivalent to the tenacity of the specimens were applied to the steelyard. The per centages of difference between the original and fractured areas are given in the Plates; also the index numbers, to facilitate reference to the accompanying Tables. Besides the lines indicating the original and fractured dimensions, Plate X. also shows the stretching or the parallel reduction in the diameter produced by the general elongation of the specimen.

Method of calculating and tabulating the results of the Experiments.—The particulars and results of the various experiments are recorded in the accompanying Tables—A, B, C, D, E. The experiments are distinguished by index numbers placed in the first column of each Table, no index number being repeated in any of the Tables. The specimens experimented upon consisted of—

90 Steel Bars,	Table A,	index numbers,		1 to 90.
195 Iron Bars,	" B,	"	"	101 to 295.
80 Steel Plates,	" C,	"	"	301 to 380.
150 Iron Plates,	" D,	"	"	401 to 550.
25 Iron Straps, &c.,	E,	"	"	601 to 625.

Making in all 540 specimens.

In Tables A, B, column 3 records for each experiment the total weight on the steelyard at the time it dropped. This is multiplied by 28, the leverage of steelyard, and there is added to the product the weight required to counterbalance the steelyard, namely, 9142 lbs. less 72 lbs. weight of the two upper shackles with their pins, or 9070 lbs. the net weight. Thus, for example, when specimen No. 1, Table A, broke, there were on the steelyard eleven 56 lb., five 28 lb., and two 14 lb. weights, = 784 lbs., making, with 38 lbs. weight of attaching hooks and chain, 822 lbs., entered in column 3; and 822 lbs. × 28 leverage of steelyard = 23,016 lbs., making, with 9070 lbs. for steelyard, 32,086 lbs., which, being divided by the area of the specimen, ·2207 (column 2), gave 145,383 lbs. (column 4), as the breaking weight of that specimen per square inch of its *original* sectional area. The bars contracting more or less, according to the quality or peculiarities of the Steel and Iron tested, as referred to when describing the plates of fractures, it was considered both interesting and important to tabulate these effects; and, accordingly, columns 6 and 12 contain, respectively, the sizes resulting from the general *stretching* of the bolts and that at the *fractures;* columns 7 and 13 giving the corresponding areas, and columns 8 and 14 the differences between these and the *original* areas. The mean differences of the various lots are given in columns 9 and 15; and in columns 10 and 16 the per centages of the same; whilst the results of dividing by the *stretched* and *fractured* areas, instead of by the *original* areas, are given in columns 11 and 17.

The total elongation of each specimen was found by noting the length (between the insides of the heads) previous to submitting it to the test, and deducting that from the length, again measured by placing the two broken pieces as close together as the nature of the fracture would admit (allowance being made for any intervening space). The difference is entered in column 18 of the Tables; the original length in column 20; the mean difference or elongation in inches in column 19; and the per centage in column 21.

The characteristics of the fracture are attempted to be given in columns 22, 23, and 24; column 24 referring to the accompanying illustrations, Plates X. XI. and XII. The particular specimen selected for illustration, as the representative of its class, is distinguished in the Tables by a heavy letter, as **A**; the others grouped under that class having a lighter letter, as A. When two letters are used, it signifies that the specimen presents mixed characteristics. Column 22 indicates whether the fracture is wholly fibrous or not; in Table A, Steel bars, "100" signifies that the fracture is entirely of a fine granular semi-lustrous appearance; "0," that it is wholly of a silky fibrous lustre; whilst in Table B, "0" indicates that the Iron is entirely fibrous; and, "100," that it is wholly crystalline, of a bright shining lustre. Intermediate numbers indicate intermediate qualities, but only approximately. The general colour of the Iron and nature of its fibre, are given in column 23.

The results are similarly recorded in the remaining Tables C, D, and E, relating to the experiments on Steel plates, Iron plates, and Iron straps, &c. They contain, however, no reference to the *stretched* dimensions, owing to the circumstance that these were not so distinguishable from the original and fractured sizes, as generally was the case in the bar specimens.

Messrs. Robert Napier & Sons entrusted their Mr. David Kirkaldy with the control of these experiments, and are satisfied that in conducting them, and in tabulating the results, every care has been taken to develop impartially the peculiarities of the various specimens tested. The routine of operations has been adhered to as strictly as possible throughout the entire series of experiments—this, in the conducting of comparative experiments, being of course an indispensable requisite—and it is believed that the results are as nearly correct as it is possible in the circumstances to have them.

TABULATED RESULTS

OF EXPERIMENTS ON THE

COMPARATIVE STRENGTH, &c., OF STEEL AND WROUGHT IRON,

By MESSRS. ROBERT NAPIER & SONS.

NOTE.—All the pieces were taken *promiscuously* from Engineers' or [illegible]
b denotes bad fracture; *r*, slightly [illegible]

Index No	District.	Names of the Makers or Works.	Description	ORIGINAL Diameter.	ORIGINAL Area.	Weight on Steelyd	Breaking Weight per square inch of Original Area.		STRETCHED Diameter.	STRETCHED Area.
				1.	2.	3.	4.	5.	6.	7.
				inch	sq. in.	lbs.	lbs.	lbs.	inch.	sq. in.
1	Sheffield	T. TURTON & SONS, Cast Steel for Tools, (from Acadian iron.)	All forged from rolled bars by the same smith, reheated after hammering, and allowed to cool gradually	·53	·2207	822	145,383	132,909	·52	·2124
2		" "		·55	·2376	908	145,177		·53	·2206
3		" "		·57	·2552	894	133,628		·55	·2376
4		" "		·59	·2734	965	132,004		·58	·2642
5		" "		·57	·2552	852	129,020		·55	·2376
6		" "		·56	·2462	663	112,242		·56	·2462
7		THOMAS JOWITT, * Cast Steel for Tools.		·56	·2462	980	145,294	132,402	·55	·2376
8		" "		·58	·2642	1008	141,159		·56	·2462
9		" "		·57	·2552	792	122,437		·56	·2462
10		" "		·57	·2552	749	117,719		·55	·2376
11		Do. Do. Cast Steel for Chisels.		·58	·2642	978	137,979	124,852	·56	·2462
12		" "		·56	·2462	852	133,737		·55	·2376
13		" "		·58	·2642	908	130,568		·57	·2552
14		" "		·58	·2642	908	130,568		·57	·2552
15		" "		·58	·2642	821	121,340		·56	·2462
16		" "		·60	·2827	858	117,757		·56	·2462
17		" "		·57	·2552	720	114,537		·52	·2124
18		" "		·58	·2642	736	112,331		·55	·2376
19		Do. Do. Cast Steel for Drifts.		·57	·2552	865	130,447	115,882	·52	·2124
20		" "		·57	·2552	865	130,447		·53	·2207
21		" "		·57	·2552	642	105,980		·53	·2207
22		" "		·57	·2552	557	96,653		·53	·2207
23		T. JOWITT, Double Shear Steel.		·56	·2462	778	125,321	118,468	·54	·2290
24		" "		·57	·2552	793	122,547		·54	·2290
25		" "		·57	·2552	763	119,255		·55	·2376
26		" "		·57	·2552	649	106,747		·55	·2376
27		BESSEMER Sheffield. (Tool). (Samples)		·75	·4417	1619	123,165	111,460	·72	·4071
28		" "		·65	·3318	1077	118,221		·64	·3216
29		" "		·74	·4300	1420	113,588		·73	·4184
30		" "		·74	·4300	1390	111,605		·73	·4184
31		" "		·74	·4300	1347	108,805		·70	·3848
32		" "		·73	·4184	1276	107,070		·72	·4071
33		" "		·74	·4300	1304	106,004		·72	·4071
34		" "		·73	·4184	1219	103,255		·72	·4071
35		WILKINSON (L) Blister Steel.		·57	·2552	735	116,183	104,298	·55	·2376
36		" "		·58	·2642	735	112,226		·54	·2290
37		" "		·60	·2827	678	99,236		·57	·2552
38		" "		·58	·2642	521	89,546		·57	·2552
39		T. JOWITT, Cast Steel for Taps.		·57	·2552	685	110,697	101,151	·55	·2376
40		" "		·59	·2734	713	106,196		·55	·2376
41		" "		·57	·2552	621	103,675		·55	·2376
42		" "		·57	·2552	442	84,036		·54	·2290
43		MOSS & GAMBLES, Cast Steel for Rivets. (Samples.)	Rolled bars ¾ in. round.	·75	·4417	1518	116,763	107,286	·71	·3958
44		" "		·75	·4417	1390	108,649		·71	·3958
45		" "		·75	·4417	1291	102,309		·72	·4071
46		" "		·75	·4417	1276	101,422		·72	·4071
47		NAYLOR, VICKERS, & Co., Cast Steel for Rivets.	Rolled bars ¾ in. round.	·75	·4417	1447	112,262	106,615	·72	·4071
48		" "		·75	·4417	1419	110,486		·71	·3958
49		" "		·74	·4300	1247	102,293		·70	·3848
50		" "		·75	·4417	1276	101,421		·72	·4071

...ores, except those marked *Samples*, which were received from the Makers.
...size at fracture; *s*, size at smallest part.

Difference between Original and Stretched Areas.			Breaking Wght per sq in of Stretched Area	FRACTURED		Difference between Original and Fractured Areas.			Breaking Wght. per sq in of Fractured Area.	ELONGATION. Length of part stretched in Column 20.				FRACTURE.	
				Diameter	Area.									Gran.	Kind.
8.	9.	10.	11.	12.	13.	14.	15.	16.	17.	18.	19.	20.	21.	22.	24.
sq. in.	sq. in	℔ ct.	lbs.	inch.	sq. in.	sq. in.	sq. in.	℔ ct.	lbs.	inch.	inch.	in.	℔ ct.	℔ ct.	
·0083	·0116	4·7	139,124	·52s	·2124	·0083	·0116	4·7	139,124	·14	·14	2·6	5·4	100	A
·0169				·53	·2207	·0169				·18				100	A
·0176				·55	·2376	·0176				·18				100	A
·0092				·58	·2642	·0092				·14				100	A
·0176				·55	·2376	·0176				·16				100	A
·0000				·56	·2462	·0000				·03				100	A
·0082	·0132	5·1	139,616	·53	·2207	·0255	·0328	12·8	151,857	·15	·14	2·7	5·2	100	A
·0180				·57	·2552	·0090				·08				100	A
·0090				·54f	·2290	·0262				·12				100	C
				·53s	·2207	·0345									
·0176				·52f	·2124	·0428				·20				100	C
				·50s	·1963	·0589									
·0180	·0210	8·0	135,597	·53	·2376	·0266	0447	17·0	150,243	·15	·17	2·4	7·1	100	A
·0186				·50	·1963	·0499				·14				100	A
·0090				·55	·2376	·0266				·11				100	A
·0090				·60f ·57s	·2552	·0090				·12				100	C
·0180				·55	·2376	·0266				·18				100	A
·0365				·53	·2207	·0620				·16				100	A
·0428				·49	·1885	·0667				·32				100	A
·0266				·52f	·2124	·0518				·16				100	C
				·48s	·1809	·0833									
·0428	·0366	14·3	135,283	·50	·1963	·0589	·0548	21·5	147,570	·30	·32	2·4	13·3	100	A
·0345				·53	·2207	·0345				·25				100	A
·0345				·50	·1963	·0589				·35				100	A
·0345				·49	·1885	·0667				·38				10	I
·0172	·0196	7·8	128,380	·52	·2124	·0338	·0497	19·6	147,396	·38	·35	2·6	13·5	100	A
·0262				·52	·2124	·0428				·30				100	A
·0176				·54	·2290	·0262				·28				100	A
·0176				·45	·1590	·0962				·35				90	A I
·0346	·0198	4·8	116,933	·72s	·4071	·0346	·0929	22·3	143,327	·40	·37	6·8	5·5	100r	B C
·0102				·64s	·3216	·0102				·16				100	B C
·0116				·59	·2734	·1566				·53				90	B I
·0116				·65	·3318	·0982				·42				90	F
·0452				·65	·3318	·0982				·47				100	B
·0113				·72	·4071	·0113				·12				100	B
·0229				·62	·3019	·1281				·35				90	F
·0113				·52	·2124	·2060				·48				50	B I
·0176	·0223	8·4	113,649	·55	·2376	·0176	·0571	21·4	132,472	·27	·29	3·0	9·7	100r	A
·0352				·53	·2207	·0435				·25				100r	A
·0275				·53	·2207	·0620				·24				100r	A
·0090				·45	·1590	·1052				·40				90r	A I
·0176	·0243	9·4	111,712	·48	·1809	·0743	·0747	28·8	142,070	·24	·28	2·6	10·8	100	A
·0358				·47	·1735	·0999				·30				100	A
·0176				·47	·1735	·0817				·26				90	A I
·0262				·52	·2124	·0428				·30				85	D
·0459	·0402	9·1	118,057	·65	·3318	·1099	·1418	32·1	158,013	·90	·84	6·8	12·4	90	F
·0459				·63	·3116	·1301				·85				76	F
·0346				·60	·2827	·1590				·85				50	F I
·0346				·59	·2734	·1683				·88				0	I
·0346	·0401	9·1	117,359	·60	·2827	·1590	·1441	32·8	158,785	·55	·52	6·0	8·7	85	F I
·0459				·61	·2922	·1495				·56				90	F I
·0432				·62	·3019	·1281				·48				95	F
·0346				·62	·3019	·1398				·50				90	F

NOTE.—All the pieces were taken *promiscuously* from Engineers' or Merchants'
b denotes bad fracture; *r*, slightly rent:

Index No.	District.	Names of the Makers or Works.	Description	ORIGINAL Diameter.	ORIGINAL Area	Weight on Steelyd.	Breaking Weight per square inch of Original Area.		STRETCHED Diameter.	STRETCHED Area
				1.	2.	3.	4.	5.	6.	7.
				inch	sq. in.	lbs.	lbs.	lbs.	inch.	sq. in.
51	Prussia.	KRUPP, Dusseldorf, Cast Steel for Bolts.	Rolled bars, round.	·92	·6650	1961	96,908	92,015	·86	·5812
52		" "		·93	·6808	1982	94,838		·84	·5441
53		" "		·91	·6504	1789	90,962		·88	[illegible]
54		" "		·91	·6504	1675	86,054		·85	·5674
55	Sheffield.	SHORTRIDGE, HOWELL, & Co. Homogeneous Metal,	Rolled bars $^9/_{16}$ in. for rivets.	·55	·2376	521	99,570	90,647	·52	·2124
56		" "		·57	·2552	536	94,349		·53	·2207
57		" "		·57	·2552	464	86,450		·52	·2124
58		" "		·56	·2462	399	82,218		·53	·2207
59		Do. Do.	Forged.	·77	·4657	1252	94,752	89,724	·72	·4071
60		" "	"	·75	·4418	1098	90,118		·69	·3740
61		" "	"	·75	·4418	1084	89,230		·70	·3848
62		" "	"	·75	·4418	1014	84,794		·72	·4071
63		T. JOWITT, Spring Steel.	Forged from ¾ in. rolled bars.	·55	·2376	378	82,719	72,529	·52	·2124
64		" "		·57	·2552	341	72,955		·48	·1809
65		" "		·55	·2376	264	69,284		·52	·2124
66		" "		·56	·2462	249	65,158		·52	·2124
67		R. MUSHET, Coleford. Received for Experiment.	Forged bolts.	·52 × ·52	·2704	412	76,206	75,119	·50	[illegible]
68				·52 × ·52	·2704	391	74,031		·51	[illegible]
69	Liverpool.	MERSEY Co., Puddled Steel.	Forged.	·75	·4417	864	75,304	71,486	·69	·3739
70		" "	"	·76	·4536	858	74,810		·70	·3848
71		" "	"	·77	·4717	866	70,634		·69	·3739
72		" "	"	·75	·4417	790	70,613		·68	·3632
73		" "	"	·76	·4536	818	70,489		·68	·3632
74		" "	"	·74	·4300	706	67,065		·66	·3421
75	Glasgow.	BLOCHAIRN Puddled Steel.	Rolled bars.	·75	·4417	861	75,114	70,166	·70	·3848
76		" "		·75	·4417	833	73,339		·67	·3526
77		" "	"	·62 × ·60	·3720	647	73,080		·58	·3363
78		" "	"	·75	·4417	826	72,896		·72	·4071
79		" "	"	·75	·4417	805	71,564		·70	·3848
80		" "	"	1·00	·7854	1219	55,006		·97	·7392
81		Do. Do.	Forged from slabs.	·75	·4417	804	71,501	65,255	·70	·3848
82		" "		·75	·4417	804	71,501		·71	·3958
83		" "	"	·75	·4417	788	70,169		·68	·3632
84		" "	"	·76	·4536	790	68,761		·72	·4071
85		" "	"	·76	·4536	762	67,082		·71	·3958
86		" "	"	·77	·4657	384	42,564		·77	·4657
87		Do. Do.	Forged from rolled bars.	·77	·4657	846	70,341	62,769	·73	·4184
88		" "		·77	·4657	832	69,500		·75	·4417
89		" "		·76	·4536	734	65,304		·72	·4071
90		" "		·77	·4657	440	45,931		·77	·4657

tores, except those marked *Samples*, which were received from the Makers.
size at fracture; *s*, size at smallest part.

Difference between Original and Stretched Areas			Breaking Wght per sq. in. of Stretched Area	FRACTURED		Difference between Original and Fractured Areas			Breaking Wght. per sq. in. of Fractured Area.	ELONGATION. Length of part stretched in Column 20.				FRACTURE.	
				Diameter	Area.									Gran	Kind.
8.	9.	10.	11.	12.	13.	14.	15.	16.	17.	18.	19.	20.	21.	22.	24.
sq. in.	sq. in.	℔ ct.	lbs.	inch.	sq. in.	sq. in.	sq. in.	℔ ct.	lbs.	inch.	inch.	in.	℔ ct.	℔ ct.	
0838	·0864	13·1	105,910	·71	·3958	·2602	·2247	34·0	139,434	1·14	1·10	7·2	15·3	10	F I
1367				·75	·4417	·2391				1·37				85	F
0422				·88*s*	·6082	·0422				0·57				100	C
0830				·62	·3019	·3485				1·30				0*r*	I
·0252	·0390	12·9	104,017	·46	·1662	·0714	·0911	36·6	142,920	·38	·55	4·0	13·7	65	F I
·0345				·46	·1662	·0690				·50				0	I
·0428				·45	·1590	·0962				·57				55	F I
·0255				·42	·1385	·1077				·76				0	I
·0586	·0545	12·2	102,329	·58	·2642	·2015	·1161	26.0	121,212	·70	·62	5·2	11·9	80	F I
·0678				·61	·2922	·1496				·87				90	F I
·0570				·68	·3632	·0786				·63				100*r*	A
·0347				·72*s*	·4071	·0347				·30				100	C
·0252	·0396	16·2	86,523	·52	·2124	·0252	·0588	24·1	95,490	·20	·45	2·5	18·0	80	D
·0743				·45	·1590	·0962				·77				0*r*	E
·0252				·50	·1963	·0418				·32				0	E
·0338				·47	·1735	·0727				·51				0*r*	E
·0204	·0154	5·7	79,655	·40	·1600	·1104	·1292	47·8	143,853	1·00	0·98	6·0	16·3	0	J
·0103				·35	·1225	·1479				0·96				0	J
·0678	·0819	18·2	87,451	·64	·3216	·1201	·1582	35·3	110,451	·85	0·84	4·4	19·1	0*r*	H
·0688				·68	·3632	·0904				·56				84*rr*	G H
·0978				·61	·2922	·1795				·90				0*rr*	H
·0785				·57	·2552	·1865				·94				0	I
·0904				·59	·2734	·1802				·92				0*r*	H
·0879				·55	·2376	·1924				·88				0*r*	H
·0569	·0582	10·9	76,699	·70	·3848	·0569	·0950	19·4	84,871	·40	0·53	4·7	11·3	65	F
·0891				·62	·3019	·1398				·87				18	G
·0357				·52	·2704	·1016				·49				0	H
·0346				·71	·3958	·0459				·45				0	H
·0569				·61	·2922	·1495				·75				0	H
·0462				·95	·7088	·0766				·24				3*br*	G
·0569	·0476	10 5	72,775	·68	·3632	·0785	·0856	19·0	80,370	·61	0·53	4·4	12·0	0*r*	H
·0459				·68	·3632	·0785				·46				0	G
·0785				·64	·3216	·1201				·78				0	G
·0465				·66	·3421	·1115				·63				0*r*	H
·0578				·67	·3526	·1010				·57				0*rr*	G H
·0000				·75	·4417	·0240				·12				0*br*	G
·0473	·0295	6·4	67,022	·73	·4184	·0473	·0551	11·9	71,231	·62	0·40	4·4	9·1	0	G H
·0240				·72	·4071	·0586				·42				0*r*	G H
·0465				·68	·3632	·0904				·40				50*r*	G
·0000				·75	·4417	·0240				·14				0*br*	G

NOTE.—All the pieces were taken *promiscuously* from Engineers' or Merchants

b denotes bad fracture; *r*, slightly rust:

Index No.	District.	Names of the Makers or Works.	Description	ORIGINAL Diameter. 1. inch	ORIGINAL Area 2. sq. in.	Weight on Steelyd. 3. lbs.	Breaking Weight per square inch of Original Area 4. lbs.	5. lbs.	STRETCHED Diameter. 6. inch.	STRETCHED Area 7. sq. in.
101	Yorkshire	LOW-MOOR.	Rolled	1·03 × 1·01	1·0403	1930	62,298	60,364	·95 × ·95	·902[illegible]
102		" "	bars 1 inch	1·02 × 1·01	1·0302	1904	60,565		·95 × ·95	·902[illegible]
103		" "	square.	1·03 × 1·01	1·0403	1882	59,390		·94 × ·94	[illegible]
104		" "		1·03 × 1·01	1·0403	1875	59,202		·94 × ·94	[illegible]
105		Do. Do.	Rolled	1·00	·7854	1504	65,166	61,798	·90	·6362
106		" "	bars 1 inch	"	"	1433	62,635		·90	·6362
107		" "	round.	"	"	1361	60,069		·90	·6362
108		" "		"	"	1340	59,320		·90	·6362
109		Do. Do.	Rolled	·69	·3712	504	62,451	60,075	·62	·3019
110		" "	bars	"	"	483	60,867		·63	·3116
111		" "	$^{11}/_{16}$ in.	"	"	455	58,756		·63	·3116
112		" "	for rivets.	"	"	448	58,228		·62	·3019
113		Do. Do.	Planed	·78 × ·78	·6084	1019	61,805	60,245	·74 × ·74	·5476
114		" "	from 1 in.	·77 × ·77	·5929	947	60,020		·72 × ·72	·5184
115		" "	sq. bars.	·77 × ·77	·5929	947	60,020		·72 × ·72	·5184
116		" "		·78 × ·78	·6084	961	59,135		·72 × ·72	·5184
117		Do. Do.	Forged	·77	·4657	805	67,876	66,392	·72	·4071
118		" "	from 1¼ in.	·78	·4779	823	67,198		·71	·3959
119		" "	round bars	·80	·5026	834	65,622		·72	·4071
120		" "		·77	·4657	755	64,871		·74	·43[illegible]
121		BOWLING.	Rolled	1·00	·7854	1519	65,701	62,404	·92	·66[illegible]
122		" "	bars	"	"	1461	63,634		·92	·66[illegible]
123		" "	1 in. round.	"	"	1404	61,602		·92	·66[illegible]
124		" "		"	"	1322	58,678		·90	·6362
125		Do. Do.	Turned	1·00	·7854	1440	62,885	61,477	·90	·6362
126		" "	from 1¼ in.	"	"	1433	62,635		91	·6504
127		" "	round bars	"	"	1382	60,817		·92	·66[illegible]
128		" "		"	"	1347	59,570		·92	·66[illegible]
129		FARNLEY.	Rolled	1·00	·7854	1475	64,133	62,886	·90	·6362
130		" "	bars 1 in.	"	"	1475	64,133		·91	·6504
131		" "	round.	"	"	1461	63,634		·90	·6362
132		" "		"	"	1349	59,642		·90	·6362
133	Staffordshire	J. BRADLEY & Co. (L) (Charcoal.) — Samples	Rolled	1·00	·7854	1304	58,096	57,216	·89	·6220
134		" "	bars 1 in.	"	"	1297	57,787		·89	·622[illegible]
135		" "	round.	"	"	1276	57,039		·89	·622[illegible]
136		" "		"	"	1247	56,004		·88	·60[illegible]
137		Do. B. B. Scrap.	Rolled	1·00	·7854	1359	59,998	59,370	·89	·6220
138		" "	bars 1 in.	"	"	1347	59,570		·89	·6220
139		" "	round.	"	"	1340	59,320		·90	·6362
140		" "		"	"	1319	58,571		·90	·6362
141		Do. S C [mark]	Rolled	·75	·4417	601	58,632	56,715	·68	·3632
142		" "	bars ¾ in.	"	"	594	58,190		·68	·3632
143		" "	for rivets.	"	"	551	55,463		·67	·3526
144		" "		"	"	537	54,575		66	·3421
145		Do. Do.	Rolled	·89	·6220	1089	63,604	62,231	·81	·5153
146		" "	bars ⅞ in.	"	"	1061	62,344		·81	·5153
147		" "	round.	"	"	1047	61,714		·82	·5281
148		" "		"	"	1037	61,263		·80	·5026
149		G. B. THORNEYCROFT & Co. T N S.	Rolled	·81	·5153	790	60,528	59,278	·73	·4184
150		" "	bars	"	"	776	59,767		·74	·4300
151		" "	$^{13}/_{16}$ in.	"	"	769	59,387		·74	·43[illegible]
152		" "	for rivets.	"	"	733	57,431		·74	·4300
153		LORD WARD, L [mark] W.R-O.	Rolled	·70	·3848	547	63,373	59,753	·63	·3116
154		" "	bars	"	"	504	60,244		·63	·3116
155		" "	$^{11}/_{16}$ in.	"	"	476	58,207		·65	·3318
156		" "	for rivets.	"	"	463	57,188		·65	·3318

Stores, except those marked *Samples*, which were received from the Makers.
***f* size at fracture; *s*, size at smallest part.**

Difference between Original and Stretched Areas.			Breaking Wght. per sq. in. of Stretched Area	FRACTURED		Difference between Original and Fractured Areas.			Breaking Wght per sq in of Fractured Area.	ELONGATION. Length of part stretched in Column 20.				FRACTURE.		
				Diameter	Area.									Crys.	Col.	Kind
8. sq. in.	9. sq. in.	10. ℔ ct.	11. lbs.	12. inch.	13. sq. in.	14. sq. in.	15. sq. in	16. ℔ ct.	17. lbs.	18. inch.	19. inch.	20. in.	21. ℔ ct.	22. ℔ ct.	23.	24.
·1375	·1444	13·9	70,131	·69 × ·69	·4761	·5609	·5028	48·5	117,147	2·31	1·89	7·6	24·9	0	Bright lightish-grey; fibre, compact and fine	N
·1275				·80 × ·80	·6400	·3900				1·80				0 *r*		N
·1564				·71 × ·71	·5041	·5359				1·80				4		N
·1564				·72 × ·72	·5184	·5216				1·65				0		N
·1492	·1492	19·0	76,290	·68	·3632	·4222	·4168	53·1	131,676	1·90	1·91	7·2	26·5	0		P
·1492				·70	·3848	·4006				1·86				0		P
·1492				·68	·3632	·4222				1·94				0		P
·1492				·68	·3632	·4222				1·92				0		P
·0693	·0644	17·3	72·685	·48	·1809	·1903	·1939	52·2	125,775	1·31	1·35	6·6	20·5	0		O
·0596				·46	·1662	·2050				1·35				0		O
·0596				·49	·1885	·1827				1·34				0		O
·0693				·47	·1735	·1977				1·40				0		O
·0608	·0749	12·5	68,840	·65 × ·65	·4225	·1859	·2843	47·3	114,410	1·60	1·69	7·1	23·8	0		O
·0745				53 × ·53	·2809	·3120				1·52				0		O
·0745				·53 × ·53	·2809	·3120				1·80				0		O
·0900				·53 × ·53	·2809	·3275				1·83				0		O
·0586	·0690	14·2	77·383	·61	·2922	·1735	·2022	42·3	115,040	1·12	1·11	5·5	20·2	0		O
·0821				·60	·2827	·1952				1·13				0		O
·0955				·58	·2642	·2384				1·23				0		O
·0357				·58	·2642	·2015				0·97				0		O
·1204	·1276	16·2	74,487	·80	·5026	·2828	·3563	45·3	114,220	1·53	1·76	7·2	24·4	0 *r*		O
.1204				·74	·4300	·3554				1·80				0 *r*		O
·1204				·75	·4417	·3437				1·80				0		O
·1492				·66	·3421	·4433				1·90				0		O
·1492	·1312	16·7	73,863	·73	·4184	·3670	·3838	48·8	120,229	1·68	1·74	6·7	26·0	0		O
·1350				·73	·4184	·3670				1·88				0		O
·1204				·70	·3848	·4006				1·90				0		O
·1204				·70	·3848	·4006				1·50				0		O
·1492	·1456	18·5	77,200	·70	·3848	·4006	·3977	50·6	127,425	1·80	1·74	6·8	25·6	0		O
·1350				·72	·4071	·3783				1·60				0 *r*		O
·1492				·69	·3739	·4115				2·00				0		O
·1492				·70	·3848	·4006				1·56				0		O
·1634	·1668	21·2	72,700	·62	·3019	·4835	·4787	60·9	146,521	2·00	1·93	6·4	30·2	0 *r*	Bright grey; fibre, very fine.	L
·1634				·63	·3116	·4738				2·00				0 *r*		L
·1634				·62	·3019	·4835				1·86				0 *r*		L
·1772				·63	·3116	·4738				1·86				0 *r*		L
·1634	·1563	19·9	74,378	·70	·3848	·4006	·4068	52·0	123,805	2·00	2·02	7·6	26·6	0 *r*		M
·1634				·69	·3739	·4115				2·06				0 *r*		M
·1492				·69	·3739	·4115				2·11				0 *r*		M
·1492				·69	·3739	·4115				1·90				0 *r*		M
·0785	·0864	19·5	70,503	·55	·2376	·2041	·2186	49·5	112,336	1·75	1·53	6·6	22·5	0	Dullish-grey; fibre, compact	Q
·0785				·53	·2207	·2210				1·34				0		Q
·0891				·55	·2376	·2041				1·42				0		Q
·0996				·50	·1963	·2454				1·60				0		Q
·1067	·1067	17·2	75,133	·70	·3848	·2372	·2253	36·2	97,575	1·80	1·62	7·3	22·2	0 *r*		Q
·1067				·66	·3421	·2799				1·85				0		Q
·0939				·82	·5281	·0939				1·16				60		X
·1194				·65	·3318	·2902				1·68				0		Q
·0969	·0832	17·1	71,540	·62	·3019	·2134	·2085	40·4	99,595	1·83	1·66	7·4	22·4	0		T
·0853				·63	·3116	·2037				1·50				0 *r*		T
·0853				·62	·3019	·2134				1·78				0		T
·0853				·63	·3116	·2037				1·54				0		T
·0732	·0631	16·4	71,621	·55	·2376	·1472	·1446	37·6	95,724	1·32	1·19	6·4	18·6	0 *r*		T
·0732				·52	·2124	·1724				1·38				3		T
·0530				·55	·2376	·1472				1·16				0		T
·0530				·59	·2734	·1114				0·92				2 *b*		T

Note.—All the pieces were taken *promiscuously* from Engineers' or Merchants'
b denotes bad fracture; *r*, slightly re[illegible]

Index No.	District.	Names of the Makers or Works.		Description	ORIGINAL Diameter. 1. inch	ORIGINAL Area. 2. sq. in.	Weight on Steelyd. 3. lbs.	Breaking Weight per square inch of Original Area 4. lbs.	5. lbs.	STRETCHED Diameter. 6. inch.	STRETCHED Area. 7. sq. in.
157	Lanarkshire	Govan Ex. B. Best.		Rolled	·77 × ·77	·5929	890	57,328	56,655	·72 × ·72	·5184
158		"	"	bars ¾ in.	"	"	890	57,328		·72 × ·72	·5184
159		"	"	square.	"	"	876	56,667		·72 × ·72	·5184
160		"	"		"	"	847	55,297		·72 × ·72	·5184
161		Do.	Do.	Rolled	·76	·4536	633	59,070	57,591	·70	·3848
162		"	"	bars ¾ in.	·76	·4536	623	58,452		·70	·3848
163		"	"	round.	·70	·3848	462	57,190		·66	·3421
164		"	"		·75	·4417	554	55,653		·71	·3959
165		Govan, Ex. B. Best.		Rolled	1·15	1·0387	1875	59,276	58,358	1·05	·8659
166		"	"	bars 1⅛ in.	1·16	1·0568	1890	58,658		1·05	·8659
167		"	"	round.	1·15	1·0387	1833	58,135		1·05	·8659
168		"	"		1·15	1·0387	1804	57,362		1·04	·8495
169		Do.	Do.	Rolled	1·02	·8171	1419	59,726	59,109	·95	·7088
170		"	"	bars 1 in.	"	"	1419	59,726		·95	·7088
171		"	"	round.	"	"	1390	58,732		·95	·7088
172		"	"		"	"	1376	58,252		·95	·7088
173		Do.	Do.	Rolled	·90	·6362	1019	59,104	58,169	·83	·5310
174		"	"	bars ⅞ in.	"	"	1012	58,796		·84	·5441
175		"	"	round.	"	"	998	56,180		·84	·5441
176		"	"		"	"	962	56,595		·84	·5441
177		Do.	Do.	Rolled	·77	·4657	671	59,820	57,400	·70	·3848
178		"	"	bars ¾ in.	"	"	671	59,820		·71	·3959
179		"	"	round.	"	"	619	56,694		·71	·3959
180		"	"		"	"	562	53,286		·71	·3959
181		Govan B. Best.		Rolled	1·13	1.0029	1989	64,575	60,879	1·04	·8495
182		"	"	bars 1⅛ in.	1·12	0·9852	1875	62,495		1·04	·8495
183		"	"	round.	1·13	1·0029	1904	62,201		1·05	·8659
184		"	"		1·13	1·0029	1619	54,245		1·10	·9503
185		Do.	Do.	Rolled	1·01	·8012	1575	66,363	62,849	·93	·6793
186		"	"	bars 1 in.	1·01	·8012	1533	64,895		·93	·6793
187		"	"	round.	1·00	·7854	1361	60,069		·90	·6362
188		"	"		1·00	·7854	1361	60,069		·97	·7390
189		Do.	Do.	Rolled	·90	·6362	1090	62,229	61,341	·82	·5281
190		"	"	bars ⅞ in.	·90	·6362	1090	62,229		·82	·5281
191		"	"	round.	·89	·6220	1019	60,453		·81	·5153
192		"	"		·89	·6220	1019	60,453		·82	·5281
193		Do.	Do.	Rolled	·77	·4657	783	66,553	64,795	·71	·3958
194		"	"	bars ¾ in.	"	"	780	66,373		·72	·4071
195		"	"	round.	"	"	747	64,390		·71	·3956
196		"	"		"	"	705	61,864		·74	·4300
197		Govan	*	Rolled	1·15	1·0387	1961	61,594	58,326	1·05	·8659
198		"	"	bars 1⅛ in.	"	"	1933	60,840		1·07	·8992
199		"	"	round.	"	"	1847	58,521		1·07	·8992
200		"	"		"	"	1618	52,348		1·10	·9503
201		Do.	Do.	Rolled	1·04	·8498	1519	60,722	59,424	·98	·7543
202		"	"	bars 1 in.	1·02	·8171	1426	59,965		·95	·7088
203		"	"	round.	1·04	·8498	1475	59,272		·95	·7088
204		"	"		1·02	·8171	1361	57,738		·97	·7392
205		Do.	Do.	Rolled	·90	·6362	1190	66,630	63,956	·84	·5441
206		"	"	bars ⅞ in.	"	"	1119	63,505		·82	·5281
207		"	"	round.	"	"	1104	62,845		·84	·5441
208		"	"		"	"	1104	62,845		·86	·5674
209		Do.	Do.	Rolled	·77	·4657	733	63,547	61,887	·70	·3848
210		"	"	bars ¾ in.	"	"	719	62,705		·71	·3958
211		"	"	round.	"	"	704	61,804		·69	·3739
212		"	"		"	"	662	59,493		·72	·4071

Stores, except those marked *Samples*, which were received from the Makers.
r size at fracture; *s*, size at smallest part.

Difference between Original and Stretched Areas. 8. sq. in.	9. sq. in.	10. ℘ ct.	Breaking Wght. per sq. in. of Stretched Area 11. lbs.	FRACTURED Diameter. 12. inch.	FRACTURED Area. 13. sq. in.	Difference between Original and Fractured Areas. 14. sq. in.	15. sq. in.	16. ℘ ct.	Breaking Wght. per sq. in. of Fractured Area. 17. lbs.	ELONGATION. Length of part stretched in Column 20. 18. inch.	19. inch.	20. in.	21. ℘ ct.	FRACTURE. Crys. 22. ℘ct.	Col. 23.	Kind 24.
·0745	·0745	12·6	64,797	·58 × ·58	·3364	·2565	·2536	42·7	99,000	1·52	1·55	8·1	19·1	0	Brightish-grey; fibre close and uniform throughout the series.	R
·0745				·59 × ·59	·3481	·2448				1·56				0		R
·0745				·58 × ·58	·3364	·2565				1·50				0		R
·0745				·58 × ·58	·3364	·2565				1·64				0		R
·0688	·0565	13·0	66,242	·58	·2642	·1894	·1712	39·5	95,248	1·82	1·48	8·2	17·3	0		S
·0688				·58	·2642	·1894				1·70				0		S
·0427				·55	·2376	·1472				1·06				0		S
·0459				·60	·2827	·1590				1·10				0		S
·1728	·1814	17·4	70,645	·90	·6362	·4025	·4208	40·3	97,821	1·66	1·67	7·0	23·8	0		S
·1909				·86	·5812	·4756				1·78				0		S
·1728				·90	·6362	·4025				1·66				0		S
·1892				·90	·6362	·4025				1·56				0		S
·1083	1083	13·3	68,140	·78	·4779	·3392	·3269	40·0	98,527	1·70	1·45	6·5	22·3	0		S
·1083				·79	·4902	·3269				1·40				0		S
·1083				·79	·4902	·3269				1·38				0		S
·1083				·80	·5026	·3145				1·32				0		S
·1052	·0954	15·0	68,446	·66	·3421	·2941	·2729	42·9	101,863	1·16	1·15	6·0	19·2	0		S
·0921				·68	·3632	·2730				1·20				0		S
·0921				·69	·3739	·2623				1·16				0		S
·0921				·69	·3739	·2623				1·08				0		S
·0809	·0796	15·6	68,018	·60	·2827	·1880	·1779	38·0	92,880	1·12	0·97	5·5	17·6	0		S
·0699				·64	·3216	·1441				0·90				8		S
·0699				·59	·2734	·1923				1·02				0		S
·0699				·59	·2734	·1923				0·82				0		S
·1534	·1199	12·0	69,161	0·95	·7088	·2941	·2517	28·2	84,770	1·48	1·19	7·0	17·0	72	Greyish; fibre close, but irregular	U
·1357				0·84	·5441	·4411				1·50				8r		S
·1370				0·92	·6650	·3379				1·42				3r		S
·0536				1·10	·9503	·0536				0·36				95		Y
·1204	·1090	13·7	73,111	·84	·5441	·2571	·2297	28·9	88,550	1·42	1·24	6·5	19·1	5r		U
·1204				·82	·5281	·2731				1·37				0		S
·1492				·75	·4417	·3434				1·60				0		S
·0462				·97s	·7392	·0462				0·58				100		Y
·1081	·1042	16·6	73,527	·68	·3632	·2780	·2289	36·4	96,442	1·26	1·20	6·0	20·0	0r		S
·1081				·72	·4071	·2291				1·14				33r		U
·1067				·67	·3526	·2694				1·41				0		S
·0939				·78	·4779	·1441				1·00				20r		U
·0699	·0585	12·5	74,246	·60	·2827	·1830	·1554	33·4	97,245	1·00	0·95	5·5	17·3	2		S
·0586				·62	·3019	·1638				1·12				4		S
·0699				·60	·2827	·1830				1·17				0		S
·0357				·69	·3739	·0918				0·50				20		V
·1728	·1350	13·0	67,046	0·93	·6808	·3579	·2635	25·3	78,139	1·70	1·17	7·0	16·7	2	Loose and irregular	S
·1395				1·03	·8333	·2054				1·04				70		V
·1395				1·00s	·7854	·2533				1·30						S
·0884				1·01	·8012	·2375				0·64				4rr		U
·0955	·1057	12·6	68,100	·96	·7238	·1260	·2094	25·1	79,373	0·74	1·07	6·5	16·4	100		Y
·1083				·82	·5281	·2890				1·50				0		S
·1410				·88	·6082	·2416				1·24				25rr		V
·0779				·90	·6362	·1809				0·80				10		U
·0921	·0903	14·2	74,535	·77	·4657	·1705	·1765	27·7	88,512	1·00	1·05	6·0	15·8	28		V
·1081				·68	·3632	·2730				1·35				1		S
·0921				·77	·4657	·1705				1·07				10		U
·0688				·84	·5441	·0921				0·80				100		Y
·0609	·0753	16·1	73,869	·60	·2827	·1880	·1635	35·1	95,319	1·27	1·09	5·8	18·8	0		S
·0699				·61	·2922	·1735				1·06				5		U
·0918				·62	·3019	·1638				1·22				0		S
·0586				·65	·3318	·1339				0·80				8r		U

Note.—All the pieces were taken *promiscuously* from Engineers' or Merchants'
***b* denotes bad fracture; *r*, slightly rust:**

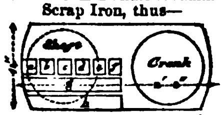
Index No.	District.	Names of the Makers or Works.		Description	Original Diameter.	Original Area.	Weight on Steelyd.	Breaking Weight per square inch of Original Area.		Stretched Diameter.	Stretched Area
					1.	2.	3.	4.	5.	6.	7.
					inch	sq. in.	lbs.	lbs.	lbs.	inch.	sq. in.
213	Lanarkshire	Glasgow B. Best.		Rolled bars 1 inch round.	1·00	·7854	1382	60,817	58,885	·92	·6650
214		"	"		1·00	·7854	1347	59,569		·91	·6504
215		"	"		1·00	·7854	1347	59,569		·92	·6650
216		"	"		0·98	·7543	1248	58,351		·90	·6362
217		"	"		0·99	·7698	1219	56,121		·90	·6362
218		Do.	Do.	Rolled bars $^{15}/_{16}$ in. round.	·92	·6650	1132	61,296	58,910	·86	·5812
219		"	"		"	"	1132	61,296		·86	·5812
220		"	"		"	"	1033	57,134		·86	·5812
221		"	"		"	"	1004	55,913		·86	·5812
222		Do.	Best Rivet.	Rolled bars $^{7}/_{8}$ in. round.	·87	·5945	925	58,823	57,092	·81	·5153
223		"	"		"	"	876	56,515		·80	·5026
224		"	"		"	"	876	56,515		·80	·5026
225		"	"		"	"	876	56,515		·80	·5026
226		Do.	B. Best.	Forged from 1 inch rolled bars.	·78	·4779	712	60,695	59,045	·72	·4071
227		"	"		·77	·4657	683	60,541		·70	·3848
228		"	"		·77	·4657	669	59,700		·71	·3959
229		"	"		·72	·4071	519	57,976		·69	·3739
230		"	"		·79	·4902	662	56,316		·75	·4417
231		Govan B. Best.		Rolled bars $^{3}/_{4}$ in. round.	·76	·4536	686	61,106	59,548	·72	·4071
232		"	"		·76	·4536	637	59,316		·70	·3848
233		"	"		·76	·4536	630	58,884		·72	·4071
234		"	"		·75	·4417	605	58,886		·71	·3959
235		Coatbridge Best Rivet.		Rolled bars $^{3}/_{4}$ in. round.	·75	·4417	679	63,577	61,723	·70	·3848
236		"	"		"	"	664	62,626		·70	·3848
237		"	"		"	"	649	61,675		·69	·3739
238		"	"		"	"	607	59,013		·71	·3958
239		Blochairn Best Rivet.		Rolled bars $^{3}/_{4}$ in. round.	·75	·4417	621	59,900	59,219	·70	·3848
240		"	"		"	"	614	59,457		·70	·3848
241		"	"		"	"	607	59,013		·71	·3959
242		"	"		"	"	599	58,506		·70	·3848
243		St. Rollox Best Rivet.		Rolled bars $^{13}/_{16}$ in. round.	·81	·5185	951	63,848	56,931	·77	·4657
244		"	"		"	"	715	56,104		·75	·4417
245		"	"		"	"	708	55,726		·77	·4657
246		"	"		"	"	551	47,248		·80	·5026
247		R. Solloch E. Best.		Rolled bars $^{11}/_{16}$ in. for rivets.	·70	·3848	490	59,226	57,425	·65	·3318
248		"	"		"	"	484	58,789		·66	·3421
249		"	"		"	"	454	56,606		·66	·3421
250		"	"		"	"	433	55,078		·65	·3318
251	Lancashire	Ulverston Rivet ⌂ Best.		Rolled bars $^{3}/_{4}$ in. round.	·75	·4417	612	59,330	53,775	·67	·3525
252		"	"		"	"	591	58,000		·65	·3318
253		"	"		"	"	591	58,000		·68	·3632
254		"	"		"	"	540	54,766		·65	·3318
255		"	"		"	"	505	52,547		·69	·3739
256		"	"		"	"	490	51,596		·70	·3848
257		"	"		"	"	447	48,870		·64	·3216
258		"	"		"	"	419	47,095		·63	·3632
259		Mersey Co., Best.		Forged from $^{3}/_{4}$ in. sq. bars.	·67	·3526	462	62,411	60,110	·64	·3216
260		"	"		·71	·3958	533	60,621		·68	·3632
261		"	"		·70	·3848	505	60,317		·67	·3526
262		"	"		·74	·4300	590	59,512		·71	·3958
263		"	"		·74	·4300	562	57,690		·71	·3958

…tores, except those marked *Samples*, which were received from the Makers.
…size at fracture; *s*, size at smallest part.

Difference between Original and Stretched Areas.			Breaking Wght per sq. in of Stretched Area.	FRACTURED		Difference between Original and Fractured Areas.			Breaking Wght per sq in of Fractured Area.	ELONGATION. Length of part stretched in Column 20.				FRACTURE.		
				Diameter	Area.									Crys	Col.	Kind
8.	9.	10.	11.	12.	13.	14.	15.	16.	17.	18.	19.	20.	21.	22.	23.	24.
sq. in.	sq. in	℔ ct.	lbs.	inch.	sq. in.	sq. in.	sq. in.	℔ ct.	lbs.	inch.	inch.	in.	℔ ct.	℔ct.		
·1204	·1255	16·2	70,260	·82	·5281	·2573	·3075	39·6	97,548	1·64	1·86	8·0	23·2	·5	Brightish-grey; fibre close and generally uniform	S
·1350				·78	·4779	·3075				1·97				1		S
·1204				·75	·4417	·3437				1·92				0		S
·1181				·75	·4417	·3126				1·88				1		S
·1336				·76	·4536	·3162				1·87				0		S
·0838	·0838	12·6	67,404	·68	·3632	·3018	·2991	45·0	107,065	1·40	1·28	6·0	21·3	0		S
·0838				·68	·3632	·3018				1·38				0		S
·0838				·68	·3632	·3018				1·22				0		S
·0838				69	·3739	·2911				1·14				0		S
·0792	·0887	14·9	67,103	·64	·3216	·2729	·2417	40·7	98,205	1·19	1·28	5·4	23·7	1		S
·0919				·67	·3526	·2419				1·28				0		S
·0919				·68	·3632	·2313				1·40				0		S
·0919				·69	·3739	·2206				1·26				3		S
·0708	·0606	131	68,003	·65	·3318	·1461	·1210	26·2	80,053	0·67	0·67	3·2	20·9	3		S
·0809				·62	·3019	·1638				0·75				0		S
·0699				·67	·3526	·1131				0·62				52		Y
·0332				·59	·2734	·1337				0·80				0*r*		S
·0485				·75	·4417	·0485				0·53				68		Y
·0465	·0519	11·5	67,333	·60	·2827	·1709	·1702	37·7	95,706	1·27	1·40	8·3	16·9	0		S
·0688				·60	·2827	·1709				1·40				0		S
·0465				·59	·2734	·1802				1·47				0		S
·0459				·60	·2827	·1590				1·45				0		S
·0569	·0585	13·2	70,893	·57	·2552	·1865	·1585	35·9	96,267	1·56	1·47	6·8	21·6	0		S
·0569				·59	·2734	·1683				1·72				0		S
·0742				·60	·2827	·1590				1·44				0		S
·0459				·64	·3216	·1201				1·17				0*r*		S
·0569	·0541	12·2	67,505	·59	·2734	·1683	·1515	34·3	89,279	1·34	1·32	6·8	19·4	0		S
·0569				·65	·3318	·1099				1·30				0		S
·0459				·61	·2922	·1595				1·25				0		S
·0569				·59	·2734	·1683				1·40				0		S
·0528	·0496	9·6	63,325	·65	·3318	·1867	·1367	26·3	77,383	1·52	1·13	6·8	16·6	90		Y
·0768				·67	·3526	·1651				1·48				0		S
·0528				·67	·3526	·1659				1·03				0		S
·0159				·79	·4902	·0283				0·50				80*b*		Y
·0530	·0478	12·4	65,590	·52	·2124	·1724	·1568	40·7	96,959	1·51	1·17	6·6	17·7	0	Brightish-grey; fibre close	S
·0427				·60	·2827	·1021				0·88				2		S
·0427				·52	·2124	·1724				1·00				0		S
·0530				·51	·2048	·1805				1·28				0		S
·0891	·0838	20·1	67,324	·50	·1963	·2454	·2147	48·6	104,680	1·57	1·45	6·7	21·6	0		P
·1099				·52	·2124	·2293				1·69				0		P
·0785				·50	·1963	·2454				1·38				0		P
·1099				·52	·2124	·2298				1·58				0		Q
·0678				·57	·2552	·1865				1·26				0		Q
·0569				·60	·2827	·1590				1·20				0		Q
·1201				·50	·1963	·2454				1·60				0		P
·0785				·58	·2642	·1775				1·29				0		Q
·0310	·0328	8·2	65,394	·53	·2207	·1319	·1215	30·5	86,295	0·60	0·71	4·2	16·9	0		Q
·0326				·60	·2827	·1131				0·68				0*r*		Q
·0322				·61	·2922	·0926				0·58				9*r*		U
·0342				·67	·3526	0774				0·64				65		X
·0342				·55	·2376	·1924				1·03				0		Q

Note.—All the pieces were taken *promiscuously* from Engineers' or Merchan[illegible]
***b* denotes bad fracture; *r*, slightly re[illegible]**

Index No.	District.	Names of the Makers or Works.	Description	Original Diameter.	Original Area.	Weight on Steelyd	Breaking Weight per square inch of Original Area.		Stretched Diameter	Stretched Area
				1. inch	2. sq. in.	3. lbs.	4. lbs.	5. lbs.	6. inch.	7. sq. [illegible]
264	Swedish	Per Eckman & Co., RF Gothenburg.	4 Flat Tilted Bars. Strips cut off.	·91 × ·64	·5824	695	48,987	47,855	·84 × ·59	[illegible]
265	Swedish	" "	"	·89 × ·66	·5874	676	47,664		·82 × [illegible]	[illegible]
266	Swedish	" "	"	·89 × ·64	·5696	640	47,384		·79 × [illegible]	[illegible]
267	Swedish	" "	"	·89 × ·64	·5696	640	47,384		·82 × [illegible]	[illegible]
268	Swedish	Do. Do.	4 Flat Tilted Bars. Forged round.	·91	·6504	826	49,505	48,232	·86	[illegible]
269	Swedish	" "	"	·93	·6806	868	49,022		·85	[illegible]
270	Swedish	" "	"	·92	·6650	805	47,534		·86	[illegible]
271	Swedish	" "	"	·90	·6362	741	46,889		·65	[illegible]
272	Russian	Prince Demidoff, CCND	4 Flat Tilted Bars. Strips cut off.	·89 × ·57	·5073	676	55,190	49,564	·84 × ·53	[illegible]
273	Russian	" "	"	·91 × ·52	·4732	505	49,049		·89 × [illegible]	[illegible]
274	Russian	" "	"	·89 × ·55	·4895	540	49,418		·81 × [illegible]	[illegible]
275	Russian	" "	"	·88 × ·55	·4840	447	44,600		·85 × ·53	[illegible]
276	Russian	Do. Do.	4 Flat Tilted Bars. Forged round.	·91	·6504	1106	65,516	56,805	·88	[illegible]
277	Russian	" "	"	·95	·7088	1105	56,447		·90	[illegible]
278	Russian	" "	"	·92	·6650	933	52,923		·88	[illegible]
279	Russian	" "	"	·92	·6650	919	52,334		·80	[illegible]
280	From Forge	Hammered Scrap Iron.		·76	·4536	552	54,070	53,420	·68	[illegible]
281	From Forge	" "		·75	·4418	524	53,739		·67	[illegible]
282	From Forge	" "		·76	·4536	538	53,205		·68	[illegible]
283	From Forge	" "		·77	·4657	552	52,665		·68	[illegible]
284	From Forge	Bushelled Iron from Turnings.		·76	·4536	608	57,526	55,878	·70	[illegible]
285	From Forge	" "		·75	·4418	590	57,290		·70	[illegible]
286	From Forge	" "		·75	·4418	538	54,626		·69	[illegible]
287	From Forge	" "		·76	·4536	552	54,070		·70	[illegible]
288	a, Length of Se.	Cut out of a Crank-shaft of Hammered Scrap Iron, thus—		·88	·6082	755	49,671	47,582	·82	[illegible]
289	b			·87	·5945	685	47,519		·82	[illegible]
290	c			·87	·5945	720	49,167		·81	[illegible]
291	d			·86	·5812	615	45,234		·81	[illegible]
292	e			1·00	·7854	1007	47,459		·93	[illegible]
293	f			1·00	·7854	979	46,450		·94	[illegible]
294	g, Cross.	and reduced to the required shape in the lathe, not on the anvil.		1·00	·7854	930	44,703	44,758	·94	[illegible]
295	h			1.00	·7854	923	44,453		·95	[illegible]



tores, except those marked *Samples*, which were received from the Makers.
size at fracture; *s*, size at smallest part.

Difference between Original and Stretched Areas.			Breaking Wght. per sq. in. of Stretched Area.	FRACTURED		Difference between Original and Fractured Areas.			Breaking Wght. per sq in. of Fractured Area.	ELONGATION. Length of part stretched in Column 20.				FRACTURE.		
				Diameter	Area.									Crys.	Col.	Kind
8. sq. in.	9. sq. in.	10. ℔ ct.	11. lbs.	12. inch.	13. sq. in.	14. sq. in.	15. sq. in.	16. ℔ ct.	17. lbs.	18. inch.	19. inch.	20. in.	21. ℔ ct.	22. ℔ ct.	23.	24.
·0865	·0969	16·8	57,484	·57 × ·37	·2109	·3715	·3490	60·5	121,065	1·42	1·67	6·0	27·8	0	Bright light-grey; fibre very soft.	K
·0790				·59 × ·44	·2596	·3278				1·74				0		K
·1272				·52 × ·35	·1820	·3876				2·03				0		K
·0940				·62 × ·42	·2604	·3092				1·50				0		K
·0692	·0838	12·7	55,285	·51	·2043	·4461	·4475	68·0	150,760	1·82	1·85	7·0	26·4	0		K
·1134				·55	·2376	·4432				1·80				0		K
·0838				·50	·1963	·4687				2·07				0		K
·0688				·51	·2043	·4319				1·72				0		K
·0621	·0521	10·7	55,559	·83 × ·52	·4316	·0757	·1568	32·1	73,118	0·48	0·80	6·0	13·3	0	Bright grey; very irregular.	
·0282				·89 × ·50	·4450	·0282				0·29				65*b*		•
·0845				·55 × ·36	·1960	·2915				1·52				0*r*		
·0335				·60 × ·42	·2520	·2320				0·90				8*rr*		
·0422	·0835	12·4	63,695	·88	·6082	·0422	·1892	28·1	77,632	0·57	0·92	6·0	15·3	100		Z
·0726				·90	·6362	·0726				0·40				90*r*		Z
·0568				·71	·3958	·2692				1·20				0*br*		K
·1624				·61	·2922	·3728				1·53				0*r*		K
·0904	·0981	20·5	67,218	·57	·2552	·1984	·1962	43·2	94,105	0·98	0·94	3·8	24·8	0	Brightish grey; fibre close and fine.	P
·0892				·56	·2462	·1956				0·96				0		P
·0904				·58	·2642	·1894				0·92				0		P
·1025				·58	·2642	·2015				0·93				0		P
·0688	·0656	14·7	65,470	·68	·3632	·0904	·1028	22·9	72,531	0·66	0·73	4·4	16·6	5		U
·0570				·65	·3318	·1100				0·84				8		U
·0679				·64	·3216	·1202				0·81				8		U
·0688				·68	·3632	·0904				0·60				8		U
·0801	·0839	12·8	53,610	·80	·5026	·1056	·1364	20·7	59,003	0·67	0·71	3·7	19·2	85	White and lustrous.	W
·0664				·81	·5153	·0792				0·60				80*r*		W
·0792				·75	·4417	·1528				0·86				80		W
·0659				·76	·4536	·1276				0·70				55*r*		W
·1204				·85	·5674	·2180				1·18	1·00	3·7	27·0	70		W
·0914				·91	·6504	·1350				0·83				63		W
·0914	·0840	10·7	49,917	·92	·6650	·1204	·0985	12·5	50,971	0·71	0·62	3.7	16·8	60		W
·0766				·95	·7088	·0766				0·54				60		W

Note.—All the pieces were taken *promiscuously* from Engineers' or Merchants'
L denotes that the strain was applied *lengthways* of the plate; C, *crossways*; *f*, size at fracture; *s*, siz

Index No.	District.	Names of the Makers or Works.	See Note.	Original. Thick. 1. inch.	Bdth 2. inch.	Area. 3. sq. in.	Weight on Steelyd. 4. lbs.	Breaking Weight per square inch of Original Area. 5. lbs.	6. lbs.	7. lbs.	Fracture. Thick. 8. inch.	Bdth 9. inch.	Area 10. sq. in.
301	Sheffield	T. Turton & Sons. Cast Steel.	L	·260 ×	2·00	·520	1447	95,360			·255 ×	1·97 f / 1·94 s	[illegible]
302		" "	"	·270 ×	2·00	·504	1511	95,144	94,289		·259 ×	2·00 f / 1·92 s	[illegible]
303		" "	"	·260 ×	2·00	·520	1418	93,796			·255 ×	1·94	[illegible]
304		" "	"	·267 ×	2·00	·534	1447	92,858		95,299	·259 ×	1·90	[illegible]
305		" "	C	·272 ×	2·00	·544	1618	99,952			·245 ×	1·84 f / 1·90 s	[illegible] / ·441
306		" "	"	·268 ×	2·00	·536	1562	98,519	96,308		·238 ×	1·79	[illegible]
307		" "	"	·268 ×	2·00	·536	1475	98,974			·245 ×	1·85	[illegible]
308		" "	"	·250 ×	2·00	·500	1333	92,788			·248 ×	1·95 f / 1·93 s	[illegible]
309		Naylor, Vickers, & Co. Cast Steel.	L	·250 ×	2·00	·500	1247	87,972			·230 ×	1·79	[illegible]
310		" "	"	"	"	"	1219	86,404			·226 ×	1·85 f / 1·79 s	[illegible]
311		" "	" Samples	"	"	"	1133	81,588			·225 ×	1·92 f / 1·84 s	[illegible] / ·414
312		" "	"	"	"	"	1090	79,180	81,719		·212 ×	1·70	[illegible]
313		" "	"	"	"	"	1076	78,396			·200 ×	1·70	[illegible]
314		" "	"	"	"	"	1047	76,772			·205 ×	1·75	·359
315		" "	C	·250 ×	2·00	·500	1376	95,196		84,435	·224 ×	1·80	·403
316		" "	"	"	"	"	1347	93,572			·230 ×	1·80	·414
317		" "	"	"	"	"	1190	84,780	87,150		·218 ×	1·72	[illegible]
318		" "	"	"	"	"	1172	83,772			·220 ×	1·75	[illegible]
319		" "	"	"	"	"	1161	83,156			·220 ×	1·76	[illegible]
320		" "	"	"	"	"	1148	82,428			·218 ×	1·71	[illegible]
321		Moss & Gambles, Cast Steel.	L	·250 ×	2·00	·500	1133	81,588			·216 ×	1·80 m	[illegible]
322		" "	"	·250 ×	2·00	·500	1105	80,020			·198 ×	1·70 m	[illegible]
323		" "	"	·238 ×	2·00	·476	1035	79,937			·211 ×	1·79 m	[illegible]
324		" "	"	·172 ×	2·00	·344	619	76,750	75,594		·138 ×	1·74 m	[illegible]
325		" "	"	·188 ×	2·00	·376	647	72,303			·140 ×	1·79 m	·251
326		" "	"	·262 ×	2·00	·524	897	70,584			·196 ×	1·65 m	[illegible]
327		" "	"	·230 ×	1·87	·430	720	67,977			·203 ×	1·64 m	[illegible]
328		" "	C	·262 ×	1·99	·521	1012	71,796		72,338	·200 ×	1·62 m	[illegible]
329		" "	"	·262 ×	2·00	·524	947	67,912	69,082		·210 m	1·72 m	[illegible]
330		" "	"	·262 ×	2·00	·524	940	67,538			·180 ×	1·55 m	[illegible]
331		Shortridge, Howell, & Co. Homogeneous Metal,	L	·190 ×	2·00	·380	1154	108,900			·183 ×	1·90	[illegible]
332			"	·180 ×	2·00	·360	976	101,105			·176 ×	1·97	·346
333			"	·190 ×	1·99	·378	990	97,328	96,280		·178 ×	1·95	·347
334			"	·190 ×	2·00	·380	876	88,416			·156 ×	1·79	[illegible]
335		" "	"	·190 ×	1·87	·355	762	85,650			·148 ×	1·65	·244
336		" "	C	·190 ×	2·00	·380	1111	105,732		96,715	·178 ×	1·90	[illegible]
337		" "	"	"	"	"	1033	99,984			·178 ×	1·88	·335
338		" "	"	"	"	"	1019	98,953	97,150		·165 ×	1·83	[illegible]
339		" "	"	"	"	"	991	96,868			·179 ×	1·90	[illegible]
340		" "	"	"	"	"	819	84,211			·165 ×	1·83	[illegible]
341		Do. Do.	C	·375 ×	2·00	·750	2274	96,989			·338 ×	1·90	·642
342		Do. Do. Second Quality.	L	·240 ×	2·00	·480	1076	81,662			·220 ×	1·90	[illegible]
343			"	·250 ×	2·00	·500	1032	75,932			·238 ×	1·94	[illegible]
344		" "	" Samples	·250 ×	2·00	·500	919	69,604	72,408		·230 ×	1·87	[illegible]
345		" "	"	·250 ×	1·95	·487	762	62,435			·230 ×	1·87	·430
346		" "	C	·250 ×	2·00	·500	1189	84,724		72,994	·244 ×	1·96	[illegible]
347		" "	C	·250 ×	1·95	·487	762	62,435	73,580		·238 ×	1·90	[illegible]

tores, except those marked *Samples*, which were received from the Makers.
t smallest part; *m*, mean size; *d* denotes that the layers are slightly disunited; *b*, bad fracture.

Difference between Fractured and Original Areas.					Breaking Weight per square inch of Fractured Area.		ELONGATION. Original Length of Stretched Part in Column 21.						FRACTURE.	
													Gran.	Kind.
11.	12.	13.	14.	15.	16.	17.	18.	19.	20.	21.	22.	23.	24.	25.
sq. in.	sq. in.	sq. in.	℔ ct.	℔ ct.	lbs.	lbs.	inch.	inch.	inch.	inch.	℔ ct.	℔ ct.	℔ cent.	
·018							·30						100	A
·026														
·022														
·043	·029		5.6		100,063		33	·32			5·71		100	A
·025							·27						100	A
·042							·40						100	B
		·050		9·5		105.937			·430	5·6		7·68		
·093							·67						100	C
·108														
·110							·69						100	C
·043	·071		13.4		111,811		·52	·54			9·64		100	C
·016							·28						100	A
·021														
·088							0·82						76	D
·082														
·095							0·96						100	B
·068														
·046	·107		21·4		104,232		0·80	·96			17·50		65	D
·140							1·08						0	E
·160							1·18						0	F
·141							1·10						0	E
		·109		21·7		108,125			·975	5·6		17·41		
·097							0·93						80	D
·086							0·90						62	D
123	·111		23·0		112,018		1·13	·97			17·32		0	H
·115							0·90						0	E
·113							0·88						0	H
·127							1·10						0	E
·111							1·06						0	E
·163							1·03						0	F
·096							1·10						0	E
·104	·127		29·2		106,554		1·17	1·11			19·82		0	F
·126							1·06						0	F
·201							1·07						0	G
·097							1·27						0	F
		·164		33·4		109,050			1·105	5·6		19·73		
·197							1·10						0	F
·163	·208		36·6		112,546		1·05	1·10			19·64		0	G
·245							1·16						0	H
·088							27						100	A
·014							·18						100	A
·031	·058		15·6		114,106		·28	·482			8·61		100	A
·101							·68						0	F
·111							·99						0	G
		·057		15·2		114.203			·491	5·6		8·77		
·042							·40						100	B
·045							·45						88	D
·078	·056		14·8		114,300		·70	·500			8·93		60	D
·040							·85						95	B
·078							·60						0	F
·108			14·4		113,305		·52			3·6	14·4		100	C
·062							·43						0	J
·038	·067		11·5		81,223		·20	·332			5·93		0	J
·070							·42						0	J
·057							·28						0	J
		·042		8·6		80.034			·256	5·6		4·57		
·032	·036		5·7		78,845		·20	·180			3.21		10	I
·035							·16						1	J

Note.—All the pieces were taken *promiscuously* from Engineers' or Merchants'
L denotes that the strain was applied *lengthways* of the plate; C, *crossways*; *f*, size at fracture; *s*, size

Index No.	District.	Names of the Makers or Works.	See Note.	ORIGINAL. Thick. 1. inch.	Bdth 2. inch.	Area. 3. sq. in.	Weight on Steelyd. 4. lbs.	Breaking Weight per square inch of Original Area. 5. lbs.	6. lbs.	7. lbs.	FRACTURED. Thick. 8. inch.	Bdth 9. inch.	Area. 10. sq. in.
348	Liverpool	Mersey Co.	L	·180 ×	1·88	·338	990	108,906			·176 ×	1·85	·335
349		Puddled Steel	″	·180 ×	1·90	·342	961	105,199	101,450		·169 ×	1·85	·313
350		(Ship Plates.)	″	·115 ×	1·90	·218	447	99,019			·109 ×	1·88	·205
351		″ ″	″	·115 ×	1·88	·216	391	92,676		93,209	·110 ×	1·84	·202
352		″ ″	C	·180 ×	1·90	·342	891	99,468			·173 ×	1·87	·323
353		″ ″	″	·180 ×	1·88	·338	748	88,800			·172 ×	1·85	·318
354		″ ″	″	·115 ×	1·89	·217	362	88,507	84,968		·112 ×	1·87	·209
355		″ ″	″	·102 ×	1·89	·193	111	68,098			·101 ×	1·88	·19[illegible]
356		Mersey Co.	L	·245 ×	2·00	·490	1583	106,110			·238 ×	1·94	·462
357		Puddled Steel,	″	·250 ×	2·00	·500	1564	105,724	102,593		·244 ×	1·95	·476
358		"Hard."	″	·250 ×	1·94	·485	1338	95,946			·244 ×	1·93*f* 1·90*s*	·471 ·464
359		″ ″	C	·250 ×	1·95	·488	1219	88,529		93,979	·248 ×	1·90	·471
360		″ ″	″	·250 ×	2·00	·500	1144	82,200	85,365		·244 ×	1·97*f* 1·92*s*	·481 ·468
361		Do. "Mild" Do.	L	·250 ×	2·00	·500	1228	86,908	77,046		·234 ×	1·87	·437
362		″ ″	″	·250 ×	1·95	·488	847	67,184		72,366	·230 ×	1·88	·435
363		″ ″	C	·250 ×	1·95	·488	876	68,848			·237 ×	1·90	·450
364		″ ″	″	·250 ×	2·00	·500	864	66,524	67,686		·235 ×	1·96*f* 1·92*s*	·461 ·451
365		Do. Do.	L	·275 ×	1·79	·492	1047	78,020			·258 ×	1·80*f* 1·77*s*	·464 ·457
366		(Ship Plates.) ″ ″	L	·275 ×	1·79	·492	819	65,045	71,532		·250 ×	1·82*f* 1·77*s*	·455 ·442
367	Glasgow	Blochairn	L	·190 ×	2·00	·380	1120	106,394			·188 ×	1·97	·366
368		Puddled Steel.	″	·190 ×	2·00	·380	1118	106,247			·181 ×	1·96	·355
369		″ ″	″	·190 ×	2·00	·380	1076	103,152	103,234		·180 ×	1·92	·346
370		″ ″	″	·190 ×	2·00	·380	1061	102,047			·188 ×	1·98*s*	·372
371		″ ″	″	·180 ×	2·00	·360	876	93,327		93,316	·173 ×	1·97	·341
372		″ ″	C	·190 ×	2·00	·380	890	89,447			·186 ×	1·96	·363
373		″ ″	″	″	″	″	826	84,710			·180 ×	1·96	·353
374		″ ″	″	″	″	″	826	84,710	84,398		·189 ×	1·99*s*	·376
375		″ ″	″	″	″	″	790	82,079			·180 ×	1·97	·355
376		″ ″	″	″	″	″	776	81,047			·189 ×	1·99	·376
377		Do. Do.	L	·312 ×	2·00	·624	1847	97,413	96,320		·300 ×	1·96	·588
378		(Boiler Plates.)	″	·312 ×	1·75	·546	1533	95,227		85,010	·286 ×	1·61	·460
379		″ ″	C	·312 ×	2·00	·624	1361	75,606	73,699		·309 ×	1·98	·612
380		″ ″	″	·312 ×	2·00	·624	1276	71,792			·300 ×	1·96	·588

Stores, except those marked *Samples*, which were received from the Makers.
t smallest part; *m*, mean size; *d* denotes that the layers are slightly disunited; *b*, bad fracture.

Difference between Fractured and Original Areas.					Breaking Weight per square inch of Fractured Area.		ELONGATION. Original Length of Stretched Part in Column 21.						FRACTURE.	
													Gran.	Kind.
11. sq. in.	12. sq. in.	13. sq. in.	14. ℔ ct.	15. ℔ ct.	16. lbs.	17. lbs.	18. inch.	19. inch.	20. inch.	21. inch.	22. ℔ ct.	23. ℔ ct.	24. ℔ cent.	26.
·012	·018	·015	6·4	5·4	109,552	100,649	·16	·212	·153	7·6	2·79	2·02	38	I
·029							·24						24	I
·015							·22						2	J
·014							·23						0	J
·019	·012		4·4		91,746		·10	·095			1·25		30	I
·020							·08						8	J
·008							·15						1	J
·008							·03						05	J L
·028	·022	·022	4·5	4·6	107,827	98,472	·28	·272	·228	5·6	4·86	4·08	85	I A
·024							·20						90	I A
·014							·34						52	I A
·021														
·017	·023		4·7		89,116		·18	·185			3·30		62	I A
·019							·24						55	I A
·032														
·063	·062	·052	12·5	10·5	96,240	80,937	·36	·345	·333	5·6	6·16	5·94	38	I
·060							·33						0	J
·038	·042		8·5		73,634		·31	·320			5·72		2	J
·039							·33						0	J
·049														
·028	·037		7·5		77,590		·22	·200		5·6	3·57		1	J
·035							·18						0*d*	J
·037														
·050														
·014	·030	·018	5·3	4·8	108,079	97,978	·22	·202	·176	5·6	3·60	3·14	82	I A
·025							·26						85	I A
·034							·30						65	I A
·008							·15						78	I A
·019							·08						80	I A
·017	·016		4·2		87,877		·28	·150			2·68		38	I
·027							·18						28	I
·004							·07						90	I A
·025							·14						5	J
·004							·08						85	I K
·036	·061	·042	10·4	7·1	107,614	92,130	·51	·625	·470	7·6	9·22	6·18	44	K
·086							·74						2	L
·012	·094		3·8		76,646		·22	·315			4·14		30	K
·096							·41						5	L

Note.—All the pieces were taken *promiscuously* from Engineers' or Merchants'
L denotes that the strain was applied *lengthways* of the plate; C, *crossways*; *f*, size at fracture; *s*, size at

Index No.	District.	Names of the Makers or Works.	See Note.	ORIGINAL. Thick.	Bdth	Area	Weight on Steelyd	Breaking Weight per square inch of Original Area.			FRACTURED. Thick.	Bdth	Area
				1. inch.	2. inch.	3. sq. in.	4. lbs.	5. lbs.	6. lbs.	7. lbs.	8. inch.	9. inch.	10. sq. in.
401	Yorkshire	Lowmoor.	L	·312	× 2·00	·624	966	57,881			·255	× 1·87	·477
402		" "	"	"	× 1·80	·562	763	54,153			·275	× 1·67	·459
403		" "	"	"	× 1·78	·555	678	50,548	52,000		·260	× 1·70	·442
404		" "	"	"	× 2·00	·624	790	49,986			·260	× 1·87	·486
405		" "	"	"	× 2·00	·624	738	47,426		51,257	·275	× 1·95	·536
406		" "	C	"	× 2·00	·624	910	55,868			·275	× 1·90	·522
407		" "	"	"	× 1·78	·555	720	52,669			·275	× 1·68	·462
408		" "	"	"	× 2·00	·624	761	48,682	50,515		·295	× 1·96	·578
409		" "	"	"	× 1·78	·555	636	48,429			·300	× 1·71	·513
410		" "	"	"	× 2·00	·624	738	47,426			·287	× 1·91	·548
411		Bowling.	L	·395	× 1·78	·703	1019	53,488			·362	× 1·71	·619
412		" "	"	·400	× 1·80	·720	1033	52,770			·364	× 1·76	·641
413		" "	"	·325	× 2·00	·650	863	51,991	52,235		·280	× 1·92	·536
414		" "	"	·400	× 2·00	·800	1147	51,485			·345	× 1·85	·636
415		" "	"	·375	× 2·00	·750	1054	51,443		49,338	·330	× 1·92	·634
416		" "	C	·375	× 2·00	·750	1019	50,136			·350	× 1·94	·679
417		" "	"	·412	× 1·78	·733	983	48,014			·388	× 1·75	·679
418		" "	"	·400	× 1·78	·712	846	46,008	46,441		·392	× 1·75	·686
419		" "	"	·400	× 2·00	·800	961	44,972			·375	× 1·95	·731
420		" "	"	·325	× 2·00	·650	676	43,074			·312	× 1·98	·618
421		Farnley.	L	·375	× 2·00	·750	1304	59,448			·320	× 1·89	·605
422		" "	"	·375	× 2·00	·750	1219	57,602	56,006		·350	× 1·91	·668
423		" "	"	·375	× 2·00	·750	1161	55,437			·320	× 1·89	·605
424		" "	"	·355	× 2·00	·710	988	51,541		51,113	·295	× 1·87	·551
425		" "	C	·375	× 2·00	·750	1019	50,136			·338	× 1·92	·642
426		" "	"	·375	× 2·00	·750	990	49,054	46,221		·325	× 1·92*s*	·624
427		" "	"	·355	× 2·00	·710	821	45,152			·330	× 1·90	·627
428		" "	"	·375	× 2·00	·750	762	40,541			·345	× 1·94	·669
429		Do. Do.	L	·245	× 2·00	·490	747	61,184			·196	× 1·86	·364
430		" "	"	·259	× "	·518	761	58,645	58,487		·212	× 1·92	·407
431		" "	"	·230	× "	·460	590	55,631		56,292	·208	× 1·95	·405
432		" "	C	·250	× "	·500	761	60,756			·230	× 1·94	·446
433		" "	"	·245	× "	·490	733	60,396			·215	× 1·94	·417
434		" "	"	·250	× "	·500	619	52,804	54,098		·237	× 1·96	·464
435		" "	"	·245	× "	·490	562	50,625			·228	× 1·95	·447
436		" "	"	·250	× "	·500	576	50,396			·230	× 1·95	·448
437		" "	"	·250	× "	·500	562	49,612			·245	× 1·96	·480
438		Do. Do.	Samples L	·750	× 1·50	1·125	2189	62,544			·645	× 1·34	·864
439		" "	"	"	× "	1·125	2034	58,686	58,487		·590	× 1·21	·714
440		" "	"	"	× "	1·125	1940	56,847			·600	× 1·25	·750
441		" "	"	"	× "	1·125	1933	56,172		56,735	·625	× 1·34	·835
442		" "	C	"	× "	1·125	1948	56,546			·655	× 1·37	·897
443		" "	"	"	× "	1·125	1948	56,546	55,033		·660	× 1·37	·904
444		" "	"	"	× "	1·125	1849	54,082			·620	× 1·32	818
445		" "	"	·745	× 1·47	1·095	1747	52,955			·670	× 1·42	·951
446	Durham	Consett.	L	·780	× 1·62	1·264	2132	54,408			·705	× 1·56	1·100
447		" "	"	·775	× 1·62	1·256	1996	51,718	51,245		·712	× 1·55	1·104
448		" "	"	·780	× 1·40	1·092	1533	47,618		48,979	·698	× 1·34	0·935
449		" "	C	·780	× 1·40	1·092	1533	47,613			·705	× 1·35*s*	0·952
450		" "	"	·840	× 1·00	0·840	1076	46,664	46,712		·775	× 0·97	0·752
451		" "	"	·780	× 1·40	1·092	1490	46,511			·737	× 1·37	1·010
452		" "	"	·775	× 1·40	1·085	1461	46,062			·710	× 1·37	0·973

Stores, except those marked *Samples*, which were received from the Makers.
smallest part; *m*, mean size; *i* denotes that the layers are rather imperfectly welded; *b*, bad fracture.

Difference between Fractured and Original Areas.					Breaking Weight per square inch of Fractured Area.		ELONGATION. Original Length of Stretched Part in Column 21.						FRACTURE.		
													Crys.	Col.	Kind
11.	12.	13.	14.	15.	16.	17.	18.	19.	20.	21.	22.	23.	24.	25.	26.
sq. in.	sq. in.	sq. in.	℔ ct.	℔ ct.	lbs.	lbs.	inch.	inch.	inch.	inch.	℔ ct.	℔ ct.	℔ ct.		
·147							·84						0	Colour generally uniform, of a light brightish-grey; fibre compact and very fine: 428 dark-grey	M
·103							·82						0		M
·113	·118		19·7		64,746		·76	·74			13·2		0		M
·138							·72						0		M
·068							·54						0i		M
·102		·095		15·9		61,065	·60		0·63	5·6		11·25	8		O
·093							·60						0		O
·046	·072		12·1		57,383		·40	·58			9·3		0		O
·042							·52						0		O
·076							·46						0		O
·084							·50						45		Q
·053							·43						30		Q
·112	·111		15·8		61,716		·69	·65			11·6		1i		M
·162							·84						0i		M
·116							·78						0		M
·071		·080		11·1		55,862	·58		0·49	5·6		8·75	0		O
·054							·27						20		Q O
·026	·050		6·9		50,009		·20	·33			5·9		10		Q O
·069							·33						0		P
·032							·25						0i		P
·145							1·03						1		M
·162	·132		17·8		66,763		1·06	1·07			14·1		4		M Q
·145							1·00						0		M
·158							1·20						0		M
·101		·115		15·5		61,028	0·58		0·82	7·6		10·85	0		O
·126	·096		13·2		53,293		0·70	0·58			7·6		0		O
·083							0·72						0i		O
·081							0·33						0bi		P
·126							1·04						0		M
·111	·097		20·0		70,538		0·77	0·83			10·9		0		M
·055							0·68						0i		M
·054		·072		15·7		65,118	0·58		0·64	7·6		8·40	0		O
·072							0·68						0		O
·036	·046		11·4		59,696		0·27	0·45			5·9		0i		O
·043							0·49						0		O
·052							0·41						0		O
·020							0·24						0i		O
·261							1·25						0		M
·411	·333		29·6		83,112		1·51	1·39			17·0		0		M N
·375							1·38						15		N Q
·287							1·08						0		M N
·228		·279		24·8		76,036	0·90		1·07	7·6		14·15	55		Q
·221	·225		20·1		68,961		0·90	0·86			11·3		8		N Q
·307							1·08						0i		O N
·144							0·60						45i		Q
·164							0·58						45i	Grey; fibre loose.	S V
·152	·158		13·1		59,183		0·54	0·50			8·93		30i		S V
·157							0·38						50		S V
·140		·131		11·7		55,616	0·40		0·43	5·6		7·68	35i		S V
·088	·105		10·2		52.050		0·50	0·36			6·43		22ib		V
·082							0·28						6		V
·112							0·26						46		S V

Note.—All the pieces were taken *promiscuously* from Engineers' or Merchants'
L denotes that the strain was applied *lengthways* of the plate; C, *crossways*; *f*, size at fracture; *s*, size at

Index No.	District.	Names of the Makers or Works.	See Note.	ORIGINAL Thick.	Bdth	Area.	Weight on Steelyd.	Breaking Weight per square inch of Original Area.			FRACTURED Thick.	Bdth.	Area.
				1.	2.	3.	4.	5.	6.	7.	8.	9.	10.
				inch.	inch.	sq. in.	lbs.	lbs.	lbs.	lbs.	inch.	inch.	sq. in.
453	Staffordshire	J. Bradley & Co.,	L	·480 ×	2·00	0·960	1683	58,534			·410 ×	1·84	·754
454		S.C. ♛	"	·500 ×	1·99	0·995	1633	55,070	55,831		·440 ×	1·85	[illegible]
455		" "	"	·500 ×	1·99	0·995	1591	53,889		53,191	·470 ×	1·86	[illegible]
456		" "	C	·480 ×	2·00	0·960	1576	55,414			·445 ×	1·94	[illegible]
457		" "	"	·506 ×	1·98	1·002	1419	48,705	50,550		·470 ×	1·89	[illegible]
458		" "	"	·500 ×	1·99	0·995	1333	47,532			·480 ×	1·95	[illegible]
459		Do. L F Do.	L	·350 ×	1·78	·623	1068	60,965			·312 ×	1·65	[illegible]
460		" "	"	·412 ×	1·80	·742	1276	60,374			·362 ×	1·70	[illegible]
461		" "	"	·388 ×	1·99	·772	1218	55,925	56,996		·345 ×	1·58	[illegible]
462		" "	"	·350 ×	1·78	·623	904	55,188			·312 ×	[illegible]	[illegible]
463		" "	"	·392 ×	2·00	·784	1211	54,819			·355 ×	[illegible]	[illegible]
464		" "	"	·470 ×	2·00	·940	1512	54,687		54,123	·428 ×	1·90	[illegible]
465		" "	C	·415 ×	1·80	·747	1162	55,697			·387 ×	1·75	[illegible]
466		" "	"	·370 ×	1·80	·666	961	54,021			·350 ×	1·76	[illegible]
467		" "	"	·480 ×	1·99	·955	1447	51,922	51,251		·455 ×	1·90	[illegible]
468		" "	"	·370 ×	1·75	·647	819	49,462			·377 ×	1·70	[illegible]
469		" "	"	·400 ×	2·00	·800	1076	48,997			·388 ×	1·95	[illegible]
470		" "	"	·388 ×	2·00	·776	990	47,410			·362 ×	1·94	[illegible]
471		Do. Do.	L	·500 ×	1·99	0·995	1833	60,697			·455 ×	1·87	[illegible]
472		" "	"	·390 ×	1·99	0·776	1204	55,131	55,708		·350 ×	1·85	[illegible]
473		" "	"	·390 ×	2·00	0·780	1105	51,295		52,566	·350 ×	1·95	[illegible]
474		" "	C	·512 ×	1·99	1·019	1533	51,025			·488 ×	1·92	[illegible]
475		" "	"	·400 ×	2·00	0·800	1105	50,012	49,425		·375 ×	1·95	[illegible]
476		" "	"	·400 ×	1·99	0·796	1019	47,238			·378 ×	1·94	·733
477		T. Wells, Best Best.	L	·500 ×	1·97	0·985	1590	54,406			·462 ×	1·92	[illegible]
478		" ♛ "	"	·500 ×	1·65	0·825	1276	54,301			·475 ×	1·62	[illegible]
479		" "	"	·510 ×	1·99	1·015	1447	48,853			·480 ×	1·93	[illegible]
480		" "	"	·510 ×	1·72	0·877	1105	45,621	47,410		·490 ×	1·69	[illegible]
481		" "	"	·510 ×	1·72	0·877	1105	45,621			·490 ×	1·69	[illegible]
482		" "	"	·306 ×	1·99	0·609	591	42,066			·298 ×	1·95	·561
483		" "	"	·304 ×	1·99	0·605	562	41,002		47,020	·296 ×	1·95	[illegible]
484		" "	C	·505 ×	1·97	0·995	1433	49,441			·484 ×	1·97	[illegible]
485		" "	"	·500 ×	2·00	1·000	1433	49,194			·470 ×	1·97	[illegible]
486		" "	"	·505 ×	2·00	1·010	1426	48,513			·480 ×	1·95	[illegible]
487		" "	"	·505 ×	1·99	1·005	1361	46,943	46,630		·485 ×	1·96	[illegible]
488		" "	"	·500 ×	2·00	1·000	1333	46,394			·485 ×	1·98	[illegible]
489		" "	"	·300 ×	1·97	0·591	591	43,347			·292 ×	1·96	[illegible]
490		" "	"	·310 ×	2·00	0·620	619	42,581			·302 ×	1·97	[illegible]
491		K. B. M.	L	·312 ×	2·00	·624	890	51,285			·280 ×	1·94	·543
492		"	"	·312 ×	1·78	·555	562	44,696	46,404		·300 ×	1·72	·516
493		"	"	·312 ×	1·78	·555	533	43,232		45,584	·290 ×	1·72	[illegible]
494		"	C	·312 ×	1·78	·555	576	45,402			·290 ×	1·73	·502
495		"	"	·312 ×	1·78	·555	562	44,696	44,764		·300 ×	1·73	·519
496		"	"	·312 ×	2·00	·624	661	44,195			·305 ×	1·97	[illegible]
497	Lanarkshire	Mossend, Best Best.	L	·400 ×	2·00	·800	988	43,992			·380 ×	1·97	·749
498		" "	"	·410 ×	2·00	·820	944	43,295	43,433		·385 ×	1·98	[illegible]
499		" "	"	·400 ×	2·00	·800	905	43,012		42,445	·380 ×	1·98	·752
500		" "	C	·410 ×	2·00	·820	961	43,875			·385 ×	1·98	[illegible]
501		" "	"	·400 ×	2·00	·800	890	42,487	41,456		·385 ×	1·98	·762
502		" "	"	·400 ×	2·00	·800	762	38,007			·390 ×	1·99	·776

·tores, except those marked *Samples*, which were received from the Makers.
mallest part; *m*, mean size; *i* denotes that the layers are rather imperfectly welded; *b*, bad fracture.

Difference between Fractured and Original Areas.					Breaking Weight per square inch of Fractured Area.		ELONGATION. Original Length of Stretched Part in Column 21.						Fracture.		
													Crys.	Col.	Kind.
11.	12.	13.	14.	15.	16.	17.	18.	19.	20.	21.	22.	23.	24.	25.	26.
sq. in.	sq. in.	sq. in.	℔ ct.	℔ ct.	lbs.	lbs.	inch.	inch.	inch.	inch.	℔ ct.	℔ ct.	℔ ct.		
·206	·169	·130	17·2	13·1	67,406	61,306	·88	·70	·51	5·6	12·5	9·00	5	Dullish-grey, of various shades; fibre, close and generally fine.	N
·181							·65						0*i*		N
·121							·58						3*i*		N
·097	·090		9·0		55,206		·38	·31			6·5		8		N V
·114							·36						1*i*		N V
·059							·20						1		N V
·099	·112	·089	15·0	11·8	66,858	61,464	·82	·73	·53	5·6	13·0	9·45	10		N S
·127							·80						15		N S
·123							·68						40		N S
·099							·74						8		N
·117							·77						0		N
·103							·56						5		N
·070	·066		8·6		56,070		·35	·33			5·9		10*i*		N V
·050							·30						30		S V
091							·40						1*i*		N V
·074							·38						5		N V
·040							·25						5		N V
·074							·30						1		N V
·154	·127	·099	14·9	11·5	65,652	59,827	·58	·60	·45	5·6	10·7	7·90	50		S N
·129							·75						1		N
·098							·47						1		N
.082	·071		8·1		54,002		·32	·29			5·1		40		S
·069							·30						5		N V
·063							·27						1		N V
·098	·056	·050	6·7	5·8	51,521	49,935	·50	·30	·28	7·6	4·0	3·70	23	Dull-grey; fibre, rather coarse	U
·056							·38						20		U
·093							·42						4		U
·049							·29						2*i*		U
·049							·27						2		U
·028							·13						9*i*		U
·019							·08						10*ii*		U
·022	·044		4·9		48,348		·23	·26			3·4		30*i*		V S
·074							·40						10		V
·074							·42						4		V
·055							·30						10		V
·040							·17						15		V
·019							·08						1*i*		V
·025							·25						1		V
·081	·059	·048	10·2	8·3	51,896	49,893	·46	·34	·29	5·6	6·1	5·20	3		U
·039							·28						0*i*		U
·056							·28						05*i*		U
·053	·037		6·4		47,891		·33	·24			4·3		0*i*		V
·036							·26						1*ii*		V
·024							·14						15*ii*		V
·051	·046	·043	5·7	5·3	46,038	44,830	·27	·25	·24	7·6	3·3	3·10	2	Grey; coarse.	W
·038							·23						30		WR
·048							·24						35*i*		WR
·058	·040		4·9		43,622		·32	·22			2·9		20		WR
038							·23						25		WR
·024							·12						2*i*		W

Note.—All the pieces were taken *promiscuously* from Engineers' or Merchants'
L denotes that the strain was applied *lengthways* of the plate; C, *crossways*; *f*, size at fracture; *s*, size at

Index No.	District.	Names of the Makers or Works.	See Note.	ORIGINAL Thick. × Bdth	ORIGINAL Area	Weight on Steelyd	Breaking Weight per square inch of Original Area.			FRACTURED Thick. × Bdth.	FRACTURED Area
				1. 2.	3.	4.	5.	6.	7.	8. 9.	10.
				inch. inch.	sq. in.	lbs.	lbs.	lbs.	lbs.	inch. inch.	sq. in.
503	Lanarkshire	GLASGOW,	L	·400 × 1·75	0·700	1084	56,317			·362 × 1·72	0·623
504		Best Boiler.	"	·660 × 2·00	1·312	2293	55,510			·620 × 1·94	1·212
505		" "	"	·375 × 2·00	0·750	1154	55,176			·345 × 1·90	0·655
506		" "	"	·375 × 2·00	0·750	1147	54,907	53,849		·350 × 1·92	0·672
507		" "	"	·400 × 1·78	0·712	1028	53,166			·360 × 1·70	0·612
508		" "	"	·580 × 1·50	0·870	1168	48,016			·532 × 1·46	0·777
509		" "	C	·400 × 1·75	0·700	1000	52,959		51,349	·375 × 1·77	0·665
510		" "	"	·375 × 2·00	0·750	1033	50,659			·372 × 1·97	0·733
511		" "	"	·400 × 1·78	0·712	916	48,761	48,848		·362 × 1·70	0·615
512		" "	"	·375 × 2·00	0·750	962	48,000			·360 × 1·95	0·702
513		" "	"	·660 × 1·50	0·990	1336	46,947			·636 × 1·49	[illegible]
514		" "	"	·620 × 1·50	0·930	1196	45,761			·585 × 1·46	0·854
515		GLASGOW Ship.	L	·188 × 2·00	0·376	398	53,370			·180 × 1·97	0·355
516		" "	"	·637 × 1·65	1·051	1590	50,989			·620 × 1·63	1·010
517		" "	"	·312 × 1·97	0·615	761	49,395			·302 × 1·96	0·592
518		" "	"	·637 × 1·50	0·955	1304	47,730	47,773		·620 × 1·47	0·911
519		" "	"	·705 × 1·50	1·057	1476	47,680			·655 × 1·48	0·969
520		" "	"	·390 × 2·00	0·780	720	37,474			·386 × 1·99	0·765
521		" "	C	·180 × 1·97	0·355	308	49,842		46,064	·176 × 1·97	0·347
522		" "	"	·312 × 1·97	0·615	761	49,395			·308 × 1·96	0·604
523		" "	"	·730 × 1·50	1·095	1448	45,310			·690 × 1·45	1·000
524		" "	"	·650 × 1·65	1·072	1890	44,766	44,355		·640 × 1·64	1·050
525		" "	"	·637 × 1·67	1·064	1362	44,366			·625 × 1·66	1·037
526		" "	"	·390 × 2·00	0·780	580	32,450			·388 × 2·00	0·776
527		Makers' Stamp	L	·425 × 2·00	0·850	1189	49,838			·390 × 1·92	0·749
528		uncertain.	"	·425 × 1·98	0·841	1161	49,489			·400 × 1·96	0·784
529		" "	"	·675 × 1·65	1·114	1619	48,835			·642 × 1·63	1·046
530		" "	"	·625 × 1·50	0·937	1308	48,766	47,598		·550 × 1·46	0·803
531		" "	"	·340 × 1·79	0·609	664	45,422			·305 × 1·75	0·534
532		" "	"	·238 × 2·20	0·476	412	43,290			·220 × 1·97s	0·433
533		" "	C	·675 × 1·65	1·114	1447	44,512		44,140	·655 × 1·63	1·068
534		" "	"	·625 × 1·50	·937	1084	42,072			·580 × 1·46	·847
535		" "	"	·425 × 2·00	·850	905	40,482			·412 × 1·95s	·803
536		" "	"	·238 × 2·00	·476	357	40,055	40,688		·236 × 1·99	·470
537		" "	"	·250 × 2·00	·500	384	39,644			·243 × 1·99	·483
538		" "	"	·330 × 1·80	·594	468	37,330			·325 × 1·78	·578
539		GOVAN Best.	L	·245 × 1·97	·483	533	49,677			·225 × 1·94	·436
540		" "	"	·365 × "	·719	878	46,806			·350 × 1·95	·682
541		" "	"	·245 × "	·483	476	46,378			·230 × 1·94	·446
542		" "	"	·380 × "	·748	847	43,831	43,943		·362 × 1·95s	·706
543		" "	"	·505 × "	·995	1047	38,570			·482 × 1·95	·940
544		" "	"	·360 × "	·709	648	38,398			·350 × 1·96	·679
545		" "	C	·245 × "	·483	419	43,069		41,743	·245 × 1·97	·483
546		" "	"	·380 × "	·748	820	42,783			·376 × 1·96	·737
547		" "	"	·505 × "	·995	1089	39,761	39,544		·480 × 1·95	·936
548		" "	"	·365 × "	·719	662	38,395			·353 × 1·95	·688
549		" "	"	·365 × "	·719	621	36,798			·362 × 1·97	·713
550		" "	"	·245 × "	·483	305	36,460			·245 × 1·97	·483

Stores, except those marked *Samples*, which were received from the Makers.
smallest part; *m*, mean size; *i* denotes that the layers are rather imperfectly welded; *b*, bad fracture.

Difference between Fractured and Original Areas.					Breaking Weight per square inch of Fractured Area.		ELONGATION. Original Length of Stretched Part in Column 21.						FRACTURE.		
													Crys.	Col.	Kind.
11.	12.	13.	14.	15.	16.	17.	18.	19.	20.	21.	22.	23.	24.	25.	26.
sq. in.	sq. in.	sq. in.	℔ ct.	℔ ct.	lbs.	lbs.	inch.	inch.	inch.	inch.	℔ ct.	℔ ct.	℔ ct.		
·077							·47						75	Grey; fibre rather coarse; crystals fine.	R
·118							·70						65		R
·095							·56						65*i*		R
·078	·094		11·0		60,522		·47	·58			9·3		43		R
·100							·50						0		U
·093							·45						10*ii*		R U
·055		·075		8·8		56,387	·20		·390	5·6		6·95	78		R
·017							·14						67		R
·007							·40						1		U
·048	·056		6·6		52,252		·28	·26			4·6		18		R U
·042							·2						45*i*		R
·076							·30						12		R U
·021							·39						7	Grey; fibre coarse; crystals generally coarse.	W
·041							·25						86*i*		T
·026							·29						22		R U
·044	·039		4·8		49·816		·28	·27			3·65		60		R
·088							·31						45*i*		R
·012							·11						65*bi*		T
·008		·034		4·1		47,580	·07		215	7·6		2·83	55		R
·011							·18						12		W
·095							·35						5*i*		W
·022	·028		3·4		45,848		·16	·16			2·11		85		T
·027							·16						90		T
·004							·05						45*bi*		T W
·101							·35						50	Dull-grey; fibre rather coarse.	R W
·057							·20						45		R W
·068							·23						2*i*		W
·134	·079		9·8		53,182		·50	·33			5·9		1		W
·075							·36						0*i*		W
·043							·35						0		W
·046		·058		7·4		48,304	·18		·235	5·8		4·2	3		W
·090							·25						2		W
·047							·08						50*ii*		T W
·006	·037		5·0		43,426		·05	·14			2·5		1*i*		W
·017							·14						2*i*		W
·016							·15						1		W
·047							·40						3	Grey; fibre generally coarse.	U
·037							·20						40*i*		W T
·037							·27						3		W
·012	·041		6·0		45,886		·27	·26			3·4		8		W
·055							·24						20*i*		W T
·030							·18						0*i*		W
·000		·030		4·3		43,255	·08		·185	7·6		2·40	2		W
·011							·15						8		W
·059							·24						37		W R
·031	·018		2·6		40,624		·13	·11			1·4		5*i*		W
·008							·07						10		W
·000							·03						3*bi*		W

Note.—All the pieces were taken *promiscuously* from Engineers' or Merchan[ts]...
i denotes that the layers are rather imperfectly w[elded]...

Index No.	District.	Names of the Makers or Works.	ORIGINAL Thick. × Bdth. (1. 2.) inch. inch.	Area (3.) sq. in.	Weight on Steelyd (4.) lbs.	Breaking Weight per square inch of Original Area (5.) lbs.	(6.) lbs.	FRACTURED Thick. × Bdth. (8. 9.) inch. inch.	Area (10.) sq. in.
601	Lanarkshire.	Glasgow, Ship Beam.	·500 × 1·96	·980	1792	60,455	55,937	·426 × 1·80	[illegible]
602		„ „	·500 × 1·96	·980	1591	54,712		·435 × 1·55	[illegible]
603		„ „	·350 × 1·97	·689	1019	54,575		·315 × 1·91	[illegible]
604		„ „	·350 × 1·97	·689	1005	54,006		·315 × 1·31*i*	[illegible]
605		Dundyvan, Ship Strap.	·688 × 1·66	1·142	1962	56,538	55,285	·615 × 1·57	[illegible]
606		„ „	·650 × 1·67	1·085	1819	55,301		·565 × 1·60	[illegible]
607		„ „	·500 × 1·72	0·860	1361	54,858		·460 × 1·67	[illegible]
608		„ „	·575 × 1·66	0·955	1533	54,444		·525 × 1·61	[illegible]
609		Mossend, Ship Strap.	·570 × 1·97	1·123	1761	51,985	45,439	·525 × 1·59	[illegible]
610		„ „	·690 × 1·00	0·690	780	44,797		·448 × 0·98	[illegible]
611		„ „	1·000 × 1·00	1·000	1088	39,534		·945 × 0·96	[illegible]
612	Staffordshire.	Thorneycroft, Ship Strap.	·480 × 1·97	·946	1590	56,649	52,789	·445 × 1·93	[illegible]
613		„ „	·470 × 1·72	·808	1276	55,443		·395 × 1·61	[illegible]
614		„ „	·500 × 1·96	·980	1535	53,112		·465 × 1·89	[illegible]
615		„ „	·470 × 2·00	·940	1419	51,917		·428 × 1·95	[illegible]
616		„ „	·470 × 2·00	·940	1404	51,470		·428 × 1·92	[illegible]
617		„ „	·500 × 1·96	·980	1361	48,141		·470 × 1·90	[illegible]
618	Durham.	Consett, Ship Angle-iron.	·570 *m* 1·66	·946	1533	54,962	50,807	·512 *m* 1·57	[illegible]
619		„ „	·570 *m* 1·66	·946	1504	54,103		·525 *m* 1·59	[illegible]
620		„ „	·528 *m* 1·72	·908	1334	51,125		·500 *m* 1·66	[illegible]
621		„ „	·700 *m* 1·00	·700	752	43,037		·640 *m* 0·97	·621
622	S. Wales.	Dowlais, Ship Beam.	·520 × 1·79	·931	1133	43,817	41,386	·478 × 1·74	[illegible]
623		„ „	·530 × 1·79	·949	1146	43,370		·483 × 1·70	[illegible]
624		„ „	·530 × 1·79	·949	1047	40,449		·506 × 1·75	[illegible]
625		„ „	·525 × 1·97	1·034	1076	37,909		·484 × ·915	·944

...res, except those marked *Samples*, which were received from the Makers.
...bad fracture: *s*, size at smallest part; *m*, mean thickness.

Difference between Fractured and Original Areas.			Breaking Weight per square inch of Fractured Area.	ELONGATION. Original Length of Stretched Part in Column 21.				FRACTURE.		
								Crys.	Col.	Kind.
11.	12.	14.	16.	18.	19.	21.	22.	24.	25.	26.
sq.in.	sq.in.	℔ cent.	lbs.	inch.	inch.	inch.	℔ ct.	℔ ct.		
·214	·141	16·9	67,606	1·19	·82	7·6	10·79	44	Grey; fibre close.	R
·175				·92				12		R U
·087				·56				2		U
·087				·60				3		U
·176	·132	13·0	63·635	·86	·61	7·6	8·03	45		R
·149				·67				14		R U
·092				·47				18*i*		R U
·110				·46				26		R U
·131	·087	9·2	50,459	·45	·29	5·6	5·18	53	Grey.	R
·055				·23				1*i*		W
·074				·18				90*i*		T
·092	·113	12·1	59,918	·49	·61	7·6	8·03	33	Lightish-grey.	R
·172				·98				0		N
·101				·68				7		N U
·105				·48				45*i*		R
·118				·60				1		N U
·087				·45				2		N U
·142	·102	11·7	58,201	·43	·44	7·6	5·79	36	Dull-grey	R
·111				·50				1*i*		U
·078				·38				18*i*		R U
·079				·43				0*bi*		W
·099	·095	9·8	45,844	·30	·27	5·6	4·82	1*i*		X
·128				·40				40		X
·064				·20				8		X
·090				·20				1*i*		X

List of Honorary Members, Members, Associates, and Graduates of the INSTITUTION OF ENGINEERS IN SCOTLAND, *at the Termination of the Second Session*, 1858–59.

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José Maria da Conceiçaõ.	George Russell.
John Hall.	Alexander M. Strathern.
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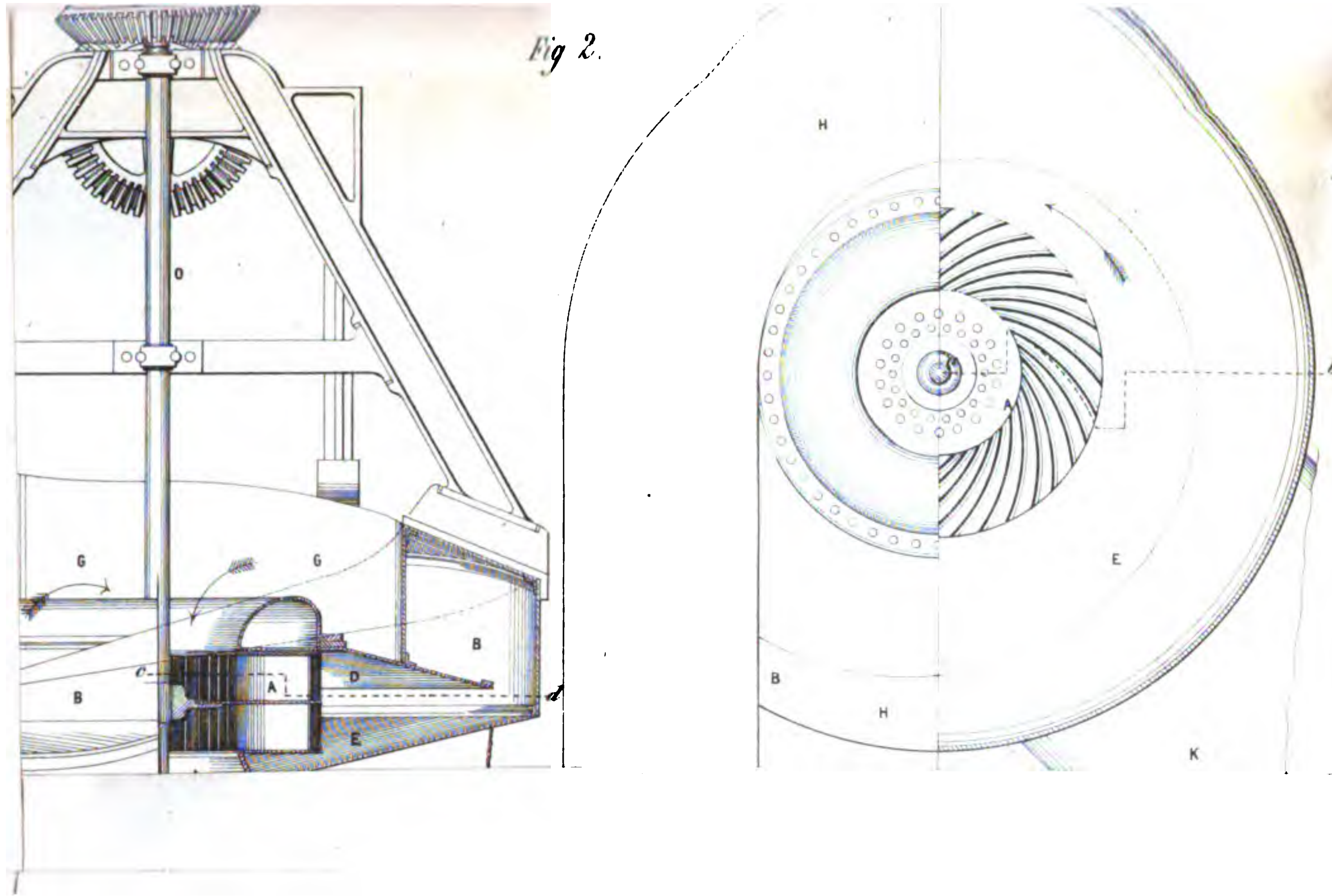
Fig 2.



FRICTION COUPLING.
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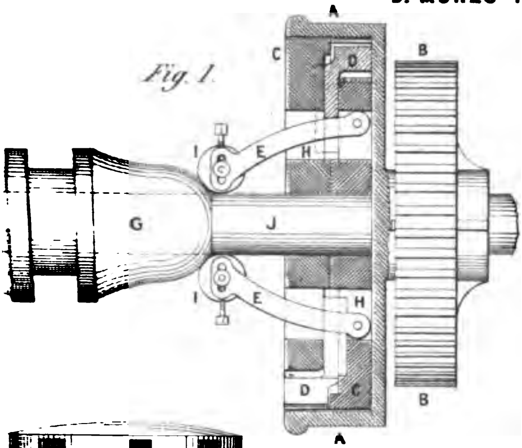

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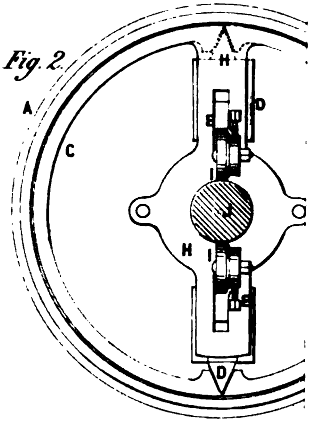
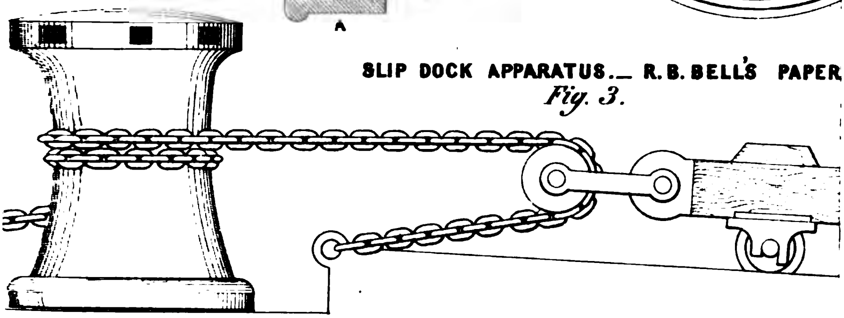


Fig. 2.

SLIP DOCK APPARATUS.— R. B. BELL'S PAPER.

Fig. 3.



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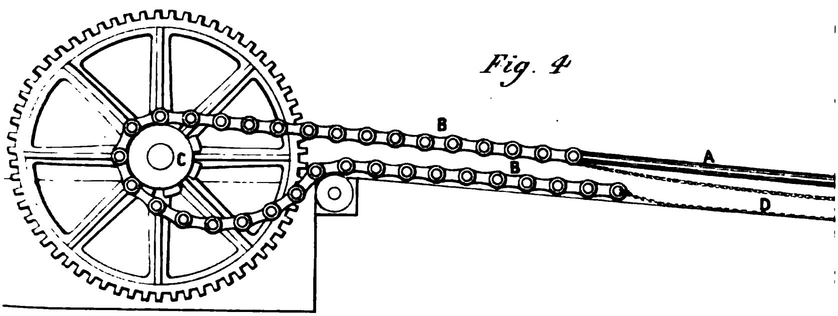

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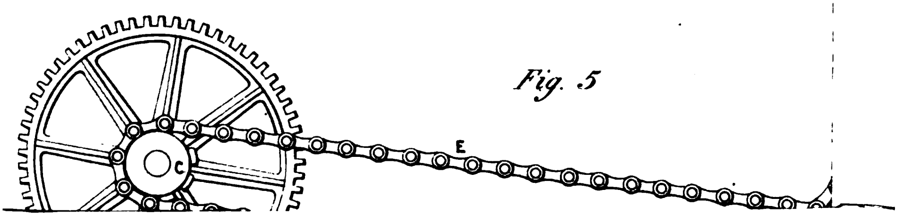

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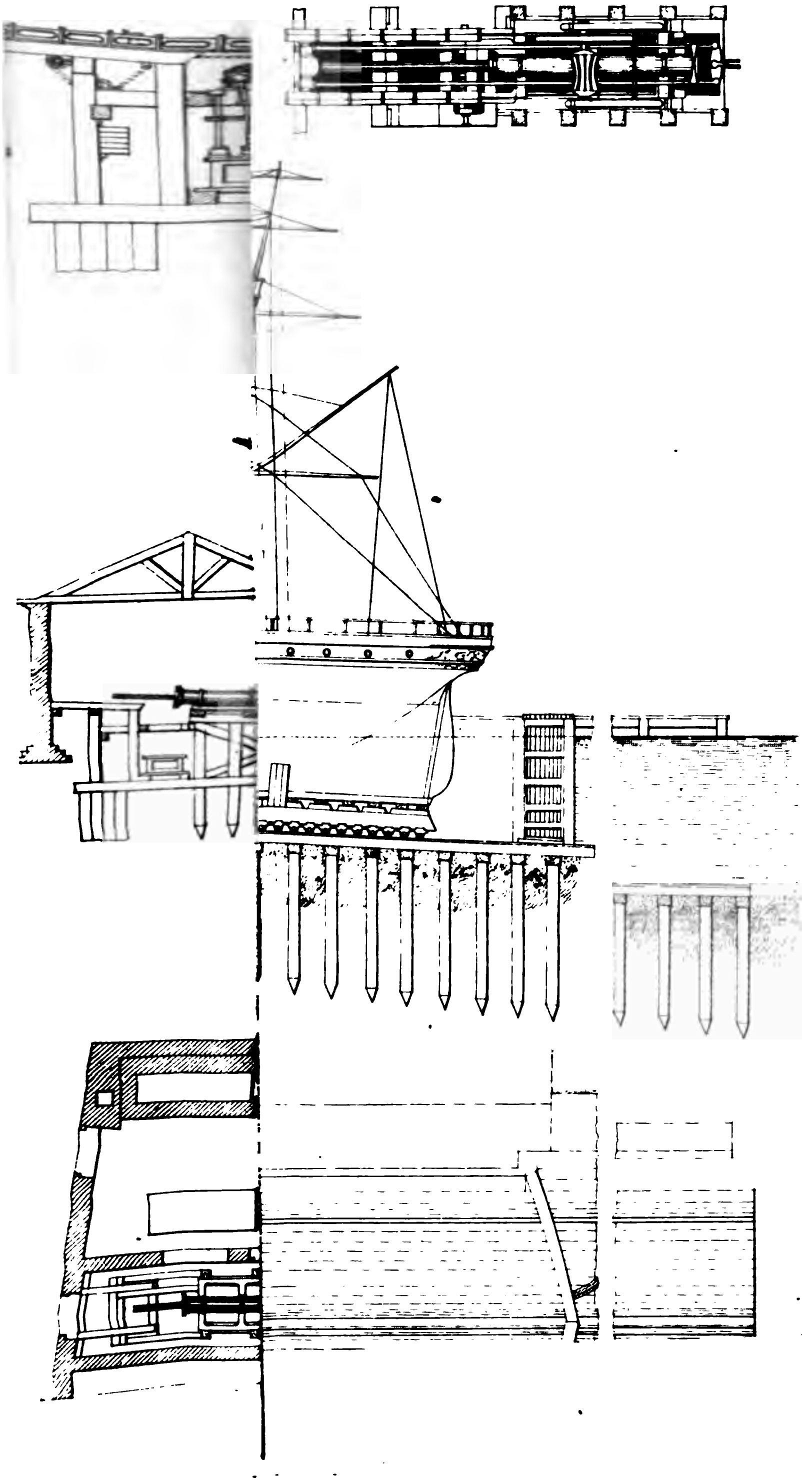
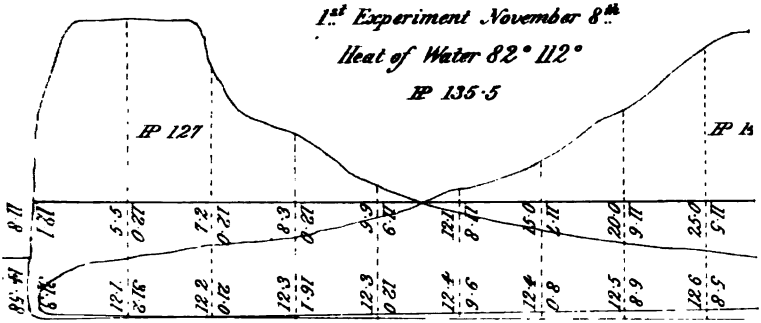
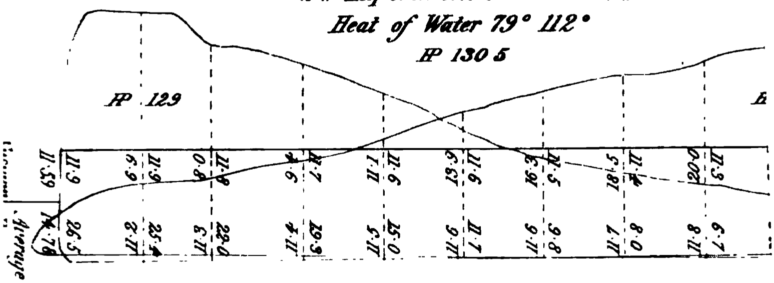


CARMICHAEL'S PAPER.

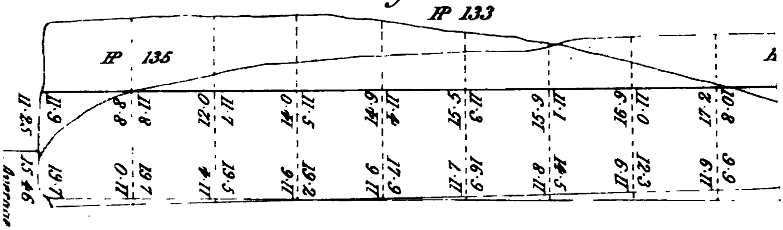
1st Experiment November 8th
Heat of Water 82° 112°
IP 135·5



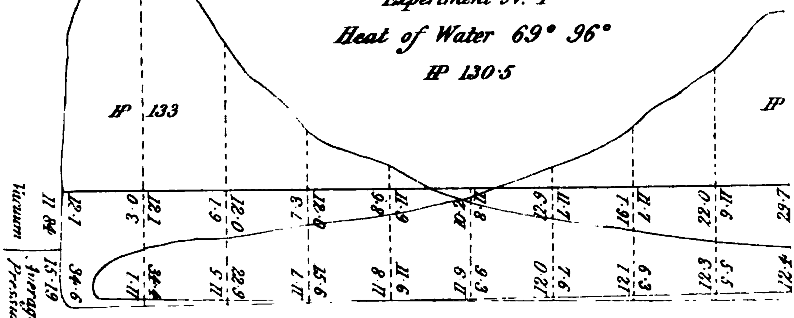
2nd Experiment November 17th
Heat of Water 79° 112°
IP 130·5



3rd Experiment November 22nd
Heat of Water 76° 119°
IP 133



Repetition & Proving of
Experiment No 1
Heat of Water 69° 96°
IP 130·5



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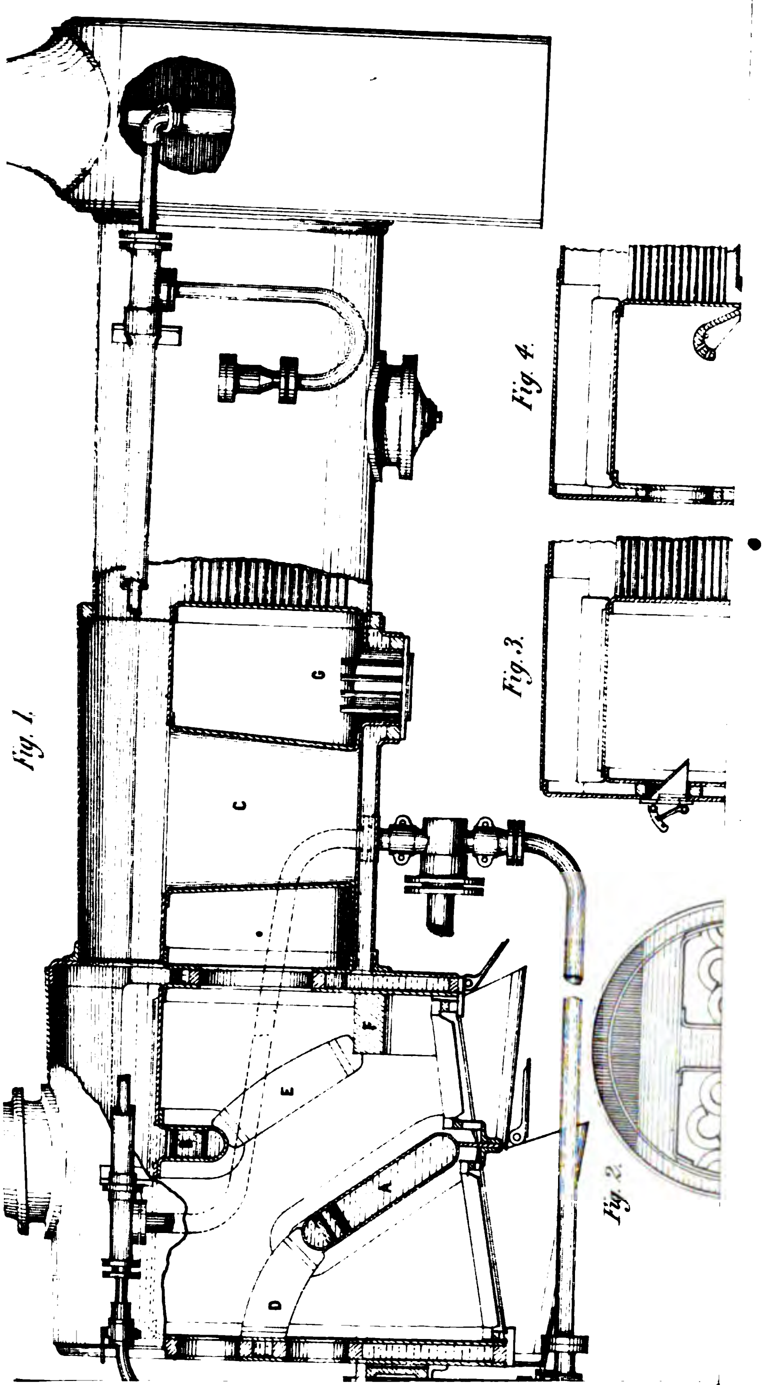

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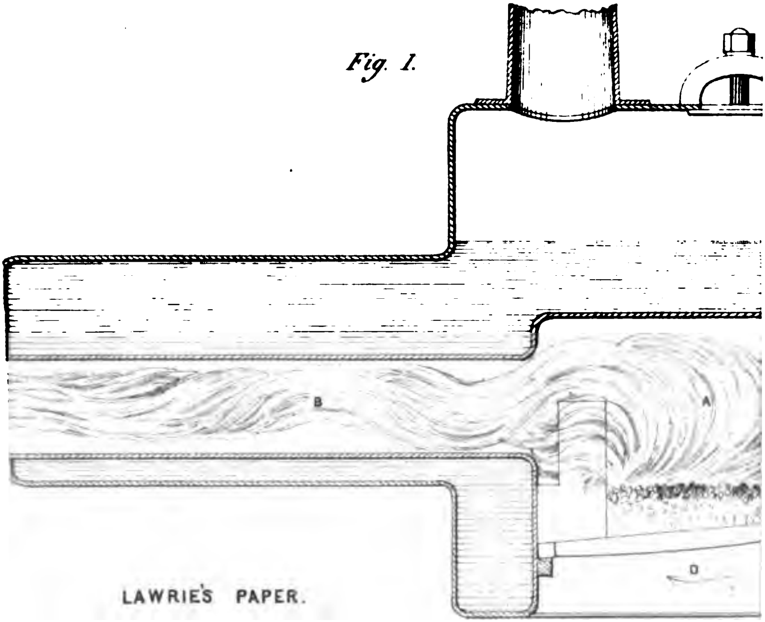
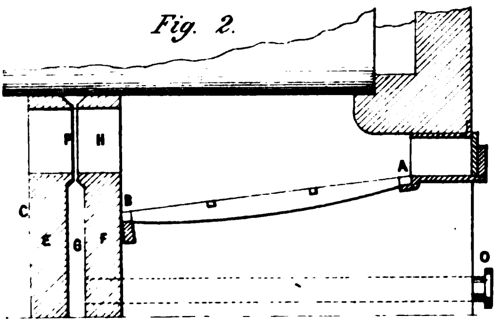


LAWRIE'S PAPER.

Fig. 2.



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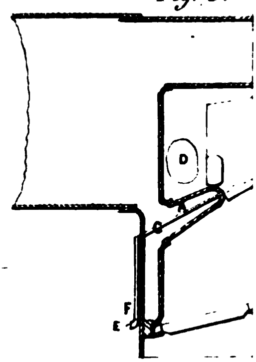

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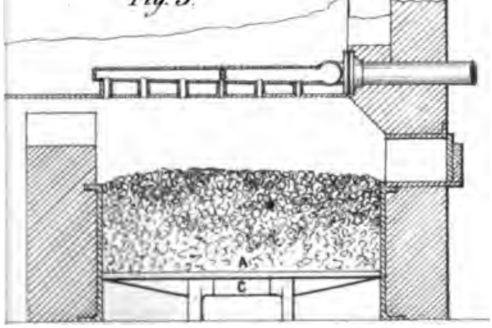

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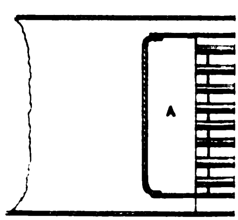


Scale for Fig. 1.

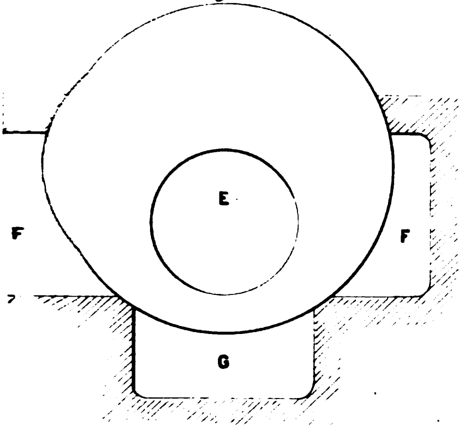
INS. 12 6 0 1 2

Scale for Figs. 2, 3, 4 & 5

INS 12 6 0 1 2 3 4 5 6 7 8 9 10 11

FURNACES AT ST. ROLLOX CHEMICAL WORKS.

Fig. 1.



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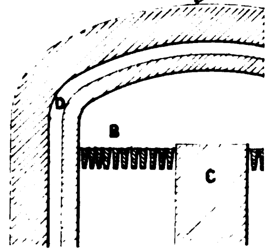

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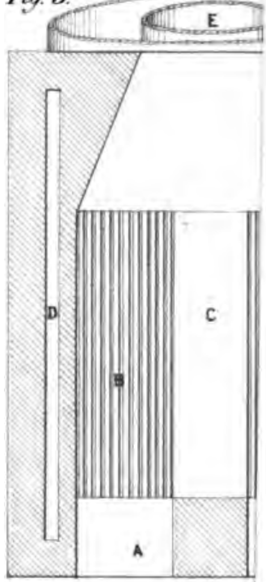

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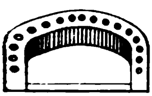
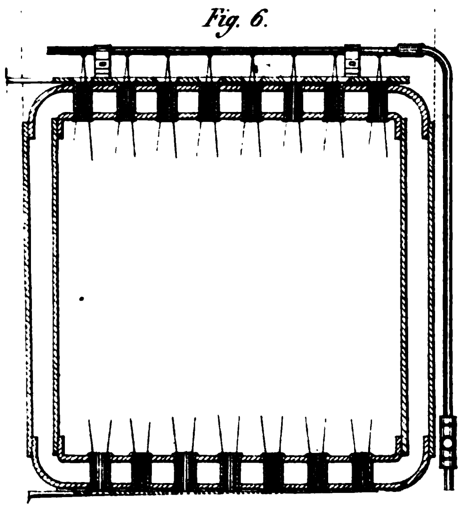


Fig. 5.

CLARK'S SMOKE PREVENTOR. *(Figs. 6 & 7.)*

Fig. 6.



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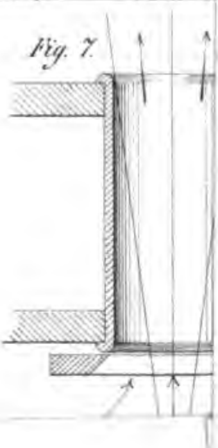
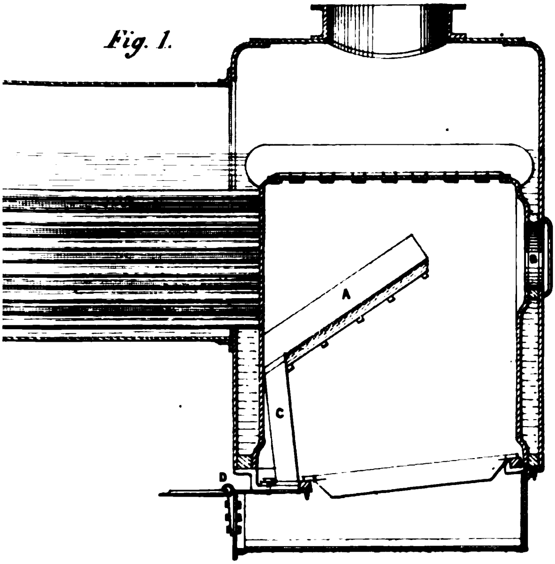


YARROWS SMOKE PREVENTOR.

Fig. 1.



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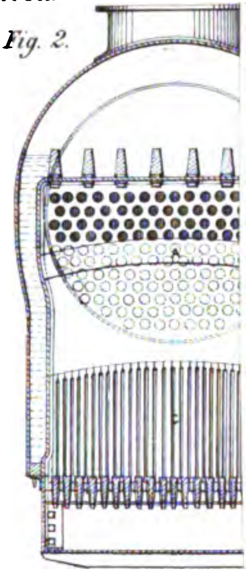
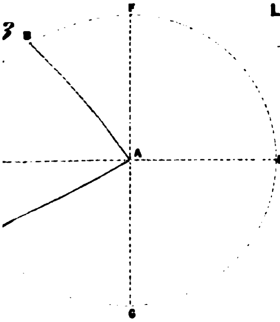


LAWRIE'S PAPER.

Fig. 3



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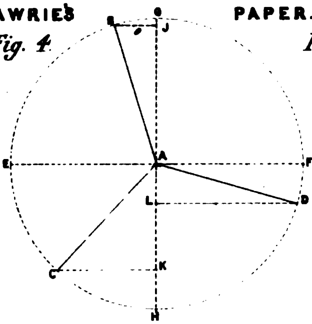

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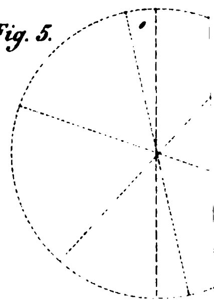
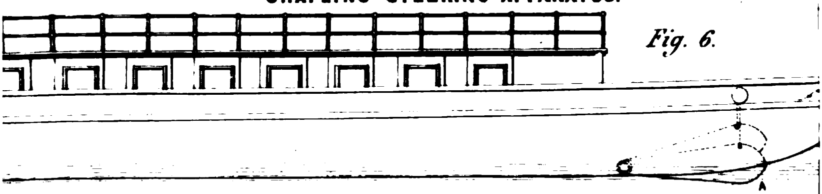


CHAPLIN'S STEERING APPARATUS.

Fig. 6.



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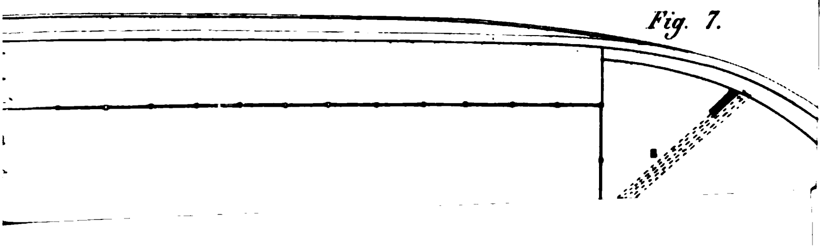

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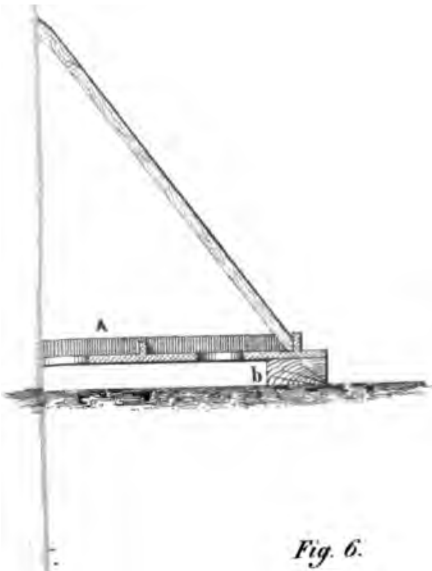

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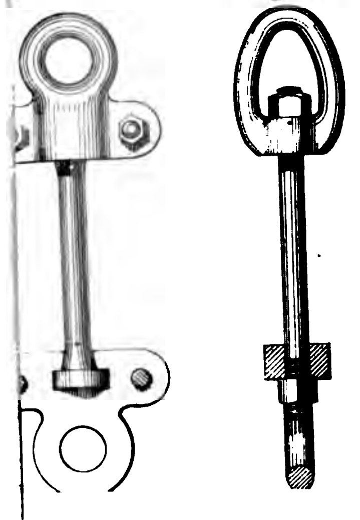

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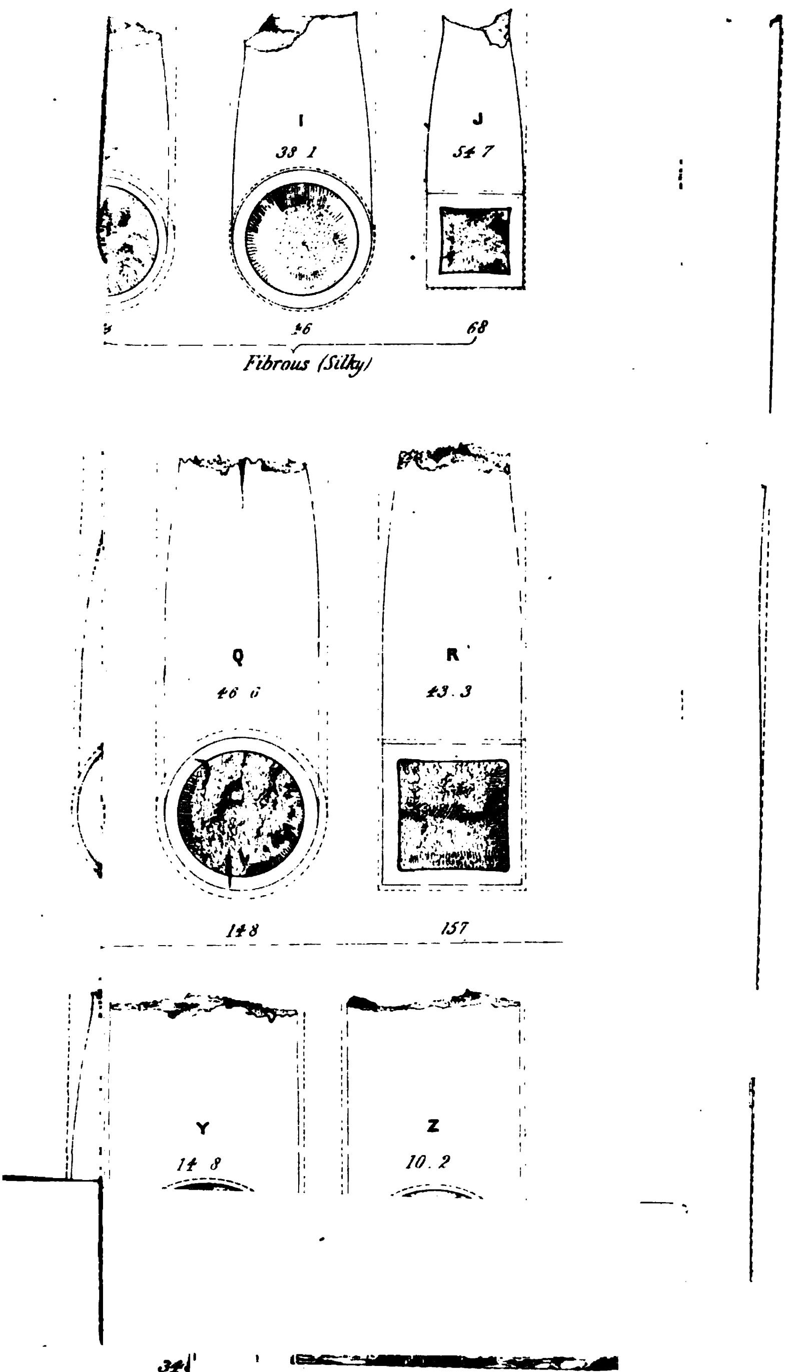

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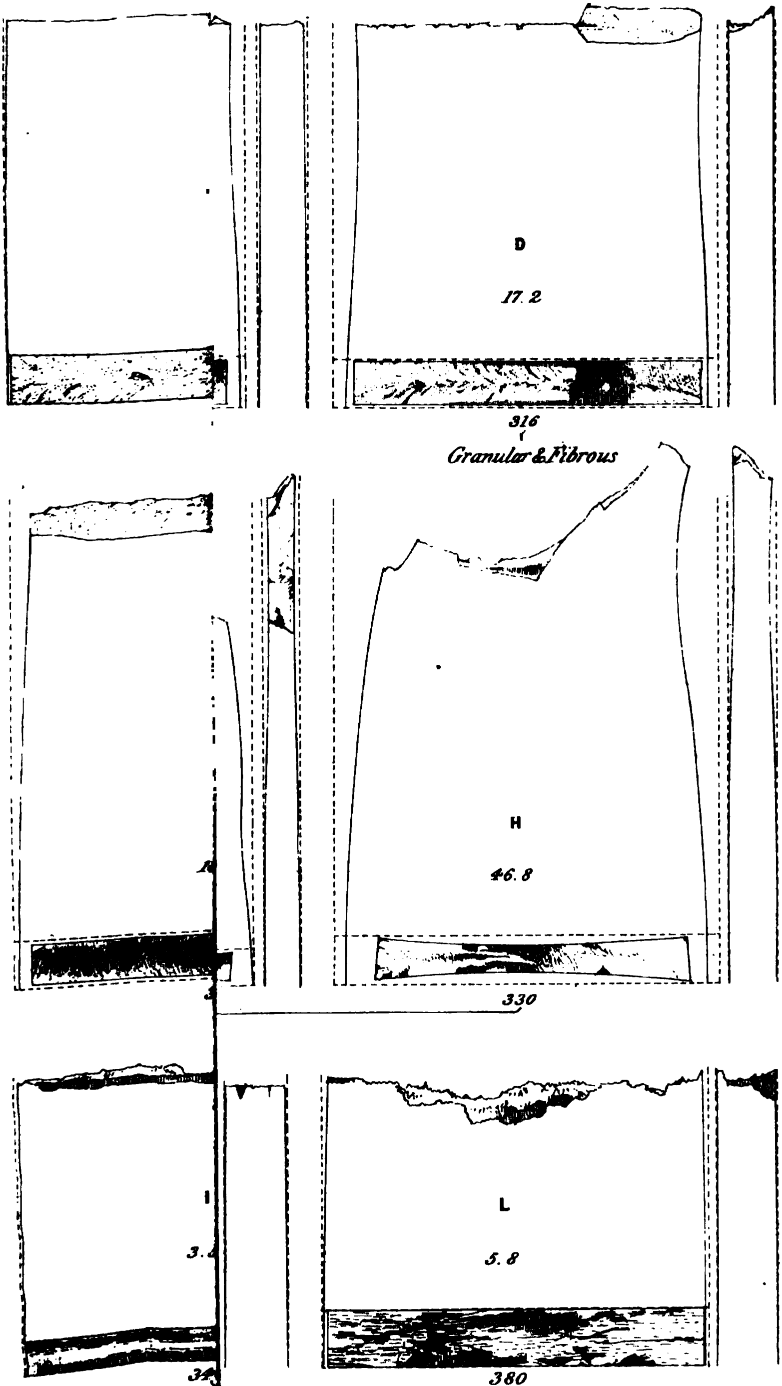

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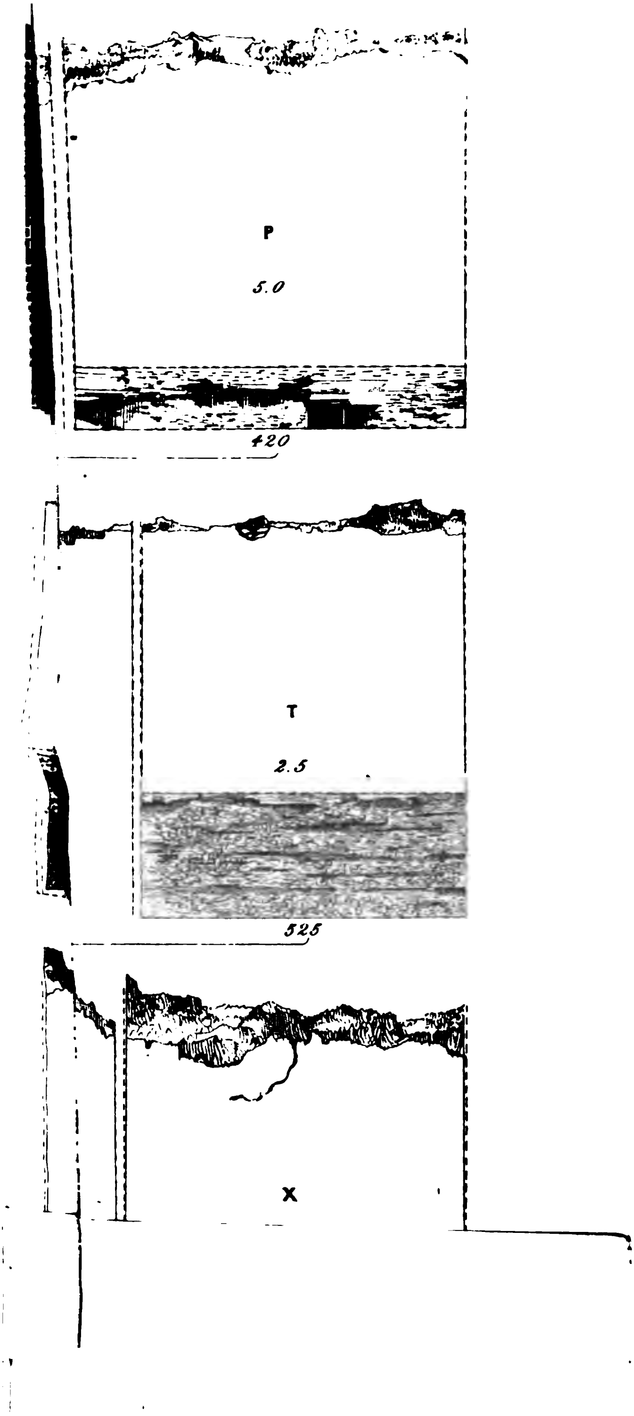
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TRANSACTIONS

OF THE

INSTITUTION OF ENGINEERS

IN SCOTLAND.

VOLUME III.

THIRD SESSION, 1859-60.

TRANSACTIONS

OF THE

INSTITUTION OF ENGINEERS

IN SCOTLAND.

VOLUME III.

THIRD SESSION, 1859-60.

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1860.

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THIRD SESSION, 1859-60.

SIXTH MEETING, 14th March, 1860.

SEVENTH MEETING, 11th April, 1860.

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 IN SCOTLAND.

SESSION 1859-60.

The First Meeting of the Session was held in the Philosophical Society's Hall, Andersonian Buildings, George Street, Glasgow, on Wednesday, 26th October, 1859—Walter M. Neilson, Esq., President, in the chair.

The President delivered the following Introductory Address:—

Gentlemen—This being the first time I have been called upon to preside over your meetings, I must take the opportunity of acknowledging the compliment you have paid me in electing me your President; but at the same time you must permit me to express my regret that I am not more able to discharge the duties I may be called upon to perform. This I feel more particularly, when remembering that I succeed my friend, Professor Macquorn Rankine, who has so ably filled this chair during the past two sessions. I therefore ask your assistance in conducting these meetings, and in any other matters I may be called upon to undertake.

It is now my duty, in opening this our Third Session, to take a cursory view of what we have done in the past year, and lay before you, as far as I am able, somewhat of a prospective view of the subjects more immediately before us for consideration in promoting the objects of our Institution.

I have much pleasure in being able to state, that our Institution continues to prosper and improve, as the reports laid before you will show. Our numbers increase; our funds are sufficient, leaving a small balance to our credit; and what perhaps is as important and satisfactory, a greater interest in our favour seems to be springing up among those from whom we are entitled to look for support and co-operation.

Our papers last Session were not numerous, but highly important; and the spirited discussions to which many of them gave rise, are a very satisfactory proof of the interest our members take in the subjects brought before them.

It is unnecessary to enumerate in detail the various papers that have been read, as they are printed in our Transactions for the year.

The papers on the Economic use of Steam, by Mr. Carmichael and others, gave ample opportunity for the expression of opinion, and the inquiry into facts on this all-important question, from which much information might be gained, particularly when aided by the sound and standard data of our valued member, Dr. Rankine, from whom I hope we will receive this Session additional information as to the results of his investigations into this subject.

The very practical matter of burning coal in locomotive engines, was fully illustrated by Mr. Stirling, Mr. Clark, and Mr. Yarrow; and the particulars of the experience of other engineers, detailed during the lengthened and interesting discussions on this subject, brought out important practical conclusions. As these gentlemen will now have had still greater experience of the various plans exhibited to us, we may expect further communications from them as to their practice.

We must notice the valuable paper by Mr. Bell on Patent Slip Docks. The immense convenience of these slip docks for such ports as our Clyde, is well known and appreciated by shipowners. Much praise is due to Mr. Bell and his partner, Mr. Miller, for the labour and attention they have bestowed in perfecting this important branch of engineering.

The various papers and discussions on marine engines and steam-vessels, British and American, could not fail to be interesting. I think, however, we might have more communications on marine machinery. The subject is a large and important one; there can be no want of experimental data and peculiar results amongst a large section of our members, which would be of value if recorded, and form most interesting subjects of inquiry at our meetings.

The subject of Patent-law Reform, which was brought before our notice by our secretary, ought still to have our attention. Whatever may be the difference of opinion as to the scale of charges enacted by our legislature for the privileges given to inventors, there can be no difference of opinion as to the propriety, or, I ought to say, the justice of applying the immense revenue obtained from patentees to the erection and maintenance of large museums, for the reception and exhibition of models of patents; and to the establishment of libraries for specifications, where, by proper care and arrangement, they might at all times be consulted without inconvenience.

We have had few papers on miscellaneous subjects, such as those on frictional gear, by Mr. Robertson; and on centrifugal pumps, by Professor James Thomson. Although such communications may not of themselves bear directly on any important branch of engineering that may be before the world, still I consider this class of papers of great value, more particularly those which relate to improvements in machines or tools. We are much indebted to the great perfection to which tools and machines have been brought for the present state of constructive engineering, in whatever department, and for the great monuments of engineering skill and enterprise that have been raised of late years. No positive improvement on any tool or machine ought to be considered too trifling a matter to bring before our meetings.

The very valuable results of experiments on the strength of wrought-iron and steel, presented by Messrs. R. Napier & Sons, deserve special notice. These gentlemen, in making experiments, originally for their own particular information, carried them out to an extent, and put them into a form, which will be found most useful; and with their usual liberality, presented the whole to our Institution, to be printed in the Transactions. The most scrupulous care and attention bestowed upon these experiments by Mr. David Kirkaldy, under whose immediate superintendence they were conducted, has contributed very considerably to the value of the production; and the manner in which the results have been brought out, in the distinct tabulated form, is highly creditable to him. We have elaborate and reliable experiments on the strength of cast-iron, in various forms, by Hodgkinson, Fairbairn, and others; but there have not been sufficient investigations into the strength of the various kinds of malleable or manufactured iron. This deficiency will, we trust, be supplied by "Napier's experiments on wrought-iron." At the present time, when the construction of iron bridges on such principles as will require the least amount of material, occupies so much the attention of engineers, a knowledge of the correct value of the material they have to deal with is of the very highest importance. Great exertions, too, are being made by manufacturers to produce an iron of higher quality than hitherto known, at a moderate cost; and it is most desirable that some standard data be established, by which they may compare the result of their labours. I trust the Messrs. Napier will allow those experiments to be carried out much farther, and that Mr. Kirkaldy will communicate to us the result of his observations and experience in conducting them, as I have reason to believe he would bring before us some very interesting and striking facts, which have never yet been noticed, and add still more to the value of his labours, for which we are so much indebted.

Your Council took a leading part in an attempt to form an association in Scotland, similar to what exists in England, for the prevention of boiler explosions, the economy of fuel, and prevention of smoke. Our exertions, however, met with no support from the public, nor from those for whose benefit more particularly the association was proposed—even those of our civil authorities who used boilers and produced smoke, declined to join in the undertaking, which was consequently abandoned.

The past year's Transactions contain memoirs of the late Mr. David Tod and Mr. Daniel Mackain, deceased members of our Institution, men whose unbroken friendship I have for many years enjoyed. Mr. Mackain took a very lively interest in our Institution, and we are much indebted to him for his zealous assistance, when in our infancy as a society.

Gentlemen—I feel it is good to meet together as we now do, were it only that we might know each other better, and be better able to appreciate each other's worth, and mourn each other's loss, as one by one we leave the fields of our labours.

The question of a decimal system of weights and measures is still much discussed. While it is everywhere admitted our systems are bad, and ought, as soon as possible, to be changed, what decimal system to adopt, and how to set about it, is a very vexed question. The advocates of Mr. Whitworth's system of the inch divided into a thousand parts appear resolved to push it into the workshops, while the committee appointed by the "British and International Decimal Association," has reported in favour of the adoption entire of the French metrical system. As you are aware, I do not agree with those who insist upon retaining our inch as the standard unit of measure of a new system; to do so, would be to commit, in my opinion, a grievous error. The metre, as subdivided by the French, appears to me to be as perfect a system as could be devised, and in every way most suitable for the purposes of the engineer. The arguments in favour of this system are many and powerful, and the difficulties in the way of its becoming universal are, I consider, little if any greater, than would exist in the changes that would be caused by adopting any other decimal system. So far as we are more immediately concerned, the question of measures is perhaps more important to us than that of weights, and as the matter will in all likelihood be decided rather by the adoption of one system or another by some of the leading engineers than by any act of the Legislature, it would be well that the members of this Institution should consider what they would recommend for the assistance and guidance of others.

The economy of the steam-engine at present occupies much attention, more particularly as applied to propelling vessels. The searching investigations of those scientific men who make it their province to inquire into the laws which regulate the action of heat in steam, and the skilful application of the knowledge to practice, now being carried out by many enterprising engineers, is likely soon to be productive of results which will be most valuable to the commerce of our country. It is gratifying to find our own Clyde foremost in this progress. Steam first floated on her waters; she first gave to the sea-waves iron-built ships; and I trust she ever will be first in the perfecting of her offspring.

Your late President, in his last year's address, noticed the successful efforts of Messrs. Randolph & Elder, who in the economy of fuel of marine engines had surpassed all other makers. We may now add the efforts of Mr. John M. Rowan, as having gone beyond an experiment in obtaining a still greater economy—a result which has created among engineers and shipowners a considerable degree of excitement and expectation, and I doubt not it will ere long be proved that the system adopted is the one to which we must look for economy of fuel in our marine engines.

I do not intend to enter into the theoretical question of the conduct of heat, as produced on the grate bars by the chemical action of combustion, and communicated to water as the best medium we know by which to develop its force in the steam-engine. Much has been written and yet will be written on each successive step, and much has to be done, as we are evidently yet far from perfection in any point of the process. Professor Rankine, at the commencement of last Session, drew your attention to several important facts relative to the laws which regulate the mechanical action of heat in steam. We are much indebted to him and to Dr. Joule of Manchester (now an honorary member of our Institution) for their valuable researches into this subject. The attention of practical engineers ought to be given to the results of these researches. We are apt to overlook that it is heat, and not steam merely, we must deal with. The combustion of the fuel ought to be so effected, that the greatest possible quantity of the heat obtained should be communicated to the water, and as little as possible lost or wasted by improper arrangement of the furnace, management of the fire, or of the draught. Much heat is necessarily carried off in the products of combustion, which we have as yet no means of utilizing. The question of volume of steam used in the cylinder of the steam-engine, so as to develop the greatest amount of force from a given amount of heat, is an important one. We may have the same quantity of heat either in a smaller or larger volume of steam; and if we condescend upon the limits to which the elastic force of the steam be allowed to extend, then it would appear that the smaller volume of steam containing the greater quantity of heat employed as the initial volume to be acted upon, gives the greater economical result in force developed. As steam on its expansion decreases in temperature, no portion of its original heat should be allowed to be taken from it by any external agency during its action in the cylinder. Not only ought the steam to be maintained at its maximum density, for its actual temperature due to the amount of expansion, but considerable gain of elastic force may be obtained by increments of heat, according to the law of elastic fluids; and particles of water held in suspension, may also thereby be converted into steam. Steam jackets, or other means of maintaining the cylinders at or above the original temperature of the steam, consequently effect economy in this respect. Superheating steam, in its passage from the boiler to the cylinder, has been practically found by Mr. Penn of Greenwich to give an economy of about 20 per cent. over the ordinary use of the same steam in marine boilers. It would be interesting to know the comparative economy obtainable by similarly superheating the steam in a steam jacket round the cylinder. I apprehend, however, a practical difficulty will be found in using anhydrous steam at high temperatures, from the absence of that lubrication which saturated steam provides. Superheating may no doubt be applied with advantage to existing steam boilers and engines, but it appears to me the great economy is to be looked for in the proper use of steam at high pressures, or rather high temperatures. For marine engines this necessarily requires surface condensation, to obtain pure water for the supply of the boilers. The three grand requirements may be stated as—a safe and suitable boiler for pressures of 100lbs and upwards; a good arrangement of engine to receive the initial force of the steam without shock or liability to derangement, and carry out expansion to the greatest practical limits; and lastly, an efficient surface condenser. I have for many years looked forward, with unshaken confidence, to the time when long sea voyages would be practicable and profitable by the means I have just named, and it gives me the greatest pleasure and satisfaction now to believe that that time is at hand, if not already come.

Without any acknowledged principle or rule, shipbuilders seem to have arrived at considerable perfection in the form of their vessels. Nevertheless, the importance of the discovery of some law by which these forms would be more definitely regulated, is acknowledged by both scientific and practical men. As you are aware, a committee appointed by the British Association have had this subject under their consideration for some time, and are endeavouring to collect data for their guidance; but as yet we have had no particular results from their labours. It is much to be regretted that our own members do not bring before us draughts of vessels they may have built, with their results. It is needless to observe how much such a practice would assist in arriving at a more definite knowledge of the proper forms of vessels, an object as much to be desired by the builders themselves as by this Institution or the public. No doubt the skill possessed by a shipbuilder in forming his vessel, is a valuable part of the capital of his business. But the general good that would accrue from the perfecting of such an important art as the modelling of vessels, ought to outweigh all narrow-minded or selfish considerations. I would therefore appeal to the liberal spirit of our shipbuilders, and should it be considered desirable not to publish to the world such data as they may favour us with, the information might be retained for the exclusive use of our own members, and not printed in our Transactions, unless by special permission.

It is gratifying to notice the success of the spirited efforts to obtain high speed by our river steamers. We may safely say that no steamers in the world surpass some of those on the Clyde in speed. The power, in proportion to the displacement necessary for such speeds as twenty miles an hour and upwards, is indeed very great. But when speed is essential to success, as is the case with the steamers in question, the cost is warrantable.

It is very different, however, with the bulk of sea-going steamers, where cargo, and not passengers, is what profits must be made from. The true value of such vessels may almost be reduced to the two following properties—quantity carried; and cost per mile. It is by these a merchant shipowner ought to judge of the value of his ship, not by its length, breadth, or horses power; these last may be left to the builder and engineer, and may constitute the cost, but not the true value of the vessel.

The construction of light draught paddle steamers for shallow river navigation, has of late had more than ordinary attention. Several such vessels for towing trains of barges, have been sent to India; but with what success they have performed the work anticipated, has not yet been made public. The difficulty in steaming against strong currents in shallow rivers is very great; the practicability, in a commercial point of view, may even yet be questionable, and some means may have to be resorted to, by which the power may be applied to the bed of the river, instead of the shallow, rapid-running stream, with which so much power must be expended to obtain sufficient resistance.

The use of the propeller in canal navigation continues to give satisfactory results. A vessel is now completed to carry passengers on the Forth and Clyde Canal, propelled by a screw. Even coal barges can be conveyed more economically by propeller engines than by horses. A simple, cheap, and easily-applied arrangement of machinery is much wanted for this purpose. The power necessary to propel a coal barge at the slow speed required is so small, that one of our members, Mr. James Ferguson, suggested a compact portable engine might be made, to fix to the deck of any barge, and be removed to another while the loading and discharging was being done. Certainly such a scheme does not appear impracticable, and would be very economical for the coalmaster.

The enormous capital invested in railways causes the question of railway economy to be one of the greatest importance in the hands of engineers. If by any means the working expenses of railways (averaging about nearly the half of the whole receipts) could be reduced, a great boon would be conferred upon the public. It may not be expected that this much-desired object will be accomplished by one great or sudden step; on the contrary, it would appear more reasonable to expect that the persevering efforts and attention of the engineer should, by gradual means and many small improvements, bring us to a more satisfactory position in this matter. I may mention the use of coal instead of coke, in the locomotive engine, as one great step towards the end in question. The practicability of using coal instead of coke in the locomotive, without producing an offensive quantity of smoke, is now admitted. We, however, have yet to know which of the numerous schemes before us—some involving complicated arrangements, others remarkable for their simplicity—gives the best economic results. Much valuable information is yet to be obtained from reliable experiments on the various kinds of coal, both as regards the economy in steaming, and the effects produced upon the fire-box and tubes by impurities in the coal.

In a series of experiments now being made upon a railway out of London, some extraordinary results have been obtained by the use of water as a lubricator for carriage axles. After running 1600 miles, a bush was taken out of an axle-box and weighed; on being compared with a similar bush that had run the same distance with ordinary grease, it was found the bush with grease as a lubricator had lost seven times the weight the bush with water as a lubricator had lost. The great superiority of water as a lubricator over any other substance known, seems to be satisfactorily substantiated; but the difficulty of retaining the water in the axle-box had not been completely overcome, although runs of upwards of 300 miles had been repeatedly accomplished, without any additional supply of water having been required.

Efforts have been made to obtain a more effective mode of quickly braking a train, in order to avoid as much as possible accidents from collisions. Various schemes have been experimented upon, and put before the public. Without enumerating them, I would only remark, that we not only require a brake that may give satisfactory results at an experiment, when the men are prepared to work them and everything is put in the best of order for trial; we require some simple arrangement that needs no preparation, but in the ordinary handling of a train is always ready to be acted upon. The engine-driver, I apprehend, is the proper person in whose hands the safety brake ought to be put; his eye is always on the road; and if he could suddenly brake all the wheels of his engine and tender, which together often equal the weight of the whole train, the concussion would be sufficient communication to the guards to let off their brakes by some spring and catch arrangement such as proposed by several inventors.

Much has been done of late years in the more economical construction of the permanent way. The average cost of lines of railway made during the last ten years may be taken at £10,000 per mile, whilst for railways made before that time the average cost was about £34,000 per mile. Recently, however, single lines have been made in Scotland at as low as about £5000 per mile. The enormous cost in forming lines with ordinary gradients, in unfavourable localities, is strikingly exemplified by those great structures, which, whilst they give to the engineer opportunities of displaying that skill and experience we may have reason to be proud of, at the same time render many great undertakings all but ruinous to their promoters. Should it be impossible altogether to avoid the necessity of such works, it is not unreasonable to expect that means may yet be discovered very much to diminish the cost of them. One thing is evident, unless we can fall upon some less expensive railway system, many thinly populated districts of our country must long remain shut out from that busy intercourse in which progress and improvement are found, and landowners there must be content with the diminished value of their lands.

Civil engineers have had full sway over the immense capital placed at their disposal in carrying out the objects of the promoters of our great schemes, undertaken for the investment of surplus capital, and for the benefit of the district of country in which the undertaking may have been located. In one view, it may not be matter of regret that the engineer has somewhat overlooked the second or ultimate object desired. It has given us the great works we have alluded to, and the results of many experiments, which, under other circumstances, the world could not have possessed. But, unfortunately, it has also bequeathed to many of these localities, favoured with such railway monuments, a perpetual and heavy tax upon that great necessity of their lives, locomotion. We cannot blame those men who have lived, and been the instruments by their great genius, skill, and industry, to fulfil the needy capitalist's demands. Their labours have been honourable, and their works most useful as examples of the past; but now, may we not rest satisfied, may we not even be satiated, with great works, and for the future be prepared to give the palm to economy of capital, in carrying out the many great and useful works yet requisite to supply the wants of advanced civilization?

The field of civil engineering is a large one, and I cannot within the limits of this short address, even were I capable, attempt to go over in detail the various departments, in which we would find a vast amount of important and interesting subjects for inquiry and discussion. The very great and apparently difficult work of the drainage of our large and increasing towns yet to be accomplished, would of itself, if touched upon, occupy all our time and attention; not to mention the supply of towns with water, of which, perhaps, we have the finest example in the world in our Loch Katrine scheme, all but completed. The construction of harbours, docks, river and canal navigation, telegraph works, and many others I must pass over, in the hopes that at a future time they may be taken up by more able hands.

Your late President last Session stated, he was sure that all the members concurred with him in regretting that that unparalleled work of Mr. Brunel and Mr. Scott Russell was still unfinished. I am sure we must now feel much gratified that the *Great Eastern* is at last, we may say, finished. The result of the gigantic practical experiment to be made by this utmost effort of the enterprise and skill of our country, is looked forward to with almost feverish expectation by all engineers, and not without great interest by the world at large.

We cannot but pause here to pay a passing tribute to the memory of Mr. Brunel, who, notwithstanding his failures and his faults, was still a great engineer. Borne down by difficulties in realizing those gigantic schemes which overwhelmed him by their greatness, it was sad to see him fall at the moment when his greatest but most hard-won victory seemed all but gained.

But we have also now to lament the loss of another chief, whose career was more successful, and his works not less great. It becomes us, met as we now are, to express our sorrow for the death of Robert Stephenson, and pay our meet tribute to his memory. Although a stranger to us here in person, his name was familiar with us as a household word. Who among us does not know the works of this great man? They are monuments from which ages will not efface his memory. I will not presume but to repeat what has already been a thousand times repeated of him, who, like all truly great men, "was as good as he was great; and the man was even more to be admired than the engineer. His benevolence was unbounded, a man of the soundest judgment and the strictest probity; with a noble heart, and most genial manners, he won the confidence of all who knew him. Without a spark of professional jealousy in his own nature, he was liked by all his fellow-engineers. He has passed away, if not very full of years, yet very full of honours. The creator of public works—a benefactor of his race—the idol of his friends." Such was the son of a once very poor man, risen to too high a fame to be tarnished by the *empty* titles of common men. He dies—the nation laments his death, and gives to his burial the highest honours of the illustrious dead.

Permit me, in conclusion, to say a few more words about our Institution. It is very gratifying to find that we seem to be looked upon with increased favour as we progress. At our commencement, many who were qualified to join us seemed indifferent, and showed reluctance to enrol themselves with us. Many of these have now come forward, and I have reason to believe others will follow their example. There are many members on our roll who never attend our meetings; many cannot conveniently do so whose names we are glad to have. But there are others who content themselves with having our transactions, and imagine they obtain all the benefit that others do who attend regularly. This is a great mistake. No doubt the greater part of the papers are printed, and also a portion of the leading discussions; but that most valuable benefit arising from communication of ideas, and the opportunities of gaining information by question and reply, is lost to the absentee, and this, in my opinion, is one of the most important advantages obtained from our meetings. I have been asked, What good our meetings could do? Now, there are men who practise engineering, in one department or another, for the mere purpose of making money, without a higher object. And there are others who, when they also desire to make money, derive much of their pleasure in life from the line of their profession. That such an Institution as we profess to support will be valued and appreciated by the latter class, I need not mention. They are conscious that everything which advances the profession or art to which they are attached will advance themselves, and they feel proud to be in the foremost ranks in the progress; but the mere money-maker may find it to be to his pecuniary loss to be in the rear of the movement, in which, and by which he lives. Engineering cannot be stationary in such times as we live in; its forward strides are so great and rapid, that any one who desires to keep up with the leaders must embrace every aid, and use it diligently. If we go into a factory or engine-work, we there see the thousand instruments, the workmanship of a thousand hands. As we look upon that noble steamer, or that fiery engine, and the architecture over which it speeds, we admire the mechanism of the machine, and the beauty of the structure; but ere the form was given to these works, the mind conceived the image of the object, and knowledge and experience were the roots from which all sprung; not the knowledge or wisdom of one man, but the perfection, step by step obtained from many minds—the brain-work of many men. Can any one say that meeting as we do to interchange the knowledge and experience we daily gain, we do no good. Do we not add knowledge to knowledge, experience to experience; assist each other's progress, and hasten forward those great works which have done so much for the comfort, the peace, and the civilization of the world?

Professor RANKINE proposed that the meeting should pass a cordial vote of thanks to the President for his very admirable address. He had never heard so full a statement of the condition of any profession as that which they had just heard from Mr. Neilson. He had gone over all those branches of engineering whose present condition and progress were matters of interest, and had pointed out in the clearest way the advantages arising from discussing them in this society. He thought that addresses such as they had now heard were of very great utility to point out the work before them, and to indicate what sort of information and what subjects for discussion required their attention. They also formed a periodical record of the progress that engineering had made, and the parts of it in which progress was needed. He proposed that a cordial and unanimous vote of thanks be passed to Mr. Neilson for his address.

A paper was then read entitled:—

On the Restoration of the Great Chimney at the Crawford Street Chemical Works, Port-Dundas, Glasgow. By Mr. D. MACFARLANE.

A lengthened discussion followed the reading of Mr. MacFarlane's paper, and a vote of thanks was passed to him for it; and also to Mr. Townsend, the proprietor of the chimney, for exhibiting the tools used in the restoration.

Professor RANKINE then exhibited and described

Mein's Improved Machine for Making Glass Bottles.

Professor RANKINE said, the object of the machine was to enable one man to do the work of four. It consisted of a mould formed in two halves, and with the neck portion turned downwards. The workman took a quantity of glass in a soft state, and after removing the top or cover, dropped it into the mould, when it settled down into the neck, in which was inserted a nozzle. He then shut down the lid or cover, and by means of a pair of bellows, introduced air through the nozzle. When the soft glass was blown into the proper shape, he opened the mould, and took the bottle out. The chief novelty of the machine consisted in the position of the bottle in the mould, and in the mode of blowing in the air. The machine was in use in the Clyde Bottle Works, St. Rollox.

A vote of thanks was passed to Professor Rankine for describing the machine; and to Mr. Mein for sending it.

The SECOND MEETING of the Session was held in the Philosophical Society's Hall, on Wednesday, 23d November, 1859—the PRESIDENT in the chair.

The following paper was read:—

Description of a Sediment Collector, and a Furnace Grate for Steam-Boilers. By Mr. JOHN BRAIDWOOD.

The importance of economy in the development of steam power, and the great dependence of that economy upon the boiler and its connections will form a sufficient excuse for describing two exceedingly simple, but practically successful improvements, in that department.

One of the improvements effects the removal of the sedimentary matters from the water used in the boiler, whilst the other improvement renders more complete the combustion of the heat-yielding fuel, and protects the fire bars.

It is, doubtless, well known that the greater part of, if not all the matters held suspended in the impure water with which manufacturers and other users of steam power are frequently compelled to supply their boilers, and which matters form thick and injurious deposits during the periods of the boiler's quiescence, are thrown to the surface during ebullition. It is of this action that the contrivance about to be described takes advantage to get rid of these sedimentary matters; and to this end a current is produced from the surface of the water in the boiler through a separate collecting vessel, and thence back into the lower part of the boiler. The apparatus is represented in fig. 1, Plate I. in vertical section, and as applied to a cylindrical boiler. It comprises a closed cylindrical iron vessel, A, which communicates with the boiler, B, by two pipes; one, C, opening into the boiler at about the water surface line, and the other, D, entering at the bottom. The water in this vessel, A, becoming partially cooled, tends, by its increased weight as compared with the corresponding column inside the boiler, to produce a current from the surface in the boiler through the upper pipe, C, through the vessel, A, and back through the lower pipe, D, into the boiler. The rate of flow from the boiler through the upper pipe, C, is sufficient to carry along the suspended matters; but on entering the vessel, A, the rate of flow becomes reduced in proportion to the increased diameter over that of the pipe, C, and the sedimentary matters are in consequence precipitated. For the purpose of collecting the matters precipitated, the vessel, A, is extended some distance below the return pipe, D, and the latter is formed with a turned-down mouth inside the vessel, A, to prevent the matters falling into it. A door, E, is provided at the bottom of the collector, A, for the periodical removal of the deposits.

Five boilers at Messrs. A. & A. Galbraith's works, St. Rollox, have each been fitted with one of the sediment collectors. Four of these boilers are each eight feet in diameter, the other being seven feet, whilst the whole are twenty-eight feet in length. The five boilers raise steam of 50lbs. pressure for an aggregate of 800 indicated horses power, and each boiler has four furnaces, two internal and two external. The sediment collectors are opened once a week, when each yields two horse-pails full of thick dark mud. The water used is from the canal, and is, perhaps, as dirty as any put to a similar use. Formerly, all this mud became incrusted on the internal boiler surface, not only injuring it, but also greatly reducing the evaporative efficiency, and necessitating frequent laborious cleanings. With the sediment collectors there is still a slight incrustation, but it never increases beyond the thickness of a coat of paint, which is not sufficient to affect the evaporative efficiency. Two of the sediment collectors are working efficiently at Messrs. Shedden & Morton's timber yard, North Street, Anderston; also, one at Mr. Austin's flour mills, Bothwell Street, and one at Mr. Melvin's engine works, William Street, Anderston.

The improved furnace grate is made with the bars inclined in plan to the horizontal centre line, or to the sides of the furnace. In broad furnaces the bars may be inclined towards each side from the centre line, but in narrow furnaces they may be all inclined one way. The intention of this arrangement is, that the air rising up between the bars may flow obliquely across them towards the inner end of the furnace, with the view of preventing the accumulation of clinkers on the bars. It is also preferred to give a slight inclination to the grate surface upwards towards the inner end, so that the green smoke from the fresh fuel near the mouth may be made to flow closely over the incandescent fuel at the inner end. This feature is not novel as applied to ordinary grates, but its combination with the horizontally-inclined bars enhances the advantage accompanying these. A model of the improved grate is exhibited, from which its construction will be easily understood. It is also shown in Plate I.; fig. 2, being a longitudinal section, and fig. 3, a plan. One of the grates has been in operation for upwards of three months at Messrs. J. & D. Dick's, engineers, Paisley, and one of them has been in use for about ten weeks at Mr. W. Gilchrist's, steam-power printer, Trongate, Glasgow. In the latter place the steam could barely be kept up to 20lbs. with the ordinary bars, whilst, since the alteration, a pressure of 25lbs. is easily maintained, and with a saving of thirty per cent. of fuel. There is no smoke and no clinkers, and the combustion is manifestly more complete than formerly. As regards durability, the bars do not show any deterioration after ten weeks' use. Several furnaces are being fitted with the improved grates, and, as far as tried, with equally satisfactory results.

The PRESIDENT considered it a very important thing to get rid of the coating in boilers, and thought an apparatus such as Mr. Braidwood's might be well applied to boilers in his own foundry. It seemed a very simple apparatus, but the best proof of its utility would be found in the results from it in practice. We had a piece of mud upon the table, but did not know how long that was in being collected.

The SECRETARY observed that, in the paper it was stated that two horse-pails full of sediment were collected per week.

In reply to Mr. Tait, Mr. BRAIDWOOD said Messrs. Galbraith had had the apparatus in use since August, 1858.

The PRESIDENT said, respecting the angular bars used in the improved grate, he could not see how so large a saving of fuel could be got in consequence of their use as stated in regard to Mr. Gilchrist's furnace, but some member might be able to explain it. Could Mr. Braidwood say whether there was any change made upon the furnace or boiler, besides the putting in of angular bars?

Mr. BRAIDWOOD, in answer to various questions, said the saving in the fuel arose from the change in the current of air. In common furnace grates, the current of air passed along a straight line through the longitudinal bars, in the same current as the smoke, and consequently at the back part of the furnace there was not a sufficient mixing for complete combustion. But his bars changed the current, making the air pass through the furnace obliquely across the bars, and become thoroughly mixed, thus insuring the ignition of all the inflammable elements of the coal. The bars of the improved grate were quite loose, being set upon bearers. They were only three-eighths thick, with spaces of the same width between. In Mr. Gilchrist's furnace the bars were previously inch-and-quarter thick, and no doubt some of the economy in fuel was to be attributed to the change in the thickness of the bars, but not all.

Mr. TAIT thought thirty per cent. of saving in fuel almost fabulous; for the whole of the ash and the clinkers from an ordinary furnace did not amount to that; so that unless there was an extraordinary saving from lessening the "blacks" emitted at the chimney, such a saving could not take place. He believed, however, that there must be some saving with this grate from the bars being thinner; but not to the extent of thirty per cent. He knew that not over twenty per cent. of the fuel was found in any ashpit, even where the furnaces were constructed very carelessly, and with very thick bars.

Mr. BRAIDWOOD said that in this case there were scarcely any clinkers or residue, almost the whole of the coal being burned.

The PRESIDENT had asked questions in order that there might be no mistake about this matter. Sometimes, for want of explanations, we got fallacious results; and he wished to guard the Institution in this respect as far as possible. Before we could take this matter as completely settled, Mr. Braidwood would require to put in as thin bars longitudinally as he had angularly, and then the result due to the angular position alone would be apparent.

Mr. BRAIDWOOD did not know that it would do to put in as thin bars longitudinally.

Mr. DOWNIE thought there was something in having a shorter distance between the bearings due to the angular position, which allowed of a much thinner bar being used, but was still inclined to think that the saving referred to was not altogether to be attributed to that.

Mr. TAIT thought the sediment collector would act very well.

Mr. DOWNIE asked if experiments had been made to test whether it caused a circulation throughout a twenty-eight-feet boiler?

Mr. BRAIDWOOD replied that if there was a current towards the instrument, the floating stuff would gather towards it, although there was not a great circulation.

Mr. TAIT considered the simple fact mentioned—that at the expiry of some months no incrustation was found to exist upon the boilers—was very satisfactory; and that the sediment in the collector was only two horse-pails full per week, showed that the water must be very clear, even although taken from the canal. The quantity of sediment collected was, in his opinion, very small.

Mr. DOWNIE thought the quantity depended on the quality of the water; for if there were lime in it, it would have been much more than that.

The PRESIDENT remarked that the apparatus was only designed for the collection of substances in mechanical suspension in the water.

In answer to questions by Mr. Milne, Mr. BRAIDWOOD said the boilers to which the sediment collector had been applied never required cleaning out at all. Previously a scale was always found upon them, but now there were neither scales nor sediment. Messrs. Galbraith's boilers had not been cleaned out since the collector was applied to them. They had been examined regularly, but there was nothing to take away. There was no need to chip off the scales, for they fell off. Previously the boilers had to be cleaned out once a month.

Mr. Milne had no doubt that, previously, if the boilers were worked at 50lbs. pressure a very considerable scale would be found upon them, requiring to be chipped off by hammer.

Mr. Braidwood said the scale was some three-quarters of an inch thick before.

The President remarked that, from the appearance and weight of the mud in a concentrated form upon the table, which had been taken from the sediment collector, there seemed to be as much vegetable as mineral matter in it, and it smelled very much of tallow. It was very light.

Mr. Milne said the place whence the water was taken for these boilers was not a navigable cut of the canal, but had been made specially for the mills.

In answer to a question, Mr. Braidwood said the boilers were for driving steam-engines, but they did not use the condensed steam again.

Mr. Tait considered that as they must use sixty cubic feet of water per hour, the deposit seemed very little. The water was of unprecedented cleanness, or the deposit would be very much greater.

Mr. James Russell said that at one time it was the practice to clean out a tubular boiler at the North Woodside Iron Works once a month, when a pailful of sandy stuff and scale had to be taken out. The practice of surface-blowing off several times a day was adopted; and the result was that they could go on for six months without cleaning; and at the end of that time the sediment was not more than what it used to be at the end of each month.

The President said we must adopt different expedients for different sorts of chemical impurities; but this vegetable matter could only be removed by means of surface collection.

Mr. Braidwood said the action of his collector was continuous, whereas the plan referred to by Mr. Russell was not. Besides, when the latter was used, a loss of heat ensued, as they could not blow off without a loss of heat.

The President thought that if the sediment collector was made deeper it would be better, and perhaps there would be more than two pailsful of stuff to be taken out per week.

Mr. Lawrie remarked, that, for many years Armstrong's apparatus had been used for collecting sediment. It consisted of one perforated cone within another; and, owing to the circulation in the boiler, the sediment found its way to it, because it was the only quiescent part of the boiler.

The discussion then terminated, a vote of thanks being passed to Mr. Braidwood for bringing the matter before the Institution.

The following paper was then read:—

On the Treatment of Steam for the development of Power.
By Mr. J. G. Lawrie.

Engineers have, within a recent period, made considerable progress in acquiring a knowledge of the principles of steam. They have become acquainted with Joule's Law, which enables them to comprehend elements of the action of steam formerly obscure. They now know that the power which can be obtained from steam is measured by the heat it contains, and that the heat necessary to raise the temperature of a pound of steam one degree is as exactly defined by, and as exactly equal to, a known amount of power, as one ton is equal to 20 cwt. By means of this knowledge the investigation of the amount of power derived from a quantity of steam used by any steam-engine is reduced to an investigation of the amount of heat contained in the steam when it enters the engine, of the amount of heat contained in the steam when it leaves the engine, and of the conversion of the difference.

Proceeding in this way the action of expansive steam-engines has been elaborately considered by scientific men; but in all the investigations with which the writer is acquainted, the engines considered have been what mathematicians would call pure or immaterial engines. No account has been taken in these investigations of the effect in the action of the engine due to the substance of which the engine, and more particularly of which the steam-cylinder, is composed. The results arrived at are therefore those that would be true if the parts of the engine were absolutely impervious to heat; and they afford important and conclusive information regarding the operation of steam on that supposition.

But, in the practice of engineers, the effect derived from steam-engines is the result due to a complicated action arising from the radiation of heat, the conduction of heat, the transference of heat, by means of the substance of the steam-cylinder, &c., from one part of the stroke to another, and also very materially the result obtained is affected by the action of the valves. In this complication care is necessary to discriminate betwixt the different causes, so as to arrive at proper conclusions regarding the effects.

In illustration of this, the opinion entertained by some engineers that the use of expansion in unjacketed cylinders is productive of no advantage, and by other engineers of loss, is, the writer believes, unwarranted by the present state of our knowledge on the subject; and he also believes that the opinion of the use of the jacket being productive of some recondite and unintelligible advantage, is equally without solid foundation. To obtain the same amount of power from an expansive engine that is obtained from one in which expansion is not used, the cylinder requires to be made of increased size, which occasions loss, no doubt, from increased radiation and increased conduction, whether the cylinder be jacketed or not, but not to an extent of any moment in the consideration of this question.

In estimating the power derived from a quantity of steam, it is necessary, as has already been mentioned, to consider the quantity of heat which the steam carries into the cylinder, and also the quantity which it carries from the cylinder. In the proportion that the latter of these quantities is less than the former, the duty or performance of the steam is increased. In an engine working without expansion, that is, with full steam throughout the stroke, a certain smaller quantity of heat leaves the cylinder than entered it, the difference having been transformed into power; and in an expansive engine in which the steam is admitted during only a part of the stroke, the duty or performance of the steam cannot be less than in the former engine, unless the steam carries from the cylinder more heat in the expansive engine than in the engine in which the steam is not expanded. Some engineers entertain an opinion very unfavourable to the use of expansion in an unjacketed cylinder; and of these Mr. Humphrys of London states broadly his opinion that the use of expansion in an unjacketed cylinder is always productive of loss, and that the amount of loss is proportioned to the amount of expansion used, the loss beginning with the smallest amount of expansion, and increasing as the expansion is increased, to an extent so great that, when the expansion is considerable, three times the quantity of coal and steam is necessary to produce the same effect that is required when expansion is not used.

The writer has mentioned that, in an engine in which steam is admitted of full pressure throughout the stroke, the quantity of heat which leaves the cylinder at the termination of the stroke is less than the quantity which entered the cylinder at the commencement; and, if the opinion of Mr. Humphrys be correct, it follows as a consequence, that, in the expansive engines, upon which he rests his opinion, the difference betwixt the amount of heat which entered and left the cylinder, when the engine worked expansively, must have been only one-third of the difference betwixt the heat which entered and left the cylinder when the engine worked without expansion.

Thus, in an engine in which the steam is admitted throughout the stroke, if the quantity of heat which enters the cylinder be represented by unity, or $\frac{45}{45}$, the quantity which leaves the cylinder, and is lost, is $\frac{42}{45}$,* leaving the difference $\frac{3}{45}$ as the quantity utilized. Therefore, in the

* These figures are got as follows:—1 lb. of coal evaporates $7\frac{1}{2}$ lbs. of water, and therefore the water receives $1150° \times 7\frac{1}{2}$ of heat $= 8625°$. One horse-power per hour,

engine upon which Mr. Humphrys experimented, the quantity of heat, if his views be correct, which leaves the cylinder and is lost, is $\frac{44}{45}$, leaving the difference $\frac{1}{45}$ as the quantity utilized when the expansion is considerable. The duty of the coal, or heat, or steam, in the two engines, is very different, being in the one engine $\frac{3}{45}$, and in the other $\frac{1}{45}$; yet, the difference in the two engines in the heat which is lost proportionally to the whole heat, is very inconsiderable, being in the one $\frac{42}{45}$, and in the other $\frac{44}{45}$. These figures bring out prominently the necessity for high perfection in the construction of engines, and the facility with which a slip may be made from a result that is good to one that is bad. There are several ways in which the good result, namely, the one in which the loss of heat is only $\frac{42}{45}$, may be diverged from; but, on a close comparison of the two engines, the expansive and non-expansive, it is exceedingly difficult to see how the effect stated by Mr. Humphrys can take place in a manner due only to expansion or non-expansion.

It has been alleged that in an unjacketed cylinder the heating and cooling of the cylinder at the beginning and termination of the stroke accounts for a loss of advantage in the use of expansion, but it does not at all account for it as identically the same operation, the same addition of heat to the steam, during the progress of the stroke, takes place in a jacketed cylinder. Except in the loss arising from the radiation and conduction due to the increased surfaces, the writer knows of no explanation which satisfactorily accounts for the results found in the experiments of Mr. Humphrys, and the loss arising from these causes cannot, under usual circumstances, be of an amount to afford the explanation.

In other experiments on this subject—in those, for example, on which a distinguished member of this Institution rests his unfavourable opinion of the use of expansion in an unjacketed cylinder—not a loss, as with Mr. Humphrys, but a result giving no advantage, as the writer under-

= 33,000 lbs. × 60; 1 foot high = 1,980,000 lbs. = 2538° of a pound of water at the rate of 780 foot-pounds for one degree. Therefore, the horse-power due to 1 lb. of coal = $\frac{8625}{2538}$ = 3·4 horse-power. But, 4½ lbs. of coal are required per horse-power in a good non-expansive engine, and therefore only $\frac{1}{3{\cdot}4 \times 4{\cdot}5} = \frac{1}{15{\cdot}3}$; or, in even numbers, $\frac{1}{15} = \frac{3}{45}$ of the heat received by the water is utilized, the remainder, $\frac{42}{45}$, being lost. In the s s. *Thetis*, at 1½ lbs. per horse-power, the heat utilized is $\frac{9}{45}$, and the remainder, $\frac{36}{45}$, is lost. In the engines by Randolph, Elder, & Co., at 2 lbs. per horse-power, the heat utilized is $\frac{6{\cdot}75}{45}$, and the remainder, $\frac{38{\cdot}25}{45}$, is lost.

stands, was obtained. The result obtained, however, in the instances to which the writer now refers, is capable of an easier and more satisfactory explanation. When expansion is used it is necessary that the steam be freely admitted to the cylinder during admission, that it be sharply cut off, and that it be retained in the cylinder hermetically till the period for its emission. These conditions, the writer believes, were not fulfilled in the experiments to which he alludes. In the steamer *Islesman*, for example, an account of which has already appeared in the Transactions of this Institution, the mode of effecting the expansion is, in the writer's opinion, of a defective character. In the account of that vessel it is stated that in a stroke of 36 inches, when the steam is admitted during four inches, the exhaust is opened at 26 inches, and the compression begins at 20 inches. In the gear, by which the valves of this machinery are actuated, the amount of expansion is increased by reducing the travel of the valves, which has the effect of checking the free admission of the steam, of unduly increasing the compression, and of opening the exhaust at a period of the stroke when it should be closed. All of these effects are disadvantageous to the development of the power of the steam.

In the same way with those engines in which the expansion valve is placed in the steam-pipe, or on a stationary plate of the valve casing, the expansion is effected in an unsatisfactory manner, and there is no doubt that in all of these cases the result, whatever it may be, is less advantageous than it would be with an efficient mode of effecting the expansion.

It may be said, however, that the diagrams obtained are satisfactory when these modes of shutting off the steam are employed, and no doubt they often are, as in the diagrams of the *Islesman*, which were exhibited in this room. Now, however, that the pressure and power of engines is measured with so much minuteness, the indicator is far from being an instrument sufficiently delicate for the purpose, and the diagrams of the *Islesman* appear to establish this fact. Even with the greatest care the indicator, in a tapering diagram, is not to be depended on for accuracy, and, with the slightest inattention, the indications are very far from the truth. In the diagram represented by A, C, B, D, fig. 24, Plate V., the indicator probably represents, with tolerable accuracy, the pressure in the cylinder, because the changes of pressure from B to A, and from C to B, are large in amount and sudden; but, in the tapering diagram represented by the line A, E, F, G, D, the changes of pressure being gradual, and, in fact, imperceptible, the pencil will necessarily fall behind the changes of pressure in the cylinder by an amount depending on the circumstances of the case, but by an amount which, in all cases, is of considerable importance, and in many of large amount. In the *Islesman*, for example, the steam is released at 10 inches from the termination of the stroke; yet the diagrams did not assume the shape represented by the line at E, F, H, D, which they ought to have done; nor is the shape of that character in any diagrams the writer has seen, although in all it ought to be more or less, as in all engines the steam is released before the termination of the stroke; and this proves either—or rather proves both—that the diagram is incorrect, and that the steam requires a considerable time to escape even into a vacuum. But, if a time so considerable is necessary for the steam to escape even into a vacuum, the multifarious plans of effecting expansion, by means of valves in the steam pipe, and valves placed over numerous small apertures through plates in the valve-casing, must be radically injurious, as they entail small tortuous passages, through which the steam cannot possibly travel with the freedom desirable.

The writer has already explained that, in his opinion, the reason why in certain cases no advantage has been derived from the use of expansion in unjacketed cylinders, does not exist in the heating and cooling of the steam cylinder, and that jacketed cylinders do not possess in that respect any material advantage; yet, in other respects, jacketed cylinders possess advantages which are exceedingly important. In steam which has not been subjected to any superheating process, a considerable quantity of water is carried in mechanical suspension, and when the steam is used to work a steam-engine with an unjacketed cylinder, a further quantity of water is produced by the condensation of the steam in the development of power. But, in an expansive engine with a jacketed cylinder, the temperature of the steam in the cylinder being lowered during expansion below that of the steam in the jacket, the latter becomes a means of superheating the steam within the cylinder, and so converts the water in mechanical suspension, as well as that due to the development of power, into steam, and effects in that way an important economy of fuel, provided the heat contained in the condensed water of the jacket be returned to the boiler. This appears to the writer to be the chief advantage of the steam jacket, and for the reason that he does not see a loss due to the heating and cooling of an unjacketed cylinder; neither does he see any very considerable advantage in a jacketed cylinder when the steam is superheated to an extent to prevent condensation during the development of power. Until, however, this superheating can be effected in a safe and mechanically simple way, the economy attainable with a jacket is unattainable without it.

Judging from the different opinions occasionally expressed regarding cylinders fitted with and without jackets, there would appear to be considerable obscurity on the subject, and the writer has thought it might not be out of place to bring the subject distinctly to the attention of the Institution, and to invite its deliverance on the question.

Mr. Lawrie, in answer to the invitation of the President, explained a diagram illustrative of his paper, and recapitulated some of the difficulties of the subject.

The President mentioned that he had had a conversation with Dr. Joule, who was a great enthusiast respecting the economy of coal, and he was of opinion that we were coming to the time when a pound of coal would produce a horse power.

Mr. Tait owned to being astonished at the statements Mr. Lawrie gave in the paper, and which he alleged were made by Mr. Humphrys.

Mr. Lawrie said the statements were made by Mr. Humphrys in a discussion at the Institution of Civil Engineers, and were repeated to him afterwards.

Mr. Tait was satisfied that all the mechanical engineers might not have experimented so very precisely as Mr. Humphrys, but the result had been great economy by their clumsy expansive arrangement. He had tried it, and found the economy great. They had in their workshop a steam-engine of 40 horse-power, driven with a consumption of 24 cwt. of dross coal per diem. The boiler was high-pressure, 35 feet long, and 5 feet in diameter. The fire did not go underneath the entire length of the boiler, but was merely at the one end, and it generated more steam in proportion to the outlay than any other boiler, whilst it was less exposed to the action of the fire than any other boiler in the work. There were two flues, each 19 inches in diameter. The furnace was 5 feet by 4 feet. It had close-fitting doors, with a little slide to let in air at pleasure. The steam-engine stroke was 4 feet. He had tried the same engine, working with full steam, at low pressure, but not with such satisfactory results. It was a very possible thing to expose a larger surface of iron to the action of the fire than corresponded to the coal consumed upon the grate; but, if the boiler was small, the iron could not be made to take heat beyond a certain limit, however intense the fire might be. Now, these two flues gave more heat than if the flame passed all round the boiler—that is, for the quantity of coal consumed. There were three conditions which he thought had been overlooked when speaking of using steam expansively, and which were necessary to obtain economy:—(1) A small charge of steam; (2) dry steam; and (3) high pressure. The reason of the advantage resulting from the small charge of steam was very obvious. It was a mistake to make steam-boilers as small as possible; for, when the steam-boiler was small, with a large charge of steam, each stroke inevitably put a considerable body of water in motion; and, when the steam went towards the cylinder, there was a tendency in the water to rise and accompany the steam. But, supposing the engine to be working with one-fourth of that charge of steam, in that proportion the tendency of the water to pass to the cylinder was diminished. Then, every one knew the benefit of having the steam dry. A very simple illustration occurred to him with reference to high pressure. If, on a railway, a locomotive engine worked at a pressure of from 30 to 40 lbs. per square inch, and moved at the rate of 20 miles an hour, with a load equal to the full pressure of steam, it would be found that a stream of water issued from its chimney; but let it go with steam of four times that pressure, and it would be found that no water at all issued from the chimney, and the locomotive would be doing its work with much less water and fuel.

The PRESIDENT remarked that this paper was on a subject which was becoming now a very prolific one, and upon which we had a good many papers last year, to be followed up, he hoped, by others this session. We had yet nearly $\frac{17}{45}$ths to utilize, although it was very satisfactory that we were diminishing the loss, for he considered the improvement of Mr. Rowan a large step in the right direction. He had no doubt that some system would be found out that would give us still greater economy in the use of coal. But the subject of expansion and steam-jackets raised questions which we could not agree upon; yet, the truth was to be found and must be sought for, although he had no doubt that a great many of the trials which had been made had given false results. He did not think that the matter had been sufficiently experimented upon, to enable us to come decisively to the conclusion that a benefit was got from the steam-jacket. He held that a steam-jacket was an excellent thing, and Mr. Lawrie admitted that water was carried forward in mechanical suspension into the cylinder. Now, we knew that a sensible amount of heat was lost in the cylinder, and his idea was that the jacket should keep up that heat; but this was a very large question, which we could not go fully into at present. There were some terms used by Mr. Lawrie which he could not agree with. He spoke of "heat transformed into power." He could not see that the two things stood in this relation to one another. The one might give the other; but he could not see how the one was transformed into the other. He was inclined to adopt the old theory—that heat gave power by merely changing from one position to another. He was sure they were all much indebted to Mr. Tait for bringing before them the particulars regarding his boiler. He understood it was a new system of firing which was used with it. He trusted Mr. Tait would prosecute further inquiries in the matter, and give them the benefit of the results in a paper at a future meeting.

Mr. TAIT said he would gladly do so. He, for one, could not see any advantage from the steam-jacket.

Mr. DOWNIE thought it was mentioned at one of the meetings last year, that in one case when the steam was shut off from the jacket, after the engine was set agoing, it gave an advantage.

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The SECRETARY said such a remark did not reach him, nor the Reporter.

Mr. JAMES RUSSELL said Mr. Scott of Greenock had told him that he had found it to be an advantage.

Mr. LAWRIE thought the advantage must have arisen from some other cause, and that beyond a doubt advantage was derived from the use of a steam-jacket.

The PRESIDENT observed that was the difficulty of the question; but if they all tried and collected as much positive data on the subject as possible, they might yet have the matter cleared up. It was, however, very difficult to get the results of trustworthy experiments.

Mr. LAWRIE said the President could do it with a vessel he had at hand.

The PRESIDENT said that was true; but when it was remembered that the calculation was that every experiment cost £50, he had some objection to it.

Mr. MILNE said there were some experiments made respecting the usefulness of the jacket 15 or 16 years ago, and they were very satisfactory. He also once saw it tested on an engine to which a jacket had been added, after it was erected. The pipe letting the steam to the jacket subsequently got broken, and when it was repaired it was conclusively shown that the jacket was of service.

Mr. TAIT said the jacket acted precisely as hair-felt and wood.

Mr. DOWNIE said that in the case to which he previously referred, it appeared that the steam was at first admitted into the jacket, and afterwards, when the engine was properly set agoing, it was shut off.

Mr. RUSSELL said it was kept on until the jacket was sufficiently heated, and they found that it was an improvement; but the improvement, to his mind, arose from retaining, and not from giving heat.

A unanimous vote of thanks was then given to Mr. Lawrie for his paper.

The PRESIDENT then vacated the chair for the purpose of reading the following remarks—Mr. Tait taking the chair—

On Locomotive Pistons.

Mr. Neilson brought before the notice of the meeting the circumstance of solid pistons being used in the locomotive engines of nearly all the Irish railways. A short time ago Mr. Cabry, of the Midland Great-Western of Ireland Railway, showed him a solid piston used by him, of which a full-sized drawing was before the meeting. This piston was remarkably light and simple, having only one solid steel ring in it about three-eighths of an inch broad. Its chief peculiarity consisted in the mode of joining the two ends of this ring by an over-lap half-check, in a plane at right angles to the piston-rod. The cost of these rings was very little, and their durability great. One of the rings shown to the meeting had run 13,000 miles; and, for experiment, another had been run 33,000 miles.

Various forms of solid pistons were used by different engineers on the lines in Ireland, where, it may be remarked, fuel is generally more expensive than in this country.

The great lightness, cheapness, and security from accidents (which frequently occur from pistons made up of pieces), appeared to be arguments so much in favour of solid pistons that it seemed curious they were not more generally adopted in this country for locomotive engines.

A short conversation ensued, in which Messrs. Downie, Milne, and Tait took part, a unanimous opinion being expressed in favour of solid pistons, which had sometimes been seen in use in engines in Scotland, and which were used regularly in steam hammers.

A vote of thanks was passed to the President for his remarks.

The THIRD MEETING of the Session was held in the Philosophical Society's Hall, on Wednesday, 21st December, 1859—Neil Robson, Esq., Vice-President, in the chair.

The following paper was read:—

On the Enlargement of the Junction Basin at Grangemouth, and the Deepening of the Communication between the Junction Basin and the Entrance Dock. By Mr. JAMES MILNE.

Fig. 1, Plate II., is a general plan of the harbour of Grangemouth, the eastern port of the Forth and Clyde navigation. The entrance dock, which has an area of 4½ acres, is entered by the Carron river from the Firth of Forth, through an entrance lock 55 feet in width, having three pairs of lock gates, with a length of 250 feet between the entrance gates, and a depth of water on the gate sills of 24 feet at spring-tides. The communication between the entrance dock and the junction basin is by the building of the junction drawbridge, which has a width of 30 feet, and had a depth of 15 feet at high water of spring-tides. This building was completed along with the building of the entrance dock in 1842.

The means of communication from the junction basin to the timber basin, and to the canal, is from the westward end of the basin, by the junction lock, which is 91 feet in length from point to point of gates, and 21 feet in width, with a depth of 13 feet 2 inches at high water of spring-tides, and a lift of 4 feet 6 inches from high water of spring-tides to the surface-level of the timber basin and the canal reach. This lock was built in 1842, and the Pig-iron wharf on the south side of the junction basin was built in 1847. These works have generally been found suitable for the trade, except that the communication between the entrance dock and the junction basin has frequently been found to be too shallow for passing loaded vessels, which incurred either the removing of such vessels to the entrance dock for completing their cargoes, or the running of water from the timber basin and the canal supply to increase the depth of water in the dock and basin; whilst the dimensions of the junction lock have been found to be too limited for passing any considerable proportion of the vessels too large to navigate the canal up to the timber basin, having an area of 12¾ acres, and which might be considerably extended. Such was the general outline of the dock accommodation at the port for vessels of too large dimensions for passing along the canal navigation, when an increasing trade rendered it necessary to consider by what means, or in what way, the requisite increase of accommodation could be most suitably, easily, and cheaply supplied.

On testing the nature of the ground by bores put down, it was found to be soft alluvial deposit to the depth of 22 feet at the junction bridge, with a gradual rise towards the junction lock, where the depth of soft deposit measured 20 feet 11 inches under the level of the surface of the coping at the junction bridge, which answers to 2 feet 6 inches above high water of spring-tides, and is assumed as the datum line for the depths herein referred to. Lying at between these depths, a stratum or bed of boulders in hard till was traced by the bores put down, throughout the lines of the new wharf wall and the cast-iron tunnel pipe; and by boring through the masonry at the junction bridge and lock, it was found that the stratum was intact under the walls, and that the walls were founded on two thicknesses of cross planking, each 6 inches thick. It may be stated that this stratum has been found unbroken throughout the scope of the new works, some portions of it being found to be softer than other portions, whilst it varies in thickness from 8 to 14 inches. The boulders were generally found closely bedded together in the till, and varying in size from that of small gravel to 8 or 9 inches through. This stratum lies on a bed of mixed fine clay and sand, from 2 to 3 feet in thickness, with soft mud under the bed of clay and sand.

After having proved the nature of the ground, and the depth to the only hard stratum within the limits of the depth for foundations, the general scheme resolved upon was to deepen the communication between the junction basin and the entrance dock to as close on the till bed as found practicable; to complete the junction basin to the width of 238 feet, giving an area of 3¼ acres in the basin; to dredge out the basin to the depth of the entrance; to deepen, widen, and lengthen the junction lock, so as to pass about three-fourths of the number of the sailing vessels arriving at the dock, from the junction basin to the timber basin; and to lay in a cast-iron tunnel pipe from the line of the new wharf wall to the old harbour, for the purpose of running water off the basin, and of scouring the mud from the old harbour.

The works were commenced by laying in the cast-iron tunnel pipe along the surface of the till-bed, from the old harbour to the line of the new wall. The pipes are spigot-and-faucet pipes, 26½ inches inside diameter, with a draw-sluice at the face of the new wall, and a hinged self-acting valve-sluice on the discharge end at the old harbour. After the pipe was laid in, a contract was made in July, 1858, for the building of the wharf wall, and excavating the bed of the basin. The height of the wall from the till-bed to the surface of the cope, is from 20 feet 9 inches to 21 feet 9 inches; the latter height being that of the section, fig. 2, Plate II. The wall is built of freestone, with ashlar in front, and rubble backing. The front line of the wall is curved to a radius of 3000 feet, the profile of the wall front to 8¼ feet under the surface of the cope being built with a batter of 1¼ inch to the foot, and from the 8¼ feet under the cope to the founds, to a concave of 40 feet radius, which gives a breadth of wall on the upper found course of 9 feet 6 inches, and a breadth of 11 feet for the lower found course. The lower found course is laid with Arden-lime mortar, on a bed of concrete averaging about 12 inches in thickness, and beaten over the till-bed. The second course of found stones is bonded on the lower course, and the first course of the ashlar and rubble is built with alternate headers from the front and the back of the wall—all with the view of so bonding the foundation and base of the wall, and extending it over so much in area of the surface of the till-bed as to guard against subsidence. The excavations at the back of the wall are partly filled up with light pottery ashes, for the purpose of lessening the weight at the wall, and of guarding against the strain of the filling in of the mud behind. Cast-iron drain pipes, with brass faces on the pipes, and leather valve faces, are passed through the wall for running off water from behind the wall.

On the ends of the wharf wall being built as close to the water-way of the former basin as the safety of the bank would permit, the water was run off by the tunnel-pipe. At the eastward end the new wall was joined to the wall of the junction bridge, and at the westward end the new wall was joined to the south wall of the basin, and a portion of the junction lock was taken down, and 40 feet in length at the lower entrance to the lock built in to the width of 25½ feet, whilst the bottom invert was lowered to 3 feet under the bottom of the present lock, this being a preparatory step to enlarging the lock; as shown in the plan, Plate II. Such portion of the entrance to the lock was thus completed as would carry the turnpike road over the lock entrance, and give the means of damming off the water in the junction basin, so that the basin and the entrance lock might be available for the shipping whilst the lock was being enlarged.

Whilst the new entrance to the lock was being built, and the walls of the basin completed, the communication between the dock and basin was also being deepened by the removal of the original invert building, and replacing it by an invert of cast-iron girders, as shown in figs. 3, 4, and 5, Plate III. As a precaution against the yielding of the entrance walls, shoring logs were fitted in, and firmly wedged between the walls. The cutting out of the ashlar bottoming and invert was begun at the end next to the junction basin. The ashlar, concrete, &c., were cleared out to the till-bed, and the first two girders bolted together, carefully placed into the line and level of the entrance, and run in with Roman cement throughout the bedding of their lower sides, and the ends of the girders were caulked up with iron cement so as to abut them firmly to the walls. All the subsequent girders were fitted in, girder to girder, in the same manner, the invert being cut out in sections of from 2 feet to 4 feet at a time, and the laying in of the girders kept as close as practicable to the taking out of the invert, so as to guard as much as possible against the risk of the water breaking through from the dock.

After the girders were laid in, bolted, and secured, they were filled up with concrete, and a surface course of hard composition brick, on bed—all beaten in flush with the upper webs of the girders, and run in with Roman cement.

The girders, when completed (except the girder at the middle, which forms the sole for the batter-doors), weighed 67 cwt. each, and measured 30 feet 6 inches in mean length, 2 feet in breadth, 12 inches in depth at the middle end, and 21 inches in depth at the extreme ends. They were made to the length in three pieces—the middle piece 21 feet in length, the one end piece 6 feet in length, and the other end piece 3 feet 6 inches in length; which, on fitting the middle pieces together alternately, end for end, gave a lapping of 2 feet 6 inches on the sides of the girders, where they joined girder to girder. The three pieces forming each girder were fitted and bolted together, and the fitting strips on the sides of the girders all planed, or otherwise dressed quite fair throughout the length, and the girders were cramped together for drilling the bolt-holes, which were all broached out, and the bolts turned to fit. The depth of the ashlar, &c., removed from the entrance, was 4 feet 6 inches, corresponding to the 12 inches in depth of the cast-iron girders put in, giving a gain of 3 feet 6 inches in depth, and a depth of water throughout the communications of 18 feet 6 inches at high water of spring-tides. Fig. 3 is a plan of one-half of the communication, showing the new bottom, with a portion of the girders clear; a second portion being shown partly filled with concrete, a third portion with the surface course of bricks, and a fourth portion as having the final coating of Roman cement. Fig. 4 is a transverse vertical section, with the old invert building indicated by dotted lines on one side, showing the gain in depth; and fig. 5 is a vertical section across the middle girder, forming the batter-door sole and the adjacent girders.

In order to get these works accomplished, a coffer-dam had to be constructed to dam off the water in the dock; and it was deemed most essential that the constructing of the dam should not deprive the trade of the passage through the junction basin and timber basin to the canal, for a longer period of time than was necessary for completing the wharf walls and the entrances. Also, as the walls of the dock are founded to such depth that they stand on the mud under the till-bed before referred to, it has been held to be unsafe to run the water out of the dock, whilst it was feared that the driving of piles for making a coffer-dam in the usual way might endanger the safety of the walls; and, looking at the difficulty of driving piles in from 20 to 24 feet depth of water, and the subsequent difficulty and risk of making a secure and tight dam between two rows of piles, the wrought-iron coffer-dam was designed and made as represented in figs. 6 to 11, Plate III.

The dam is wholly made of wrought-iron; the framework is formed of nine girders, each girder 40 feet in length, 4 feet in depth at the middle, and 21 inches in depth at the extreme ends; the bow sides of the girders being made to a radius of 80 feet, and the string sides to a camber of 3 inches. The girders are made of angle irons, all rolled in one length to the span of the dam, and the girders, Nos. 2, 3, 4, and 5, from the bottom, have web plates (also rolled in one length to the span of the dam) fitted between the angle irons, which form the bows and strings. The sections of the parts of the girders decrease in size from girder, No. 1, at the bottom, to girder, No. 9, at the top of the dam, and the spaces between the girders increase from bottom to top, so as to make the strength of the dam nearly uniform with the pressure of water due to the depth. The bottom of the dam is framed of T-iron ribs, and covered with $\frac{3}{8}$-inch plates, all curved outwards to strengthen the bottom against the pressure. The girders are plated all over outside, the plates on the back of the dam all upright, the upright joints butted and joined by covering strips, and the longitudinal joints lapped and rivetted on the girders. The plates on the front of the dam are in lengths of 25 feet for the middle of the dam, and in such breadths as to lap the plates on the two girders for joining longitudinally, and the upright joints of these plates are joined by covering strips double rivetted by $\frac{1}{2}$-inch rivets. All the other rivets are $\frac{5}{8}$-inch rivets, pitched in at distances of $2\frac{1}{2}$ inches between centres, along the rows which require caulking, and 5 inches between centres for the other rows of rivets. The plates vary in thickness from $\frac{3}{8}$-inch at the bottom of the dam, to $\frac{1}{4}$-inch thick at the top. A sluice tunnel, 18 inches square, passes through the dam, with a draw-sluice on the back of the dam for shutting off or running water through the dam, and a pipe of 6 inches diameter, with a two-way tap-cock in the pipe, is fitted to the front and back of the dam, near the bottom, for running water into or out of the dam. By this pipe and tap-cock the dam was filled for being sunk, or emptied for being floated, or the height of the water in the dam regulated to the height of the water in the dock. The whole weight of the iron-work in the dam, tunnel, and pipe, is $20\frac{1}{2}$ tons. The strengths of the parts of the dam were calculated to support a pressure of 20 feet depth of water, but the greatest height of water ever on the dam was about 19 feet.

The dam was made at Maryhill, and was launched into the Kelvin dock at three o'clock one afternoon, towed to Grangemouth, and set to its place, and the water run off from behind the dam on the following day. By filling in about a boat-load of tan bark and ashes round the back of the dam for safety, and for compensating for the inaccuracies in the fitting of the dam to the wall, the dam was made as tight as could be wished, and remained so until the works were ready for its removal, when, by running the water out of the dam, and filling the basin (on the 31st October last), the dam rose from its seat and was floated out of the way, giving an immediate free thoroughfare for again passing the shipping between the dock and basin.

Mr. Milne having described two models illustrative of his paper, as well as pointed out on diagrams the various parts which it discussed, in answer to various inquiries, said that the till-bed he had mentioned was also called a gravel bed—particularly in the locality of Grangemouth. No water passed through it, and although they had bored 50 feet through the bed, no hard material was come to; indeed, it was said, no hard substance would have been reached unless they had bored 100 feet. They had placed the girders close upon the till-bed, thereby protecting this bed, and at the same time taking advantage of it to support the walls. There was a depth of 24 feet of water at the main-lock entrance, and at the place where the recent deepening operations took place there was a depth of 18 feet, which was found to be sufficient for passing through four-fifths of the vessels that arrive at the port. No doubt had they excavated the till, and gone down to the clay and mud, they would have had difficulties to contend with, requiring different expedients. The till-bed must be dredged out before vessels drawing more water than 18½ feet could pass by the Carron river to the docks. In deepening the entrance the stop-gates were done away with, and batter-door checks and sill were provided as a substitute, but the stop-gates had not been shut oftener than twice in the last ten years.

Mr. Bell thought Mr. Milne's plan of using cast-iron girders was a very good one. He had never seen it before carried into effect, as usually heavy and expensive stone-work was employed.

Mr. Milne said that the cast-iron girders were put in at less cost than the stone-work which was taken out; and, in reply to Mr. Alexander, added that, if they had taken out stone-work, they could not have obtained the additional depth by rebuilding in a stone invert on the till-bed.

Mr. Bell remarked that they would have shaken the walls if they had put in the stone-work under the surface of the bed.

Mr. Milne said that they went to the bottom of the walls, not without some fear that the dock might break in upon them; but they had made the trial, and effected their purpose.

The CHAIRMAN said he did not gather whether the paper stated the cost of the operations and the additional water-surface gained.

Mr. MILNE replied that they had gained 2½ acres of water surface, and there was more than that available. They had also gained 3½ feet in depth over ¾ acre. In the timber basin they had an area of 12¾ acres, which could be increased to 15 acres. The whole work, including the proposed taking out and rebuilding of the junction lock, will cost about £1800. The cost of the coffer-dam was £401.

The CHAIRMAN remarked that the paper read was a very useful and practical one. There was one novelty that had been used in the operations, and that was a cast-iron bottom casing, which had never been used before. Several plans had been proposed to deepen this entrance, as he happened to know, and it had been doubted whether it could be done by the use of cast-iron; but Mr. Milne had succeeded. It was evident that its use had saved great expense in excavation, which would have been required had masonry been employed; for, with cast-iron, Mr. Milne had done it in 12 inches, whereas it would have required 4½ feet for masonry; and if he had gone much deeper, he would likely have brought in the side walls. The next novelty was the use of the iron coffer-dam. Mr. Milne had told them that, if he had used piling, he might have had to go 20 or 30 feet without finding a bottom, which would have been a waste of timber and time. Mr. Milne had likewise told them that he had founded the walls of the extension of the basin upon a till-bed, which was known in the locality as the "Gravel-bed"—a stratum of rounded stones and iron sand, which formed a sort of natural concrete, very impervious to water, and quite capable of carrying masonry of the height of 20 or 30 feet. He founded his walls upon that bed, without having any piling or anything else, whilst below there was a bed of mud of great depth, so that they would have some notion of the use of this gravel-bed, and its importance in sustaining the superincumbent walls. He believed that in the construction of the former docks at Grangemouth, which were executed under the superintendence, and according to the designs of an eminent man, Mr. (now Sir) John M'Neil, this gravel-bed was cut through; and the consequence was, that he deprived himself of this natural foundation for the walls, and had to make an artificial foundation by laying layers of 9-inch planks, three inches thick, side by side, and then crossed, in three or four rows, upon which he founded his walls at great expense. They did not stand, however, but bulged out, and had to be supported at considerable expense by buttresses of masonry. This all tended to show the use of such practical papers as the present; for it was quite plain that Mr. Milne's founding upon the gravel bed had been quite safe, and that at an immense saving upon the previous cost. Of course, Mr. Milne had had the experience of those who had gone before him, or perhaps he might have gone through the gravel bed, and got into the mud also. He considered that the thanks of the Society were justly due to Mr. Milne.

Mr. BELL exhibited a specimen of the mortar used in similar operations, which was composed of Arden lime, and which he said was quite as good as Welsh lime.

Mr. MILNE said that the mortar known as Charleston lime was about as good as Arden lime.

A vote of thanks was passed to Mr. Milne.

The following paper was then read:—

Improvements requisite in Iron Ship-Building. By Mr. W. Simons.

There is at present an opinion abroad that the construction of iron shipping is susceptible of considerable improvement; and, when we consider the working joints of a modern iron vessel, which are three times more numerous than in one built of timber, this opinion may be held to have some foundation. Since the commencement of iron ship-building, little attention has been paid to the arrangement and combination of the material of which an iron vessel is composed; and too much reliance has been placed on the well-known tenacity and strength of the new material, irrespective of its manufacture, form, or scientific arrangement. To illustrate this, it may be mentioned that it is only within the last few years that longitudinal keelsons, stringers, or clamps, have been carried through the thwartship bulkheads, the usual plan with hundreds of iron vessels having been to stop or break off all internal longitudinal fastenings at each bulkhead—a practice, the destructive nature of which has been frequently exemplified in many iron vessels that have gone on shore, these breaking asunder exactly in the line of the bulkheads, like a postage stamp; and, amongst others, one need only be reminded of the destruction of the iron ships *Tayleur*, *Birkenhead*, *Indian*, and *Royal Charter*. And, when we think of the extraordinary dimensions of the larger class of iron vessels, many of which exceed 300 feet in length, whilst they are not over 36 feet beam, the necessity of greater longitudinal and diagonal fastenings will be sufficiently apparent.

To remedy this defective construction, the improvements which the writer now brings under the attention of this Institution are directed.

Diagonal Beams.—First of these improvements are the writer's diagonal beams; the principle of which is that each range of beams is placed in the reverse diagonal direction to the range immediately above or below it. Every vessel of moderate size has two ranges of beams; some of large tonnage have three ranges; and, in the Royal Navy, four to five ranges of beams. On reference to fig. 1, Plate IV. (which represents a 900-ton ship of iron now being built by the writer, on the new system, for a Liverpool firm), it will be observed that the beams are so placed as to form collectively a complete system of diagonal trussing. Hitherto beams have been placed at right angles to the vessel's side, one over the other, on the same frame, and merely forming a connection between the vessel's sides and a framework to receive the deck. Consequently, when the fabric at sea lies over under a press of sail, there is no thwartship arrangement to prevent her straining; and instances are extant of 2000-ton vessels so beamed having, in such a position, yielded as much as 25 inches on each tack. This change of structure in such a position, it is submitted, will, with the new arrangement of diagonal beams, be impossible. Along each range of the diagonal beams on each side the hatchways, are rivetted fore and aft, in long lengths, strong plate-iron stringers, marked C on the plan; these, together with the beam gunwale stringers on each deck, being considered a sufficient fore and aft tie to each range of beams. The diagonal beams may be placed at various angles. On the vessel now being built they are placed at the angle of 80°, as best answering the combined purposes of a thwartship connection and of a diagonal truss. Various modes of diagonally trussing deck beams have been tried, to form the deck on the old principle into a serviceable framework to resist straining, but with little success; and it is submitted that the system now described, forms, with less expense and material, a far stronger fastening, especially in connection with the writer's other improvements.

Waterways and Knees.—The writer's improved iron waterway is shown in plan in fig. 6, and in section in fig. 7, Plate IV. Every beam end has a vertical projection of about 7 inches, and from 27 inches to 40 inches broad, according to the size of the vessel, the inside edges being rounded. On the upper part of each of these projections is rivetted angle iron, on which is secured the plate-iron waterway, D, butting close to the gunwale sheer strake, and rounded over inside where it joins the deck. To the inside of this edge and along every beam, is rivetted, in long lengths, strong angle iron, marked E. The usual iron stringer is thus superseded, and also the wood waterway. Where any of the frames project up through the iron waterway, a doubling piece, F, is secured water-tight round the frame, and upon the iron waterway. The projections on each beam under the waterway form also improved knee fastenings to each beam end, and supply what has hitherto been greatly required, a knee above the beam as well as below—a knee fastening universally adopted, and understood in the Royal Navy. This iron waterway, if desired, may be adopted with the common beams, and it is submitted that it forms a stronger beam-end connection than any yet constructed.

Plating.—The object of the writer's new system of plating iron vessels, is to supersede the objectionable slips or filling pieces at present used between the frames and plates; and with this view the external plates are placed close to each frame, leaving their fore and aft edges 2, 3, or 4 inches apart. This narrow space is then filled in with a projection seam plate of the section shown in fig. 5, Plate IV., and also in fig. 7; and in lengths of from 20 to 40 feet by about 10 inches broad. This projection or rib fits into the space between the seams, and also rests on every frame, to each of which it is secured by one or two centre rivets, in addition to the usual rivetting of its fore and aft edges. From the extra length of these projection plates, they overlie several plate butts or joints, and thus form along every fore and aft seam a series of external clamps and fenders, calculated to greatly increase the strength of the vessel's side. Their adoption allows the scantling of the other material to be considerably but safely reduced, which, with the saving from no slips being required, will be more than equivalent to the additional rivetting. At the same time it is submitted, that a single rivetted ship so built will be equal in strength to a double rivetted vessel as commonly plated. Although Fairbairn states that from his experiments a double rivetted joint is two-thirds the strength of the plate itself, the writer denies the possibility of having the 4000 plate joints of a large iron vessel so carefully secured in workmanship, material, and finish, as in Fairbairn's solitary experiments; and the weakest part of a floating body is the measure of its strength as a whole: whilst, from the numerous vertical joints or butts in an iron vessel as hitherto constructed, it is impossible to prevent straining to a greater or less extent, particularly in vessels of great length or large tonnage. The *Royal Charter* is described as having broken at the plate butts, like a pack of cards. It is submitted that with external clamps in lengths of 30 to 40 feet on every seam, overlapping all the plate butts, as in this new system, the vessel's side is bound together in such a manner as to render straining or breaking of the butts impossible.

Plate Butt Frames.—The improvements to which your attention is next requested are the butt frames, shown in front elevation in fig. 3, and in section in fig. 4, Plate IV. In place of the common mode of securing the vertical joints or butts of the external plates between the frames, they are secured each on a frame in the following manner:—There is bent round the exterior of every alternate angle iron frame a continuous plate of the same breadth and thickness as the ordinary butt straps. This plate is double-punched throughout, and attached to the frame; the butts are then arranged to be rivetted upon this continuous butt strap frame, most of the rivets going through the angle iron frame. If desirous of adopting longer outside plates in the vessel, every third frame, instead of every alternate frame, may be constructed as described. The continuous butt strap may be also used, if preferred, apart from and between the frames, in one or two lengths, stretching from keel to gunwall. In this system no short butt straps are required; and, it will be obvious that, by a ship's butts being fastened each on a frame, the strength of the vessel is greatly increased.

Hold Stanchions.—This portion of the writer's improvements is shown in fig. 2, Plate IV., and as enlarged in figs. 8 and 9. The hold stanchions at present in use in iron vessels, are in two vertical lengths of round iron; one about 6 feet, resting on the hold beams, and the other length underneath that from the hold beams to the keelson. It will be evident that the only property these possess is a vertical support to the deck, and that they do not contribute in any degree to the strength of the vessel. To remedy this defect, the writer places the hold stanchion in one length from upper deck to keelson, and in a diagonal direction, so as to resist either a compressional or tensional strain. In the vessel, of which plans are now exhibited, they are made of 5 by 1¾ inch flat iron. At their extremities they are strongly secured to the beams and keelson, and at their points of intersection are rivetted together; whilst, where they cross the line of the lower beams, a double central angle-iron back-to-back stringer is rivetted in long lengths to every stanchion and beam. A similar angle-iron may, if desired, be also secured along the junction of their upper extremities with the upper deck beams. The angle of these stanchions in the drawing exhibited is 60°, that being found best suited to the convenience of the hatch arrangements in this vessel; but the angle may be varied. It may be observed in the plan that the hatchways can be easily left clear, and when a mast intervenes the stanchion is circled round it. These stanchions form a vertical central range of diagonal trusses, at a part of the vessel requiring support which it has not hitherto had, and it will be of great service in connecting together two strong frame-works, namely, the vessel's bottom, and her upper-beam platform.

The writer also places these diagonal stanchions in a thwartship direction, and this he has found to reduce vibration in steamers, besides clearing the screw shaft trunk. These stanchions are also made in one length, and are shown in fig. 10, Plate IV.

Keelsons.—The next portion of the improvements is the new keelson, shown in side elevation in fig. 8, and in section in fig. 9, Plate IV., and which is formed on a different principle from, and of greater strength than any yet adopted. It also forms a suitable, necessary, and sufficient abutment, on which to receive and secure the lower extremities of the diagonal hold stanchions. It is formed as follows:—All or every alternate floor is made to project up in the middle in the form of a square, or these projections may be rivetted on to the side of the floor. Round these projections are fixed angle irons, to which on top and sides, or either, are rivetted in long plates the box keelson. The sister and bilge keelsons may be formed in the same manner. The keelson required by Lloyd's in their highest classed iron vessels, entirely depends on four rivets attaching it to the reverse angle iron of each floor; the consequence being, that when by any accident the strength of the vessel's bottom is tried, these rivets, of course, break, leaving the strength of the iron floors untested, whilst, with the above improved keelson, the floors are so well fastened to the keelson, that they must break before the keelson will yield.

Iron Masts.—On reference to fig. 11, Plate IV., it will be observed that the writer places topmasts in the interior of the iron lower masts, in place of outside, as is the usual practice. The topmasts are struck or lowered into the interior of the mast. The fid is placed through a square hole in the lower mast-head, and into a square notch in the topmast heel, which is thus prevented from turning or descending. The futtock shrouds are reversed and fastened to the top of the lower mast-head, and formed to resist a compressional in place of a tensional strain, thus admitting of the lower yard being slung 4 feet nearer the lower mast-head, in consequence of which the lower mast may be 4 feet shorter. It will also be evident that no cap nor truss bow is required. The writer also places winches with their spindles through an iron mast, and having the gearing either inside or outside. One arrangement is shown in elevation and plan in figs. 12 and 13, Plate IV. Any weakening of the masts by the holes is compensated for by double plates.

Additional Improvements.—A new mode of constructing iron ships on the diagonal system is shown in fig. 14, Plate V.

The plating is composed of two thicknesses of metal, lying in the contrary diagonal directions, and securely united together. By this mode of construction, lighter plates may be used, and, as a point of strength, neither keel nor frames are essential, but internal longitudinal stringers, clamps, and keelsons may be used with advantage; and it will be obvious that these can be fitted and secured to the vessel's side in a better manner than when frames intervene. It will also be clear that with this system of plating an iron vessel, the butts of the plating can be so distributed as to be equal in point of strength to the whole; not, as at present, with each butt a point of weakness in all iron vessels, which have been found so frequently to break at these parts. One thickness of this diagonal system of plating may be used in connection with frames placed in a diagonal direction in the contrary way, as shown in fig. 15, Plate V. Timber vessels of above 2000 tons have been constructed on this system with economy and success.

In connection with the writer's diagonal beams, the deck planks may be placed diagonally, but in the reverse directions, as shown in figs. 16 and 17, Plate V.; fig. 16 showing the after-half of the upper deck, and fig. 17 the forward-half of the lower deck. These decks are strongly secured to the beams with screw bolts, and to each other; and, to increase the strength, may be of hard wood. Advantage is thus taken of the deck to strengthen the fabric, and it will be apparent that the objectionable butts in a longitudinal deck are superseded.

The writer also proposes to apply the same principle to the wood or iron ceiling of an iron vessel, placing it diagonally, and forming it into a source of strength to the vessel in place of a source of weakness, as at present; such improved ceiling being made either close or open.

A model was exhibited showing the relative tensional strength of the diagonal and the common beams. The same model also served to elucidate the relative strengths of the vertical and diagonal hold stanchions.

The CHAIRMAN suggested that perhaps it would be as well to postpone the discussion of the paper until the next meeting, as there were few iron-ship builders present.

Mr. SIMONS said he thought many of the engineers present were quite competent to discuss the subject; and he would be pleased if they would be kind enough to give their opinion upon his improvements.

In answer to questions, Mr. SIMONS said that his improvements did not contemplate any alteration in the way of fastening the vertical butt plates, of which there were about 3000 usually, but he proposed only using about 300 of the long butt straps. In communicating with Lloyds, they said they would give the vessel now being built the highest character when finished. The fore-and-aft plates may be either single or double rivetted; but it was submitted that a single-rivetted ship of this construction would be as strong as a double-rivetted one of the old construction. The longitudinal plates were in lengths of 30 and 40 feet. The present kelson was of very little service as a fore-and-aft support to the ship; but in the improved kelson it was of great use in that way. The water-tight bulkheads were made in the ordinary manner, with this exception, that the angle beams went right through the bulkheads, and were made water-tight round them; and every longitudinal fastening in the ship went through the bulkheads. In the ship being constructed there were only two bulkheads, as it was an East Indian merchant ship, 190 feet long. There was no ship at sea on this principle. This was the first one that had been built, and it was nearly completed. All the improvements indicated in the paper had not been adopted in it, but the most of them had. He did not apprehend any weakness in that part of the mast where the winch worked, or where it was otherwise pierced, as double plates were put on all such places. It was only proposed to make the lower mast of iron, and the top mast would be lowered by sliding inside of the lower mast.

Mr. GILCHRIST did not agree with Mr. Simons' plan of turning the futtock-shrouds upside down, nor with their smallness, as he did not think they would be strong enough.

Mr. SIMONS did not think them of great importance, and instanced the usage of Holland, America, and Prussia in support, where there were no futtock-shrouds at all.

Mr. GILCHRIST admitted that it would be a great improvement if they could do without them.

In answer to the Chairman, Mr. SIMONS said that the diameter of the rods of the futtock-shrouds was 1¾ inch. The strain upon them was not great. No provision had ever been made in any iron vessel for cutting away the masts in a storm. He did not think it necessary. He thought the vessel might be got off the shore without cutting them away.

The CHAIRMAN said that in the report of the Board of Trade upon the wreck of the *Royal Charter*, it was stated that there might have been a chance of saving her if her masts had been cut away in time.

Mr. SIMONS said that was a matter of opinion only. He then drew attention to the greater strength of vessels built under his new plan; and mentioned that a ship of 300 feet long had been known in a storm to vary in straightness to the extent of 25 inches, which could never occur with this new system.

The CHAIRMAN asked if he had ever thought of longitudinal bulkheads?

Mr. SIMONS answered that he had not. A person in Liverpool had, but the difficulty of the stowage would be insurmountable.

The CHAIRMAN said that it was quite clear to him, that if there had been a central bulkhead in the *Eagle* she might have been saved.

Mr. CHAPLIN suggested whether the weight of the cargo stowed upon the diagonal stanchions would not be likely to injure the ship.

Mr. SIMONS did not apprehend such a thing; but were it to occur it would be easy to strengthen them by increasing their dimensions.

Mr. BELL said that Mr. Bielby had a boat built with an angle-iron frame, and a wooden skin over the whole of it.

Mr. GILCHRIST said there was a boat of that sort built at the time of the *Telegraph*.

Mr. TAIT remarked that, after the fate of the *Telegraph*, she was taken to pieces.

The CHAIRMAN said the thanks of the meeting were due to Mr. SIMONS for his paper. The discussion might be again opened next meeting, as they expected to have a paper on the same subject then. The vote of thanks was unanimously awarded.

The discussion of this paper was resumed at the next meeting.

A paper was then read—

On Cast-Iron as a Substitute for Stone in Seats for Steam-Engines and other Machinery. By Mr. JOHN DUFF.

A discussion followed the reading of this paper, and a vote of thanks was passed to Mr. Duff.

The FOURTH MEETING of the Session was held in the Philosophical Society's Hall, on Wednesday, 18th January, 1860, conjointly with a meeting of the Philosophical Society. The chair was occupied by Dr. Thomas Anderson, President of the Philosophical Society, during a portion of the meeting, and during the remainder by Walter M. Neilson, Esq., President of the Institution of Engineers in Scotland.

The following paper was read:—

On Incrustation of Boilers using Sea-Water. By Mr. JAMES R. NAPIER.

In Volume IV. of the *Proceedings of the Philosophical Society*, is a paper by Mr. James Napier, chemist, on the Incrustations of Steam-Boilers. Feeling much interested in his suggestions, his method was tried on board the *Islesman*, on a voyage to the north of Scotland in 1858, in order, if possible, to see the effect. At 9h. 30m. half a pound of dissolved soda ash was forced into the boiler along with the feed-water; at 11h. 30m. another half pound was forced in; at 3h. 30m. one pound was forced in; and at other times more was put in. The only effect observed by these operations was making the water in the guage-glass of a milky appearance, within a few minutes after the soda was introduced, and it continued so for probably an hour after each injection, a small pipe near the surface of the water allowing a continuous discharge from the boiler. These experiments showed, that, if the system proved economical, a simple plan could easily be arranged for carrying it out. But as Mr. Napier, in his paper, states "that this sort of crust (sulphate of lime) cannot be avoided by care or mechanical means, except by keeping the salt in the water under its crystallizing quantity, which would necessitate such an amount of blowing off and supply as would render it expensive," the expense of both methods has been calculated—the chemical one of neutralizing the sulphate of lime with soda, and the mechanical one of an abundant discharge and supply, so as to keep the sulphate of lime under its crystallizing quantity.

It is necessary for this purpose to know the relative proportions of feed-water, and water required to be discharged, in order to prevent scale or crust. Many writers treat this crust as if it were common salt, and instruct how to make and graduate instruments for ascertaining its quantity, the graduations being effected by observing the depths to which the instrument sinks in water in which certain proportions of common salt has been dissolved. They say, "Sea-water contains 3 per cent. of salt, and when the boiler contains less than 12 per cent. there will be little or no crust;" therefore, it is necessary to blow off 3-12ths or 1-4th of the feed water, in order to prevent the formation of crust. This reasoning, however, is unsatisfactory, as it is evident to any one who has the sense of taste that the crust is not common salt; and chemical analysis shows that sea-water from the English channel, although it contains nearly 3 per cent. of common salt, contains only about ·8 per cent. of the materials forming the crust, and only ·14 per cent. of the material of which, according to Mr. Napier, upwards of 90 per cent. of the crust is composed. It is also shown by analysis that a saturated solution of this material, sulphate of lime, in cold distilled water, is as 1 to 380, and as 1 to 388 in boiling water, or 25·7 parts of lime to 10,000 of solution. Mr. Napier, however, found 203 grains of sulphate of lime per gallon in water taken from a boiler off Ailsa Craig. Its density is not stated; but I have assumed it to contain twice its natural quantity of saline matter, or its density to be 1·0548, sea-water being 1·0274; this gives the ratio 203 to 73,836, or 1 of sulphate of lime to 364 of solution, or 27·47 of sulphate of lime to 10,000 of solution. This proportion, it is inferred, is either a saturated solution, or such as the engineer of the vessel found little or no crust formed in. For want of better data, 28 of sulphate of lime to 10,000 of solution is assumed as the limit of saturation in boilers using sea-water, working at pressures not exceeding 20 lbs. above the atmosphere. This is equivalent to discharging $\frac{14}{28}$, or one-half of the feed water. This assumption is confirmed by the practice of the British and North American Mail Company; by Mr. Napier's Ailsa Craig engineer, who was evidently blowing off nearly this amount; and by an experiment of Mr. Thomas Rowan, one of Dr. Penny's pupils, made for the purpose of ascertaining when the sulphate of lime and when the common salt deposited. He found, when he

evaporated 2-10ths of the water, a trace of sulphate of lime deposited.
" 4-10ths do. do. do.
" 5-10ths, the sulphate of lime began to deposit in larger quantities.
" 6-10ths, do. do. decided quantities.
" 8-10ths, sulphate of lime deposited in very large quantities; also magnesia and salt began to form.

Mr. Rowan's experiment, although indefinite as to the quantities, shows that the sulphate of lime begins to deposit before even one-half of the water is evaporated. It is probable, therefore, that this quantity, or more, would require to be discharged, in order to prevent the formation of crust in boilers.

A saturated solution of common salt, in distilled water, is given as 27 of salt to 100 of solution, and a saturated solution in sea-water is said to be 36 of salt to 100 of solution. The former ratio has been chosen for this comparison, so that $\frac{270}{2710}$, or only 1-10th of the feed-water would require to be discharged in order to prevent the formation of common salt, and 8-10ths to be neutralized by soda, to prevent the deposit of sulphate of lime, the 1-10th discharged being a saturated solution of sulphate of lime and common salt. It is thus shown that by the chemical method, it is necessary to discharge 1-10th of the feed-water, and neutralize the sulphate of lime in 8-10ths of it with soda, according to Mr. Napier's method, to prevent crust; and, by the mechanical method, it is necessary to discharge 5-10ths.

The quantity of soda ash (supposed to contain 50 per cent. soda) is found by the formula $\frac{62}{68}$ of $\frac{14}{10,000}$ of $\frac{8}{10}$ of feed-water.

For the purpose of illustrating the expense of both methods of preventing crust, and also the loss by the blowing-off method, the case of a vessel has been taken working at a temperature of 270°, and evaporating at that temperature 7½ lbs. of water from 100° per lb. of coal.

		Ordinary Method.	Chemical Method.
Sea-water supplied to boiler, temp. ...	100°	15 lbs.........	8·33 lbs.
Water discharged, ...	270°	7·5 lbs.........	·83 lbs.
Water evaporated, ...		7·5 lbs.........	7·5 lbs.
Total heat evaporating from 100° at 270° = 1092 + $\frac{3}{10}$ (T_1—32)—(T_2—32) = 1095·		8215·5°	8215·5°
Heat discharged, ...		1275°	142°
Fuel consumed in evaporation, ...		1· lb. coal ...	1· lb. coal.
Fuel consumed in preventing crust, ...		·155 lbs. coal	·0172 lbs. coal + ·0085 lbs. soda ash.
Total Fuel, ...		1·155 lbs. coal	1·017 lbs. coal + ·0085 soda ash.

Thus, it is seen that it requires only 172 lbs. coal + 85 lbs. soda ash, containing 50 per cent. soda, to be as efficient in preventing crust, as 1550 lbs. of coal alone, which evaporates 7½ lbs. water from 100° at 270°. And these methods are equally expensive when the soda ash is 16·2 times dearer than the coal. This ratio varies with the efficiency of the fuel and the temperature of evaporation.

Although when coals are 10s., and soda ash £10, Mr. Napier's method is more expensive than the ordinary one of discharging the saturated water, there are many cases where it is probable the owners of vessels would profit by its adoption. In long voyages, for example, a vessel requiring, by the ordinary mode, 1155 tons of coal, would, by Mr. Napier's method, require 1017 tons coal, and 8½ tons soda ash, or 1025½ tons weight. There would be a saving in money, therefore, of 138 tons coal at *x*/ + 129 tons freight at *y*/ — 8½ tons soda ash at *z*/, or if coals are 10s. per ton, freight £3, and soda ash £11 per ton, the saving would be £362. That boilers, however, can be worked till the water in them is nearly saturated with common salt, or that the soda ash can be so accurately proportioned as to *exactly* neutralize the sulphate of lime, are problems which are believed to be new, and have not yet been attempted. The considerable saving which may be effected shows that the method is worthy of a trial.

From the foregoing example of a vessel worked at a temperature of 270°, it is also seen that a quantity of fuel, equal to 15½ per cent. of that which produces evaporation, is consumed by the ordinary blowing-off method, in order to prevent crust, and this amount increases with the temperature. Brine chests have been frequently used for the recovery of this notable loss; but apparently from a misapprehension of the quantity of water necessary to be discharged, and a want of knowledge of the amount of surface required to absorb the discharged heat, of a capacity greatly too small for their purpose. If Peclet's formula for calculating this surface is to be trusted, those chests on board the West India mail steamship *La Plata*, and some of the British and North American Company's packets, are 1-15th to 1-20th of the size that would be efficient. When these brine chests, regenerators, or heat economizers, therefore, are made with a *sufficient* amount of surface, so that abundance of water can be supplied to and discharged from the boilers, with little loss of heat, then there will be no incrustation of boilers, and a probable saving of from 12 to 13 per cent. of their fuel. Peclet's formula, or Professor Rankine's reduction of it, which gives the probable amount of surface required for a difference of temperature of 140° between the feed and the discharged water, at 1-10th square foot per lb. of brine discharged per hour, becomes under the same circumstances, and when the quantity of brine discharged is equal to the quantity of water evaporated, 1-10th square foot of surface per lb. of water *evaporated* per hour. The introduction of Dr. Joule's spiral wires to the system will probably render less surface efficient. This amount of discharge and surface, it is expected, will prevent incrustation, and save 9-10ths of the heat at present lost by the ordinary method of blowing off.

A discussion followed the reading of this paper, and a vote of thanks was passed to the author.

The following paper was then read:—

Particulars of the working of the Steam-Engine and Boiler at the Scotland Street Iron Works. By Mr. WILLIAM TAIT.

Three years ago, the writer commenced a series of experiments for the purpose of verifying in some measure the advantages alleged to be derived from the use of high-pressed steam, worked more or less expansively, as compared with steam of a lower pressure, worked in the usual way. Those experiments, however, were soon abandoned, because the engine was very often worked late, and occasionally all night, with a load at night probably not more than one-half of that which constituted the day's work. It was also found inconvenient to attend at night to take pressure diagrams. Similar experiments were again instituted a few months ago, and although not so complete as were originally intended, they may yet be interesting to those occupied with similar pursuits. The economic conditions under which a given weight of coal is made to perform a given amount of work, form an important object of inquiry.

The experiments were commenced with steam at a pressure on the safety valve of 55lbs. per square inch, cutting off the steam in the cylinder at one-sixth of the stroke. These experiments were meant to be continued from week to week, and on each succeeding week with 4 inches more steam in the cylinder, until three-fourths of the stroke was arrived at; but this intention was departed from in consequence of the very irregular and often excessive quantity of coal required to keep up the steam. This irregularity arose from the circumstance of the boiler top being wholly unprotected from the weather, in consequence of which, when winter came, with rain and snow, the consumption of coal was increased from 25 to 30 per cent. over the usual average quantity. The experiments were therefore discontinued for a few days until the boiler and steam-pipes were covered—the boiler with hair felt and bricks, and the pipes with felt, saw-dust, and wood.

On Monday, 12th December, 1859, the experiments were resumed with the expansion valve set to cut off the steam at one-fifth of the stroke, and were continued until Saturday, 31st December—3 weeks; and from Monday, 9th, until Saturday, 14th January, 1860, being 4 weeks in all, or 240 hours. Diagrams were taken several times a-day, and the mean accepted as showing the actual quantity and force of the steam in the cylinder. M'Naught's Indicator was used, and its accuracy was occasionally tested both on the boiler and valve casing alongside of Bourdon's pressure gauges, the one in fact checking the accuracy of the other. The coal was accurately weighed, and the quantities recorded represent every pound that was consumed, including the getting up of the steam in the mornings, gathering the fire at night, and on Sundays. The ashes and clinkers were also carefully weighed.

The evaporation was tested by measuring accurately the surface area of the water in the boiler, and noting its height on the gauge glass before starting the engine at 10 o'clock A.M., and at 3 o'clock, P.M., and stopping again at 12 o'clock, and at 5 o'clock P.M., until respectively the fall of the water was ascertained. The engine was stopped for the purpose of letting the water be as quiescent as possible. This again was partially checked by noting the quantity of water taken from a cistern.

The boiler is represented in Plate VI., fig. 1 being a sectional plan, and fig. 2 a vertical longitudinal section. It is 32 feet 6 inches long, by 5 feet 2 inches in inside diameter, with two flues passing through it longitudinally, each 18 inches in inside diameter. The fire grate measures 4 feet by 3 feet 3 inches, and the ashpit is fitted with doors. On the centre of each door is a fan valve for regulating the admission of air. The wall A at the side of the grate nearest the chimney is built close up to the boiler. There are air holes in this wall, the air being supplied by a valve in front of the building at B. This air is of course to aid in abating the smoke nuisance. The furnace bridge rises to within 5 inches of the boiler, allowing about 510 square inches for the passage of the gases, or about 40 inches per foot of fire grate. There is no part of the outer shell of the boiler exposed to the action of the fire excepting the part above the furnace, and onwards to where the flame turns upwards to the flue tubes. The recipient surfaces computed by the usual method are equivalent to about 23 horse power. At C, between the boiler and damper, there is another bridge which rises to a level with the centre of the tubes, the opening over it being about 300 square inches. The gases after passing this bridge descend and pass beneath the damper into the chimney. The steam-pipe to the engine is 49 feet long by 5 inches in diameter, and is carried through the chimney at D, where it is divided into 4 pipes made of copper, and joined to the iron pipe in the brickwork of the chimney. These pipes possess in all about 26 feet of surface, and may take up a little, a very little of the heat manifestly going to waste up the chimney.

The engine is high-pressure with cylinder, 20 inches in diameter, and a stroke of 4 feet, and it made with great regularity 34 strokes per minute —this at any rate being the mean velocity. The cylinder is not jacketted, and has no covering of any kind. The slide-valves are worked by eccentrics both for steam and expansion. Figs. 3 and 4 represent two pairs of top and bottom diagrams taken from the cylinder.

The following are the data and mean results of four weeks' observations:—

Length of boiler,	32 ft. 6 in.
Diameter of do. (internal),	5 ft. 2 in.
Number of flues,	Two.
Diameter of do. (internal),	1 ft. 6 in.
Area of under surface of boiler exposed to the fire,	61 ft.
Do. end of boiler exposed,	8 ft.
" flues,	306 ft.
Heating surface per indicated horse power,	10 ft. 7 in.
Quantity of water in boiler (6 in. above flues),	351 cub. ft.
Do. per horse power,	10·028 cub. ft
Steam space in boiler,	208 cub. ft.
Do. per horse power,	5·94 cub. ft.
Area of fire-grate,	13 sq. ft.
Do. per horse power,	53·5 sq. in.
Water evaporated per hour,	25·8 cub. ft.
Do. per horse power per hour,	·73 cub. ft.
Time of working,	240 hours.
Coals consumed,	68,544 lbs.
Do. per hour,	285·6 "
Do. per horse power per hour,	8·08 "
Pounds of water evaporated per pound of coal,	5·65 "
Clinkers and ashes,	3509 "
Per centage of do. to the coals consumed,	5·1 per cent.
Thickness of fire-bars,	1 inch.
Spaces between do.,	⅝ inch.
Description of coal used,	Wishaw dross.
Heat of feed-water,	124° Fahr.
Pressure of steam in boiler,	40 lbs.
Do. in valve-casing,	40 "
Initial pressure on piston,	35 "
Average do. do.	13·65 lbs.
Travel of piston before steam is cut off, nearly	10 in.
Indicated horses power (usual method), viz.: $\frac{\text{area of cylinder} \times \text{effective pressure} \times \text{ft. travelled per min.}}{33 \cdot 000}$	35·33.
Length of steam-pipe,	49 ft
Diameter of do.	5 in.
Method of superheating. By 4 copper pipes through chimney 3⅝ in external diameter—length 28 feet—heating surface,	26·4 ft.
Temperature of steam in boiler at 44 lbs.,	292° Fahr.
Do. in valve-casing at 44 lbs.,	291° Fahr.

The temperature of the steam in the boiler and valve-casing was tried, for the purpose of ascertaining whether any and to what extent heat was imparted to the steam by the copper pipes in the chimney. In the valve-casing the temperature was 1° lower than in the boiler; the one was 2°, and the other 3° below what was due to the pressure. This discrepancy was no doubt owing to currents of cold air, and, at the valve-casing particularly, to the radiation of heat from the surface of the part where the thermometer was applied. At times, however, the temperatures were uniform and correct.

The pressure in the boiler and in the casing was indicated by Bourdon's gauges, and showed a nearly absolute uniformity—the greatest variation being from one pound to one and a half pounds; the excess being sometimes in the boiler and sometimes in the casing.

Regarding the quantity of coals consumed, it must be noted that the weather was nearly constantly wet during the experiments; the coals were brought in daily as required, and were weighed often when saturated with water; this water forming, in some instances, a large per centage. The weather also had an adverse effect on the boiler. The stock of coal in the work was kept small to prevent the temptation to any excess in firing.

The steam space in the boiler is noted, because it is large in proportion to the quantity of steam used at a single stroke of the engine; this quantity, including the filling of the steam-port, was about 2¼ cubic feet, which was just about one eighty-third part of the steam in the boiler. This circumstance prevented in a great measure the liability of the water to pass off with the steam—water passing off in that way, accounting satisfactorily for the apparently very great success attending many experiments on record; the success being in direct proportion to the amount of priming, or water carried off with the steam. It is doubtful whether or not any material benefit was derived from so partial an attempt at superheating, as was tried in the present experiments.

The heat in the flue was high, and, on several occasions, melted zinc; in fact, it was melted on every repetition of the experiment if allowed to remain long enough in the flue. Five pounds of iron, after being hung in the flue for some hours, gave 6° of heat to a cubic foot of water, and copper gave the same result, whilst five pounds of fire-brick gave 8°. It would thus appear that the gases entered the chimney at a temperature of about 720° Fahrenheit. A close approximation to the temperature of the gases in a flue is obtainable by suspending a piece of iron in it until saturated with the heat, and then immersing it in six times its weight of water. The number of degrees of temperature acquired by the water multiplied by 60 gives the temperature of the gases.

The writer has to express his regret that the intention with which he commenced these experiments has not been more fully carried out. Although he foresaw difficulty in arriving at strictly true comparative results, in consequence of the power of the engine being so much in excess of the work it had to perform, and of the continual variation in the quantity of that work, the difficulty has proved much greater than he ever anticipated, even without the subject of the comparative results to be obtained by different degrees of expansion having been entered on.

The PRESIDENT was afraid this paper would appear very dry matter to some of the gentlemen present belonging to the Philosophical Society; but yet it was a most important one, for the economy of fuel was now a very important subject. Not only would the proprietors of steam-engines be benefited by a saving in fuel, but the public would also participate in it. If they considered for a moment the great quantity of coal consumed in steamers and locomotives, they would see that a small saving in fuel per horse-power would amount to hundreds of thousands of pounds per annum. That economy and saving had been arrived at by close-worked experiments, such as those which Mr. Tait had now favoured the Institution with. He would be glad to hear any remarks upon the subject of the paper.

Referring to the illustrations, Mr. DAVISON, from New York, said the boiler was of a form very common for high-pressure engines in America. Generally the fire was so placed as to allow the heat to pass first under the boiler, and then through the flues, instead of passing first through the flues as in this country. That plan was adopted for safety and economy in fuel, the economy being generally more than that which Mr. Tait had recorded, with a greater proportionate fire-surface. The boilers were generally pretty well covered or protected from radiation.

Mr. TAIT remarked that at first his furnace had an area of 19 square feet, but he had reduced it to 13 square feet; and for this reason that the surface being so very large, he had always too much steam, when he had a fire upon the grate sufficient to cover the grate-bars.

Dr. RANKINE asked what was the ratio of square feet of heating surface of the boiler to pounds of coal consumed per hour.

Mr. TAIT answered that it was 285 lbs. of coal to a heating surface of 375 feet, or about 4 feet of surface to 3 lbs. of coal.

In answer to other questions as to whether the air-spaces in the furnace wall were not too small, and as to the heat of the water let into the boilers, Mr. Tait said, that so far from that being the case, the damper of the furnace, which was 22 inches wide, had never to be raised above five inches. In fact, he could consume any reasonable quantity of coal in it. The draught was far too great for the size of the furnace. They had been feeding the boiler with water at 140°; but he expected that they would soon feed it with water at 180°.

Mr. BROWNLEE expressed his wonder that condensing engine-boilers should even be fed with water at less than 200°, it being so easy to have it heated even above that point.

Dr. Rankine said, that in high-pressure engines it seems to have answered well to condense the steam at 200° or thereabouts, and to feed in water to the boilers at 200°, or a little higher, and thus save the fuel. He believed that was done in Mr. Beattie's locomotives, and was found to save fuel considerably.

Mr. D. More said he had been much pleased with an inspection of the Scotland Street Engine Works; but it struck him that, instead of reducing the size of the furnace, if the position of the fire had been changed, it would have been found that less of the heat would go up the chimney. If the flues were extended, he believed that little or none of the heat would in that way escape.

The President said that the great use and value of such experiments arose from the thorough accuracy with which they were made. Such experiments—whatever the result might be, whether they showed great economy and success, or a failure—if they were reliable, served important ends; and he had reason to know that Mr. Tait had been working at these experiments for a very long time, and had spent much of his time upon them, and they had cost a considerable sum of money, as all practical experiments did; and therefore he thought the Institution were much indebted to him. He proposed a vote of thanks to Mr. Tait accordingly, which was passed unanimously.

The following paper was then read:—

On the Density of Steam. By Professor W. J. MACQUORN RANKINE.

It has been known for some time that the Density of Steam deviates from the laws of the perfectly gaseous condition, and deviates more and more as the pressure increases.

A formula for deducing the density of a vapour from its pressure, temperature, and latent heat, was first deduced from the Mechanical Theory of Heat, by Professor Clausius, in 1849.

The writer, in the absence of precise experimental data, made use of a formula substantially identical with that of Clausius, to compute tables of the volume and density of steam for practical use, which have been published in his work *On Prime Movers*.

Experiments have for some time been in progress by Mr. Fairbairn and Mr. Tate, on the density of saturated steam at various boiling-points, part of which were communicated to the British Association in September, 1859. In the following table, the results of these experiments are compared with those of the theory, computed by the aid of the tables of volume and density before mentioned.*

"Specific Volumes" of Steam, as computed from the Mechanical Theory of Heat, and as determined by the experiments of Messrs. Fairbairn and Tate:—

Temperature Fahrenheit.	Ratio of Volume of Steam to that of Water at 60 degrees. By Theory.	By Experiment.	Difference.
136°·88	8276	8262	+ 14
160°·016	4790	4911	— 121
171°·55	3722	3710	+ 12
175°·15	3433	3426	+ 7
182°·32	2960	3045	— 85
188°·09	2630	2621	+ 9
197°·48	2180	2147	+ 33
244	936	896	+ 40
245	920	890	+ 30
257	756	751	+ 5
262	698	684	+ 14
268	635	633	+ 2
270	616	604	+ 12
288	506	490	+ 16

* (Note added in August, 1860.)—The experiments in this table consist principally of those laid before the British Association at Aberdeen in 1859. A more extensive series of experiments, including some on superheated steam, have since been made by Messrs. Fairbairn and Tate, and communicated to the British Association at Oxford.—(*Civil Engineer and Architect's Journal*, August, 1860.)

The PRESIDENT said that this was one of the periodical instalments with which Dr. Rankine favoured the Institution, and which were very valuable to them, and tended to help on the general improvement in economy of fuel. It was most satisfactory to find that the hypothetical results, published long before any of these experiments had been made, were borne out by them, as it showed the correctness of the data from which they had been worked out.

Mr. BROWNLEE had given some attention to this subject, but had not before seen the first half of the above table of experiments, which agreed remarkably well with the density as deduced from the mechanical theory of heat. He referred to experiments which had been made by Regnault at low pressures, in which the apparent maximum density was about ·646, being greater than that observed by Messrs. Fairbairn and Tate at similar temperatures. When, however, the temperature was increased 3° or 4° beyond that which belonged to the pressure, the density fell to nearly ·622 (being the theoretic density of gaseous steam), at which it remained nearly constant at higher temperatures. The relative weight of equal volumes of air and gaseous steam, when taken at similar temperatures and pressures, being constantly as 1 to ·622, their rate of expansion must be the same. The apparent density and rate of expansion, when near the condensing point, is much greater; but this, it was suspected by Regnault, might partly arise from particles of water adhering to the surface of the glass. Various experimenters have given the density of steam of atmospheric pressure at ·622 to ·625, but in those experiments the density was never observed exactly at the boiling temperature, but always at a temperature somewhat exceeding that which belonged to the pressure, this being necessary to dislodge particles of water which adhered to the surface of the glass globe, inside which the water was evaporated. Some experiments made in a different manner by Southern and Crichton, at pressures of 40, 60, and 80 inches of mercury, show a greater density than that found by Messrs. Fairbairn and Tate. Although, therefore, the density of steam, as determined by the latter gentlemen, is greater than has generally been believed, it is, at the same time, less than was found by Southern and Crichton; and it is gratifying to find that those, the latest experiments, agree so closely with deduction made from the mechanical theory of heat, a subject which had been so ably treated by Professor Rankine.

Dr. RANKINE said there were one or two things that he might state in connection with this matter. The whole of the experiments made in obtaining the results in the table had been made with steam at the point of saturation. He thought that Mr. Brownlee was right in saying that a small amount of superheating would bring the steam into a condition in which it would very nearly follow the laws of perfect gases, the heat overcoming the force which caused it to deviate from these laws. Then as various experiments had been referred to, he might state that those of Mr. Siemens had given densities greater than those which had been observed by Mr. Fairbairn. This might be accounted for by the attraction between glass and steam. If steam were put into a glass vessel it would be found that there was a film of water lining the inside of the vessel; and supposing the volume of that vessel to be measured, and the density of the steam ascertained by weighing, the result would be too great. As to the decimal ·622 or thereabouts, as the specific quantity of gaseous steam, it was most probably correct, as it agreed with the sum of the weights of the chemical components of steam as ascertained by experiments on the density of oxygen and hydrogen.*

Mr. Brownlee said that in Mr. Siemens' experiments he had not apparently made any allowance for this attraction of steam for the glass, so that the apparent expansion was much greater than it really was. He had himself gone over the same kind of experiments, and had clearly observed the error from this attraction of the particles of the glass-surface, but when he got clear of that attraction he found no difference between the expansion of air and gaseous steam. There was another error he thought Mr. Siemens had fallen into. In computing the expansion, he made no allowance for the evaporation of the mercury, so that a thirtieth part of what he had computed as steam must have been vapour of mercury.

The thanks of the meeting were then voted to Dr. Rankine for his paper.

Mr. Simons then read some additional remarks regarding

Improvements in Iron Ship-building,

which are incorporated in his paper, page 36. The discussion of the subject was resumed.

Mr. Lawrie objected that the want of cross frames in the diagonal vessel would detract from its strength.

Mr. Simons in reply to that and some questions, said that there had

* (Note added by the author in September, 1860.)—By an experiment made by MM. Sainte Claire Deville and Troost, the density of steam of atmospheric pressure at 850° cent., = 662° Fahr., was found to be ·623, agreeing almost exactly with that computed on the supposition of its being perfectly gaseous.—(*Ann. de Ch. et de Ph.*, March, 1860.)

been a diagonal vessel built which carried 2500 tons. The calculation was that the new mode of building would be much cheaper, because he held that in a diagonal vessel, with two thicknesses of plates, they might almost dispense with the vertical bands. It was not likely that Lloyds would at once agree to dispense with them however.

Mr. J. R. Napier rather thought this double plating would be found to be considerably more expensive, and he could not see that there was any gain, if they had only double butts. He would not have the vertical frames, he would rather have longitudinal ones. He could not say that he approved of the windlasses being passed through the masts, as compared with the old established plan of making things where they could get at them easily. He did not know either that the iron masts were an advantage, as there was a great difficulty in getting them cut away in an emergency, like that of the *Royal Charter*.

Mr. Simons said that the winch arrangements in the iron masts could be made substantial by double plating around them, and as for the danger of iron masts, that seemed to be considered very little, as ten out of every dozen ships were now made with them. Some large ships had appliances attached for collapsing the masts, and letting them fall overboard.

Mr. Chaplin had no doubt that if they were cleared of the rigging, the iron masts would go over the side with their own weight.

Mr. Simons mentioned that there was an iron ship of 900 tons being constructed, which would give the new principle a fair trial.

The President regretted having been absent at the previous meeting when this question was brought before the Institution. He thought this subject could not be too much before them. Both the press and the public had been recently speaking against iron ships altogether, whereas they ought to have confined their remarks to weak vessels, which he was sorry were ever made. If weak vessels were placed in such awkward positions as that in which the *Royal Charter* was put, no other result could be anticipated. No doubt that vessel broke up very soon; but he was glad to have an opportunity of stating that in his belief, and he was not a ship-builder, the ship-builders were not in the smallest degree to blame. If blame is to be attached anywhere for iron ships being too weak or too light for carrying cargo and passengers, it ought to be put upon the ship-owners and the public, and that did not require any elaborate reasoning to prove. It was a fact that when a purchaser went to buy a ship, the first thing he asked was the price, and he scarcely ever inquired about the quality of the vessel. This was carried out to such an extent that people frequently went to one builder, and afterwards finding another who would build a ship a little cheaper, the latter was preferred to the former, although the relative strength of the ships would be very different.

Now, this system had produced its fruit, for of course builders had to live by their trade like others, and were anxious to get as many contracts as possible. The press grumbled and said that they did not use good iron; but the answer to that was ready—We can't afford to buy good iron: we can't give the price. If shipowners would give them more money, or if the public would let them alone, and Lloyds not interfere so much with shipbuilders, ships would be produced which would do credit to all concerned. This was the first paper on this subject they had had; but he hoped that others would soon be brought forward. He proposed a vote of thanks to Mr. Simons, and hoped he would continue to give them the result of his experience in the matter of ship-building.

The Fifth Meeting of the Session was held in the Philosophical Society's Hall, on Wednesday, 15th February, 1860—the President in the chair.

The following paper was read:—

On Hydraulic Presses, and some Improvements in their Construction.
By Mr. David More.

The first invention that gave an impulse to the construction and useful working of the hydraulic press was that of Mr. Bramah, who, about the year 1795, discovered and patented his peculiar packing for the neck of the cylinder, and which is still universally used in these machines. Before that time the principles of the hydraulic press were thoroughly understood; but the great and seemingly unconquerable difficulty of rendering the working portion of the machine perfectly water-tight, prevented its general application to any useful purpose. It may therefore be conceived that, so soon as Bramah's invention was made public, no time would be lost in taking advantage of this simple and economical method of using water as a means of multiplying and transmitting pressure wherever it was applicable.

It is stated that the first application of his invention, and superintended by Bramah himself, was for the uprooting of several large trees that stood in the way of some agricultural operations. This was comparatively but a light task, and yet there is no doubt it would be looked upon with great interest and some anxiety by many who still remained sceptical as to the great power the invention was said to have developed.

It is unnecessary in this paper, and before this society, to enter further into details regarding the early history and progress of this machine; especially as our time can be more profitably occupied in setting forth its various capabilities as now employed, discussing improvements in its construction, and the difficulties connected therewith.

One of the most common purposes to which the hydraulic press is applied is that of packing goods for shipment; and when we consider the many million bales of merchandise of various kinds that are annually transmitted from one country to another, we are prepared to find that great advantage has been taken of this most powerful method of reducing bulk to facilitate stowage and diminish freight. Formerly, cotton was shipped from the United States almost in the condition in which it left the plantation, and being but loosely packed, the difficulty often occurred that the ship was unable to stow a sufficient quantity to bring her into sailing trim. To obviate this evil large packing establishments have been erected at the principal seaports of the Southern States, and when the shipping season comes round these are fully engaged repacking the inland bales to suit the requirements of the merchants. The cotton presses at New Orleans are many of them very powerful, and the general method of working them is to put in two or three of the country bales, and press them so hard that they occupy less space than would have contained one in its original state. The principal features to be observed in the manufacture of cotton presses are rapidity of action and great pressure, thus combining two principles in mechanics requiring almost unlimited strength. For working their presses one firm in New Orleans has a set of pumps arranged and acting in the following manner:—A pair of high-pressure steam engines, with 10-inch cylinders and 30-inch stroke, is set on a bed plate containing four 2¼-inch gun-metal force pumps, with 12 inches stroke. These pumps are coupled directly to the working beams of the engines, and are capable of raising the piston or ram of a 12-inch press—exerting a pressure of 300 tons—3 feet per minute. The engines are supplied with steam at a pressure of 80 lbs. per square inch.

In all the manufacturing districts of our own country hydraulic presses are largely employed in the dressing and finishing of the various textile fabrics that form so large a portion of our produce; and for this purpose they are made of various shapes, sizes, and strengths, to suit the different degrees and style of finish that may be required. In some cases cold pressing is sufficient, while, in other cases, hot plates of malleable iron are interspersed among the goods—in order to produce an appearance that will cause them to sell well when brought into the market.

For expressing oil from seeds, fatty matter, &c., nothing has yet been invented in any degree equal to the hydraulic press, and it is doubtful if anything better can be devised; for in it are combined the principal qualifications that render this operation successful. In working an oil press it is necessary that the power should be brought on gradually, to allow time for the globules containing the oil to burst, otherwise the bags or wrappers in which the seeds or fatty matters are placed would be rent in pieces. This object is easily attainable by applying variable speeds to the force-pumps, or by employing two or three pumps of different sizes—the larger ones being fitted with self-acting apparatus for disengaging them when arrived at their maximum pressure, and the small one being thus left to finish the operation slowly.

Within the last ten years great improvements have been made in the presses adapted for this purpose. The old system of bags or wrappers for enclosing the materials to be pressed has been nearly altogether supplanted by cast or malleable-iron cylinders, closely pierced with small holes, through which the oil escapes while under pressure; and a still further improvement is now in operation by which these perforated cylinders are done away with, and the oil allowed to run free from every part of the press. This improvement consists in having two presses, one of a light construction, merely for shaping the cakes, preparatory to their being placed in what is called the finishing press, which last is a very powerful and effective machine. The construction and working of these presses will be afterwards explained; but in the meantime it is proper to observe that they are made under a patent granted to a gentleman of the name of Wilson, for many years resident in one of our colonies, and who has devoted much of his attention to this useful and important subject.

Another excellent invention, also patented, is that of the lead rod and pipe machine. In this apparatus the hydraulic pressure is employed for forcing lead in a half-melted state through dies of various sizes, corresponding to the outside diameter of lead pipes, and they can be made in lengths much longer than was formerly practicable. One of these machines has been erected in the arsenal at Woolwich for the purpose of making the lead rod from which the rifle bullets are formed, and has proved eminently successful.

The patent hydraulic purchase for slip docks is another useful and beneficial application of the same principle; but as it has been thoroughly described in a paper read before this society by Mr. Bell last Session, it requires nothing but a passing notice here.

Scott's patent keel-block is another invention deserving of notice, especially to shipbuilders, as it is important for them to know how far a ship requiring repair retains her original outline, and to be able, with little trouble or expense, to set all fair again before proceeding to strengthen or alter her where she may be found defective.

Maccaroni, so much used on the continent, as well as in this country, is now manufactured by means of a hydraulic press. Formerly it was squeezed through the small holes in the copper cylinder containing the dough by means of a screw or long lever; but this process was so slow that at last it was found necessary to apply hydraulic pressure, which has proved eminently successful. The hydraulic cylinder is eight inches in internal diameter, and the cylinder for the dough about eighteen inches.

There is a very useful purpose to which the press has lately been applied. In forming coffer-dams it is sometimes necessary to drive sheet-piling, and in doing so it often happens that one of the piles is diverted from the perpendicular; when it has to be withdrawn. This is frequently a difficult operation; but the difficulty has, in a great measure, been overcome by the application of a hydraulic cylinder, worked by a small hand pump—two men, with the greatest ease, drawing the longest pile.

I need not dwell any longer on the application of this power in its various forms, but proceed now to the more important part of the subject —the construction of the working part of the machines, difficulties connected with the same, and improvements suggested. In the manufacture of hydraulic presses of whatever form, and for whatever purpose, the parts requiring the greatest care and attention are the cylinder and piston; for on these depend the thorough efficiency of the whole machine. The first thing requisite in the piston is, that it be made of strong hard iron, very close, and uniform throughout; and, secondly, that it be accurately turned and made truly parallel from end to end, and then carefully polished to facilitate its working smoothly through the neck leather of the cylinder. To procure a good cylinder is of still greater importance, as it is generally the heaviest part of the whole machine, and requires to be completely finished before it can be proved or tested; and if the casting should prove unsound, as is often the case, the whole labour expended, not to speak of the trouble and expense of recasting, constitutes a serious item in the cost of construction. To obviate this difficulty, many forms of cylinders have been tried—one maker preferring a flat bottom of equal thickness with the sides, and causing the casting to be poured with the mouth upwards. Another form is that of the bottle bottom, which for many years was considered the best that could be devised, and even yet has many advantages to recommend it to our notice. Cylinders with the bottom shaped in the form of a pear are much used by the English makers, and often with good results.

On Plate VII. are represented the various forms mentioned above. Fig. 1 is cast with the mouth down, and run with three or four pouring gates or runs round the bottom. A serious objection to this form of cylinder is that the bottom frequently blows square off. To obviate this objection, cylinders have been cast of the form shown by fig. 3, which has proved more successful. Many engineers adopt the form of cylinder shown in fig. 2, and the invariable practice is to cast those made on this principle with the mouth uppermost. A frequent source of annoyance with this construction is the porous nature of the iron near the mouth; into this part of the cylinder the water is easily forced, and soon finds its way up past the packing in the cylinder. This, however, only occurs when the casting has been poured by several small runs or gates. The usual method now is to carry up the head of the cylinder 18 inches or 2 feet above the working part, and afterwards cut off this extra portion in the turning lathe; by this means the casting is rendered solid in every part.

The only other form now to be mentioned is that which is almost invariably adopted in Scotland, and is represented in fig. 4. Cylinders of this construction are cast mouth downwards, and the pouring gate is made so large that it embraces fully more than half the thickness of metal on the side of the cylinder all round. The gate is carried up from 2 to 3 feet above the bottom of the cylinder, and, when in the lathe, is cut off at such a length as will leave sufficient thickness to render the bottom tight. Although cylinders formed on this plan have been very successful, I am of opinion that the great mass of metal in the gate is very objectionable, as it must undoubtedly be the means of causing the casting, when cooling, to shrink unequally, and thus produce a radical defect in the cylinder. This idea is supported by the fact that when cylinders on this construction burst, the bottom is generally blown off at the same time, tearing a portion of the body along with it, as shown in fig. 5.

Having suffered much annoyance, and been put to a great deal of expense by defective cylinders, the firm with which the writer is connected decided on trying an experiment on a large scale:—Requiring a powerful press for our own business, we have constructed one with a 16-inch piston, and made the frame-work in the following manner, as shown in figs. 6 and 7, Plate VIII. Instead of having the cylinder hanging on the bottom sill or frame, it is made like an ordinary steam cylinder, without a bottom, a strong malleable iron ring being put on each end to prevent it splitting vertically. The pillars are made of sufficient length to pass down the sides of the cylinder and through the bottom frame, which is placed under it. A plug on the bottom frame carries a packing, to render the joint between it and the cylinder water-tight. The whole press is thus screwed firmly together, so that before the bottom can be blown off the pillars must give way, which is a very unlikely thing if made of sufficient strength and good material; in point of fact, the scrap-iron pillars, if at all properly proportioned, are rarely torn asunder.

It only remains to be stated that this press has now been in operation for some time, and it has been subjected to a very severe proof, remaining long under pressure, and small quantities of water forced into the cylinder at intervals, this being a far greater test of strength than continuous pumping. The experiment has been entirely successful, which is more remarkable when the quantity of material is considered; there being nearly 14 tons of cast-iron, and 3 tons 6 cwt. of malleable-iron in the machine.

Mr. MORE remarked that he was of opinion that the cylinders of hydraulic presses ought to be left at least six or eight months after being cast before they were brought into operation. He was of opinion that iron cast in masses like that of cylinders, did not come to a perfectly set state for six or eight months after casting. There was another thing he was also anxious to bring before them, and that was that he did not consider that the quality of iron they were now getting in Scotland was suitable for that class of castings. The English engineers cast their cylinders thinner than they did in Scotland, and they could put a pressure of 3 tons per square inch upon them; whereas they in Scotland could only trust 2½ tons upon theirs, and often they were thicker in the sides than those of English make. He would likewise call their attention to the fact that hydraulic presses burst often with less strain upon them than what had been upon them at some former period, and that they always burst some time after the pressure was applied, and not when the men were working the pumps. It was generally found that the press was left set, that in about a quarter of an hour afterwards a crack was heard, and that when they repaired to the place they found the press was burst. The theory he had to explain this was, that the friction of the water upon the side of the cylinder produced a certain amount of heat, which expanded the iron, although not to a degree that could be measured, yet in a degree that caused the damage. The press being set, the cylinder cools down; and as the water will not yield, something else must give way. Then, as regarded the breaking, with less strain than formerly. The press might have been tested at 250 or 300 tons. He believed that the cylinder might then begin to give way, and every time that it was afterwards used the crack became larger, from the water being driven into it, and thus by and by it burst at a comparatively light pressure. He had split up a cylinder, and found water about the half thickness of it, which appeared to have been confined in the body of the metal, and which must have been crushed into it inside. He believed, therefore, that in trying a press, no more than the working pressure ought to be put upon it; and that the testing of a press at 300, which ought only to have been put to a pressure of 250 tons, was the cause of the press breaking.

In answer to Mr. R. Brown, Mr. MORE said that the price of English-made cylinders delivered in Scotland was £9 10s., and Scotch-made sold at £8 10s. and £9.

Mr. R. BROWN said it was easily accounted for; because Mr. More said that the English were made 10 cwt. lighter than the Scotch. The English made them lighter, and they cost a great deal more, for their iron was much dearer. So far as he was aware, instead of the quality of the Scotch iron falling off, in a great many instances it was getting better;

and he believed that the deficiency complained of by Mr. More was more to be attributed to the ironfounders than the ironmasters.

Mr. More said he did not know that. This he did know, that thirty years ago 3½-ton cylinders were in common use, but now he could not trust them under 4½ tons.

The President.—They were formerly made of cold-blast iron?

Mr. More.—Yes.

Mr. Downie said that the large cylinders at the arsenal at Woolwich were made one-half Scotch iron, and the other half Hematite. He conceived that the strength of iron depended a good deal upon its proper mixture. No doubt but that the price was the great bugbear. It was likely those cylinders with the flat bottoms (fig. 1, Plate VII.) would give way at the corners. They would find them leak; in consequence of which, the form of cylinder represented in fig. 2 had been tried, as in it the iron gets fairer play than in the angular form.

Mr. More said they were making one for Messrs. Robert Napier & Sons with a bottom and a head, and with a bit cut off the head.

Mr. Bell thought the plan of the false bottom was good, but that it would not do in all cases; for instance, in the slip purchase, where they had no bolts.

Mr. Downie, with reference to leaving castings some time properly to cool, remarked that it had been found in America that guns had become stronger by lying aside for a while after being cast.

Mr. Davison had heard of experiments of that kind in America, and the reason assigned for it was that the atmospheric changes by expanding and contracting the metal made it stronger, by relieving any unequal strain that might exist in it; but whether this could not be done better by artificial means, he was not certain. He might mention that he had made a hydraulic press in small pieces, for the purpose of being carried on mules across the Andes, no piece of which was over 150 lbs. weight. The whole was made of malleable-iron and brass, screwed together. The cylinder was made of malleable-iron rings, fitting into each other an eighth of an inch. The whole press was put together, and tested to 300 tons on an eight-inch cylinder. They took it to pieces, and sent it to its destination, where, although they had no very good mechanics, they found no difficulty in fitting it together again. Of course, the making of such a press was very expensive. That press was used for packing salt. In South America they packed all their salt by means of fire, by putting it into an earthen vessel, and then pouring hot brine upon it. But, by the use of this press the fuel was saved, which was no inconsiderable part of the expense of manufacture. The press made it into 10-inch cakes, and a pressure of 150 tons would make it as solid as the old fire process. He believed the iron of America was better generally than that of this country. They found often that gun scrap-iron was useful for making cylinders of presses, the bottoms of which were not generally made so thick there as here. With regard to testing guns, the plan adopted in America was to take one out of a parcel cast of the same iron, and fire it until it burst, and then they assumed that the others were capable of standing so many charges. Was there any gauge to tell the pressure upon the hydraulic press?

Mr. MORE said there was one in use at the Victoria Docks, and he believed it worked very well. The difficulty was not to find the pressure at a given point, but to find the amount of friction as the power increased when the press began to work?

Mr. DAVISON said he had used as a gauge a plunger of $\frac{5}{8}$ths at one end, and $\frac{3}{4}$ths at the other, both ends being fitted water-tight, without packing, into a cylinder. The water introduced at the centre pressed upon the annular surface, and the pressure was measured by a spring attached to the small end of the plunger. With this he obtained very accurate results up to a pressure of two tons per square inch.

The PRESIDENT invited remarks upon Mr. More's theory of heat being given out by water under pressure.

Mr. MORE said that he put a thermometer into the bottom of one cylinder, and he made a very fine strip, with which to measure the circumference, and he found that the cylinder was expanded, and bore out the opinion that the breaking took place gradually.

Mr. MILNE said that the cooling of the metal would throw a strain inside as well as outside, and the draw was to the inside.

Mr. DAVISON mentioned an instance in which he said the inside must have cracked first.

Mr. DOWNIE said that in all these cylinders there was a spongy part between the core skin and the outer skin, and which yielded to them.

Mr. DAVISON said he had observed the pipes leading to hydraulic presses become heated, and that, he thought, might proceed from the friction of the water passing through the pipes.

Mr. HUNT thought the heat would arise not only from the friction of the water through the pipes and passages, but also, and probably to a greater extent, from the concussion to which the water was subjected by the pumping action.

Mr. MORE thought the idea of gradual breaking under alternate strains was not confined to hydraulic machines; for he remembered seeing a section of a railway axle after it was broken, and it bore marks of not having given way at once. He thought it was an essential thing to let large castings cool gradually in the pit.

The PRESIDENT said that the gradual breaking of crank axles was quite common.

Mr. RUSSELL said that where he had known them split there was always a little hydraulic action taking place, from there being, as it appeared to him, a small aperture in the side of the cylinder at which the water insinuated itself, and the pressure being so immense, tended to burst it. One remarkable instance of breaking from a change of temperature had occurred with a casting for one of Condie's coke bruisers. It was cast and put out into the yard, and while there it broke asunder by its own weight. The section of metal was about 6 inches, and the depth of ridge was about 3 inches; but the distribution of metal was so shockingly bad that the casting of 32 or 34 tons broke, during the night, after being exposed for a few hours to the weather.

The PRESIDENT said that such occurrences were not very extraordinary. On one occasion he saw a very large casting made for a Spaniard. He would have it made of certain proportions, and although he was told it would certainly break immediately, he insisted on its being cast. It was done and turned out under his own inspection. Two or three days afterwards the Spaniard was dancing round it in great spirits, when it gave a crack and fell in two, to his great consternation.

Mr. BELL asked whether it had been found out how Big Ben was broken?

The PRESIDENT said he suspected that the metal had not been properly mixed.

Mr. HUNT said it was stated that the founders had told Mr. Denison that it would break, but he insisted on their using a too brittle sort of metal.

Mr. MORE did not think that iron-founders ought to be blamed for cylinders bursting. He quite believed that Scotch founders were equal to those of any place; but he believed that the practical difficulty was the expence of Hematite and Blaenavon iron, and the getting a sufficient price to enable them to make cylinders from a mixture of it.

Mr. RUSSELL said that there was Hematite iron now manufactured in this district.

The PRESIDENT said that in Marseilles he had seen a kind of reservoir of power, where the engines and pumps worked a series of very long loaded rams—some 12 or 15 feet long—the whole of them receiving the power from the pumps, which power was applied for expressing oil from seed by merely turning valves.

Mr. HUNT said that Sir William Armstrong had applied that system very considerably.

Mr. MORE said that he had forgotten to mention that they had altered a press at Garnkirk for making bricks. Presses were also used frequently at paper-mills; and at Kelvindale paper-mills one was used for a hoist.

The President remarked that this was a very interesting subject, and had been very ably brought before the Institution. There was apparently great difficulty with the Scotch iron, in obtaining a sufficiently strong close-grained casting, and the reason why a mixture of cold-blast iron was not used, was explained in the candid admission that they could not afford to pay for English iron. It was well known that the Scotch iron was very varied in quality, so much so that they could scarcely cast two cylinders of exactly the same grain or character. If they cast one the one night, and another the next, they would certainly find them different. They knew that the hot-blast could produce inferior iron; but they knew, also, by experience, that by remelting once or twice or thrice, they got a much better iron. By that means they could improve iron greatly, and especially Scotch iron. They also found in their experience much stronger iron from air furnaces than from cupolas. He was sorry that they knew so little about the true nature of pig-iron. It was a very difficult material to experiment upon, being so difficult to melt carefully; and then an alteration in the quality or quantity of coke in the furnace, as well as of the blast, modified the whole matter. However, they must be guided by practice; and by using air furnaces, by melting and remelting, and by a proper mixing of iron, he had no doubt it would be considerably improved. He concluded by moving a vote of thanks to Mr. More for his paper.

Mr. R. Brown could hardly agree with what had been said about Hematite and Blaenavon iron. They must not look at them as purely English ores, as they were only so in part. They were not bands or seams of iron-ore, but peroxides. They contained occasionally as much as 90 per cent. of pure iron, and on the average 65 per cent. Though they were used in all classes of machinery of great strength, such as hydraulic cylinders, still the greater part of Scotch irons was of a much stronger nature than the majority of English irons. He would like it to be known here that Scotch iron was certainly quite equal if not superior to most English irons.

The President said that Mr. Brown was quite right in saying that Hematite and Blaenavon were not English ores peculiarly, and also that there was a great deal of iron in England immensely inferior. In order that no misunderstanding might take place upon the subject, he might state that there was some very inferior iron used in England, as, for instance, that of the Middlesborough districts, and which was not admitted into contracts. In talking of the very highest class of iron, he supposed that they must go to England for it, because they could not get a cold-blast iron here; but if they adopted the process of remelting, they could in Scotland produce iron quite equal to the cold-blast iron of England.

Mr. Downie said that if they made a careful selection from among the Scotch irons they would be well served; but there was this difficulty that the founder had to contend with, and that was that he could not depend on getting a sufficiently hard iron.

Mr. R. Brown said that from what he knew of the founders of Glasgow, he could say that some of them did not make their selections from the good brands in the market as they ought to do. He stated that there had been a discovery of Hematite ore in large quantities in the Dumfries district, which it was likely would come into the market after a considerable outlay, in a few years.

The vote of thanks to Mr. More was then passed.

The following paper was then read:—

Description of arrangements for applying a Hot-blast to Locomotive Furnaces. By Mr. William Morrison.

The writer's arrangements for supplying heated air to the furnaces of locomotives are shown in Plate IX., fig. 1 being a longitudinal section through the fire-box of a locomotive, and fig. 2 a back elevation. The air is taken from the ash-pan, A, in passing through which it is heated by the downward radiation from the fire. An air pipe, B, communicating with the back end of the ash-pan, A, is carried up through the foot-plate, C, and forms a continuous passage with a duct, *b*, fixed on the outside of the fire-door, D, and moving with the door clear of the pipe, B, when necessary. The air entering through the fire-door is directed downwards by a deflecting hood, E, fixed on the inside of the fire-door, so as to meet the ascending gases, these gases being constrained to move towards the fire-door before entering the tubes by the fire-clay arch, F. In practice the improved arrangements have been found to give not only the absense of smoke, but also an important saving in fuel. In order to obtain a measure of the improvements the particulars of six experiments were noted, three with the hot-blast, and three without it, and the results are as follows:—

Comparative results obtained with and without Morrison's Hot-blast fcr Locomotives—

	Experiment.	Miles per day run.	Miles per hour.	No. of trains.	No. of carriages.	Coals consumed per day.		Coals per mile.	Minimum temp. of atmosphere.	Maximum temp. of hot-blast.	Pressure of air in lbs. per square foot.	Remarks.
						cwts.	qrs.	lbs.	degrees.	degrees.		
With Hot-blast.	I.	68	...	12	4	10	2	$17\frac{3}{10}$	30	200	...	Frost and snow.
	II.	68	...	12	4	10	2	17·3	30	212	...	Do. do.
	III.	78	25	14	4	11	1	16·3	35	220	...	Do. do.
Without Hot-blast.	IV.	68	15	12	4	12	1	20·1	30	...	$9\frac{1}{2}$	Sleet and snow.
	V.	71	20	12	4	14	3	23·2	30	...	10	Do. rails heavy.
	VI.	68	25	12	4	13	1	21·8	38	...	$11\frac{1}{2}$	Frost and snow.

Dimensions of the Engine experimented on—

Cylinders, - - - - - -	10 inches.
Stroke, - - - - - - -	15 inches.
Driving-wheels, - - - - - -	5 feet.
Area of fire-grate, - - - - - -	4·75 feet.
No. of tubes, - - - - - -	88.
Working pressure of steam, - - - -	100 lbs per square inch.
Sectional area of ash-pan, - - - -	224 square inches.
Do. do. air-pipe at the fire-door, - -	18 square inches.
Quality of coal used, Drumclair.	

Mr. Morrison, at the request of the President, gave an explanation of the construction of the fire-box. He said the fire-box was made in the ordinary way. The air-tube was attached to the ash-pan, and the air was supposed to be drawn in by the action of the blast in the chimney. They found that there was a great pressure there, and that the air entered with great velocity. On trying it experimentally, he had found the air rushed in at the rate of fifty miles an hour; and also on trying the thermometer below the foot-plate of the engine, it registered 220°, but that was the full range of the instrument used. On running the engine backwards, he found that the air entered with a pressure of only about 1½ lbs. per square foot less than when running forwards. He had found that the introduction of hot air into the fire-box had reduced the smoke very much; in fact, when the engine was in motion there was little or no smoke emitted. He had burnt Drumclair coal in all the experiments.

Mr. More said he had applied the same principle to a fixed engine. It must be of very great use in a locomotive.

The President said this seemed to be a new scheme of smoke burning. He conceived, however, that the table of experiments showed the effect of the introduction of heated air as against no air at all. Now, it would be very satisfactory if Mr. Morrison would carry his experiments a little further, and show the difference between hot air introduced into the fire-box and cold air. Then they would get at the economy caused by the use of heated air.

Mr. Morrison consented to bring up a statement of further experiments, in accordance with the desire of the President.*

A vote of thanks was then passed to Mr. Morrison for his paper, and the meeting adjourned.

* Page 87.

THE SIXTH MEETING of the Session was held in the Philosophical Society's Hall on Wednesday, 14th March, 1860—the PRESIDENT in the chair.

The following paper was read:—

On the Construction of Battle-ships. By Mr. WILLIAM SIMONS.

Owing to the security inspired by a lengthened peace, and to the contented lethargy of government, the unprotected state of our navy has only recently attracted the attention of the country. The idea of more efficiently shielding a sailor in battle seems only now to have received attention; neither until recently did it occur to the admiralty that it was possible to protect our old timber-built battle-ships from shot, by which, as the records of our navy show, many such were sent to the bottom. At the battles of the Nile and Trafalgar the only protection afforded the combatants was a wooden bulwark, 18 inches thick, through which the shot even at that time soon smashed a passage, frequently passing out again on the opposite side; whilst the loss of life at our naval engagements clearly demonstrated that British sailors were cowards only in one thing, "Fearing to be afraid." Why should a British sailor not be protected during battle, and have the same care taken of him as a British soldier? We are all of us familiar with the trenches, the facines, the earthworks, and angled bastions of land warfare; and why should we persist in thinking a few inches of soft wood a sufficient bulwark for the protection of our sailors, irrespective of the costly fabrics on which they fight? The writer fears the reason hitherto has been, that the ancient wooden walls of England have been considered perfect as machines of war and as bulwarks of defence.

But during the last few years the nation has arrived at a different conclusion, that, though these wooden walls were the cradle of their renown, under modern artillery they were likely to become the coffins of their fame, consequently the plan (borrowed, the writer believes, from the French) of casing our battle-ships with thick iron, was thought absolutely necessary, and has been in several instances adopted, on a principle which the writer hopes to show is erroneous; but which, if combined with suitability of form and construction, may be made to resist modern shot as well as the walls of Cherbourg or the forts of Cronstadt.

It will be unnecessary to refer to the millions we have already spent in the building of timber battle-ships, a construction without durability or defence, and liable to many of the worst characteristics of decay, such as wet rot, dry rot, and the teredo navalis; and although the strongest and hardest woods have been tried in their defence, such as Greenheart, Liveoak, Morung saul, Ironbark, and Teak, it has been with no greater success in resisting shot. For these reasons, and seeing the progress of scientific gunnery, the writer submits that the time has now arrived when iron should be substituted for wood in the construction of our battle-ships.

It is admitted that nature in every operation is perfect; and if we examine the crocodile, the elephant, the tortoise, the rhinoceros, the buffalo, &c., all of which are protected with a defensive armour more or less impenetrable, amongst other valuable hints, we shall learn that none of them expose a flat surface of resistance to the enemy, their sides and backs being more or less angular, circular, or pointed; and I submit that this principle should form a leading feature in the formation of iron cased battle-ships.

Fig. 25, Plate V. is the half section of a battle-ship built of iron, having its sides from the waterline up to the gunwale formed angular, fore and aft, with the apex of each angle in the centre of each line of gunports. It will be observed that, from the adoption of iron, this mode of construction can be easily obtained. To the interior point of each angle, the extremities of the iron deck-beams are secured. From the waterline up this angular iron framework is covered with 2¾ inch thick steel or iron; which is securely rivetted to the framework and beam-ends, and caulked watertight. Outside of this, from the waterline up to the gunwale, there is built a verticle bulwark of timber, built and planked the same, and in construction, material, and fastening, similar exactly to the side of a wood battle-ship, and with or without the seam plates marked C, to be afterwards described. At the top and bottom where it amalgamates with the iron hull also at every point of contact with the angled side, this timber side is strongly secured with screw-bolts and other fastenings, and thus forms a complete junction with the iron fabric.

Fig. 26, Plate V. is the section of a timber battle-ship as at present constructed, having the principle of angular protecting plates applied to its interior. Such vessels may by this means be protected from shot, and rendered of some service. This is done in the following manner:—2½ inch thick steel or iron plates are bent into the angular form and placed along each gun-deck, having the exterior angle on a line with the middle of the gunports. These are then strongly bolted to the ship's side and to the wood beams, above and below. Sufficient room is left at the junction of the shield with the ports to depress, elevate, or manœuvre the guns.

The advantages of constructing battle-ships on this principle are, that the cannon-ball, after having spent its force in passing through 2 feet of oak, or the side of our present timber fleets, will be retarded in its further course of destruction by coming in contact with the internal steel shield at an angle; and it is submitted that even the balls from the Armstrong or Whitworth guns will be unable to penetrate this system. The writer also believes, that if the hull is built of iron, according to the plan shown in fig. 25, and with a moderate thickness of the shield plates, the displacement would not exceed that of an ordinary wood battle-ship.

It is well known that there are at present building four iron-cased men-of-war; two of them each of 3268 tons, and two of 6039 tons each. The total cost of these will be £1,355,000. Their sides are being cased externally in the usual vertical position with 4-inch iron fastened to 18 inches thick of wood. The hulls are of iron, but defective in principle; and the writer believes these vessels will be found to be a mistake, which might not have been the case had the designs and specifications been thrown open to the country. £5000 offered for the best plans of such fabrics would not have been a large sum to pay for them; and the result might have been a more prudent expenditure of the above enormous sum.

Fig. 18, Plate V, is a section of the timber side, having between the seams of each plank a long steel plate from $\frac{3}{4}$ to $1\frac{1}{4}$ inches thick, and 10 inches broad, the inside edge abutting against the vessel's vertical timbers, and the outside edge either flush or projecting. These plates are placed about 6 inches asunder, so as to prevent a large cannon-ball passing between them. They are also bolted vertically to the planks above and below. Figs. 19 to 21 show modifications of this system of construction; fig. 21 being a front view.

Where an external iron-casing is adopted, it may be made of the improved sections shown in Figs. 22 and 23, Plate V. Here, instead of a perfectly-flat surface, the casing is formed with projecting angles and oblique surfaces disposed horizontally, and is practically much stronger than the same amount of metal arranged in the ordinary way. The section shown in Figs. 22 and 23 may also be adopted for metal shields inside the timber bulwarks.

Professor Thomson said he had listened with great pleasure to the short paper just read; the details of the plan had been shortly and clearly explained, but some study would be required before a decided opinion could be pronounced as to them. Without doubt, however, a general principle of improvement had been brought forward in the paper—a principle that had occurred to him frequently as being the right principle, although he had never made mention of it, unless in conversation; that is, putting the wood outside the iron in battle-ships. From a consideration of dynamical laws, it was evident that in the direct concussion upon the external iron side of a ship, the entire momentum of the cannon-ball must be imparted to the block of iron, enabling it to destroy the wood within. If they considered the prodigious effect upon the deck of a ship by the recoil of a cannon, and the care expended in managing the breaching, so as not to permit it to come into contact with any part of the hull, they would form an idea of the effect of a concussion on the side of an iron-sheathed ship, and the necessity for doing something to mitigate it. Now the momentum communicated depended upon the relative masses of the iron plate and shot. When, for instance, a 64 lb. or 1 cwt. shot was used, there was not much safety given by iron plates. He did not know the dimensions nor the weight of one of the great masses of iron made to sheath war-ships; but however heavy it might be, it could not do away with the destructive power coming against it. If the wood were placed outside the iron, however, the destructive power of the shot would be in great measure destroyed; for the velocity of the shot in passing through a foot of wood would be considerably reduced. The concussive force in the one case acted through an inch instead of through a foot as in the other. He had no hesitation in saying that the proper place to put the wood was on the outside of the iron in ships, whatever the details might be, which he left for further consideration; but he was strongly of opinion that if ever they were to have serviceable iron war-ships, they must have wood, or some other comparatively soft protecting material outside the iron.

Mr. Simons said that the iron-plates for ships were about 15 feet long, 2 or 3 feet broad, and weighed about 4 tons.

Professor Thomson said that the weight of a gun throwing 68 lbs. shot was 95 cwt., so that these plates were nearly equal to the weight of a gun. From that, it followed that the mechanical value of the momentum of the iron plate would be rather more than equal to that of the the backward momentum the gun acquired in delivering the shot; and they knew what effect that would have upon the timbers of a ship. But if the shot was gradually brought up by coming into contact with wood, then the resisting power of the iron would be usefully brought into play, and the tendency to crack the iron would be greatly diminished.

The President said that Mr. Simons' paper was somewhat remarkable for its shortness and its novelty. It struck one almost at once as standing to reason that the proposed mode of constructing war-vessels would better resist the force of shot than the external iron-plate surface. The mode of construction explained in the paper was conceived upon a rather different principle from that at present adopted; as he understood it, it was intended to partly absorb the momentum of the ball in the external wood. They must all agree with Professor Thomson that there was a novelty about this paper which was very interesting and exceedingly useful, if worked out. They would, therefore, all join in giving Mr. Simons a vote of thanks.

The following paper was then read :—

On the Form of Ships. By Mr. J. G. Lawrie.

If the form of ships is imperfectly understood, the cause is not due to an absence of opportunities for observation, nor to a want of desire for the improvement of these opportunities. Few subjects within the range of an engineer, are more important than the improvement of shipping, few have received greater consideration, yet none are less indebted to the genius of a single individual. Different sciences and different arts owe their exactitude and progression of improvement to single names that stand preeminently forward; but the science of ships and the improvement of shipping have been but little due to single achievements, either of theoretical investigation or of practical research.

The subject, "The Form of Ships," embraces the formation of that part of a ship under the water, and also of that part above the water. The formation of that part under the water is regulated chiefly by scientific considerations, involving facility of propulsion and cubical capacity; while the formation of the part above the water is chiefly governed by convenience, and the attainment of elegance. The scientific considerations upon which depends the facility of propulsion are of the highest order, and are still beyond the grasp of analytic expression. Elegance in the formation of the upper part of a ship, depending in some measure upon taste, is inherently incapable of exact definition, and whether any ship possesses the utmost attainable elegance has been and will continue to be a question upon which those interested in the subject will differ more or less in opinion. There are ships which by common assent are pronounced to be inelegant and unshapely, while on the other hand there are ships which all agree in thinking are handsome, and about which the only difference of opinion is as to the order or rank in which they should be ranged in respect of their elegance.

Clyde ships the writer believes belong to the class admitted to be handsome. With few exceptions they have a similarity of appearance, or family likeness, constituting the Clyde form; but as in the human form small differences increase or mar elegance, so in ships similar differences, comparatively minute and insignificant, in combination account for the difference in the appearance of the work of different builders. Those acquainted with the practice of the different shipbuilders on the Clyde could without much difficulty recognize their ships, from features of construction unobserved by those less acquainted with the subject, but which in reality proclaim the builder as distinctly as his name. Of those so distinguishable, the ships of Mr. John Wood of Port-Glasgow possess in the writer's opinion a symmetry and grace not surpassed nor indeed approached by those of any of his rivals. To Mr. Wood the writer would assign no only the highest rank as a builder of handsome ships, but would ascribe to him the authorship of the form as respects beauty which is imitated by all his compeers on the Clyde, and in proportion as the imitation is perfect, the ships possess the grace and elegance so much admired. Mr. Wood's claims to superiority are, however, confined very much to matters of beauty, other builders having contributed more to the attainment of speed and efficiency. Of these builders, the Dennys of Dumbarton, namely, the late Mr. William Denny and Mr. Alexander Denny, possess high claims. These gentlemen within the last twenty years were mainly instrumental in producing the Clyde form of ships. Having been educated in early life by the brothers John and Charles Wood in the refinement of building elegant ships, trained by Mr. Scott Russell to a knowledge and to an appreciation of the fact, that the formation of the lines of a ship materially affects the facility of propulsion, and witnesses of all Mr. Russell's more perfected experiments, no men had more favourable opportunities of acquiring a knowledge of the improvement of shipping; and to their credit be it said these opportunities did not pass unimproved. In 1842, under their guidance, the river steamer *Lady Brisbane* was built, the first* of the improved class of steamers on the Clyde, the first of a train that have not been equalled in this country, and that have not been proved to be equalled in any other. These gentlemen, the Dennys of Dumbarton, being aided by the opening introduction of iron in shipbuilding, imparted with signal success the same features of construction to sea-going vessels that had proved to be of so much advantage in river navigation, and by combining in one model the separate excellencies of Wood and Russell, neither of whom had yet acquired the ability of doing so, they produced a class of vessels remarkable alike for beauty of form, and facility of propulsion.

In the formation of the improved lines which Russell pointed out, and the Dennys adopted, no precise law or plan was followed, and for the sufficient reason that no definite law or plan to follow was known. Even now that part of science—the formation of the part of a vessel under water—is no farther advanced, and although there are shipbuilders and other persons who have an affectation of knowing the best form for the part of a ship under the water, their pretensions have no foundation whatever. No form is known which has been shown, or can yet be shown, to be the best. The extent of our knowledge is limited to the fact that certain forms

* In 1840 the *Flambeau* was built by the late Mr. Robert Duncan of Greenock with Mr. Russell's aid, and was the fastest vessel on the river at the time. The *Flambeau*, however, being built of timber afforded only a limited introduction of Russell's views, and being short of steam, the form of ship received imperfect justice.

are inferior to other forms, that Mr. Wood's spoon-bow is inferior to the sharp or hollow-bow, but the knowledge is possessed by no one which is necessary to define the form either of the fore-end, or of the after-end of a ship, which shall produce the best and most economical effect.

Scott Russell, in his series of papers and investigations of this subject propounded that by forming the entrance water lines hollow, the water impinging was thrown aside with accelerated motion, and therefore with great economy. No doubt the water which does impinge and travel in a hollow line is thrown aside with accelerated motion, and is therefore thrown aside more easily than when it impinges on a convex line as at B, and when it is therefore put in motion, with greater or instantaneous rapidity. But that advantage applies only to the part of the whole water displaced which impinges on the part of the line which is hollow; and to define, therefore, the best form of even the fore-end of a ship in accordance with the views of Mr. Russell, it is necessary to show the kind of hollow in the line at the part which is hollow, the form of the part of the line which is not hollow, and also the direction in which this line is to be drawn on the ship, as there are reasons to believe that the water is not thrown aside in horizontal lines, but rather that it is thrown aside in other directions diagonal to a horizontal plane. No part of that information has Mr. Russell yet satisfactorily explained, even for the fore-end of a vessel, so far as the writer knows, and if it has not been done for the foreend of a ship, still less has it been done with respect to the after-end.*

Mr Russell has, however, the distinguished merit of showing† or enforcing the fact, that the form of the lines is very material to facility of propulsion, and that the old spoon or rounded form, resembling a duck's breast, is not the form which is most conducive to the attainment of facility of propulsion. Mr. Russell's papers on the kindred subject—the motion of water in waves, and on the laws of waves, which are of a masterly character in one of the most difficult departments of science,

* None of Mr. Russell's published papers read before the British Association with which the writer is acquainted, contain this information, nor do his papers in the *Encyclopædia Britannica* contain it. His views have been verbally expressed, and are as yet known only traditionally. Whether his paper communicated to the Institution of Naval Architects in March, 1860, will, as published, contain it, remains to be seen; it was, however, communicated by request of the Institution (so Mr. Russell says), for the express purpose of conveying a statement explanatory of his views and theory.

† Mr. Russell, in the article Steam Navigation in the *Encyclopædia Britannica*, acknowledges that the observations made by Asheton Smith had independently led Mr. Smith to a conviction of the advantage of hollow lines. There is, however, no doubt that Mr. Russell by his continued efforts made the subject his own, and deserves the credit of enforcing it.

furnish the name to his system of shipbuilding, but they have not been shown to furnish more than the name.

Other writers on the form of ships have dogmatized on their methods of construction, without possessing the ability to support their views by one substantial reason. In hydrodynamic science, no advance whatever has been made in the solution of the problem regarding the form of a ship which would produce the maximum effect.

Although, however, the science of the formation of ships has not been solved synthetically, it is capable of valuable examination in the results obtained. Although, the means have not been devised by which to assign inductively, the dimension and form of ship which shall perform certain duties with the best effect, means do exist by which different ships can be compared in the work they perform. By these means, the relative efficiency of the ships thus compared becomes known, and the shipbuilder is instructed which to follow as the preferable form. The means by which this information regarding steamers is obtained, consist in comparing the work performed by different ships with the power of the engine necessary to perform it, and in the inverse proportion of the power necessary is the superiority of the form of the ship. The work performed by ships is measured by the gross weight moved, and by the velocity with which it is moved, neither of which is alone sufficient for a comparison of the efficiency of one ship with another. It has, however, been not uncommon in investigations of this subject to use modes of calculation involving only facility of propulsion, and to direct attention rather to the means of reducing the work to be performed by engines in propelling ships, or to the means of increasing the velocity of ships, than to an examination of the ultimate effective results performed by the ships. Colonel Beaufoy proceeds in this way, and in his method the resistance to the motion of the ship, or the power of the engine exerted, is measured by an expression,* involving the weight of water put in motion in the advance of the ship, the velocity with which it is put in motion, and the friction of the ship in passing through the water. M. Marestier in an able report drawn up in 1824 by order of the minister of marine in France, on steam navigation, uses a method similar to that of Colonel Beaufoy, or, what is equivalent to it, in conjunction with the power exerted by the engine, to elicit the relation efficiency of steam

* The formula of Colonel Beaufoy is, when put analytically, $R = f a w \times \frac{v^2}{2g}$ in which f = constant factor depending on the form of ship; a = area of midship section; w = weight of a cubic foot of water; and $\frac{v^2}{2g}$ = height corresponding with the velocity of the vessel.

vessels.* In this report by Marestier the procedure adopted is, in fact, to ascertain in a direct manner the form of vessel which lessens the resistance to propulsion, or the changes of form which would produce that effect; and, in an indirect manner, by comparison with the displacement of the ship, to find the form which produces the best result. Other writers have adopted the same plan of investigation, but it is apparent that the resistance to the motion or advance of ships may be reduced without increasing their efficiency, and it is therefore indispensable in a comparison of the performance of ships to embrace both the facility of propulsion and the gross weight moved. To obtain a comparison of ships by one calculation, and to exhibit the efficiency in one expression, another formula of great value and simplicity has been devised. This more complete expression or formula is based on the displacement of the ship, the friction of the rubbing surface, the velocity, and the power; or, in other words, is a comparison of the work performed in overcoming the resistance to the motion of ships with the power used to perform that work and to overcome that resistance—the comparison being expressed in terms of the work performed by the ships, instead of being expressed in terms of the lineal dimensions of the ship. The formula is obtained as follows:—

In ships of precisely the same form, so that one is twice as large as another, or half as large, or in some other proportion larger or smaller, the lengths, breadths, and depths of these ships are proportional to the cubic roots of the displacements, that is, are proportional to $D^{\frac{1}{3}}$, if D represents the displacement. But every dimension of these ships being in this proportion, it follows that the area of the midship section is proportional to $D^{\frac{2}{3}}$; and, for the same reasons, it follows that the surface of the bottom of the vessels rubbing against the water is also proportional to $D^{\frac{2}{3}}$. If the ships, though of different displacements, and of different magnitude, be of precisely similar form, it follows that the two sides of ships form, at every corresponding part, the same angles; and hence, in the advance of the ships, the water at the bow will be displaced, and at the stern replaced similarly. For these reasons the direct resistance† to

* The formula of Marestier is $V = 2{\cdot}53 + \left(\frac{n \times h \times c \times p^2}{B}\right)^{\frac{1}{3}}$, in which 2·53 is a constant factor depending on the form of the ship; n = revolutions of engine; h = the height of mercury which the steam will support; c = length of stroke of engine; p = diameter of cylinder; B = draft of water multiplied by breadth of midship section. Plainly this formula, which is based on the area of the midship section, does not convey any information regarding the efficiency of the ship, unless the displacement be taken into consideration also.

† It has been usual to assume the head resistance to vary as the area of midship section, and the reasons may be shown as follows:—The space, S, or width of the ship, diagonal or horizontal, through which the water has to be moved to permit the ship to pass, is pro-

the advance of the ships, if the forms be similar, varies as $D^{\frac{2}{3}}$, and the rubbing surface varying as $D^{\frac{2}{3}}$, the friction which is found to be in proportion to the surface rubbing against the water, also varies at $D^{\frac{2}{3}}$, irrespectively of the draft of water of the ship. Hence, the gross resistance to the advance of the ships consisting of the two parts, direct resistance proper, and friction of the rubbing surface, each of which varies in proportion to the square of the velocity, is expressed by $V^2 D^{\frac{2}{3}}$; and consequently the quantity of power which must be exerted by the engines to propel the vessel, D, at the speed, V, is represented by $A \times V^3 \times D^{\frac{2}{3}}$, if the form of the vessels be precisely the same. The efficiency of the ship is therefore expressed by $A \times \frac{V^3 D^{\frac{2}{3}}}{\text{Ind. H.P.}}$, or by* $\frac{V^3 \times D^{\frac{2}{3}}}{\text{Ind. H.P.}}$, which expresses the relative amount of power necessary to propel at the same speed each form of ship of a size having the same displacement. This formula, which is called an index number, is admirably adapted to inform the shipowner of the comparative excellence of different steamers, that excellence being in direct proportion to the

portional to $D^{\frac{1}{3}}$, and the time in which the water has to be moved through S is also proportional to $D^{\frac{1}{3}}$; hence, if f represents the force applied to the water to move it, it follows, by the laws of accelerated motion, that $S = ft^2 \therefore f = \frac{S}{t^2} = \frac{1}{D^{\frac{1}{3}}}$. But the time during which this force is exerted being proportional to $D^{\frac{1}{3}}$, the quantity of work performed to overcome the head resistance = area of midship section $\times \frac{1}{D^{\frac{1}{3}}} \times D^{\frac{1}{3}}$ = area of midship section. In the same way it may be shown that the stern resistance is also proportional to the midship section. The draft of water being increased in proportion to $D^{\frac{1}{3}}$, the head resistance is overcome under an increased pressure proportional to $D^{\frac{1}{3}}$, but that is neutralized by a similar counteracting pressure at the stern, arising from the same cause.

* To make the investigation of this formula more elementary, let v, d, p, be the speed, displacement, and indicated horse-power of a steam vessel; V, D, P, the speed, displacement, and indicated horse-power of another steam vessel of precisely similar form—it follows, from what has been already explained, that $p : P :: d^{\frac{2}{3}} : D^{\frac{2}{3}}$, if the speed of the two steamers is the same, and equal to v; therefore, $P = \frac{p \times D^{\frac{2}{3}}}{d^{\frac{2}{3}}}$ for the speed, v, and $v^3 : V^3 :: \frac{p \times D^{\frac{2}{3}}}{d^{\frac{2}{3}}} : \frac{p \times D^{\frac{2}{3}} \times V^3}{d^{\frac{2}{3}} \times b^3}$; $\therefore$ the power to propel the vessel, D, at the speed, V, if the efficiency of the two vessels is the same $= \frac{p}{d^{\frac{2}{3}} \times v^3} \times D^{\frac{2}{3}} \times V^3$. If the efficiency of the two vessels be different, the power necessary to propel the vessel, D, at the speed, V, will be greater or less than that amount in proportion to the efficiency; $\therefore$ efficiency of D : efficiency of d :: $\frac{p}{d^{\frac{2}{3}} \times v^3} \times D^{\frac{2}{3}} \times V^3$: indicated horse-power actually exerted; $\therefore$ efficiency of D $= \frac{p}{d^{\frac{2}{3}} \times \iota^3} \times \frac{D^{\frac{2}{3}} \times V^3}{\text{Ind. H.P.}} \times$ efficiency of $d = \frac{D^{\frac{2}{3}} \times V^3}{\text{Ind. H.P.}}$ if the constants be each put equal to unity.

magnitude of the index number, that is, to the magnitude of the quantity expressed by $\frac{V^3 \times D^{\frac{2}{3}}}{\text{Ind. H.P.}}$. If the engines and propelling machinery in the ships compared are of different efficiency, it is necessary, for the different purposes of the shipbuilder and engineer, to separate the effects of the ships and engines; or, if it be desired to carry the investigation still farther, it is easy by this formula, or by modification of it, to elicit the comparative efficiency of the ship itself, of the boilers, the engines, and the propelling machinery. To point out in this paper the modifications of the formula necessary for the purpose, which are perfectly obvious, might have an appearance of complicating it, while, in reality, it is of the most simple and beautiful character. It elicits the relative excellence of the ships compared, and, although it gives no aid towards defining the form and dimensions of a ship to perform assigned duties, it instructs the shipbuiler which type of ship, of those already submitted to trial and measurement, should be adopted.

This information is of the highest importance, and it is satisfactory to find the accuracy of the formula* materially confirmed by experiments with the ships—H.M.S. *Desperate*, H.M.S. *Minx*, H.M.S. *Retribution*, *Onyx*, *Banshee*, and other vessels, in which experiments the speed of the ship was found to vary sensibly with the cube roots of the power employed. It has been at various times alleged, and has been strongly urged by Mr. Scott Russell, that the form of vessels should be designed specially with relation to the speeds at which they are to be worked, and that if the vessels be driven at a greater or less speed than that intended, the difficulty of propulsion is vastly increased. If this in reality was the fact, the formula would be valueless, but in none of the experiments with the vessels already named was such a result obtained, or any appearance of it. Such an effect may, or rather, no doubt, does occur in canal navigation, where the action of the water is confined within narrow limits, but in open water it does not appear to be so—at all events within the range of the experiments already

* Mr. Thomas Hawkesley of London proposes by the formula—

$$V = 29 \left[\frac{\text{Ind. H.P.}}{72\ A\left(\sin^2 \frac{\theta}{2} \times \sin^2 \frac{'\theta}{2}\right) + S} \right]^{\frac{1}{3}}$$

to express the definite relation of the velocity V, the area of the midship section A, the rubbing surface S, and the indicated horse-power by means of a measurement of the angles $\theta\ '\theta$, of the bow and stern lines. Mr. Hawkesley does not explain how these angles are to be measured, and it appears impossible to measure them, because these angles vary at every level or depth, because it is unknown on what diagonal ribband line they should be measured, and also because, even if the measurements were made, it is unknown in what degree the angles formed by surfaces at different depths affect the whole result.

mentioned, and in these experiments the results were those due to very different speeds and very different forms.

To Mr. Lloyd, chief engineer of the navy, is due the merit of first fully appreciating the great value of this formula, or index number for the efficiency of ships, and through his instrumentality, it has been extensively employed in investigating the properties of the ships of the navy. In 1850 a list of the steamers in the navy was made, with the index number due to each calculated by this formula. Another similar list was made in 1856, and a third list is in course of preparation, which will probably be completed in about twelve months. Mr. Lloyd, in the preparation of these lists has performed a most valuable service to the navy—a greater service than has ever been performed by any other marine engineer in employment of the Crown.* These index numbers disclose differences in the efficiency of ships little anticipated, and in these disclosures, furnish solid groundwork for future improvement. No other means exist by which to obtain information so valuable for the improvement of ships; and it is surely remarkable that the use of this formula is being but slowly introduced in the merchant service. To the ships of the mercantile navy it has been rarely applied; but it is nevertheless the fact, that concerning those only which have been so examined is definitely accurate information possessed regarding their efficiency.

The list of ships in the navy proves, that vessels like the yacht *Fairy*, though built expressly for efficiency, are inferior to others in which no such refinement was attempted. That the *Arrogant*, a frigate designed and built by one of the most honoured naval constructors in H.M. service, is scarcely superior to the block ships; and not being intended for special service like the *Fairy*, the inefficiency cannot be explained in the same way as in that vessel.

Mr. Lloyd confined his published use of the formula to ascertaining the index number, or coefficient of the different ships in the navy, but Mr. Atherton, chief engineer of H.M. Dockyard, Woolwich, in a very able treatise, called "The Capability of Steam Ships" has elaborated the subject, to develop in a striking manner the advantage of employing the best form or type of ship in mercantile enterprise. In this treatise, it is shown clearly, that the difference in the cost of freight by vessels which to appearance are not materially different may be and is as much as 50 per cent.—a difference which is at once detected by the application of this formula. The writer is acquainted with no means which would more rapidly improve

* In saying so, it is right to mention that Mr. F. P. Smith was not in the service of the Crown at the time he introduced the screw-propeller. Since the reading of this paper, the writer has ascertained that Mr. Lloyd is also the author as well as the introducer of the formula $\frac{V^3\ D^{\frac{2}{3}}}{\text{Ind. H.P.}}$

the efficiency of ships, than a rigorous application of this formula, nor any other means of so thoroughly convincing shipowners that the efficiency of ships is of greater value than a considerable difference in price. It would, besides, frequently appear that with the best intentions ships are built of injudicious proportions, and that at less cost ships could be produced which would perform the same work with less power, and less current outlay.

For example, the four large ships that are being built for the Holyhead and Dublin station, of which three are being built by Laird in Liverpool, and one by Saumda in London, have a length equal to ten times the beam. These ships are very sharp with comparatively small displacement, and it would be interesting to ascertain whether they really prove to be efficient. The writer is not acquainted with any proof that proportions, in which the length is equal to ten beams, and the displacement small, are good.

In the list of navy ships the most efficient are not the longest, and a vessel called the *Wave*, built some years ago on the Thames, with a length equal to 14 beams, proved to be far short of a success.

In the absence of accurately-ascertained information to guide the shipbuilder, the desire for great length in vessels of high speed is easily explained. Every vessel, with a determinate power and at a given draft of water, will go faster, if the lines are sharpened, while retaining the length, breadth, and depth unaltered; and there is no limit to this effect until the lines be sharpened so much as to destroy the stability of the ship. But it is forgotten that, in thus sharpening the lines to increase the speed, the ship is actually made smaller; and it is omitted to be observed, that when the sharpening is carried to a certain extent, the operation cannot be continued, with the advantage that would be obtained by diminishing the length, breadth, and depth, which in reality would retain the vessel of the same size as with more sharpened lines, and a more extended surface. This explanation, suggested by the formula itself, sufficiently removes the apparent paradox, that while sharpening a vessel more and more increases her speed, yet a vessel can be made too sharp for the attainment of the highest possible speed.

On analogous principles the efficiency of sailing ships could be similarly compared; but, as their days are numbered, such an investigation would possess little interest.

In conclusion, the writer repeats that in his opinion nothing would so speedily conduce to a considerable improvement in the form of ships, to the instruction of shipbuilders, and to the advancement of the science of steam-shipping, than a constant and rigorous use of the valuable formula $\frac{V^3 D^{\frac{2}{3}}}{\text{Ind. H.P.}}$.

NOTE.—The impression is common among both shipowners and shipbuilders, and is largely acted on, that a full form of ship, so as to carry a large cargo, is necessarily what is called a good poor man's ship; but this formula very distinctly upsets the idea that there is a difference in the form which is best for a rich man and a poor one. For both that form is the best which is most adapted for performing work with the greatest economy, and the form which is the best to effect that purpose at one speed, is also the best for every other speed. In addition to the best form of ship, there remains the important question of the best and most economical power and speed. If the power be too small, the speed will be so slow that the current outlay will swallow up the return derived from the small quantity of work performed; while, on the other hand, if the power be too great, the return, though quicker, will not be sufficient to meet the increased current expense. There is, therefore, plainly for every different trade in which a ship can be employed, a certain speed and certain amount of power, which will yield the largest profits. The amount of power, which affords this maximum effect, depends upon the following elements:—

D = Total displacement of ship.
$d \times$ D = Part of displacement available for cargo, engines, coal, &c.
p = H.P. Ind.
v = Speed in knots per hour with power, p.
W = Weight of machinery per H.P. Ind.
w = Do. of coal and stores consumed per H.P. Ind. per hour.
c = Current expense of ship per hour.
^1c = Do. of engines per H.P. per hour in harbour.
^2c = Do. do. do. in voyage.
Time in harbour = a, hours.
Do. voyage = b, hours with power, p.
Total passage money = m
Cost of earning passage money per hour = $^2c \times m$.
x = Any other H.P. Ind.
$'v$ = Speed due to the power, x.
Freight per ton = f.
Profit per voyage = Earnings — cost.

$$\text{Profit in a given time} = \frac{\text{Earnings — cost.}}{\text{Time of voyage + time in harbour.}}$$

Proceeding in the usual way to find the value of x, which shall make "Profit in a given time" a maximum, an equation is obtained of the form, $x^{4/3} + ax + bx^{3} - c = o$; and one root of this equation is the amount of power which produces the highest result or profit in the circumstances enumerated.

The PRESIDENT regretted that Mr. Lawrie was not present to answer any questions that might be asked.

Mr. SIMONS said he was not favourable to the wave-line system as a whole, although he approved of parts of it. He considered it a fallacy, and disagreed with Scott Russell upon it. The first ship built at Greenock 10 or 12 years ago upon the plan—the *Flambeau*—was a total failure. Then there was the yacht *Britannia* built upon the same principle; and, after much being said in her favour, she was beaten by an American-built yacht. Various others had been built, but he never had heard of their success. A gentleman had been sent for by the British admiralty, with the view of consulting him as to building a vessel on the same principle; but he published an elaborate document, proving its disadvantages. He believed, however, that there were some good things in the wave system which could and had been applied in ship-building.

Mr. INGLIS said that Mr. Scott Russell had built two vessels, the *Victoria* and the *Adelaide*, which were the greatest failures.

The PRESIDENT said this was a very important subject; and it would be well if they could come to some practical result upon it. There were a good many shipbuilders members of the Institution; but he regretted that they did not bring forward the data that might be expected from them. He believed there was a good deal of truth in the assertion that shipbuilders in building for speed exercised a good deal of guess work. He feared that a carpenter made the form of his ship pretty much as if he took a wedge of brown soap, pared it, and then held it up, and looked at it again and again, until he was pleased with the symmetry of its form. He believed they had no very correct rules to go by, except perhaps it was the making of one ship like some other which had proved successful; but the curiosity was, that they found two ships, made as they believed exactly alike, giving different results. This "index number" might be a very good thing for comparing one ship with another; but it gave us no assistance in modelling a ship beforehand. We were still very far from having any definite rule for forming a ship, or for giving the results demanded. As to the wave-line, he must say he was not prepared to condemn Mr. Russell's system so much as Mr. Simons had done. It might not be suitable for ocean steamers, but for river vessels he thought it had done very well. He was not sure, but he thought that the *Flambeau* was the quickest vessel on the river at the time.

Mr. SIMONS did not think she ever exceeded seven miles an hour. He did not condemn the wave-line in all particulars, but he condemned it as a whole. He had built a yacht partly on the principle, which had never been beaten. Her bow was formed on Mr. Russell's calculations of the bow; but the other parts were not on the same principle.

A vote of thanks was then passed to Mr. Lawrie for his paper.

Professor WILLIAM THOMSON then exhibited an "*Improved Portable Atmospheric Electrometer*," which he had recently contrived. He explained its construction and performed experiments with it in illustration. The instrument proved itself to be an extremely sensitive indicator of the electrical condition of the surrounding atmosphere.

The PRESIDENT said he had no doubt that they were all much gratified by Professor Thomson bringing this instrument before them. It was a wonderfully-delicate instrument, to measure a delicate medium which they did not know much about. The instruments formerly in use could not tell the quantity or the quality of the electricity in the atmosphere; but Professor Thomson's indicated both.

A unanimous vote of thanks was then passed to Professor Thomson.

The PRESIDENT, in resuming the discussion of

Mr. Morrison's mode of supplying Heated Air to Locomotive Furnaces,

explained a model showing the arrangement, and remarked that the mechanical details of the plan were very simple, and seemed to do very well. He then explained, that at last meeting Mr. Morrison had given the results of experiments with hot air, showing great economy in fuel; but inasmuch as these experiments had only been compared with experiments with no air at all, the Institution had requested Mr. Morrison to make a few further experiments to supply this defect. He had kindly promised to do so, and the result was in the hands of the secretary.

The SECRETARY read Mr. Morrison's report, which was to the effect that the Locomotive had been worked six days with cold air admission, and six days with hot air, and that there was a saving of 624 lbs. of coal in favour of the hot air in the consumption for the week, the total miles run and coal consumed being as follows:—

With cold air, 418 miles, 8216 lbs. coal; or—19·6 lb. per mile.
With hot air, 428 miles, 7592 lbs. coal; or—17·7 lb. per mile.

The PRESIDENT said he had been told by the stoker, who had assisted in the experiments, that the fire was much more vivid with the hot air than the cold, and that the place where the cold air was admitted was characterized by blackness.

A vote of thanks was passed to Mr. Morrison.

THE SEVENTH and LAST MEETING of the Session was held in the Philosophical Society's Hall, on Wednesday, 11th April, 1860, WILLIAM JOHNSTONE, Esq., Vice-President, in the chair.

This was the Annual General Meeting for the election of office-bearers for the Fourth Session, 1860–61.

The following paper was read:—

On an Improved Smoke-consuming Furnace. By Mr. J. MOFFAT.

The theory of combustion is now well understood. There must be a given temperature, and a given supply of air. The temperature necessary for consuming common cannel is from 800° to 1000° Fahrenheit. But it sometimes rises much higher; as, for instance, from 1000° to 1400° —as ascertained by Mr. Fairbairn of Manchester; whilst the bars of furnaces are occasionally melted, which shows that the temperature then rises to 2700°, the temperature at which iron melts. The temperature necessary for the combustion of the gases from coal is somewhere about 1000°. The supply of air necessary to the full combustion of common coal amounts to 150 cubic feet for 1 lb. of coal, and of that quantity 105 cubic feet are required for the consumption of the carbon, and 45 cubic feet for the consumption of the gases. The writer believes that, weight for weight, the hydrogen, or light carburetted hydrogen, is more productive of heat than the carbon; indeed, it has been estimated that it is four times as effective, and therefore it is highly desirable to burn all the gases. With this end in view all furnaces ought to be constructed, as is the case with those of Prideaux and Williams. The one permits the air to go in by slits in the door, and the other allows it to enter beyond the bridge; both with the view of mixing the air with the gases evolved on the dissolution of the coal. The writer's attention has been turned to this subject in consequence of the steamer *Adela* being found to produce a large quantity of smoke, although her furnace doors are pierced with holes. In trying to cure this, the furnace doors were kept open a little, but still she made a fog of smoke through which the captain could not see his way. It is well known that the combustion of coal in locomotives is assisted by having slits in the furnace doors, with internal deflectors over them to throw the air down upon the gases as they rush up through the fuel. It occurred to the writer that a contrivance of that kind would be useful in the *Adela;* and accordingly he planned the apparatus, which is shown in longitudinal and transverse vertical section in figs. 3 and 4, Plate IX. The apparatus consists of a casing, A, inserted along the centre of the furnace in a direction from front to back. This casing, which is of cast-iron or of fire-clay, is divided by transverse vertical partitions, so as to form a series of passages through which the air rises from the ash-pit, and the air passages are surmounted by a curved cover, B, which causes the air to be deflected downwards on the fuel on either side. Of course, the only matters of interest in connection with this plan are the results obtained. The prevention of the smoke has been complete. The flues are now kept quite clean; whilst, as regards the consumption of coal, it may be stated that in the first trials made, the aft boilers were fitted with the apparatus, and the fore ones were left as before. There was a great saving in fuel with the aft furnaces, but it is probable that at first the men were more careful in firing these. At first there was a saving of a waggon out of six, but since then the boilers had been all fitted with the apparatus, and had now been going for about three months. The coal actually burnt in the first three months of the year was as follows:—January, 405 tons, 12 cwt.; February, 360 tons; and March, 384 tons. In February there was one trip fewer than in the other two months. This showed a saving of five per cent. of coal. The writer is not able to state the cost of the apparatus, and the resultant saving will only be ascertained by further trials now going on.

The CHAIRMAN trusted that Mr. Moffat would give the Institution the benefit of his further experiments on an early day of next Session.

Mr. LAWRIE said that the saving in fuel was just what might have been expected, seeing that it had occurred in other experiments of the same nature. The chief benefit from the apparatus would be the stoppage of a large emission of smoke, so destructive of everything in a passenger ship.

Mr. MOFFAT said he might add that the *Adela* was fitted with superheating apparatus, and they had found—what had been discovered by many who had tried superheated steam, that the great heat dried up the lubricating matter in the cylinder, and consequently they had to mix the superheated steam with common steam from the boiler. The superheated steam was of about 350°, whilst the heat corresponding to the pressure was only 250°. They had expected, along with the advocates of superheated steam, a very large saving of coal; but in this they were quite disappointed, as not the slightest change had taken place in the quantity of coal used.

In answer to Mr. N. Robson, Mr. MOFFAT said that the apparatus had been in use since the last week in January.

Mr. D. More said that this subject was at the present time occupying a large amount of public attention, and the procurator-fiscal of Glasgow was prosecuting many, either in a summary way before the sheriff, or by taking them into the Dean of Guild Court, whence, it was well known, that it was difficult to get out at a less cost than £40 or £50. Therefore, information of the kind given by Mr. Moffat was of very great use. There was no doubt that a great deal of the smoke in the city of Glasgow arose from boilers being too small, from careless building, and from careless firing. If these evils were removed, he had no doubt that the smoke could be greatly reduced—a thing of the greatest importance to the town. He might mention, in connection with this subject, that they had erected in their works a Cornish boiler, 21 feet long, 6 feet 6 inches in diameter, with two flues 30 inches in diameter, the furnace being inside. That boiler was of 20 horses power, and there was no smoke with it. It was only fired three times a day. The fuel that damped down the fire on the Saturday kept it going until half-past eight on Monday morning, when it was damped down for breakfast-time, and then went on until half-past one, when it was again fired and damped for dinner. It was fired for the third time at half-past five o'clock, when it was damped down for the night. This was at least a great saving to the arms of the firemen. He was therefore greatly in favour of the Cornish class of boiler.

The Chairman said that on the London and South-Western railway the plan explained by Mr. Moffat had been adopted in part in nearly all their locomotives, and now there was scarcely one of their engines in which they did not burn coal, and that without any smoke, simply by directing down the air to meet the current of gases as they were evolved by combustion from the fuel. By this means they effected a saving of about 8s. 6d. a ton; for it was found that a ton of good blind coal at 5s. went as far as a ton of coke at 13s. 6d.

Mr. Hunt said that the plan explained by Mr. Moffat for consuming smoke would be of great use in the river steamers. If it were possible to get rid of the smoke in the river steamers, it would be one of the greatest boons that could be conferred upon the citizens of Glasgow.

Mr. Moffat said, in answer to Mr. N. Robson, that the apparatus described could be applied to all kinds of furnaces; and, in answer to Mr. Downie, he said that the top part of the casting gave way first. He had tried fire-bricks in an iron frame, but, as the apparatus had not been well made, they had not answered. He had no doubt good fire-brick would serve admirably.

The Chairman said that fire-bricks were regularly used in Beattie's patent locomotive engines of the London and South Western railway.

Mr. Downie suggested that the top might be of fire-brick, but Mr. Moffat thought the best way would be to make them entirely fire-brick.

The thanks of the Institution were then passed to Mr. Moffat for bringing the subject before them.

Mr. David More then made some remarks on the subject of

The Ventilation of Public and other Buildings,

in the course of which he explained a working model of a system of ventilation devised by Mr. G. W. Muir.

A discussion ensued, and a vote of thanks was passed to Mr. More.

List of Works presented to the Institution during the Session 1859–60:—

"The Steam Engine and other Prime Movers." From the Author, Prof. W. J. Macquorn Rankine, C.E., LL.D., &c., &c.

"The Present State of the Longitude Question." From the Author, C. Piazzi Smyth, Astronomer-Royal for Scotland.

"The Autobiography of a Seaman," Vol. I. From the Author, the Earl of Dundonald.

"On the Resistance of Glass Globes and Cylinders to Collapse:" by Wm. Fairbairn, C.E., F.R.S., and Thomas Tate. From Wm. Fairbairn, Esq.

"Address of G. P. Bidder, Esq., President of the Institution of Civil Engineers." From the Author.

"Proceedings of the Institution of Mechanical Engineers" for November 3, 1858; January 26, May 4, July 27, and September 6 and 7, 1859. From the Inst. M. E.

"Transactions of the Royal Scottish Society of Arts," Vol. V., Part 3. From the R.S.S.A.

"Transactions of the Institution of Civil Engineers of Ireland," Vols. I. to V. From the Inst. C.E.I.

"Mitchell's Steam-Shipping Journal," Nos. 1 to 34. From the Editor.

The thanks of the Institution were voted for these donations.

The Treasurer presented his accounts and statements in accordance with Rule 15; and Messrs. Wilkie and Simons were appointed Auditors in accordance with Rule 17, to examine the same.

Abstract of Treasurer's Accounts—Session 1859–60.

Dr.	£	s.	d.	£	s.	d.
April 13, 1859.						
To Balance from Session 1858–59.						
Cash in Union Bank, ...	£346	0	0			
Cash in Treasurer's hands, ...	5	19	0			
				351	19	0
April 11, 1860.						
To Subscriptions—						
94 Members, at £2 2s., ...	197	8	0			
14 New Members, at £3 3s., ...	44	2	0			
1 Associate, ...	1	11	6			
2 New Associates at £2 12s. 6d.,	5	5	0			
7 Graduates, at £1 1s., ...	7	7	0			
				255	13	6
To Cash for copies of the Transactions, 8 Vol. I., 5 Vol. II., ...				4	1	0
To Interest from Union Bank, ...				16	12	0
				£628	5	6

Cr.	£	s.	d.	£	s.	d.
April 11, 1860.						
By Secretary's Salary 1 quarter, Session 1858–59; and 3 quarters, Session 1859–60, ...				£100	0	0
By fees to Officer and Janitor, ...				7	0	0
By Rent of Hall, Session 1858–59; and Gas for Session 1857–58, ...				16	0	0
By cost of 300 copies of the Transactions, Vol. II., including Circulars, Stationery, &c.,				95	13	0
By Postage, Porterage, &c., ...				6	9	3
By Reporter, balance for Session 1858–59, ...				3	3	0
Balance—						
Cash in Union Bank, as per pass-book, ...	393	12	0			
Cash in Treasurer's hands, ...	6	8	3			
				400	0	3
				£628	5	6

After their examination, the Auditors presented the following Report:—

Glasgow, 11*th April*, 1860.—We have examined the foregoing statement, and compared it with vouchers, bank book, &c., and find it correct, there being in the bank Three hundred and ninety-three pounds twelve shillings, and in the Treasurer's hands Six pounds eight shillings and threepence, in all, Four hundred pounds and threepence to be carried to the credit of the Institution.

(Signed) John Wilkie, Wm. Simons, } *Auditors.*

The thanks of the meeting were voted to the Auditors.

The following gentlemen were duly elected Office-Bearers for the Fourth Session (1860–61), of the Institution, in accordance with Regulations 24, 35, 36, 37, and 38, which were read:—

President.

Walter M. Neilson, Esq.

Vice-Presidents.

William Johnstone, Esq.

Neil Robson, Esq.

James R. Napier, Esq.

Councillors.

William Tait, Esq.

Archibald Gilchrist, Esq.

Hugh Bartholomew, Esq.

William Simons, Esq.

James Brownlee, Esq.

David M'Call, Esq.

James Milne, Esq.

John Wilkie, Esq.

Robert Faulds, Esq.

W. J. Macquorn Rankine, Esq., LL.D.

Treasurer.

David More, Esq.

Secretary.

Edmund Hunt, Esq.

A CONVERSAZIONE was held by the Institution, in the Corporation Galleries, Sauchiehall Street, Glasgow, on Tuesday, 17th April, at 8 P.M.

A large and valuable collection of machines, models, and drawings was exhibited.

In the absence of the President, on account of serious indisposition, a few introductory remarks respecting the origin and progress of the Institution were made by NEIL ROBSON, Esq., Vice-President, after which C. PIAZZI SMYTH, Esq., Astronomer-Royal for Scotland, addressed the meeting on the subject of

Distance Measuring in Russia;

and was followed by W. J. MACQUORN RANKINE, Esq., LL.D., who spoke on the subject of

Instruction in Musketry.

The substance of the remarks on "Distance Measuring" is embodied in the following paper:—

On Distance Measuring in Russia, for the Purposes of War as well as Peace. By Professor C. Piazzi Smyth, Astronomer-Royal for Scotland.

Having been intrusted this evening with the duty, equally gratifying and honourable, of attempting to address to you a few words on "Distance Measuring in Russia"—I would beg to commence by explaining, that what little I have to lay before you under this title, consists merely of a few light—but perhaps more or less characteristic particulars accidentally picked up during a visit to St. Petersburg, in the course of last summer.

The general subject of distance measuring may be considered to be peculiarly connected with Russia; inasmuch as the enormous extent and remarkable flatness of that great empire, do, in a manner, render the measurement and marking, and recognizing and accomplishing of horizontal distances, one of the leading occupations in Russian life.

Approach that land from wherever you will; or, as my wife and I did last July, from the Gulf of Finland side, and how extensively and oppressively this idea of horizontal distance is brought out before you. Your first glimpse of the country consists of long thin coast lines—lines that seem interminably long and level, though minutely serrated with fir-tree tops. After days and days of sailing along them, you have still these long and level unbroken lines on either side. For relief you turn to the sky above; but there the horizontal extent of the country is too often reflected back again to your eye, in the equally long and never-ending perspective of uniformly-sized clouds, equally scattered through the unbroken vapour plane, that lies parallel for a thousand miles with the similarly unbroken Russian land.

Flatness and horizontal extent are indeed everywhere; and in everything they are the dominant characteristics. You land in St. Petersburg, and how flat a sheet forms the country all around! For miles and miles the broad imperial streets go branching out to every side, without the smallest impediment from inclination of soil. You drive beyond the town, and travel only over the flattest of plains, where a thin blue horizon line, as if the edge of the ocean itself, ever accompanies you in the distance.

The prevailing idea is even brought out in domestic life; as too we soon had an opportunity of witnessing; for having had an introduction to a family circle of some position, our host kindly pointed out, and explained, as it were, after the following manner, on our first evening there, the various guests at his long and hospitable supper table. "That one," said he, "just opposite you, is a cousin, who has come to spend the holiday season with us, from his home, which lies about four hundred miles beyond Moskva; and that one is a relation of my wife's, who has arrived on a similar errand from the north-east country, after having been nearly four weeks on the road, travelling night and day; and that one has come from 15° of latitude south of us, while that one just beyond him has lately been planting out colonists in Siberia, at a distance of 47° of longitude from here." This surely seemed to be enough for one family gathering; but before the evening was concluded a brother of our host dropped in, with his wife and child, from far-off Astrakan, bringing tales of outlandish doings amongst the Bashkir tribes between the Caspian Sea and the Sea of Aral; and in a few days after came an astronomical friend from a three years' scientific journey to the Amoor River, on the coasts of the Ochotsk Sea—a distance of more than six thousand miles of solid continent, nearly level the whole of the way.

Our entertainer on this occasion was no other than the acting Director of the Great Central Imperial Observatory at Pulkova, viz., M. Otto Struve; and, besides other duties, he superintends much of the more scientific part of the extensive works undertaken by the Topographical Corps of Russia. Hence he is much occupied with questions of distance-measuring of every kind and degree; and having chanced to pay a visit to Edinburgh in 1850, shortly after the Ordnance Survey—an operation which reflects so much credit on our corps of Royal Engineers—was commenced in that district, he now asked us, with interest and animation, whether the map of all Scotland was by this time completed?

"Oh, no!" we replied, "that was too much to expect; the mapping of so vast an extent as the whole country must necessarily spread over many, many years. And though we in Great Britain rather keenly felt the nuisance, and something of the absurdity too, of having to wait from thirty to forty years for a complete map of our country, yet we did not see how it could possibly be produced in a less space of time!"

"Well," said he in return, "if the Russian survey went on only at the same rate as the British, we should have to wait, according to the amount of surface to be measured, rather more than twelve thousand years before we possessed a complete map of this empire."

"Then what plan do you follow to get over the ground more quickly?" we enquired.

"Why, here," replied he, "more than a hundred years ago, that truly far-seeing man, Peter the Great, perceiving at a glance that the trigonometrical operations, then coming into favour with the more civilized West-European nations, were not much better than Utopian in their application to his immense territories, struck out a plan for himself, based on exact astronomical determination of the latitudes and longitudes of all leading points. To this end he founded the Academy of Sciences in St. Petersburg; and, furnishing it with a large number of astronomical quadrants, of much larger size and greater powers of accuracy than generally in that day considered suitable for field work,—he sent out the academicians every year, to fix as many points as they could by means of geographical astronomy, and followed them by military officers to fill in between. And this system," said our host, "is still going on, though the outward features are somewhat changed; for the labours of the academy have been chiefly handed over to professional astronomers; and the English quadrants have been replaced by prism circles, which are now all constructed at the observatory, by our own workmen, and on the model which our continued experiences have proved to be the most practical and useful in the field. For latitude, we depend almost entirely on altitudes of the Pole star, measured with alt-azimuth instruments; and for longitude, chiefly on chronometers. These are carried in spring boxes; and every summer we start forth in quick travelling carriages, describing with our stations so many loops over the country, in order to eliminate changes of the watches' rates during the journey, besides testing them continually by star observations."

For the peaceful purpose, then, of mapping down the overpowering agricultural extent of that large empire of the north and east, the science of geodetical astronomy, in its highest degree of theoretical refinement and most advanced state of practical accuracy, is in constant daily requisition. A great deal of surveying proper also goes on in special localities; and as an example, our host himself had just begun a grand levelling operation, intended to stretch from the Gulf of Archangel right across Russia to the Black Sea. In connection with his account of this great work, he took us to look at some of the levelling instruments and staves which he had employed; and while we were admiring their construction, he suddenly asked us, in a most significant manner—

"Can you measure the distance of an object of unknown size, merely by having a view of it for a moment or two from one spot of ground where you may chance to be standing?"

"Yes," we replied, "we can, by means of an instrument carrying its own base line—an idea that we carried out, though rudely, a few years ago, to meet a case reported to have occurred in that unhappy Crimean war."

"Well now, how strange," he replied, "for my instrument is on that principle, and was to meet cases occurring, or expected to occur, about the same time at Cronstadt. And what was the length of your instrument?"

"Five feet."

"Five feet!—why that is just the length that I chose for mine; and here," said he, "it is," as he brought out of an adjacent store-room a five-foot wooden tube, armed with certain optical fittings, and resting on a three-legged theodolite stand.

The instrument thus produced was, then, what may be termed a distance-measurer for purposes of gunnery; and an exact knowledge of distance is a most important object to be secured, as our country now knows so well, whenever accurate firing at long ranges is required. But though knowing the general fact, all our countrymen are not perhaps quite so well aware of what constitutes the only correct principle on which such distances can be absolutely determined; for otherwise, they would not be so well content, as too many of them are, with certain routine rules depending on visibility—a quality which any changes in the transparency of the atmosphere, or in the illumination of objects, and still more, the absence of objects having a right form, figure and size, may render utterly erroneous.

We were called on, for instance, while still in Edinburgh, and just before starting for Russia, by the inventor of a certainly very neat plan, of moving in an equal degree, and in opposite directions, two micrometer wires in the field of a military telescope; and much he, the inventor, wanted us then and there to give him a testimonial, that his contrivance was an infallible means of measuring distances for all the purposes of gunnery.

The distance was to be ascertained, be it understood, by measuring with the two wires the angular subtense of any man who might be seen at the spot, whose distance was desired to be known; and then, on assumption of his height in feet, computing how far off he must have been, according to the usual rules of plane trigonometry. An excellent plan this would be, doubtless, if you were always certain of seeing a man on your exact shooting ground, and, if the said man was always six feet high, exactly, even to the hundredth part of an inch, neither less nor more; but a very misleading plan if the man be not of that height; and an impossible plan if merely part of a man, or no man at all be visible—as when a rifleman has hid himself, partly or completely, according to approved sharp-shooting tactics, behind a tree or a stone wall. But to all these objections to the principles of his plan, the inventor only returned the stereotyped excuse for answer, that a man is *always* assumed by the military authorities to be six feet high for the purpose of distance-measuring; and a certain regimental officer, to whom he had shown his telescope with the two wires, had told him, only the day previous to his visit to us, that he had never in his life before seen so scientific an instrument.

"Oh, then," said M. Struve, "a pretty mistake your British inventor, and the officer too, would have made upon some of our Russian soldiers, according as they had seen in the distance either one of the Preo-brajenski

Guard, who stands, with his bear-skin shako, above seven feet high; or a little Finlander sharp-shooter, who, with his flat blue-cloth cap and short stature, is under four and a half feet. Yes, indeed, a pretty mistake; for the real distance might have been almost double, or only half, of whatever the telescope and its micrometer wires made it appear to be."

Now, M. Struve's own distance-measuring instrument, depended on no such varying and distant base line as that just described, but on its own length, which was a constant, evidently capable of being determined with the greatest precision; and its action was thus:—when you looked at any object through the instrument, certain reflectors, set at either end, gave you a view from both these ends at once. Hence resulted optically, two images of everything you looked at; and these images were always separated by a quantity, precisely equal to the apparent length of the instrument itself, as it would be seen from the place of the object under observation. The measure, therefore, of the separation of these optical images became equal, on a certain scale, to a measure of the distance of the object from the observer; and thus, this desired result of distance was quickly arrived at, and without any assumption of the nature or size of the object observed; while the method was equally applicable by night and by day, if only a spark of light, or anything with a definite edge, or portion of an edge, were visible in the field of view.

Such, then, was the distance-measurer, devised and constructed by the Russian astronomer, for improving the accuracy of fire in the guns at Cronstadt.

But was it used there?

Well, thereby hangs a tale. The inventor urged the employment of the new instrument on the war-office of his country; but was curtly told that present methods were good enough, and no others were wanted. He pressed the authorities, therefore, with the case of an enemy's ship, holding her men concealed, and coming up slowly, with designs of mischief, to one of the forts; how would they then, at any particular instant, determine the distance? Oh, they would fire a shell or two and find out by the drop.

"Why, the expense of one firing," returned the astronomer, "from one of your large guns, would supply every fort in Cronstadt with a distance-measurer!"

Then the astronomer followed up that reply, by getting one of the officers out to the Observatory on a dark night, and there showing him in a telescope, pointed to the long straight road leading right away for nineteen versts to St. Petersburg, a single carriage light, with the request, "Will you oblige me by telling me the distance of that light?" But such a question was declared to be absurd; for a single light, of unknown size and intensity, just seen looming through the darkness and snowy haze, without anything to compare it with, gave no recognized means of mensuration. "Then you shall see," responded the astronomer, "how easily my distance-measurer will solve the problem," and in half a minute the distance was stated in national sajenes; and in a few minutes more, by a second and a third measure, it was proved which way the carriage was moving, to or from the observers.

There was no resisting altogether such a demonstration as this; so a board of celebrated admirals and generals was presently appointed to report on the instrument, and the inventor's hopes ran high. Who is there, too, who could not sympathize with him; for had he not invented a something in the time of his country's direst extremity that might be of vital service to her; and now he was going to see her adopt, and profit by his invention? After having been all his life, in the ill-understood and worse-appreciated position of merely a "savant," of only an improver of difficult points in the arcana of science, comprehended by few in the present age, and looking rather for approval to the mind of posterity, hewa now about to take rank amongst his countrymen in time of war, as one who could give them effectual help in their national measures for resisting a forcible invasion of their common fatherland! Alas! for his patriotic hopes; for he heard one morning soon after that his cherished invention had been condemned.

Why, and wherefore, he earnestly enquired. It could not be because the principle was deemed defective, for that he had mathematically demonstrated to be true; and surely not because the principle was inefficiently carried out in practice, for the optical work was in the highest style of finish peculiar to the best astronomical instruments!

Oh! on no such reasons as those, he was told, had sentence been passed: and so it proved. Great officers of state, it seems, in all countries, have shorter methods of proceeding than those painful and laborious processes which are followed, and thought necessary, by plodding scientific men; and something like the following turned out to have been the very compendious system on which the officials had proceeded in the present case. They began by laying down the dogma, that any really good modern invention in Russia must have long since been discovered in England; and, if discovered there, would, as an equal matter of course, have been brought into use by the British Admiralty. They had then, therefore, only to inquire, whether any instrument like M. Struve's was presently employed in English men-of-war; and having found on inquiry that no such apparatus was known there, they considered themselves to have arrived, logically as well as commendably, at an undeniable proof, that the distance-measurer of the astronomer of Pulkova was not a good or useful invention, and decerned accordingly.

There matters might long have remained, had not the *Russian* Admiralty the unspeakable advantage of being presided over by a chief, who is not only a statesman, but also a really learned, as well as practical seaman; fully understanding naval affairs, because he has worked at them with able head and ready hand from his earliest years. This chief was the Grand-duke Constantine; and some rumour of the matter above-mentioned having chanced to reach him, he instantly ordered all the parties down to Cronstadt, there to try the new instrument in his presence, and ascertain its capabilities in the open air. The season was winter, a Russian winter too; but under the Grand-duke's all-compelling supervision, long lines were soon measured over the ice, in radiating directions, from one of the outer forts; and on poles or other marks being erected at the end of such lines, the distance of each object was instantly given, by the new "distance-measurer" merely looking at them out of the cannon embrasures. These determinations, being presently compared with the notes of the chain-measurers on the ice, produced such a conviction in the mind of the inspecting chief, that he at once empowered the astronomer to construct a large number of his "absolute distance-measurers" for use in Cronstadt. Hence, the Russian artillery has now, most probably, a more exact, economical, and scientific means of measuring distance, than either army or navy of any other European power can show.

Such, then, are a few stray gleanings connected with some particular cases of the art of "distance-measuring" as at present practised in Russia; and greatly is it to be desired that other members of this active and flourishing young "Institution of Engineers in Scotland," would also contrive an opportunity for visiting that giant empire of the north and east, throughout whose whole extent so much is presently stirring of eminent interest to all cultivators of practical science. Of interest, too, to men of every variety of calling; for there, in Russia, will they find a people of indomitable energy, of high morality, and of orderly inclinations; in number over fifty millions, with remarkable unity of language, and possessing a greater portion of the earth's habitable surface, than history has ever yet recorded as in the possession of a single race. And if we have hitherto not heard much of this people in the realms of science and literature, it is not because its members have not the capabilities within them; indeed, on the contrary, when you begin to communicate personally with them, you become astonished, as Baron Haxthausen has well remarked, at their acuteness of understanding, their force of imagination, and the greatness of their intellectual gifts;—there are no boors, says he, among the Russian common people. But it is rather because they have been kept back hitherto by great natural and national causes, which took them many ages to triumph over. Tartar domination, for instance, and other consequences of the immense horizontal extent and extreme flatness of their country; affording a people jealous of liberty no mountain fastnesses to retreat to, when invaded by barbarous hordes.

Those times, however, of the childhood and pupilage of the Russian tribes are passed, and nobly are they now beginning to move forward in the grand scheme of European civilization. European civilization, we say advisedly, for a genuine European people they are, in spite of a trite but shallow Napoleonic maxim to the contrary. They may be the youngest of the European family of nations, but are as surely the most numerous; and as certainly, from the very nature of all their innate feelings and ideas, the most un-Asiatic, or rather, the most European, of all the Europeans; a nation, therefore, in whose ultimate full development, the dearest hopes and most exalted aspirations for the progress of mind in civilized man are intimately bound up.

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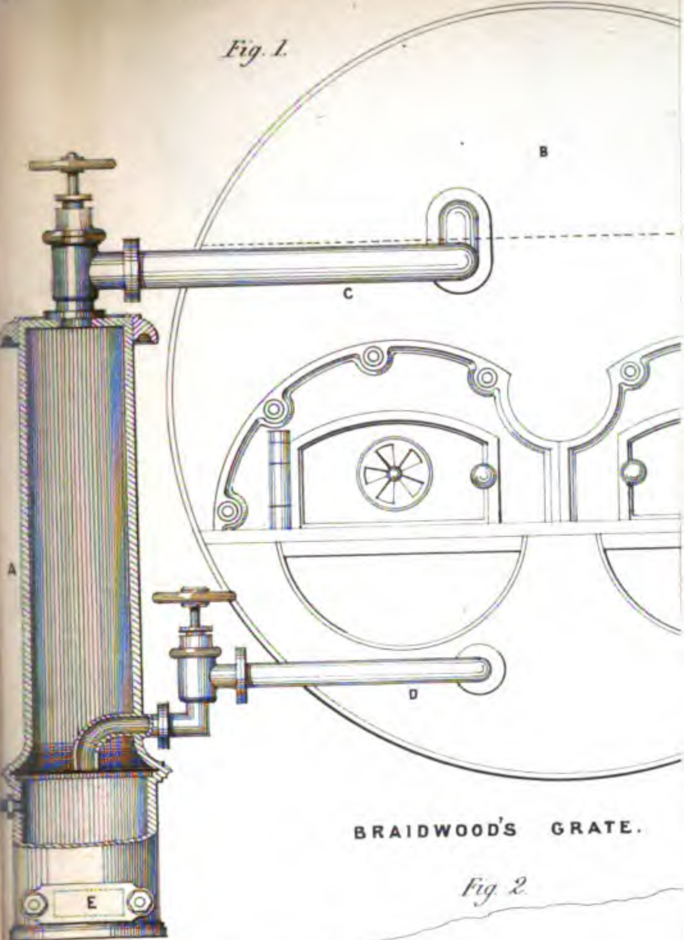
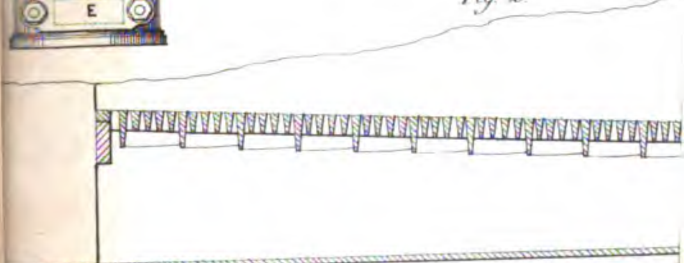
Fig. 1.



BRAIDWOOD'S GRATE.

Fig. 2.



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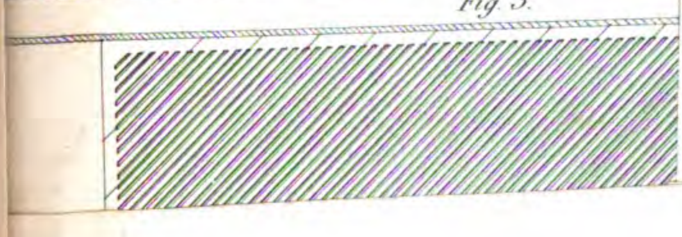
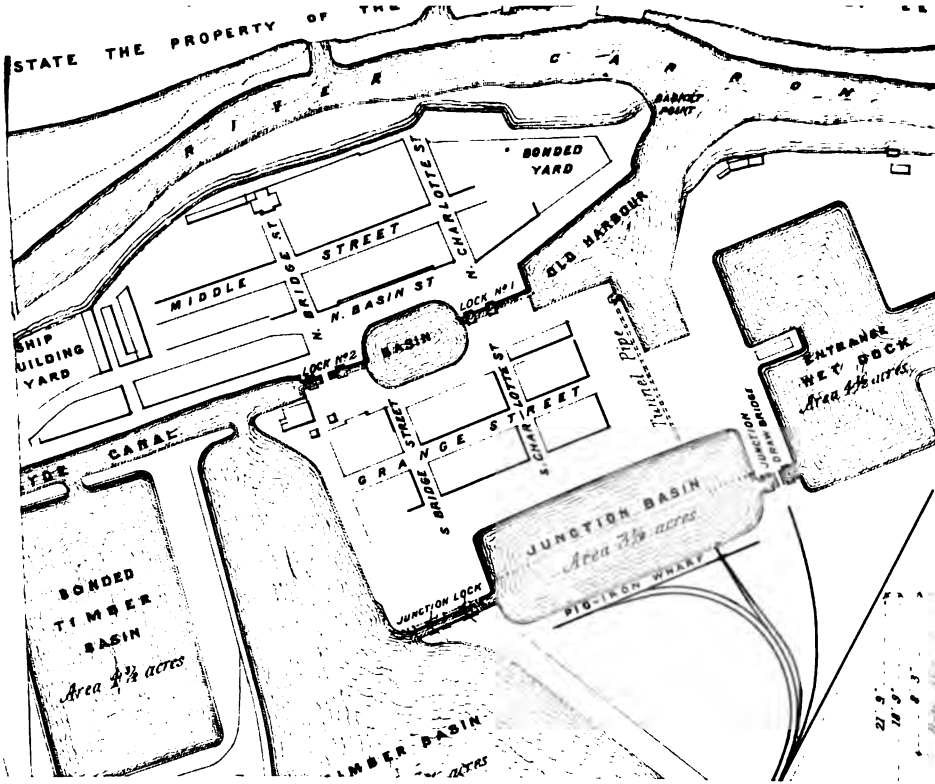
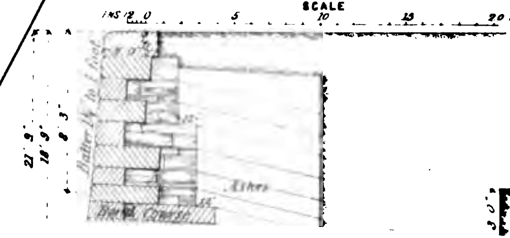
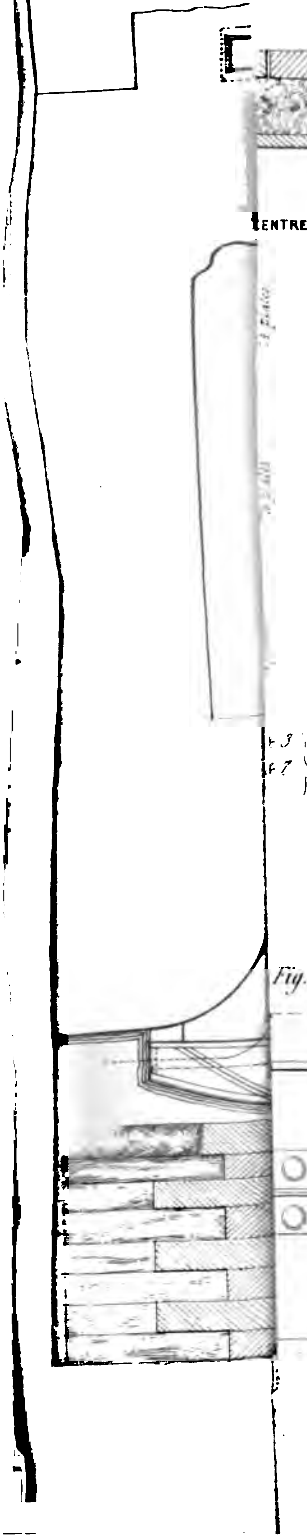




(Fig. 2)

SECTION OF WALL





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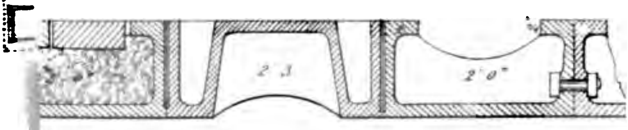


Fig. 7
SECTIONAL ELEVATION.

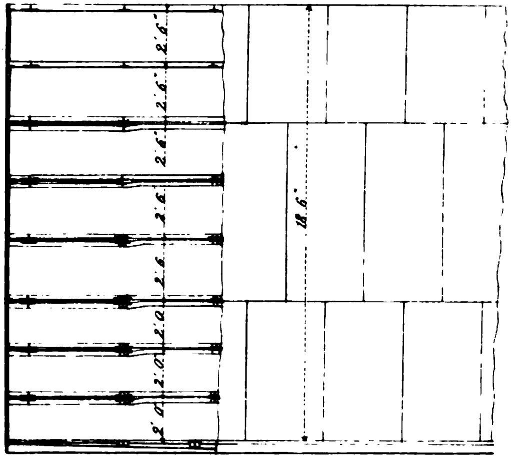


Fig. 9. PLAN OF GIRDERS 2, 3, 4 & 5

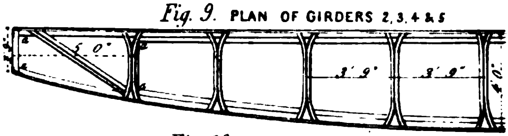


Fig. 10. PLAN OF GIRDER 1.

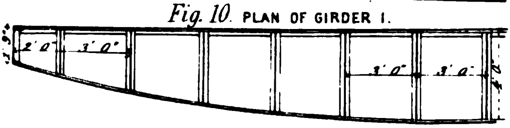
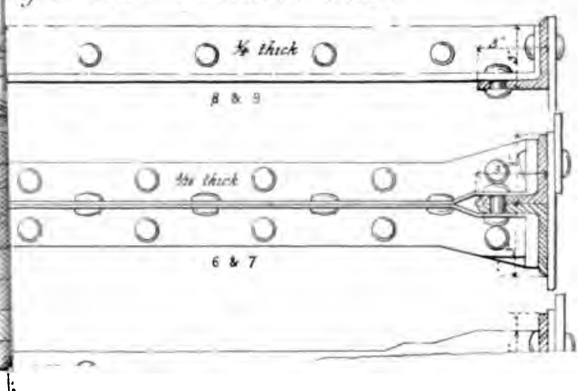


Fig. 11. ENLARGED SECTIONS OF GIRDERS



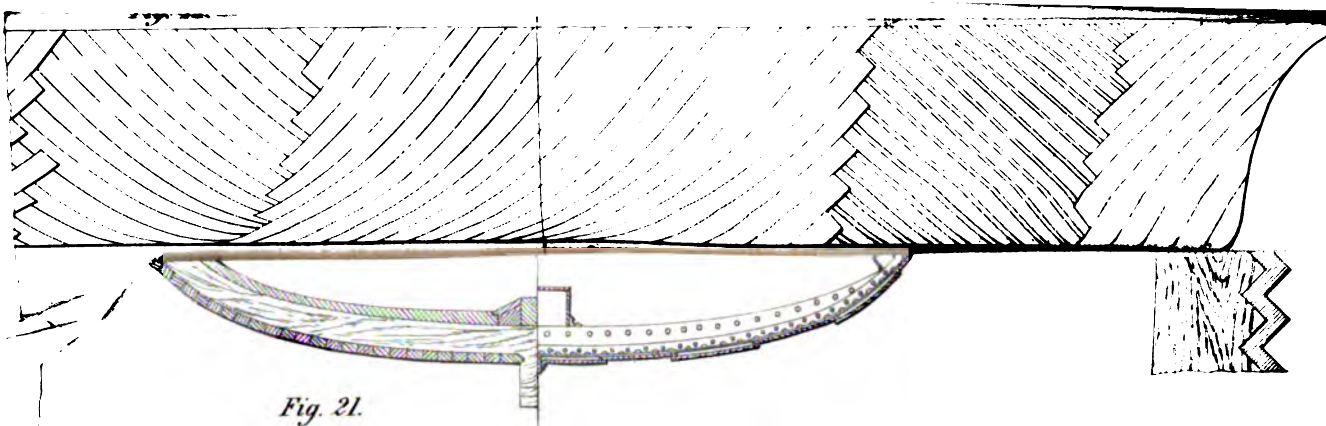
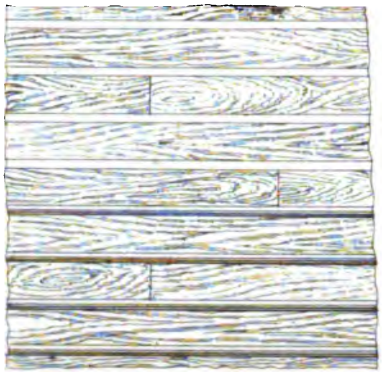
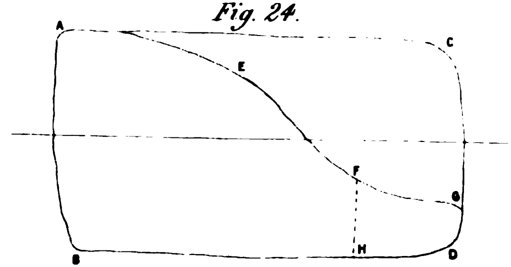


Fig. 21.



LAWRIE'S PAPER.

Fig. 24.



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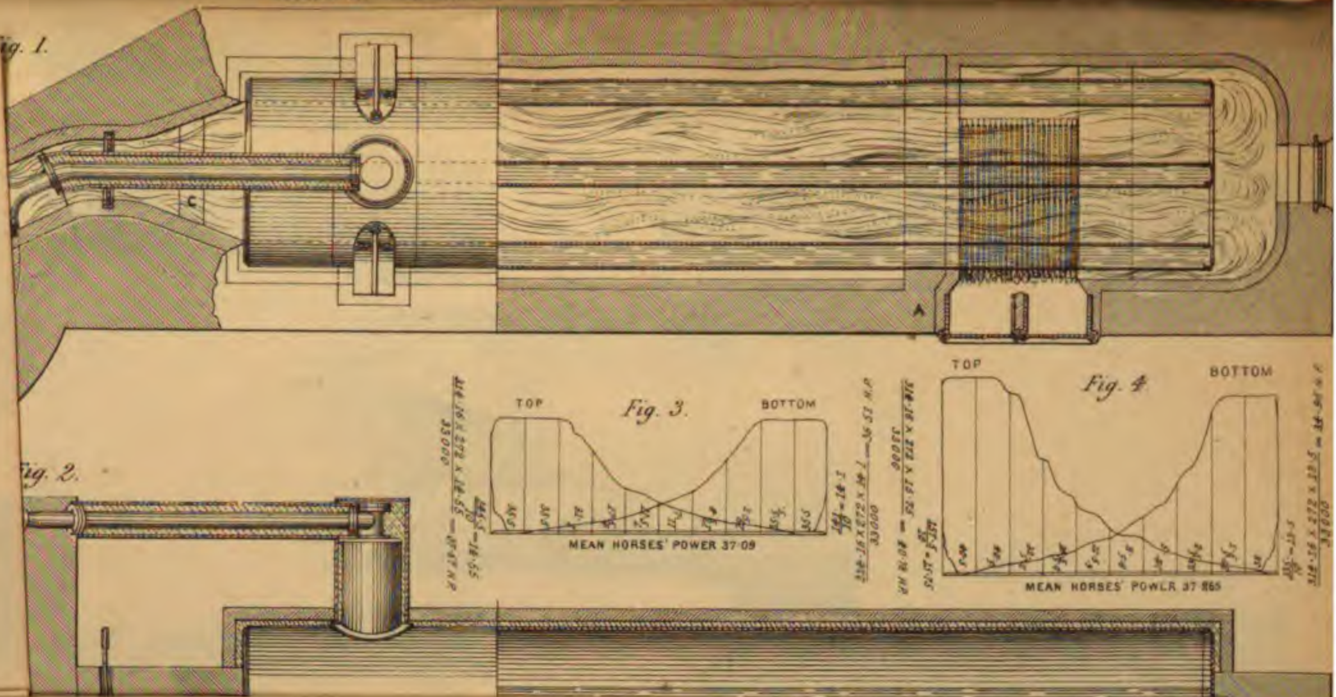
BOILER AT SCOTLAND STREET IRON



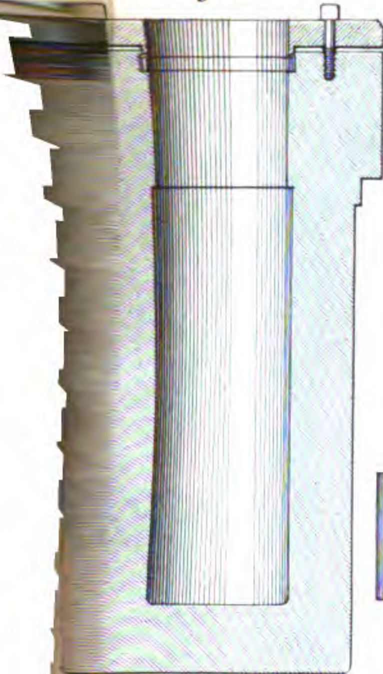


Fig. 5

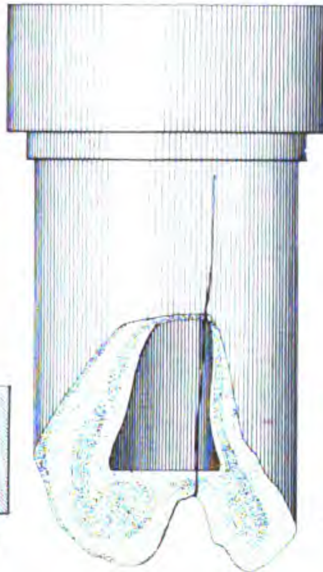


Fig. 3.

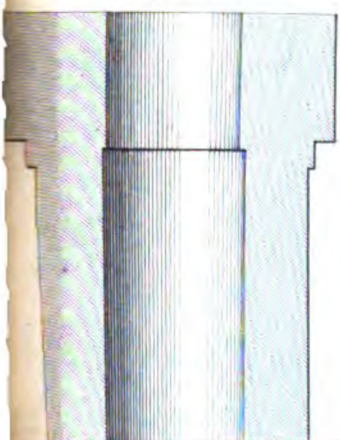
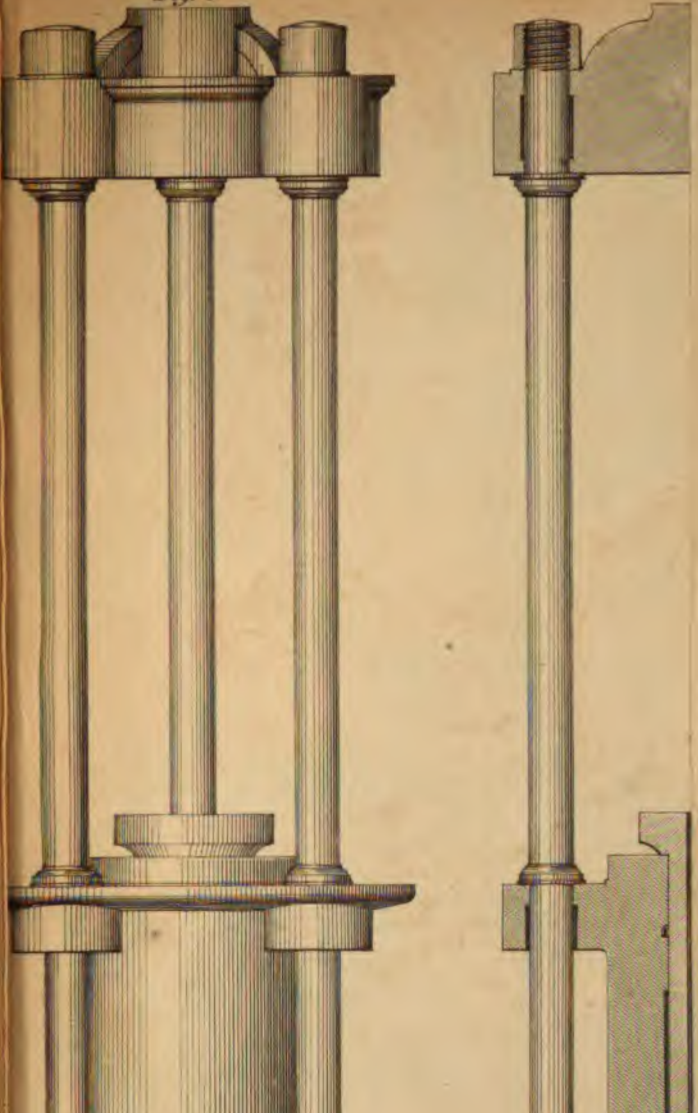
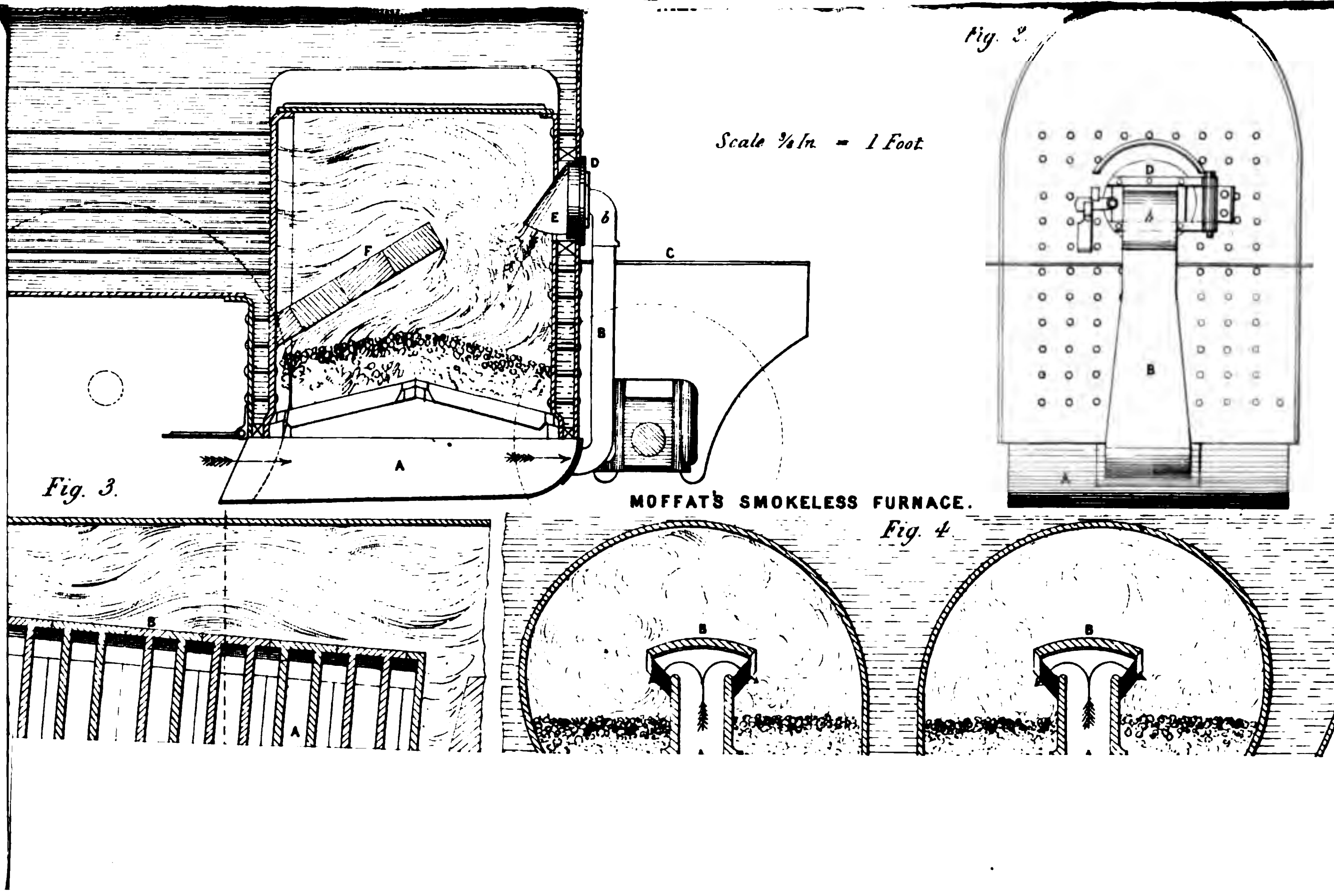


Fig. 6.





MOFFAT'S SMOKELESS FURNACE.